Stability Analysis of Minimum Broken Top Layer Thickness of Rock Drilling Chamber in a Mining Site Based on Midas/GTS

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Abstract. The determination of the reasonable thickness of the top layer of the large-diameter deep-hole stope is one of the important process parameters that must be considered in the high-stage mining recovery. The thickness of the top layer can ensure that the large-diameter deep-hole stope is not easy to collapse after the formation of the empty zone. To ensure the stability of the rock drilling chamber. According to the similar mine experience and mechanical model, the scientific and reasonable top-level safety thickness range is calculated. The three-dimensional numerical simulation of MIDAS/GTS is used to verify and optimize the stability of different top layer thicknesses. From the perspective of displacement and stress, comprehensive simulation analysis is carried out. After comprehensive comparison of angles, the optimal thickness of the top layer is determined to be 9 m.

1. Introduction

A lead-zinc mine is mined by a large-diameter deep-hole stage empty-field post-filling mining method. The determination of the reasonable thickness of the top layer of the large-diameter deep hole stop is one of the important process parameters that must be considered in the high-stage mining recovery [1]. The thickness of the top layer can ensure that the large-diameter deep hole stope forms an empty area, and it is difficult to break the top layer. Collapse to ensure the stability of the rock chamber. Too small a safe thickness to break the top layer is easy to collapse, too large a safe thickness to break the top layer when the top blasting is performed, the explosive consumption is large and easy to form a large block, and at the same time, under the condition of the maximum single-shot amount of the determined top-breaking blasting, The thicker the broken top layer, the more it affects mining efficiency [2].

Therefore, it is of great significance for the optimization of the thickness of the top layer of the large-diameter deep hole stop rock chamber, which is the prerequisite for ensuring safe and efficient production of the mine. In this paper, based on similar mine experience and mechanical model, the scientific and reasonable top thickness safety thickness range is calculated. The finite element analysis software MIDAS/GTS is used to simulate and determine the optimal top layer thickness.
2. Numerical analysis model construction

2.1. Selection of physical and mechanical parameters of rock mass
This time value simulation involves four types of mineral rock and one type of filling body, including surface weathering zone rock group, weak weathering zone rock group, unweathered zone rock group, ore body and backfill, combined with various engineering reduction methods proposed by experts at home and abroad. The modulus of elasticity is generally reduced to 1/3-1/5, and the tensile strength and cohesion are generally reduced to 1/7-1/10. According to the rock mechanics parameters recommended in the mine rock mechanics research report [3], the physical and mechanical parameters of the ore after the reduction of the project are shown in Table 1.

| Rock name                        | density (g/cm³) | Elastic Modulus E (GPa) | Poisson's ratio μ | tensile strength σt (MPa) | C (MPa) | φ (°) |
|----------------------------------|----------------|-------------------------|------------------|---------------------------|---------|-------|
| Surface weathering zone          | 2.59           | 11.35                   | 0.29             | 0.59                      | 1.10    | 35    |
| Weakly weathered zone            | 2.56           | 15.68                   | 0.23             | 0.82                      | 1.41    | 36    |
| Unweathered belt group           | 2.60           | 16.72                   | 0.19             | 1.17                      | 2.34    | 41    |
| Ore body                         | 2.72           | 14.73                   | 0.25             | 0.86                      | 1.62    | 39    |

2.2. Model establishment

2.2.1. Model calculates. size range and calculation model The model is a cuboid region including the middle section of 320m, the x direction is the ore body direction, the y direction is the horizontal thickness direction of the ore body, that is, the length of the stope, and the z direction is the vertical direction of the ore body [4]. According to the simulation model of the mining scheme of mining area mining, the mining yard is 15m wide, the stope is 65m long, the stage height is 60m, and there is a 4m top column. According to the experience excavation, the impact range is 3~5 times of the excavation area. In order to reduce the influence of boundary constraints on the calculation, two pillars and one mine room are arranged in the direction of the ore body. The model is taken as the middle section of the main section of 320m. The scope of the excavation is 3m. The size of the 3D model is 255m long, 325m wide and 300m high [4]. In order to ensure the safety of mining in the mining area of the test site, it is proposed to carry out numerical simulation of the excavation process of different top layers of the rock drilling chamber, analyze the displacement and stress state of the thickness excavation of the top layer of different slopes, and compare and analyze the best solution [5].

