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Study on Formation Mechanism of Karst Collapse Column in Sima Coal Mine Based on UDEC

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Abstract

Karst collapse column is a kind of special geological structure widely existing in coalfields of North China. Once the collapse column causes water inrush, it will not only cause serious economic losses, but also often accompanied by casualties. It is one of the geological structures which should be emphasized to prevent in coal mining. Therefore, studying the causes of karst collapse columns is of great significance to ensure the safe and efficient mining of coal resources. Taking the karst collapse column of Sima Coal mine as the research object, this paper studies the formation mechanism of karst collapse column by numerical simulation method. The results show that the final development height of the karst collapse column is 186m, and the collapse process can be divided into four stages: early slow collapse, middle fast collapse, late slow collapse and late filling and compaction.

Keywords

Karst collapse column; Formation mechanism; Numerical simulation; Height of development.

1. INTRODUCTION

At present, the shallow buried coal resources in the central and eastern regions of China are gradually exhausted, and the mining area is gradually extended to the deep. Due to the influence of the deep environment such as high ground stress, high gas and high water pressure, disaster accidents such as rock burst, gas explosion and water inrush frequently occur. The coal mining in the lower group of the North China type coalfield is mainly threatened by Ordovician limestone water in the floor. This kind of water inrush is often caused by the concentrated water channel, and the collapse column is easy to cause the mine water inrush accident with Ordovician limestone water because it can store and conduct water itself. It is one of the geological structures that should be emphasized to prevent in the mining process. Regarding the genetic mechanism of karst collapse column, different scholars analyzed from various aspects of karst collapse column and held different opinions, but their opinions converged on the necessary conditions for the formation of karst collapse column. Firstly, there should be a space for the collapse of the collapse column, that is, there should be soluble rock layer which has been dissolved and formed a certain space. The second is to have active groundwater dynamic conditions; The third is the regional tectonic change caused by the change of ground stress [1]. Jia Guiting [2] studied the origin of plaster dissolution in caves that led to the formation of karst collapse columns. Hou Enke [3] studied the filling characteristics of collapse columns in Caocun coalfield by means of drilling and believed that collapse columns in Caocun coalfield developed on the basis of Ordovician limestone karst caves. Chen Shangping [4] proposed the hydrothermal origin of the caves that led to the formation of karst collapse columns. Taking Xishan coalfield as the research background, Fu Junhua [5] discussed the relationship between geological structure and karst caves under collapse columns. Li Zhihao [6] took Huaibei coalfield as the research background and analyzed the influence of groundwater on karst development under different structures by numerical simulation method. Yang Hongwei [7] studied the dissolution characteristics of the soluble strata under the Changpingjing field and believed that the sulfate - carbonate mixed soluble strata were the basis for the formation of karst collapse columns.Liang Liunie [8], taking Lu 'an Mining area as the research object, discussed the relationship between soluble rock strata and collapse columns and believed that soluble rock strata were the basic conditions for the formation of collapse columns.

With Sima Coal Mine as the research background, this paper carries out numerical simulation research on the formation process of karst collapse column, which can provide basis for late deep mining, prevention and treatment of collapse column, and is of great significance to ensure the safe and efficient mining of coal resources.

2. PROJECT OVERVIEW

Sima Coal Mine is located to the southeast of Lu 'an Coal Mining District, which is located in the middle part of the eastern edge of Qinshui Coal field.The regional stratigraphic division belongs to the North China stratum and the southwest Zhongshan stratum.The general strike of the strata is NE-NE, and it gently dips to the west. It presents wavy undulation along the strike and dip, and the dip Angle is 5-15°.Strata from east to west, from old to new, Ordovician, Carboniferous, Permian, Mesozoic Triassic, Cenozoic Neogene, Quaternary.

There is no large surface water body in Sima Coal mine, and there is only a seasonal river in the well field, which flows 12km to the north and then flows into the Shizi River, which is also a seasonal river and finally flows into the Henan source of Turbid Zhangzhou.The mining area can be divided into six main aquifers and two main aquifers.

