Experimental Study on the Coupling Mechanism of Early-strength Backfill and Rock

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Experimental Study on the Coupling Mechanism of Early-strength Backfill and Rock

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Abstract. In order to study the interaction mechanism between the ore rock and backfill at the early stage, paraffin is chosen as the cementing agent. Based on the damage mechanics and fractal theory, the interaction mechanism between the ore rock and backfill is characterized by the relevant tests on the complex of proportioned ore rock and backfill with resistance strain gauge, crack propagation, microscopic imaging and AE. The experimental results showed that: 1) Through the axial loading test, compared with the early strength of the cemented filling and paraffin mechanical deformation characteristics, the stress and strain curves of the two had a common linear deformation law, while in the early strength of the filling elastic capacity strong, with a certain degree of resilience. 2) The bearing capacity of the backfill was weak, but the deformation ability was strong. During the bearing process, the deformation of the upper load was mainly caused by the ore rock, which leaded to the damage of the rock. 3) The distribution of AE points during the co-carrying of the filling and the ore rock was monitored by the acoustic emission instrument. The damage occurred mainly in the contact zone between the backfill and the ore rock zone. The corresponding AE point distribution also validated the crack happening.

1. Introduction
It will improve the safety and stability[1-2]of the stope to backfill the goaf timely. The mechanism of the interaction between the surrounding rock and the backfill is still a difficult problem, we have many researches about the backfill, but less about the interaction between the backfill and the surrounding rock. There is even only qualitative description about the interaction between them early, and not yet found the effective results of quantitative analysis for the time being. Therefore, in this paper, the experimental study on the early strength of the simulated fused body with fully refined industrial paraffin is carried out, and the interaction between the early strength filling and the surrounding rock is carried out. Recently, most of mines chose the cemented tailings filling method, which the strength of it is about 2-4 MPa. However the backfill to the underground mining field is fluid-like and has no self-stabilizing ability. Furthermore, its early strength is also low (except when a coagulant is added to it). In order to the mine can carry on the continuous safe operation, for which, it is necessary for the tailing cement’s backfill to have a rapid strength growth process. There on the improvement of backfill’s early strength[4-6]. Due to different mechanical characteristics of mine tailings and the complexity of field geological condition, the problem of the early strength of tailing cement’s backfill cannot be completely solved. Since it is still insufficient, which is necessary to study the method that improve the early strength of the backfill through additives, and it is also important to understand the interaction between the tailing cement’s backfill and pillars.
2. Mechanical deformation characteristics of early-strength backfill

On the basis of the present proportion the mines’ backfill, which is selected to be resizeable. Five samples were taken and the average value (due to the micro-destruction of the individual samples or the individual differences in the test data, some proportioned samples were not the average values of five testing data) was used for the cementations tailing backfill in the ratio of 1:4 to 1:12. After 28 days, the uniaxial compressive strength and elastic modulus increased with the increase of cement content, while the variation of Poisson’s ratio backfill decreased. (Fig.1).

![Figure 1](image1.png)

**Figure 1.** Physical and mechanical properties of different ratio of backfill

For the convince of study and comparison, we chose the cementations tailing backfill in the ratio of 1:10 from 9 kinds of proportions to test the stress in the different ages. While studying the interaction between cement backfill and ore rock, it turned out to be different from the on-site sample for cutting and drilling, and under holing, due to which, the similarity principle of the ore rock was adopted. The simulation of the backfill needs to find alternative analog materials. Considering the sample with cement tailing ratio of 1:10, the axial load test was carried out on the sample from 1 days to 9 days by computer controlled electro-hydraulic servo universal testing machine. The relevant stress-strain curve is shown in Fig. 2.

![Figure 2](image2.png)

**Figure 2.** Stress-strain curve of 1d-9d backfill

3. Similar simulated experiment

It obligate the space of 45mm×45mm×100mm in the cube box, which the obligated space is simulated proportion material of backfill, and the rest of it is cement-powder proportion rock simulated material. In the process of loading, we carried on the ultrasonic monitoring and sound emission monitoring. Before the loading failure, we scan the situation of complexes sample’s surface crack growth. Thus, we can achieve the characterization study between the rock and backfill.

