Large - Scale Unstable Collapse Mechanism of Filling Stope ＆ Its Environmental Grouting

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Abstract. In order to study the law of the destruction of stope collapse of unstable rock and ore filling body underground metal mine. Based on 3DEC discrete element program for the operating platform, taking a collapsed mine ore zone as the project background, and combined experiment of indoor physical mechanics, the dynamic evolution of the unstable rock in this area was studied, and the stope collapse failure slip pattern was revealed. The results show that the ore above instability collapsed stope amounted to sank parties about 2m, the two bodies of the filling body slipped to the mined-out area until the destruction under the action of extrusion. Secondly, Stope produced a total damage when the maximum shear strain zone in the collapse zone is fully penetrated, at this time, "U-shaped" instability of the collapse of the affected area is formed, resulting in the adjacent six stoves to become a dangerous area of mining. Lastly, according characteristics of filling body movement and mode of deformation, the general idea and idea of the reinforcement of the stope in the area of hidden danger is determined, and grouting Grouting reinforcement recommendations are proposed on this basis. The results can provide technical support for the subsequent mining stope in those collapse hazard areas.

1. Introduction

With the depletion of metal mineral resources, the old ideas and thinking of "mining the rich ore to abandon the poor" should be changed for underground metal mines[1~3], and how to exploit difficult mining or remote complex ore bodies should be considered[4~5]. In the past mining, due to the control of the ground pressure and the overall grasp of the mining sequence were ignored, unreasonable mining steps can easily lead to stope collapse, the safety and efficient recovery of the surrounding pillars were directly affected[6~8]. So how to mining pillars in extremely complex environment was worthy of study. Especially to find out the scope of influence in the collapsed area was the key points to solve similar problems[9~10]. A large-scale lead-zinc mine in china uses a filling method to mining the ore body, As shown in Figure 1 below, in the process of mining No.0 stope, due to the combined effect of factors such as improper mining sequence and poor quality of the filling body, resulting in some security incident occurred including its upper ore body appears to sink as a whole, the surrounding area collapsed and suddenly roof fall, it making the surrounding adjacent a few pillars of the mining field has been greatly affected. Recycling this part of the difficult mining resources need to solve the primary problem were determine the amount of subsidence and the impact of the collapse area. For such complex environment analysis of mechanics, obviously, the existing mechanical state cannot be truly reflected by the simple mechanical model in the collapsed area, and the numerical analysis method is more mature and reliable means to study this problem, because the traditional finite element analysis method can only simulate the bending deformation of the block, The block cannot produce relative sliding and breaking[10~11]. The advantage of 3DEC software was that it can be better to achieve the separation between the block, rotation and block the process of collapse, and the block can be broken with the new block to achieve contact and mechanical analysis[12~13]. In terms of underground engineering, especially mining works, stope mining and the formation of a mined-out area, the surrounding rock will produce cracks or large-scale collapse, under such conditions, 3DEC software makes the simulation more reasonable of underground mining engineering[14]. Therefore, based on 3DEC as a platform, combined with rock physics and mechanics experiments, ore body and filling body collapse and movement law was discussed in the collapse area, on this basis, grouting reinforcement measures were proposed for the ore body to provide protection in the collapse of the area.

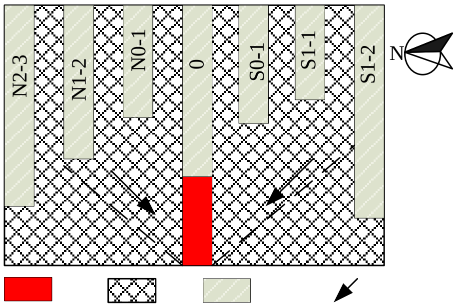


Fig. 1 Status of instability collapse area

2. Build a numerical model

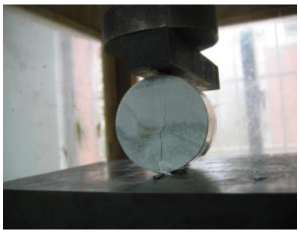
2.1 Physical mechanics parameters.

The physical and mechanical parameters of the ore rock used in the numerical simulation were mainly from the laboratory test, as shown in Figure 2 below. At the same time, because the natural rock were rich in joints and weak surface, its physical mechanics parameters are often much smaller than the labs obtained from the laboratory. Therefore, the mechanical parameters of the ore rock were selected to be 0.1 times which the data obtained from the test [15], as shown in table 1. For the determination of joint surface mechanics parameters, and cohesion force C, friction angle φ, normal stiffness Kn, tangential stiffness Ks can be obtained by triaxial test,and using the formula (1) and (2) to solve[16], As shown in Table 2.

