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Analysis of Interaction Mechanism Between Early Strength Cemented Filling Body and Ore Rock

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Abstract. The mechanism of the interaction between the early cemented filling body and the ore rock is the key to improve the filling efficiency and effect. In order to study the mechanism of the interaction between the early cemented filling body and the ore rock, the paraffin was chosen as the research object, and strain gauge and resistance strain gauge were used to monitor and compare the crack propagation characterization. Numerical simulation model is established to compare the distribution of strain and safety factor. Through the comparison of five kinds of working conditions, such as the comparison of the non filling, the single filling body, the double filling body, the asymmetric distribution of the double filling body, and the creep failure of the filling body, the stage stop upward horizontal staggered afterwards filling mining method based on the critical filling block impact impulse is put forward. The experimental results show that the wax can be used as the early strength simulation material of cemented filling body; it can effectively reduce the stress concentration in the mining stope and pillar adjacent horizontal staggered; under the same load, it can reduce the area of plastic failure area. After the failure of the filling body, it causes the sudden change of the mechanical deformation behaviors of the interaction between the early cemented filling body and the ore rock.

Key words. early cemented filling body, ore rock, crack propagation, deformation behavior, contacts, composite materials.

1. Introduction

Most of the current mining continuously changes from caving method to filling method. In the process of using mine filling method, the usage of cemented filling is very wide. Most of the researches focus on the interaction between the late strength of cemented filling body and the ore rock. As for cemented filling body, before filling, the researches on the formation of ore mining goaf and the interaction with ore rock

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after filling are less. For the strength of the filling body, based on the hardening time, it can be divided into three stages: prophase, metaphase and anaphase, among which because of the short time in the prophase and metaphase, they are called early strength. About the early cemented filling body, Wang Jian [1], Tian Junbin [2], Zhou Xu [3], Lin Zhixiang [4], Sun Wenbiao [5] and so on just study the excitation activator activation or add related materials, improve the early strength of cement rather than the effect of the low early strength cement body on the ore rock contact zone and pillar stability. In order to study the mechanical interaction between early strength cemented filling body and ore rock, through the mechanical deformation test, the paraffin wax is chosen as the cemented filling in early strength. As a kind of cementing material, paraffin has little application in the similar simulation test, but not much. Xin Yajun etc.[6] uses paraffin and river sand two kinds of materials to match sample module and do the uniaxial compressive strength tests. Dong Jianhua's experiments show that the deformation modulus increases with the increase of paraffin content, which is basically proportional to the relationship. The deformation modulus decreases with the increase of oil content, which is inversely proportional to the deformation. Li Shugang [7,8], Lin Haifei etc [9] control the strength of materials by adding oil into the wax. Under the same ratio of paraffin and sand, with the increase of the oil content in the sample, the compressive strength decreases obviously, and the lack of strong compressive strength changes due to simply using of paraffin wax and sand gets eliminated which makes the controllable range of the compressive strength of the utility model wider and can be widely used in the simulation of rocks. Deng Xiaoqian [10] used the paraffin wax and sand of 100:12 as the materials for the similar model. Li Li etc. [11] used the river sand, wax and hydraulic oil as the main factors affecting the similar materials to simulate the solid gas coupling similar materials. According to the geological conditions of Shandong undersea gold mine complex and the similarity theory to establish the geological mechanics model, Chen Hongjiang etc [12] used the solid paraffin and liquid paraffin as gelling agent of similar material configuration. These studies mainly consider the effect of paraffin wax on the uniaxial compressive strength and elastic modulus of the composite, which is composed of paraffin wax. Zhang Shunjin [13] and Li Yuanhai [14] used the transparent sample of liquid paraffin, thirteen alkane mineral oil and silica powder mixture. Zhang Jie [15] studied on the fluid solid analogue test material with paraffin as gelling agent. Lian Huiqin etc. [16] stirred evenly sand, gypsum, calcium carbonate, paraffin and Vaseline according to a certain proportion and pressed into the sample. These studies mainly use the water resistance of paraffin wax and apply it to the simulation of solid-liquid coupling. All of these involved using the paraffin wax as one of the relevant materials in the study, but can not be directly used as a cement filling of the relevant simulation test.

