Calculation Methods and Parameters Analysis of Mining Failure Depth of Coal Mining Face

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Abstract. The research on the mining failure depth of coal seam floor is of great significance for the prevention and control of floor water and gas extraction. It is an extremely important part of coal mining process and has always been a key issue for scholars engaged in mining industry research. On the basis of referring to a large number of previous research results, this paper summarizes the calculation methods of floor failure depth caused by coal seam mining, introduces the theoretical methods commonly used for floor mining failure depth at home and abroad, and analyses the sensitivity of its parameters, aims to provide some references for relevant research.

Introduction

When mining above confined water, floor water-inrush accident caused by floor fracture and aquifer communication caused by mining influence has always been one of the major problems affecting coal mine producing safely. Since 1971, due to frequent floor water-inrush accidents [1-5], the relevant departments have attached great importance to this problem and established many key issues on floor water-inrush problem. Many scholars and field workers have done a lot of work on floor water inrush, and have gotten remarkable results. Many important theories of floor water inrush have been put forward, the "lower three zones theory" [6], the "key stratum theory" [7], the "in-situ fracture and original destruction" [8], and the "lower four zones theory" [9] etc. These theories provide the necessary theoretical basis for accurately predicting floor water inrush, and they all contain a common research content-determination of floor failure depth. How to accurately calculate the floor failure depth and control its maximum value within the permissible range is still one of the key problems to be solved urgently. Accurate determination of the floor failure depth is helpful to reasonably set up water-proof coal pillars, determine the direction of roadway excavation, evaluate the safety of mining and put forward effective measures to prevent water-inrush accidents, and provide scientific suggestions for safe production of coal mine.

It is precisely because of the importance of calculating the floor mining failure depth, the calculation methods have been paidly attention by scholars, and it is also a hot spot in mining engineering research. A number of new research results have begun to emerge, and many scholars use different methods to study it from different perspectives. Based on the previous research results, this paper introduces the main methods of calculation of floor mining failure depth in detail, aims to provide reference for relevant researchers to engage in the research of this field.

Calculation Methods and Parameters Analysis

The Formula under the Theory of Elasticity [10]

According to Mohr-Coulomb failure criterion and elastic mechanics, the maximum failure depth of floor is as follows:

\[
h_i = \frac{n + 1}{2\pi} H \left( \frac{2\sqrt{K}}{K - 1} \cos^{-1} \left( \frac{K - 1}{K + 1} \right) \right) - \frac{R_i}{\gamma(K - 1)}
\]

(1)
where: \( n \) - Maximum abutment pressure coefficient, generally 2-3; \( \phi \) - average internal friction angle of floors; \( \gamma \) - average bulk density of floors; \( K = \frac{1+\sin\phi}{1-\sin\phi} \); \( R_c \) - uniaxial compressive strength of rock mass, \( R_c = \frac{2c \cos \phi}{1-\sin \phi} \).

The Formula under the Theory of Slip Line Field in Plastic Mechanics\(^{[11]}\)

Based on the geometric relationship and logarithmic spiral equation, the depth of the ultimate plastic failure zone under the condition of ultimate abutment pressure is deduced as follows:

\[
h_i = \frac{0.015H \cos \phi e^{\left(\frac{\pi \gamma^2 \phi}{4} \right)}}{2 \cos \left(\frac{\pi}{4} + \frac{\phi}{2}\right)}
\]  

(2)

Yanqing Zhang\(^{[12]}\) also gave a formula for calculating the floor failure depth based on the plate model theory:

\[
h_i = \frac{1.57 \gamma^2 H L}{4R_c^2}
\]  

(3)

Based on rock mechanics, damage-fracture mechanics and rock pressure control theory, Longqing Shi deduced the theoretical calculation formula of floor mining failure zone in the lower four zones theory:

\[
h_i = 59.88 \ln \left( \frac{K_{\text{max}} A H}{\sigma_1} \right)
\]  

(4)

where: \( K_{\text{max}} \) - maximum concentration factor of mine pressure; \( \gamma \) - bulk density of overlying strata; \( \sigma_1 \) - fracture strength of floor fissures.

In order to study the relationship between these parameters in the above theoretical formulas and the floor failure depth, the relationship between the mechanical properties of floor rock and the floor failure depth is analyzed. Formula (1) takes \( n = 2.5, \gamma = 0.026 \text{ MN/m}^3, \) and \( \phi = 30^\circ, \) make \( H \) equal 300m, 450m and 600m, respectively. (In these latter formulas, all parameters under different mining depths are same without special explanation). For \( c, 0.3 \text{~to} 1.2 \text{ MPa} \) is taken, and the curve of floor failure depth varying with rock cohesion under different mining depths is obtained (Figure 1). In formula (4), \( K = 2.8 \) and \( \sigma_1 = 13 \text{~to} 31 \text{MPa} \) are used to obtain the curve of failure depth with the strength of floor rock mass cracks under different mining depths (Figure 2).
Four theoretical formulas and curves of formula (1), formula (2), formula (3) and formula (4) are compared:

We discuss the relationship between mining depth and failure depth of four formulas (Figure 5). It is found that the floor failure depth increases with the increasing of mining depth. The results of formula (1), formula (2) and formula (3) are approximately the same below 400 m mining depth, but there is a big gap when mining depth is greater than 400 m. These formulas has better applicability when the mining depth is not large.

Discuss formula (1), formula (2) and formula (3) on the relationship between internal friction angle and failure depth of rock mass (Figure 6) can be obtained. Formula (1), formula (2) and formula (3) reflect the opposed change law, the failure depths of formula (1) and formula (3) decrease with the increasing of internal friction angle, the failure depth of formula (2) increases with the increasing of internal friction angle, we can verify the change trend reflected by formula (2) is not consistent with the actual situation. The formula (1) only satisfies the actual situation in a certain range, and the negative value appears after 26°. Obviously, it is not valid. Formula (3) has better applicability, and the results obtained have higher reliability.

Mining depth and inclined length of working face are both the reflection of external conditions, and the mining depth determines the magnitude of abutment pressure, while the inclined length of working face is more related to the magnitude of mining pressure and the structure of floor fissures. They play a role in promoting the failure of the floor, as shown in Figure 4 and Figure 5.

Figure 1, Figure 2 and Figure 3 are all reflections of the failure resistance of the floor rock mass. Cohesion $c$, internal friction angle $\phi$, rock uniaxial compressive strength $R_c$ and fracture strength $\sigma_f$.
are physical parameters of the floor rock mass, which determine the failure resistance of the floor rock mass, and the stronger the failure resistance of the floor rock mass, the deeper the damage is.

**Conclusion**

With the deepening of research, the theories of floor mining failure are becoming more and more mature, and many experts and scholars put forward the theory well applied to engineering practice. The theoretical calculation methods of floor failure depth are more diversified, but the formula based on elasticity theory are not applicable to practice. The formulas based on plasticity theory or damage fracture mechanics can be well applied to practice, and the accuracy and reliability of calculation results are greatly improved.

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**References**