$$K_n = 1.75 J_{RC} + 2\left(\frac{J_{CS}}{J_{RC}}\right) - 7.15 \tag{1}$$

$$K_s = \frac{100}{L \bullet J_{CS}} \bullet \tan\varphi_r \tag{2}$$

(a) Uniaxial pressure test



(b) Tensile strength test

Fig.1 Rock mechanical parameters experiment

Table 1 Rock mass physical and mechanical parameters

Type of rock body	γ/(g·cm^{-2})	E/Gpa	ν	σ_c/Mpa	σ_t /Mpa	c/Mpa	φ(°)
surrounding rock	3.1	9.18	0.24	12.9	2.11	3.56	39.6
ore body	3.46	17.4	0.25	14.3	2.37	3.05	36.3
filling body	3.23	5.7	0.23	0.35	0.12	0.35	38.1

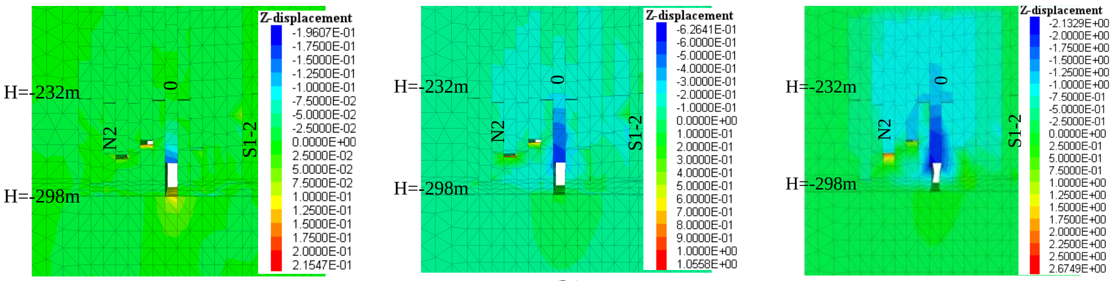
Table 2 Ore rock interface mechanics parameters

Type of rock body	Normal stiffness /(GPa)	shear stiffness /(GPa)	c '/MPa	Φ'/(°)
surrounding rock	0.5	90	0.3	26.4
ore body	0.4	180	0.24	25.5
filling body	0.2	20	0.05	22.1

2.2 The boundary condition of the model.

The 3DEC model has six free faces, horizontal and bottom boundaries were fixed at a speed of 0. Ore body buried depth of -280m, so the equivalent load γg , γg was applied to the top boundary of the model. Because the motion of the rock mass was an irreversible process, the vibration of the rock block in the equilibrium position was avoided, damping should be added to absorb the kinetic energy of the system, and the calculation of the adaptive damping was used.

3. Analysis of Key Rock Mechanics Problems in Unstable Collapse

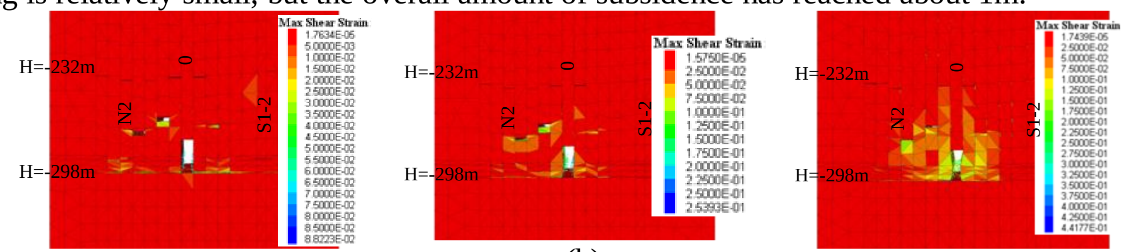


(a) (b) (c)

Fig.3 Vertical displacement of the scope of the collapse area

3.1 Displacement and Evolution of Vertical Displacement in Vertical Direction.

From the vertical displacement diagram shown in Figure 3 above, when NO.0 mined-out area is formed, the basic movement pattern of the ore body and the filling body in the collapse area is moving in the direction of NO.0 mined-out area. The ore body has subsided as a whole above NO.0 mined area, the maximum displacement value decreased about 2m, and both sides of the NO.N0 and NO.S0 of the filling body is also toward the NO.0 mined-out area down and squeeze, and resulting in a chain effect of the whole stope, making NO.N0-1, NO.N1-2, NO.S1 stope have appeared in varying degrees of sinking, and because the lower chamber of the NO.N0-1 and NO.N1-2 stope were not filled, resulting the amount of sinking is relatively large in this two places, its maximum displacement reached about 2.35m. While the lower chamber of NO.S1 stope has been filled. So the two piles of the amount of sinking is relatively small, but the overall amount of subsidence has reached about 1m.



(a) (b) (c)

Fig.4 The maximum shear strain zone connection with the collapse of the scope

3.2 Change law of maximum shear strain.

As can be seen from Figure 4, when the calculation is over, in the figure, an obvious maximum shear strain increment is formed, the magnitude of the shear strain increment is About 10^{-1}. Its maximum value is about 4.4×10^{-1}. The area where the maximum shear strain increment occurs is mainly located in the lower part of the NO.0, and finally one of the largest shear strain increments is formed, its shape is roughly U-shaped curve. Because these locations are mostly filled or backfilled waste rock, due to its poor shear capacity caused. Therefore, it is most likely that the overall instability occurs along this through band.