2. The Advance of the Key Blocks in the Filling Area's impact impulse

The underground filling mining method usually is the dichotomy mining, dividing the orebody into rooms and pillars. In the process of mining, mining the first mining house, according to a specific process, filling stope empty area after mining or remaining as supporter. Through the relevant experimental study, it is considered that the main role of filling body is the space constraint and stress transfer. In the interaction with ore rock, it does not have a large support capacity, but the stress concentration of the destruction of the display space. In order to study the impact damage problem caused by the gob stoping without filling form.

$$F \cdot t = mv, \tag{1}$$

Such as stope goaf roof rock's key block break caused by stress concentration and deformation accumulation, assume the weight of the key block is M. If the mined area is not filled, after the free fall (gob height is H),at the end of the impact, the speed of the key block is:

$$v = \sqrt{2gh}, \tag{2}$$

If the space is small, just formed a key block, assuming the key block in the moment of impact speed is constant, impact distance of that moment is ΔS, the time for the impact of the the key block is:

$$t = \Delta s/v = \Delta s/\sqrt{2gh}, \tag{3}$$

Then the impact force of the key block is:

$$F = \frac{2mgh}{\Delta s}. \tag{4}$$

Generally speaking, the variation range of the impact distance of the key blocks in the underground mine is small, and if the value is assumed to be constant, the impact force of the key block is directly related to the height of the gob. If the H is small, or almost zero after full filling, then the key block does not have the space to create impact energy. If the empty area is large, a number of key block caving caused by the stress concentration appearance, will form a mutual impact in key block caving process, easy to cause the greater impact force than the simple free fall, thus causing more damage. Therefore in the backfill mining process, we need to understand the two main functions of filling body are the limitation the display space of key block impact force's damage after filling the area of filling, and the self stabilizing role of filling body. Self stabilization is the ability of continuous mining, improving the efficiency of filling mining, and resisting certain roof load and lateral extrusion load. The two main functions based on, this paper puts forward a new mining method – stage stope and pillar upward horizontal staggered afterwards filling mining method. The ore block is divided into several stages, each stage is divided into several segments and make room and pillar mining of adjacent upper and lower horizontal staggered mining backfilling (see Figure 1).The mining method will mine the room and pillar at the same time, and all the adjacent level room and pillar can be mined at the same time. The mining efficiency is greatly improved, to avoid the low efficiency of the dichotomy mining and the uncertainty of whether the pillar is mined. But this kind of mining method has a higher requirement on the

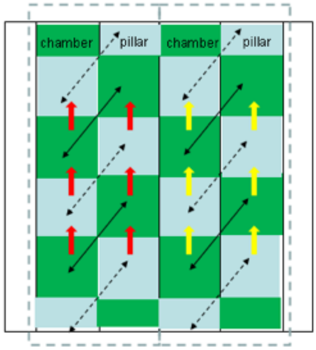


Fig. 1. Stage room pillar layered staggered afterwards filling mining method

early strength of the filling body, so it is necessary for the mine to strictly enforce the water cement ratio and the addition agent of the accelerator.

To further understand the interaction mechanism between the double early strength filling body and ore rock caused by the mining of room and pillar at the same time, the similar simulation experiment and numerical simulation test were carried out.

3. Similar Simulation Test

In order to study the mechanical deformation of adjacent stope and pillar upward horizontal staggered afterwards filling mining method, the specimen were made. First of all, in the 100mm×100mm×100mm, the corresponding filling body position is fixed by polyethylene foam, then pour the ratio ore rock, after maintaining for 7d, extract polyethylene foam, and pour fully refined industrial paraffin particles after melting (see Figure 2). After the whole sample was maintained 28d, carry out the corresponding loading test.

Under the axial loading, the internal crack of the ratio sample gradually expands, and it will extend to the surface when it is destroyed, and form the crack propagation line with the vertical crack as the main line. When there are early filling body in proportion in the sample, under the influence of the axial loading, internal crack propagation shows certain regularity, mainly along the backfill and rock contact surface expansion, the internal of the filling body damages during loading. When the filling body distribution under staggered, under axial load, failure form of complex rock body and filling for the formation of shear angle is 45 degree of damage in filling body. In order to simulate the upper part of the non-uniform load, take the upper one of the double filling body direct contact with the loading plate, and the upper load transmits jointly through the rock and backfill, simulating the failure modes after the rock and backfill compaction after creep failure of backfill. When the filling body and the ore rock complex are loaded, the filling body on the upper level is destroyed, and the stress of the lower level of the ore body is destroyed, and there are more powdery material in the inner part of the ore rock.