3.1. Crack evolution

The computer-controlled electro-hydraulic servo universal testing machine was used for loading. When the sample was destroyed, the five PET cut sheets were used to cover the surface wall of the specimen, drawing the crack line. Then, some photos were taken and some images were drawn using the drawing
software. Furthermore, the fractal dimensions of the other faces are shown in Fig. 3. The front and back elevations of the surface wall, which were highly destroyed, were scanned into a binary image. In order to better learn the surface stress concentration and crack propagation of the ore rock backfill, with the paraffin as the cementing agent, the solid paraffin and tailings were mixed and later heated. When the paraffin melted, the liquid paraffin and the tailings were evenly mixed, dumped into the dry ore rock model and observed. After the solidification of paraffin, the sample was immersed in the molten paraffin, so that the sample had a better integrity of wax coating, which was helpful for observing the microcrack propagation and spreading trend of the sample surface after loading.

For the sake of convenience of illustration, a composite of tailing paraffin simulation of the backfill is taken as an example. The fractal dimension of the crack line of each surface of the composite body is obtained by the box dimension method. It can be seen from Fig. 3 that the fractures mainly occurred on the left and the frontal plane, and the corresponding fractal dimensions reached 0.759 and 0.871. The fractal dimension of the other faces is shown in Table 1.

**Table 1. The fractal dimensions of each surface**

| Facade                      | Fractal dimension, D |
|-----------------------------|----------------------|
|                             | Facade               | Left facade | Back facade | Right facade | Bottom   |
| Paraffin                    | 0.918                | —           | 0.848       | 0.778        | 0.788    |
| Tailing+paraffin            | 0.585                | 0.759       | 0.871       | 0.652        | 0.585    |
| Upper: paraffin Bottom: cement tailing | 0.767 | 0.678       | 0.788       | 0.678        | 0.585    |

**3.2. Acoustic emission characteristics**

In order to illustrate and compare the convenience, paraffin is as a filling simulation of complex. The acoustic emission point distribution of the composite specimen during the loading process was monitored by means of an acoustic emission meter (full name: DS2 series full information acoustic emission signal analyzer). The acoustic emission point mainly occurs in the contact zone between the backfill and the ore rock, see Fig. 4.
During the loading process, the acoustic emission meter continuously monitors the generation of the ringing count, which predicts that the internal damage of the composite specimen may be related to the ringing count during the acoustic emission monitoring process. To this end, the introduction of damage variable \( D \), the establishment of damage variable and ringing count changes in the relationship, namely:

\[
D = \frac{S}{S_m},
\]

(1)

Where: \( S \)-the number of ring count counts at each time point, \( S_m \)-the total number of ring counts, \( D \)-damage variable.

In order to better study the effect of loading on the complex, the strength ratio is proposed, that is, the different loads are divided by the maximum compressive load,

\[
\psi = \frac{F}{F_m},
\]

(2)

Where: \( F \)-compressive strength value, \( F_m \)-maximum compressive strength value, \( \psi \)-intensity ratio coefficient.

Finally, the variation curve of the damage coefficient and the intensity ratio curve of the composite is plotted.

For the composite specimen, with the increase of the intensity ratio coefficient, the damage variable showed a large increase in the initial period, which showed a slow growth process, see fig.5.

4. Conclusions

1) Based on the axial loading test, compared with the early strength of the cemented filling and paraffin mechanical deformation characteristics, the stress and strain curves of the two had a common linear deformation law, while in the early strength of the filling elastic capacity strong, with a certain degree of resilience, so that the paraffin simulation in the early strength of the cemented filling was reasonable and feasible.

2) When the early-strength backfill was co-bearing with the ore rock, the bearing capacity of the backfill was weak, though its deformation capacity was strong. During the load-bearing process, the upper load was mainly borne by the ore rock through the adjustment of deformation, which ultimately
led to the failure of the ore rock load-bearing. When the sample’s damage extended from the interior to the free face, the cracks extended mainly along the contact surface of the ore rock and backfill, resulting in the tensile destruction of the sample surface wall and the attenuation value of the magnetic field strength.

3) The distribution of AE points during the co-carrying of the filling and the ore rock was monitored by the acoustic emission instrument. The damage occurs mainly in the contact zone between the backfill and the ore rock zone, and the corresponding AE point distribution also validates the crack happening.

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Author Contributions
Mingxu Wang finished all the work, including planning the sample collection and test, archiving the experimental results, analyzing the experimental data, initiating the writing of the manuscript and so on.

Conflicts of Interest
The authors declare no conflict of interest.

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