4. Grouting reinforcement process

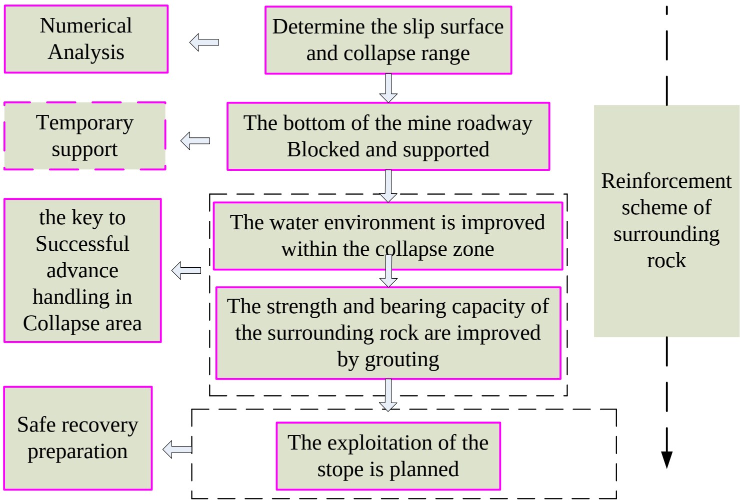
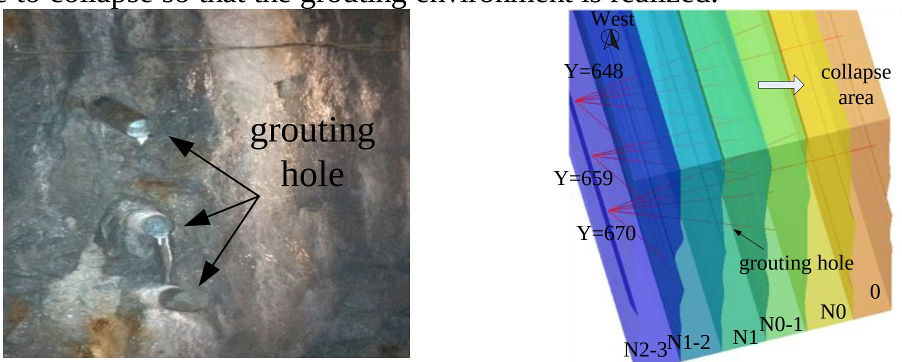


Fig.5 Reinforcement program within the surrounding rock of hidden area

In the follow-up stope mining, to ensure high-quality filling under the premise of combining numerical analysis results, in order to improve the lithology of the surrounding rock, The key factor in controlling the filling body to continue to sink and destroy is to enhance the carrying capacity of the filling body. The strength of the filling body in the U-shaped collapse area is effectively improved to improve its overall stability. According to this, the following basic principles of surrounding rock control are put forward, that is, first the water environment of the surrounding area is improved, and the key factor in the success of grouting is that the self-carrying capacity of the surrounding rock is improved. The overall grouting reinforcement process is shown in Figure 5.

Mainly for the maximum shear strain through the band was grouting reinforcement Unstable collapse area within the slip line, including crushing zones and plastic zones, specific site grouting situation shown in Figure 6 below, That is, drilling holes are arranged in the rock chamber in the safe area outside the collapse area. Its effect is, on the one hand to detect whether the ore body continues to sink, On the other hand is that to ensure that the filling of the hollow and cracks were blocked and reinforced under the ore body, to ensure the stability of the filling after the subsequent mining, and will not continue to collapse so that the grouting environment is realized.



(a) Hole grouting reinforcement (b) Engineering arrangement

Fig.6 Measures of grouting reinforcement

5. Summary

1) After the excavation, the ore body which at the top of the mined-out area gradually settles downwards, the maximum amount of sinking is about 2 meters, and the pillars also produce different

degrees of settlement, And both sides of the filling body is also moving towards the mined-out area, The filling body near the mined-out area first enters the yield state. When the displacement value is no longer convergent, the two-body filling body slides down to the mined-out area under the action of squeezing.

2) the maximum shear strain increment first appears on both sides of the mined-out area under the unloading effect, and with the increase in computing time, its scope gradually expanded and extended to the upper part, At the same time, there are varying degrees of maximum shear strain in the range of about ten stope, That is, the overall damage when the maximum shear strain zone is fully penetrated, "U-shaped" collapse area affected area was formed.

3) The range of predicted collapsed areas is analyzed by numerical analysis, The ore body and the filling body is detected and grouting reinforcement in the collapse of the affected area, it is estimated that the actual subsidence of the ore body to achieve environmental grouting recycling.

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