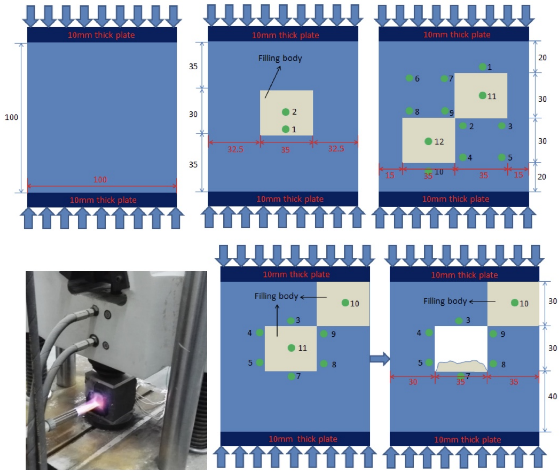


Fig. 2. Schematic diagram of various sample designs

Table 1. Physical and mechanical parameters of rock and backfill

Lithology	Modulus of elasticity /GPa	Poisson's ratio	Bulk density /kN·m^{-3}	Compressive strength /MPa	Tensile strength /MPa	Cohesive force /MPa	Angle of internal /(°)
Ore stone	42.4	0.30	41.2	118.5	8.2	8.32	33.6
Filling body	0.6	0.29	22.4	2.4	0.62	28	0.6

4. Numerical simulations

4.1. Model establishment and boundary conditions

Through the numerical simulation, according to the relevant data of laboratory tests of physical and mechanical parameters of rock's (see Table 1), combined with the physical and mechanical rock and backfill parameters, establishes the numerical model. It is mainly, in the process of loading, the variation of plastic zone in the wall and the change of equivalent principal strain. After the model is divided into 92769 parts, the number of nodes is formed, and the number of faces is 63665.

Considering the convenience of comparison and the formation of a suitable type of plastic failure zone, the 50MPa load between the maximum bearing capacity of the ore rock and the cemented filling body is chosen as the applied load on the surface of each working condition. The other boundary conditions are the same, that is, the bottom is fixed, the four surfaces are free surfaces, and the plastic zone and the change of the surface strain are simulated under axial loading.

4.2. Simulation results and analysis

In order to characterize the mechanical deformation characteristics of rock mass and early strength filling body under different working conditions, the distribution of safety factor and the variation of internal and surface strain are compared with each other.

4.2.1. safety factor distribution analysis

When there is only one filling area in the middle of the ore rock model, the lateral side of the gob side is taken as the research object, and the plastic failure area is 1.23 times that of the plastic failure area. It is indicated that the filling area is more favorable to the stability of the side contact between the rock and the backfill. At the same time, the safety factor of cemented filling body is larger than that of rock under load. There forms a clear dividing line on the contact surface (see Figure 3), and the other conditions are the same situation, which shows that under the action of 50MPa, the cemented filling body does not play the role of bearing, and mainly depends on the bearing capacity of the rock.

