Influence research of weak layer on slope sliding mode and stability

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Abstract. Weak layer is an important factor leading to slope instability, which cannot be ignored in slope stability analysis. In order to explore the influence of weak layers on the slope slip mode and stability of the slope, this paper selects typical open-pit mine slopes containing weak layers as the engineering background, and comprehensively uses geological survey, laboratory tests, theoretical analysis and other methods to verify the characteristics of slope geological structure and physical mechanical properties of soil, at the same time, uses simplified Bishop method to analyze the change law of slope stability under the change of weak layer dip angle, and finally clarifies the influence of weak layer on slope slip mode and stability. The results show that: the initial dip angle of the weak layer is 6°, the corresponding stability factor is 1.553 and the initial landslide mode is the combined failure of shear arc and weak layer. As the dip angle of the weak layer increases, the slope stability coefficient decreases. When the dip angle of the weak layer increases to 56°, the slope slip mode is transformed into the translational failure formed by the weak layer, and the stability factor is reduced to 1.055 at this time.

1. Introduction

Weak layer is the weak structural surface in the slope body, due to its weak mechanical properties, it is an important disaster-causing factor that cannot be ignored in slope stability analysis [1]. In the current slope engineering practice, the landslide disasters caused by weak layers are numerous. Therefore, it is great significance to ascertain the influence of weak layers on slope slip patterns and stability for preventing landslide disasters and reducing landslide disaster losses [2].

At this stage, a large number of scholars have carried out research work on the influence of weak layers on slope stability. Huang Runqiu [3] analyzed large-scale landslide accidents in the field of slope engineering in China since the 21st century, and proposed that weak layers are an important factor inducing slope landslides. Ma Jingjia [4] clarified the influence law of weak layer on slope stability by means of mechanical theory analysis, and realized the optimized design of open-pit mine slope shape. Xia Dong [5] used the typical open-pit mine slope as the engineering background, clarified the creep characteristics of the weak layer by means of laboratory tests, and proposed a long-term strength and stability analysis method for the weak layer. Wang Dong [6] explored the influence of the weak slope along the slope on the slope slip pattern through numerical simulation technology on the basis of analyzing the characteristics of weak layers, and optimized the shape of the slope. Xiao Xian [7]
analyzed the factors influencing the stability of slopes with weak layers, and explored the influence of weak layer morphology on slope slip patterns and stability through improved genetic algorithms. Obviously, a large number of scholars have conducted extensive research in this field and achieved many scientific research results, but there are still certain deficiencies in this research field. The influence of the weak layer on the slope stability is extremely complex and is controlled by many factors. At the present stage, the research results have relatively little research on the influence of the weak layer dip angle on the slope stability, the instability and damage of the slope is precisely affected by the weak layer.

In response to this problem, this paper takes the typical open-pit mine slope as the engineering background, explores the slope slip mode and stability change law by changing the weak layer inclination angle, and provides important scientific means for the open-pit mine slope stability analysis and landslide disaster management Theoretical basis. The research results in this paper are of guiding significance for the study of slope stability with weak layers, and have theoretical analysis significance and engineering reference value for slope stability analysis of open-pit mines.

2. Overview of engineering geology
This article selects the south slope of Shengli East 2nd Open-pit Mine as the engineering background. The slope engineering overview is as follows.

2.1. Project overview
Shengli East 2nd Open-pit Mine is located in the central and eastern part of Shengli Coalfield. Its main structural form is NE-SW, and the two wings are asymmetrical and wide syncline. The mining area is 49.63km², with an average length of 8.0km from east to west and an average width of 6.6km from north to south.

The designed production capacity of the first phase of the open pit mine is 10Mt/a, and the designed production capacity of the second phase is 30Mt/a. The southern mining boundary is bounded by the coal seam outcrops and the F8 and F8-1 faults, and is checked level by level based on the boundary stripping ratio of 6m³/t. The north, east and west sides all use the mineral rights boundary approved by the Ministry of Land and Resources as the surface boundary, and the deep boundary is the No. 6 coal seam floor (partially 6 under 2 coal seam floor). The recoverable reserves in the mining boundary are 3821.98Mt, the recoverable raw coal is 4024.80Mt, and the average stripping ratio is 2.93m³/t.