From old to new, the aquifers are the middle Ordovician limestone karst fractured aquifer (extremely water-rich aquifer), the Carboniferous Taiyuan Formation limestone karst fractured aquifer (weak water-rich aquifer), the Lower Permian Shanxi Formation sandstone fractured aquifer (weak water-rich aquifer), the Permian Shihezi Formation sandstone fractured aquifer (weak water-rich aquifer), and the bedrock weathering zone Fractured aquifer (weak water-rich aquifer) and Quaternary alluvial pore aquifer (weak water-rich ~ medium water-rich aquifer).

The main water barrier consists of the middle and upper Carboniferous bottom water barrier group composed of mudstone, sandy mudstone and aluminous mudstone between the Ao-Huding boundary and the floor of No.15 coal seam. It is generally 15m thick and mainly blocks the hydraulic connection between the lower Ordovician aquifer and the upper aquifer.Composed of mudstone, sandy mudstone and aluminous mudstone, the water-bearing interval water layer of Permian sandstone is distributed in layers among each aquifer, forming a parallel composite structure and blocking the vertical hydraulic connection between each aquifer.

The Quaternary aquifer is widely distributed in the region, which is mainly replenished by atmospheric precipitation.The bedrock weathering zone aquifers receive replenishment from Quaternary aquifers in areas with relatively thin quaternary coverage.

3. NUMERICAL SIMULATION SCHEME

With the X5 karst collapse column model of Sima Coal mine as a reference, two-dimensional numerical simulation models with the diameter of karst cave of 60m, 80m, 100m (the actual collapse column of Sima Coal mine), 120m and 140m were established in UDEC, as shown in

Figure 1. According to the actual collapse column data, the height of karst cave is 15m and developed in the Ordovician limestone strata.The bottom of the karst cave is 42.5m away from the lower boundary of the model, and the size of the numerical model is 600×350m. The cave is divided into 11,715 blocks and 1,948,577 small units, the length of which is between 0.5 and 10m.

The left and right edges and bottom of the model are fixed, and the equivalent overburden load of 9.8MPa is applied to the top.Elastoplastic mechanics hypothesis and Mohr-Coulomb model were adopted in the model. The rock mechanics parameters used in the model were measured through rock mechanics tests, as shown in Table 1.