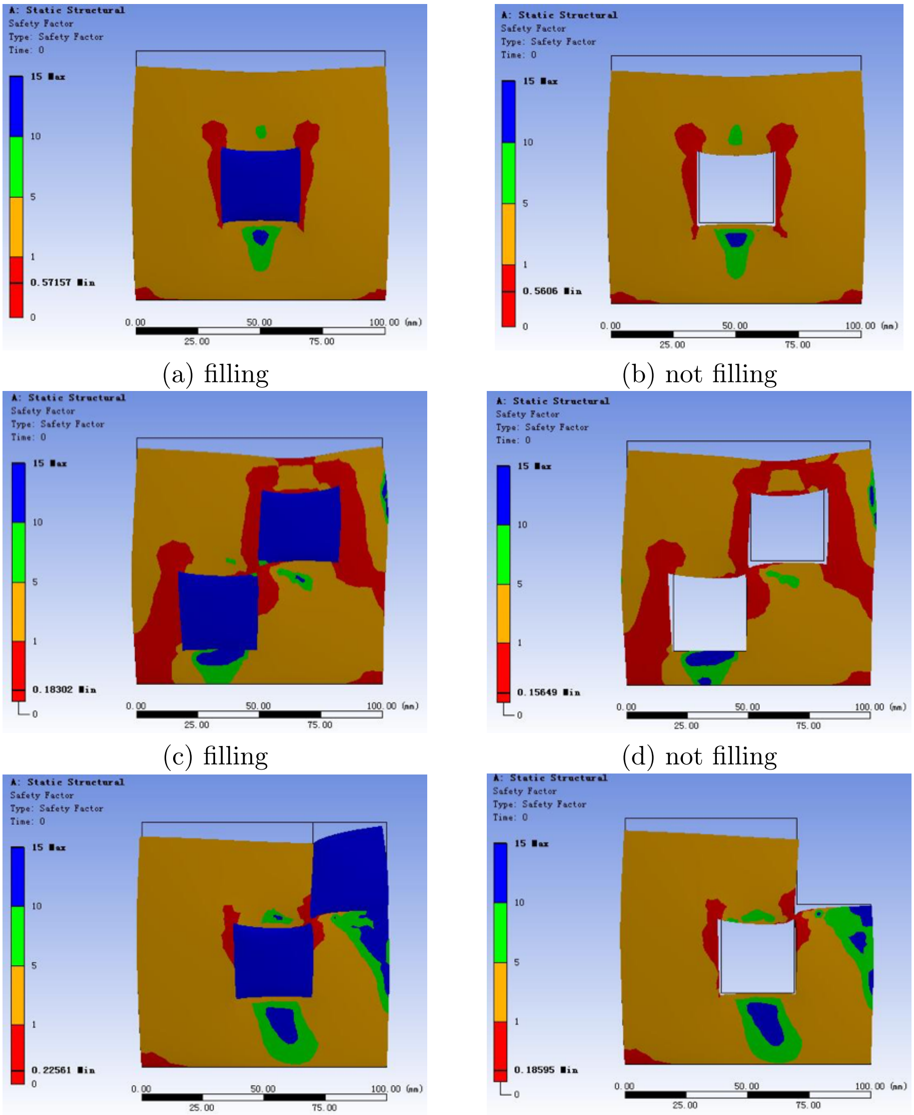
Due to the small physical mechanics of filling parameters, when the model surface is loading, the safety and stability of the internal filling coefficient is large, and plastic failure occurs mainly in the filling area at the side. For the double filling body in the geometric center and at the top of the right, the plastic failure zone formed between the two is larger. Double filling in the geometric center is much larger than that in the upper right condition, if starting from the filling area of side of the plastic zone, calculating the continuous plastic damage area, the condition of plastic damage area in the geometric center is 10.87 times in the top right condition. Compared with the goaf filling condition, the plastic failure area is larger when the goaf is not filled.

4.2.2. strain value analysis

From the figure 4 can be seen, the influence of the stope empty area without filling produce than filling, variation and distribution is similar to the corresponding safety coefficient.

According to the change of the strain value of the monitoring points in the transverse series, in the case of the double filling body in the middle of the model, the deformation of the filling body is larger than that of the filling (see Fig.5).

And the strain values of the single filling body and the double filling body in the upper right are generally smaller than those in the middle. Mainly in the following position: horizontal series monitoring points range from 0-20mm, 43-57mm, 77-100mm, and longitudinal series of monitoring points range from 0-27mm, 40-60mm, 69-100mm. While in contact surface of two different levels of filling body staggered, the strain value of the double filling body in the middle either horizontal or vertical, are larger than that of other conditions. The maximum strain value is 3.25 times of the maximum strain value under other conditions, in the horizontal and vertical series monitoring point of view.