2.2. Topography
Shengli Coalfield is located in the middle and eastern part of the Inner Mongolia Plateau, on the northern slope of the west of the Greater Xing'an Mountains. It is a plateau hilly terrain with an elevation of 970.0m ~ 1326.6m and a relative height difference of 356.6m. The geomorphology in the area is composed of four geomorphic units: structural denuded topography, eroded accumulation topography, eroded accumulation topography, and lava platform. Shengli East No. 2 Opencast Mining Area is located in the transition zone between the eroded accumulation terrain and low gentle hilly terrain in the middle and east of Shengli Coalfield. It is mainly characterized by hilly and rounded terrain and distributed in a large area in the open area, followed by the valley plain terrain, the terrain is relatively the altitude is 990m ~ 1213m, and the relative height difference is 223m.

2.3. Stratigraphic lithology
The south formation of Shengli East 2 Open-pit Mine is composed of the Shengli Formation of the Quaternary, the Cenozoic Upper Pliocene, and the Mesozoic Cretaceous Lower Peyan Flower Group from top to bottom. The Quaternary is distributed throughout the region, and the lithology is mainly composed of light yellow to gray-yellow gravel and coarse, medium and fine silt and sub-clay, sub-sand, and overburden. The thickness of the whole layer is 1.00m ~ 128.92m, and the average thickness is 37.01m. The thickness changes gradually thinning from southwest to east and northeast. The Tertiary system is distributed throughout the Pliocene, and the lithology is mainly composed of alluvial alluvial
gray-green gravel, sandstone and brown-red, off-white to gray-green clay. The thickness is generally from 8.40 to 103.00m, and the average thickness is 45.26m. The Bayanhu Group Shengli Formation is the main coal-bearing stratum in this area. The bottom boundary of this group is the bottom plate of the 11th coal group. The main lithology is coal seam, gray to off-white siltstone, mudstone, fine sandstone, coarse sandstone with conglomerate; a total of 13 coal seams. The thickness is 30.02 – 720.50m, and the average thickness is 354.83m.

Based on the previous research results of slope stability and the geological results of surrounding open-pit coal mines, the physical and mechanical indexes of the rock mass are finally determined. The physical and mechanical indexes of the selected rock and soil are shown in Table 1.

| stratum         | cohesion c/KPa | internal friction angle θ/° | rock weight γ/KN/m³ |
|-----------------|----------------|-----------------------------|---------------------|
| disposal        | 25             | 19                          | 19                  |
| fourth          | 20             | 33                          | 20.5                |
| third series    | 150            | 26                          | 18.5                |
| mudstone        | 120            | 28                          | 22.2                |
| weak layer      | 10             | 10                          | 10                  |

3. Slope stability analysis

In this paper, the simplified Bishop method is used to analyze the slope stability. This method assumes that the sliding surface is in the shape of an arc or an approximate arc, and solves the slope stability coefficient based on the static balance condition and the moment balance condition.

In the initial state, the dip angle of the weak layer is 6°. At this time, the corresponding slope stability coefficient is 1.553. At this time, the slope slip mode is the combined failure of the shear arc weak layer. At the same time, in order to find out the influence of the weak layer on the slope stability, the slope stability coefficient is solved by changing the dip angle of the weak layer.

![Fig. 1. Slope stability coefficient change curve](image)
It can be seen from Fig. 1 that as the dip angle of the weak layer increases, the slope stability coefficient decreases. When the dip angle of the weak layer is between 6° and 56°, the slope slip mode is combined failure of the shear arc weak layer. When the dip angle of the weak layer reaches 56°, the slope slip mode is converted to the formation of the weak layer Translational damage. The weak layer serves as the bottom sliding surface of the sliding body, and improving or maintaining the strength of the weak layer is a key factor for improving and managing the slope.

4. Conclusion
In this paper, based on the engineering geological characteristics of the south slope of Shengli East No. 2 Open-pit Mine, we deeply study the influence of weak layer morphology on the sliding pattern and stability of the slope. This paper mainly formed the following conclusions

1) The factors influencing the stability of the south slope of Shengli East 2nd Open-pit Mine are analyzed, and the potential slippage pattern of the slope under the action of weak layers is clarified.

2) The influence of weak layer morphology on slope slip mode and stability is revealed. When the weak layer dip angle is less than 56°, the slope slip mode is combined failure of shear arc weak layer, on the other hand, When the dip angle of the weak layer is greater than 56°, the slope slip mode is the translational failure caused by the weak layer.

3) The weak layer as the bottom sliding surface of the sliding body will greatly reduce the slope stability. The south slope of Shengli East 2nd Open-pit Mine is significantly affected by the weak layer, and maintaining the strength of the weak layer is a key factor in managing the slope.

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