2.2.2. Meshing After. The simulation model is built, the mesh is divided according to the position and attribute of the model. The entity divides the mesh by automatic meshing. The cell type is tetrahedral node unit and the excavation calculation part (mine and the mine room) is a refinement grid. The cell size of the excavation is 1m×1m×1m, the cell size of the pillar is 2m×2m×2m, the outer part is the roughened grid, and the outer elevation is 0~100m. The belt has an elevation of 100~200m for the ore body, and the elevation is 200~300m for the weakly weathered zone. The overall mesh division and calculation part of the mesh are shown in Figure. 1-2. Calculated 182,846 cells, node 46754 [6] [7].
2.2.3. Model boundary condition. Since the ground stress test is not clear, the model is loaded in the negative direction of the z-axis by the self-weight stress method. The boundary x=0, x=255, y=0, y=325, z=0 five planes are constrained by zero. The top of the model loads the actual elevation of the mining area to the top of the model and the uniform weight load is 2.05Mpa.

2.3. Numerical simulation calculation step

(1) Calculate the initial stress field and clear the displacement;
(2) Calculate the excavation of different rock drilling chambers;
(3) Calculate the ore body caving with different thickness of the top layer, leaving only the top layer [6] [8].

3. Numerical simulation results

Through the similar mining survey and structural mechanics method, load transfer intersection method, thick span ratio method, Platts arch method, aspect ratio beam plate method and other theoretical methods, the reasonable thickness of the broken top layer is between 7.3m and 10.7m. Therefore, the numerical simulation calculations are to select thickness values of 7.5m, 8.0m, 8.5m, 9.0m, 9.5m, 10.0m, and 10.5m.

From the perspective of this model, the rock drilling chamber is a strip-shaped column type, and the displacement, minimum principal stress and maximum principal stress under different excavation conditions of the top layer are analyzed, and it is better to compare the thickness of the top layer. Mining activity and its stability [9] [10].

3.1. Displacement result

From the simulation results of MIDAS/GTS software, the maximum displacement of the roof sinking occurs on the roof of the ore body after mining (That's the bottom of the top). The maximum displacement displacement of the bottom plate appears on the bottom plate of the ore body mining, which is in line with the actual mining displacement law. According to the simulation results, under the condition of leaving 7.5m thick broken top layer: the displacement of the top plate of the rock chamber is 7.264mm, the displacement of the bottom plate is 4.939mm; under the condition of leaving the top layer of 8.0m thick: strip The displacement of the roof of the inter-column rock chamber is
7.229mm, and the displacement of the bottom plate is 5.024mm. Under the condition of leaving the top layer of 8.5m thick, the displacement of the roof of the rock chamber is 7.238mm, and the displacement on the bottom plate Move 4.961mm; under the condition of leaving 9.0m thick broken top layer: the displacement of the roof of the rock chamber is 7.151mm, the displacement of the bottom plate is 5.105mm; under the condition of leaving 9.5m thick to break the top: between the strips The displacement of the roof of the column rock chamber is 7.167mm, and the displacement of the floor is 5.016mm. Under the condition of leaving the top layer of 10.0m thick, the displacement of the roof of the rock chamber is 7.283mm, and the displacement of the floor is upward. 4.999mm; under the condition of leaving the top layer of 10.5m thick: the displacement of the roof of the strip-shaped column is 7.331mm, and the displacement of the bottom plate is 5.504mm;