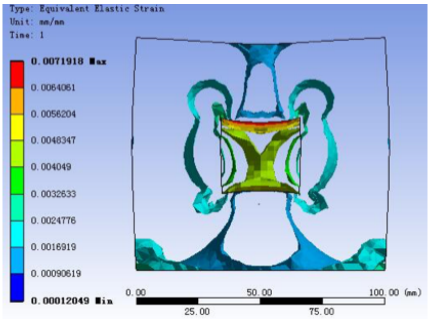


(a) filling (b) not filling

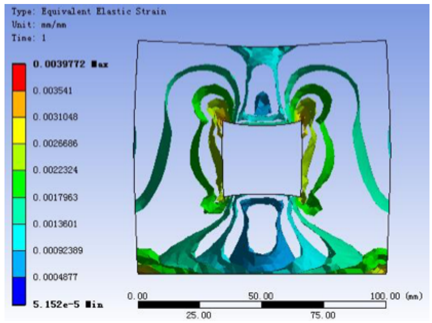
(c) filling (d) not filling

(e) filling (f) not filling

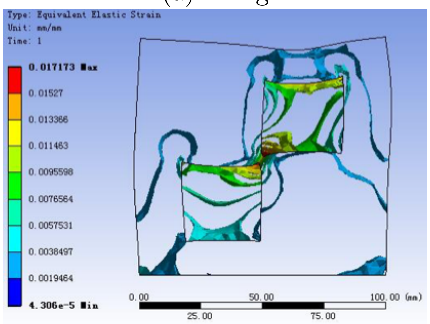
Fig. 3. Distribution of safety factor



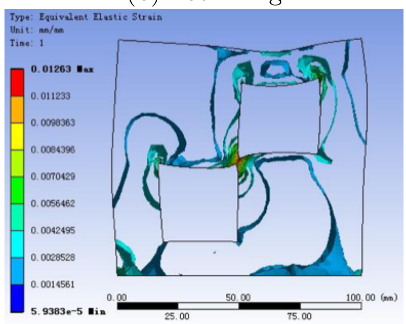
(a) filling



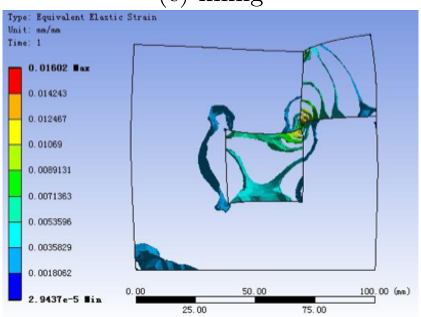
(b) not filling



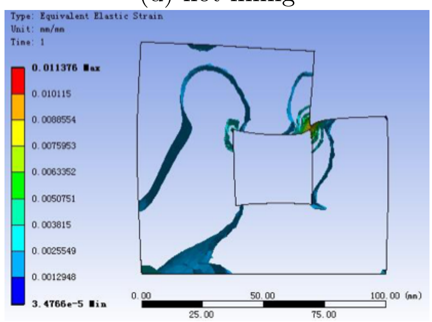
(c) filling



(d) not filling

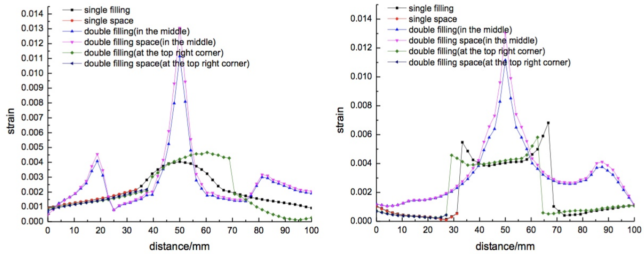


(e) filling



(f) not filling

Fig. 4. Equivalent elastic strain isosurface



(a)horizontal (b) longitudinal

Fig. 5. Strain values of transverse series monitoring points

5. Conclusion

1) Advance the key block impact impulse of the filling area, and based on this propose stage of stope and pillar layered staggered afterwards filling mining method, in order to improve the efficiency of mining.

2) The early strength of cemented backfill mechanical deformation and related mechanical deformation characteristics of paraffin were compared, the stress-strain curve is consistent, indicating the early strength of filling simulation of paraffin is feasible. At the same time in the production process of the specimen, the superiority of the paraffin melting and casting, greatly improves the efficiency of the test sample preparation, and has reached the expected results, which illustrates the paraffin as the simulated early strength of filling has certain applicability.

3) Through the indoor test of similar simulation experiment and numerical simulation, simulate the double filling body's the mechanical deformation characteristics in the process of existence, and through the room and pillar mining and filling in time, it can play a role in relief. In the process of stress concentration and accumulation, the mining efficiency is improved and the backfill is filled in time, which can effectively reduce the range of plastic failure zone. The plastic zone formed after filling in the middle of the geometric filling is reduced by nearly 1/4. By reducing the bearing area of the roof, the unfilled plastic zone is 10.87 times larger than that after filling.

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