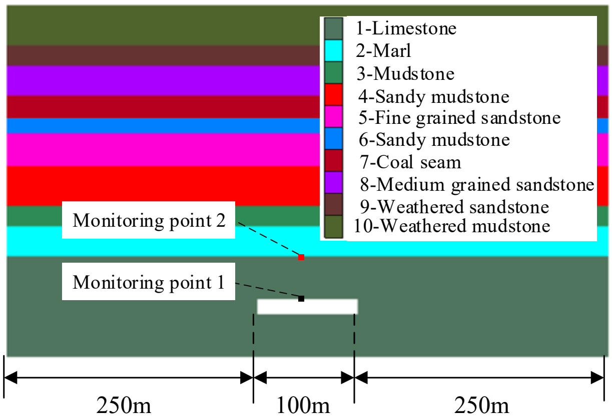


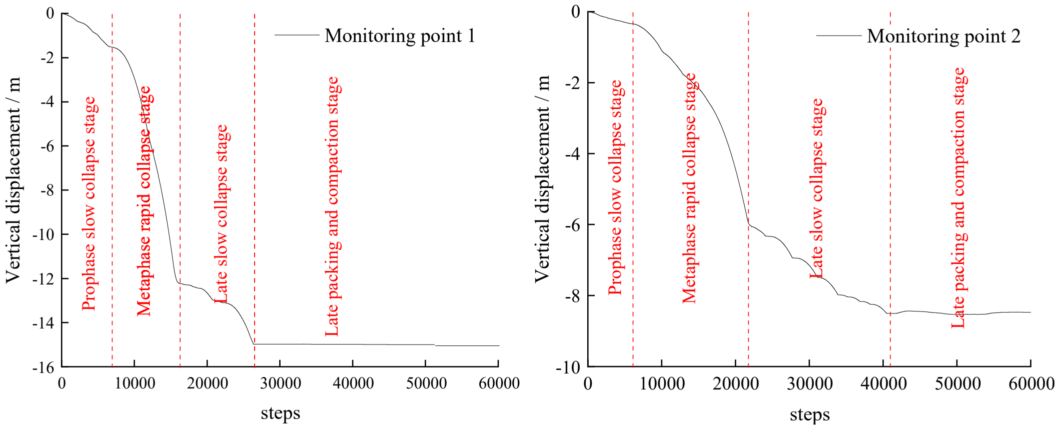
Figure 1. Numerical model diagram

Table 1. Physical and mechanical parameters of rock

Structural plane	Normal stiffness /$\times 10^{9}$N/m	Tangential stiffness /$\times 10^{9}$N/m	Cohesion /MPa	Angle of friction /°	Tensile strength /MPa
Lestone	24.32	16.65	0.50	37.00	0.20
Mrl	22.92	15.06	2.00	38.00	1.00
Mdstone	21.99	14.71	1.50	25.60	1.00
Sandy mudstone	21.99	14.71	1.50	30.00	0.90
Fine grained sandstone	20.39	14.65	1.00	37.00	0.20
Sandy mudstone	20.39	14.06	2.00	30.00	0.50
Coal seam	20.63	14.15	1.00	24.00	0.20
Medium grained sandstone	22.63	14.99	2.00	30.00	1.00
Weathered sandstone	20.98	14.65	0.50	27.00	0.20
Weathered mudstone	20.84	14.06	2.00	20.00	1.00

4. ANALYSIS OF STRESS AND DISPLACEMENT CHARACTERISTICS OF KARST COLLAPSE COLUMN DURING COLLAPSE STAGE

The vertical displacement of monitoring points on the upper and lower surfaces of karst cave roof in the process of collapse is shown in Figure 2. It can be seen that the collapse of karst cave roof can be roughly divided into four stages: slow collapse in the early stage, rapid collapse in the middle stage, slow collapse in the late stage and filling and compaction in the late stage. This law is extended to the whole collapse column formation process for analysis.



(a) Monitoring point 1 (b) Monitoring point 2

Figure 2. Vertical displacement change curve of monitoring points during Karst Collapse Column collapse in Sima Coal Mine

FIG. 3, FIG. 4 and FIG. 5 respectively give the model diagram, vertical displacement diagram and vertical stress diagram of collapse column of Sima Coal mine.

(1) Prophase slow collapse stage

The primary rock stress of the karst cave roof begins to lose balance due to the influence of the karst cave, as shown in Figure 5(a). During the redistribution of the stress of the karst cave roof, a tensile stress zone around the column is generated, and the vertical stress inside the column is about 1.94 Mpa. Under the influence of karst cave, the roof of karst cave produces tensile changes. Because the tensile strength of rock strata is far less than the compressive strength, the vertical tensile stress of rock strata above the karst cave is greater than the tensile limit of rock strata itself, resulting in the rock strata above the karst cave being damaged by the tensile stress and starting to collapse. As shown in FIG. 3(a) and 4(a), the vertical displacement on the left side of the collapsed rock layer is greater than that on the right side.At this stage, the collapse of karst cave roof only occurred in limestone layer, and stratification also occurred in the lower part of the adjacent marl layer. At this time, the development height of the column was about 58.5m.