3.2. Minimum principal stress result

From the simulation results of MIDAS/GTS software, the minimum principal stress (tensile stress) appears in the middle of the floor of the rock chamber, and the top layer is broken. The back side of the bottom plate and the ore body after excavation meets the actual mining displacement law. According to the simulation results, under the condition of leaving 7.5m thick broken top layer: the minimum principal stress of the rock chamber in the inter-column column is 0.920Mpa; under the condition of leaving the top layer of 8.0m thick: the minimum principal stress of the rock chamber in the inter-column layer is 1.047Mpa; under the condition of leaving 8.5m thick broken top layer: the minimum principal stress of the rock chamber in the inter-column column is 1.743Mpa; under the condition of leaving 9.0m thick: the minimum principal stress of the rock chamber in the inter-column column is 0.799Mpa Under the condition of leaving 9.5m thick broken top layer: the minimum principal stress of the rock chamber in the inter-column column is 0.883Mpa; under the condition of leaving the top layer of 10.0m thick: the minimum principal stress of the rock chamber in the inter-column column is 0.840Mpa; Under the condition of 10.5m thick broken top layer: the minimum principal stress of the rock chamber in the inter-column column is 0.956Mpa.

3.3. Maximum principal stress result

From the simulation results of MIDAS/GTS software, the maximum principal stress (compressive stress) appears in the bottom plate after excavation of the ore body, which is in line with the actual situation. Mining displacement law. According to the simulation results, under the condition of leaving 7.5m thick broken top layer: the maximum principal stress of the rock chamber in the inter-column column is 16.516Mpa; under the condition of leaving the top layer of 8.0m thick: the maximum principal stress of the rock chamber in the inter-column column 16.549Mpa; under the condition of leaving 8.5m thick broken top layer: the maximum principal stress of the rock chamber in the inter-column column is 16.482Mpa; under the condition of leaving the top layer of 9.0m thick: the maximum principal stress of the rock chamber in the inter-column column is 16.137Mpa Under the condition of leaving 9.5m thick broken top layer: the maximum principal stress of the rock chamber in the inter-column column is 15.954Mpa; under the condition of leaving the top layer of 10.0m thick: the maximum principal stress of the rock chamber in the inter-column column is 15.954Mpa; Under the condition of 10.5m thick broken top layer: the maximum principal stress of the rock chamber in the inter-column column is 16.024Mpa.

4. Analysis of the minimum thickness of the top layer of rock drilling chamber

4.1. Displacement analysis

According to the results of numerical simulation, the statistics of the top and bottom displacements of the rock chamber are shown in Table 2. The displacement curve is shown in Figure 3 and Figure 4.
Table 2. Statistics on the sinking displacement of the top plate of different rock mass chambers

| broken top thickness (m) | Displacement of roof subsidence (mm) | Displacement amount on the top plate (mm) |
|-------------------------|-------------------------------------|-----------------------------------------|
| 7.5                     | 7.264                               | 4.939                                   |
| 8.0                     | 7.229                               | 5.024                                   |
| 8.5                     | 7.238                               | 4.961                                   |
| 9.0                     | 7.151                               | 5.105                                   |
| 9.5                     | 7.167                               | 5.016                                   |
| 10.0                    | 7.283                               | 4.988                                   |
| 10.5                    | 7.331                               | 5.004                                   |

According to the analysis of the displacement angle of the top plate, it can be clearly seen from Figure 3 that when the thickness of the broken top layer is 9m and 9.5m, the displacement of the roof is the lowest, which is beneficial to the stability of the top layer. The analysis of the displacement angle of the bottom plate can be seen from Figure 4. When the thickness of the top layer is 7.5m, 8.5m and 10.0m, the displacement of the bottom plate is the lowest, which is good for breaking the top layer.

Figure 3. The displacement curve of the top plate with different broken top thickness

Figure 4. Displacement curve of the bottom plate of different broken top layers

4.2. Minimum principal stress and maximum principal stress analysis

According to the results of numerical simulation, the statistics of the minimum principal stress and the maximum principal stress of the top layer of the rock chamber are shown in Table 3. The displacement curve is shown in Fig.5 below. The displacement curve is shown in Fig.6 below:
It can be clearly seen from Figure 5 that when the thickness of the broken top layer is 9m, 9.5m, 10.0m, the minimum principal stress value is the lowest, which is good for breaking the top layer stability; as can be clearly seen from Figure 6, when the thickness of the broken top layer is 9.5m, when the maximum principal stress value is the lowest, it is good for breaking the top layer stability.

**Table 3.** Statistics of minimum principal stress data of rock chambers with different thicknesses

| Broken top thickness (m) | Minimum principal stress (Mpa) | Maximum principal stress (Mpa) |
|--------------------------|--------------------------------|-------------------------------|
| 7.5                      | 0.920                          | 16.516                        |
| 8.0                      | 1.047                          | 16.549                        |
| 8.5                      | 1.743                          | 16.482                        |
| 9.0                      | 0.799                          | 16.137                        |
| 9.5                      | 0.883                          | 15.833                        |
| 10.0                     | 0.840                          | 15.954                        |
| 10.5                     | 0.956                          | 16.024                        |

**Figure 5.** Minimum principal stress curve of different broken top layers

**Figure 6.** Maximum principal stress curve of different broken top layers
4.3. Comprehensive comparative analysis

Because the conclusions of the top layer stability are inconsistent due to different analysis angles, it is necessary to comprehensively compare and analyze the reasonable value of the safe top layer thickness under the strip-column rock chamber structure.

In order to facilitate direct analysis, the superiority of different broken top layers was scored. The score is based on the minimum value $X_{\text{min}}$ of each row of data, and the score is divided by the base of the data. Then comprehensively compare the thickness of different broken top layers, and recommend the minimum safe broken top layer thickness under the strip-shaped column rock drilling chamber structure. The superiority score table is shown in Table 6:

| Broken top thickness (m) | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 |
|-------------------------|-----|-----|-----|-----|-----|------|------|
| Roof displacement (mm)  | 0.984 | 0.989 | 0.988 | 1.000 | 0.998 | 0.982 | 0.975 |
| Floor displacement (mm) | 1.000 | 0.983 | 0.996 | 0.967 | 0.985 | 0.990 | 0.987 |
| Minimum principal stress (Mpa) | 0.869 | 0.763 | 0.459 | 1.000 | 0.905 | 0.952 | 0.836 |
| Maximum principal stress (Mpa) | 0.959 | 0.957 | 0.961 | 0.981 | 1.000 | 0.992 | 0.988 |
| Total score              | 3.812 | 3.693 | 3.403 | 3.949 | 3.888 | 3.916 | 3.787 |

It can be seen from Table 4 that when the thickness of the broken top layer is 9.0 m, the score is 3.949, which is the highest. Therefore, if the rock chamber is arranged with the strip-shaped column, the top layer is 9.0 m.

5. Conclusion

Through the similar mine survey results and theoretical calculations, it is concluded that the safe thickness range of the lead-zinc mine is 7.5m~10.5m. Then through the MIDAS/GTS three-dimensional numerical simulation to verify and optimize the stability of different broken top layer thickness, comprehensive comparative analysis from the displacement and stress angle, from the perspective of the simulation results, the conclusion is drawn: if the rock chamber is arranged by the strip column It is recommended to leave a thickness of 9.0m to break the top layer. In the actual blasting construction process, the broken top layer is always stable, there is no collapse phenomenon, and there is less bulk after blasting, and the mining efficiency is guaranteed, indicating that the research results are in good agreement with the actual situation.

Acknowledgments

This work was financially supported by Scientific Research Project of Hunan Provincial Department of Education (Item Number: 19C1377).

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