(2) Metaphase rapid collapse stage

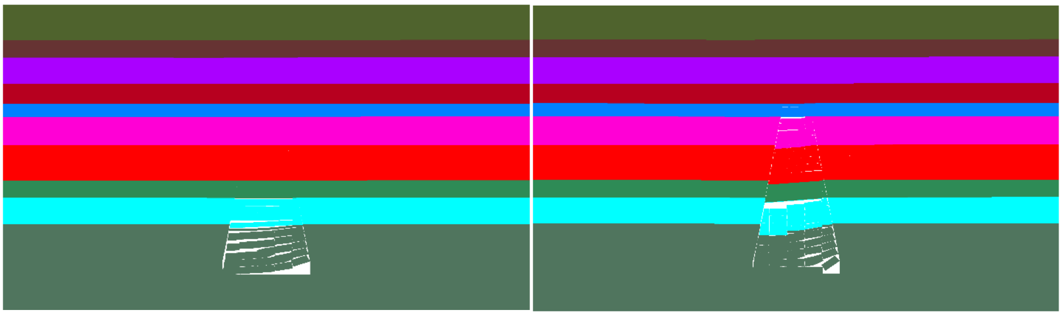
As shown in fig. 5(b), with the collapse of overlying strata in the karst cave, the vertical stress inside the column increases somewhat compared with the previous slow collapse stage. At this time, the maximum vertical stress inside the column is 2.05mpa. As shown in FIG. 3(b) and 4(b), due to the influence of the triangular zone at the bottom of the cave, the overall vertical displacement of the collapsed rock strata presents a ladder shape with larger left side and smaller right side, and the cracks between the collapsed rock blocks on the right side are significantly larger than those on the left side.

(3) Late slow collapse stage

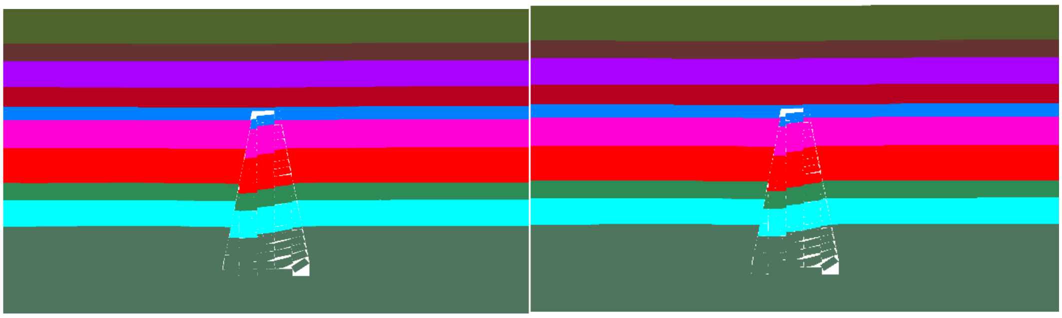
As can be seen from Figure 5(c), at this time, the maximum vertical stress inside the column is 2.49MPa. With the collapse of the upper rock layer, the rock block that has collapsed at the bottom begins to appear a compaction zone, and the rock layer near the left side of the cave floor changes from the original tensile stress to compressive stress, which is because the cracks formed by the collapse between these rock masses are compacted. From the original tension state to the state of compression. As shown in FIG. 3(c) and FIG. 4(c), the displacement on the left side of the column is less than that on the left side, and the gap is roughly between 4-6m. At this stage, the column developed to the sandy mudstone level 175m away from the cave floor, with a height of about 186m.

(4) Late packing and compaction stage

As shown in figure 5(d), from the late slow collapse stage to the late filling and compaction stage, the maximum vertical stress of the column has not changed significantly, but the range of tensile stress has narrowed. It can be seen from figures 3(d) and 4(d) that at this stage, the column has stopped collapsing upward, that is, the final height of the column is 186m, the same as the late stage of slow collapse.

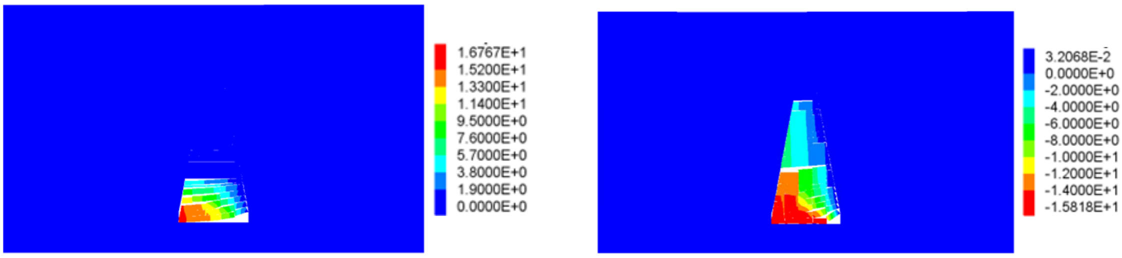


(a) Prophase slow collapse stage (b) Metaphase rapid collapse stage

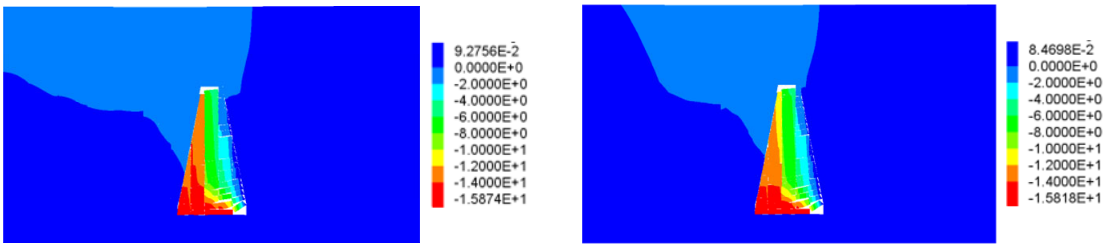


(c) Late slow collapse stage (d) Late packing and compaction stage

Figure 3. Model diagram

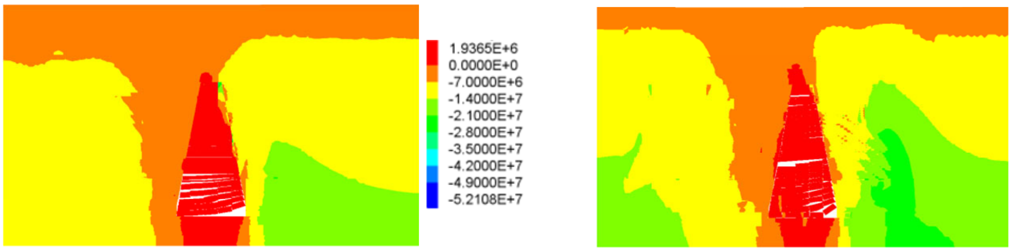


(a) Prophase slow collapse stage (b) Metaphase rapid collapse stage

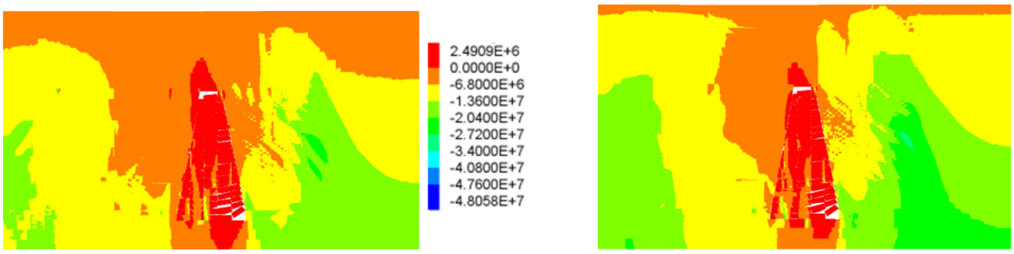


(c) Late slow collapse stage (d) Late packing and compaction stage

Figure 4. Vertical displacement diagram



(a) Prophase slow collapse stage (b) Metaphase rapid collapse stage



(c) Late slow collapse stage (d) Late packing and compaction stage

Figure 5. Vertical stress diagram

5. CONCLUSIONS

In this paper, Sima Coal Mine is used as the background to establish a numerical simulation model for the formation of karst collapse column. By analyzing the stage characteristics and stress displacement characteristics of karst collapse column. he conclusion is as follows: the final development height of the karst collapse column is 186 , and the collapse process can be divided into four stages: early slow collapse, middle fast collapse, late slow collapse and late filling and compaction.

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