Stability Monitoring of Goaf Based on Remote Sensing Image

Zhongcheng Zheng *, Yijiang Zhu

CHINA SOLIBASE ENGINEERING Co., Ltd. Beijing China, 101300

* Corresponding Author Email: zzc521zzc@163.com

Abstract. Large scale mining of coal resources is a major factor causing goaf collapse in China. According to the statistics of 21 major coal mining provinces, the area of coal mining surface subsidence is up to 4.5 billion m2, posing a great threat to the regional ecological environment and people's lives and property. The rapid development of remote sensing technology has changed the traditional field survey method and has become one of the important means of environmental monitoring. Information can be obtained not only by photography, but also by scanning. The amount of information obtained by remote sensing far exceeds that obtained by conventional traditional methods. Based on remote sensing images, this paper studies the stability monitoring of coal mine goaf, establishes a ground pressure monitoring network suitable for the actual situation of the mining area, and carries out long-term effective ground pressure monitoring. Through remote sensing images, we can fully grasp and avoid the hazards of the goaf. Remote sensing technology has the characteristics of wide use, large detection range, and rich information acquisition. It can comprehensively obtain the basic information of the mining area environment, and then monitor the mining area environment.

Keywords: Remote sensing image, Coal mine goaf, Stability monitoring.

1. Introduction

In the process of mining and utilization of coal mines, many environmental and geological disasters have been caused due to various factors such as awareness, methods and policies, which restrict the sustainable development of China's social economy, among which the problem of goaf collapse is particularly prominent. Large scale mining of coal resources is a major factor causing goaf collapse in China. According to the statistics of 21 major coal mining provinces, the area of coal mining surface subsidence is up to 4.5 billion m2, posing a great threat to the regional ecological environment and people's lives and property. The stability of the goaf has a significant impact on the safe production of the mine. The goal is mainly concentrated in the west, and its mining elevation range is+830m~+530m [1]. The combined development mode of adit, ramp and blind inclined shaft is adopted, and the room pillar mining method is adopted. The mining sequence is from top to bottom, and the trackless vehicle transportation is adopted; Manganese ore is divided into middle sections along the dip, with an elevation of 25m between the middle sections. The middle transport roadway is driven along the vein. Each middle section is divided into ore blocks every 60~80m along the strike. Ensuring the stability of the goaf is a necessary guarantee for safe and normal production, and roof caving is an important manifestation of the instability of the goaf.

The initial mining time is short, and the mining is carried out when the filling and other supporting technologies are not available. The hazards of the goaf formed by underground mining are manifold, which may lead to wall spalling, roof fall, water inrush, earthquake, rock burst, rock burst, ground pressure, ground collapse, ground fissures, and the resulting landslide, debris flow, surface vegetation damage, etc. The goaf cannot be filled in time or the strength of the filling body cannot be guaranteed, and the wall spalling of the pillar is serious, it has left a hidden danger for the next recovery of ore pillars [2]. The rapid development of remote sensing technology has changed the traditional field survey method and has become one of the important means of environmental monitoring. Remote sensing is the product of modern science and technology. It can not only obtain the information of the visible light band of the ground object, but also the information of the microwave band. Information can be obtained not only by photography, but also by scanning. The amount of information obtained by remote sensing far exceeds that obtained by conventional traditional methods.

At present, the environmental problems in the development of mine resources have attracted extensive attention from all walks of life, but the traditional environmental monitoring methods can no longer meet the needs of environmental protection in the rapid development of mineral resources development. How to monitor the mining area environment quickly and efficiently has become an urgent problem to be solved [3-4]. Based on remote sensing images, this paper studies the stability monitoring of coal mine goaf, establishes a ground pressure monitoring network suitable for the actual situation of the mining area, and carries out long-term effective ground pressure monitoring. Through remote sensing images, we can fully grasp and avoid the hazards of goaf. Remote sensing technology has the characteristics of wide use, multiple detection means, large detection range, and rich information, and can comprehensively obtain the basic information of the mining area environment, then monitor the mining area environment.

2. Design and installation of goaf monitoring scheme

2.1. Stress monitoring system

On-line stress monitoring system is used to monitor the stability and bearing capacity of the pillar in the stress concentration area at the boundary of the goaf, and give an early warning when the pillar is unstable. If the mined-out area collapses, and the pillars in the mined-out area are not completely destroyed, the pressure of the rock strata above the mined-out area cannot be directly transmitted to the monitoring pillars, and the stress monitoring data will not change drastically, so that an early warning cannot be issued in time [5]. The basic principle of on-line stress monitoring system is to find out the location and trend of stress change in goaf by monitoring the relationship between rock mass movement, roof fracture, crack development and surrounding rock stress in real time, so as to realize real-time early warning and prediction of rock mass fracture danger zone and degree [6]. The monitoring system is mainly composed of pressure sensor, communication optical cable, monitoring host and monitoring server. The monitoring system is shown in Figure 1.

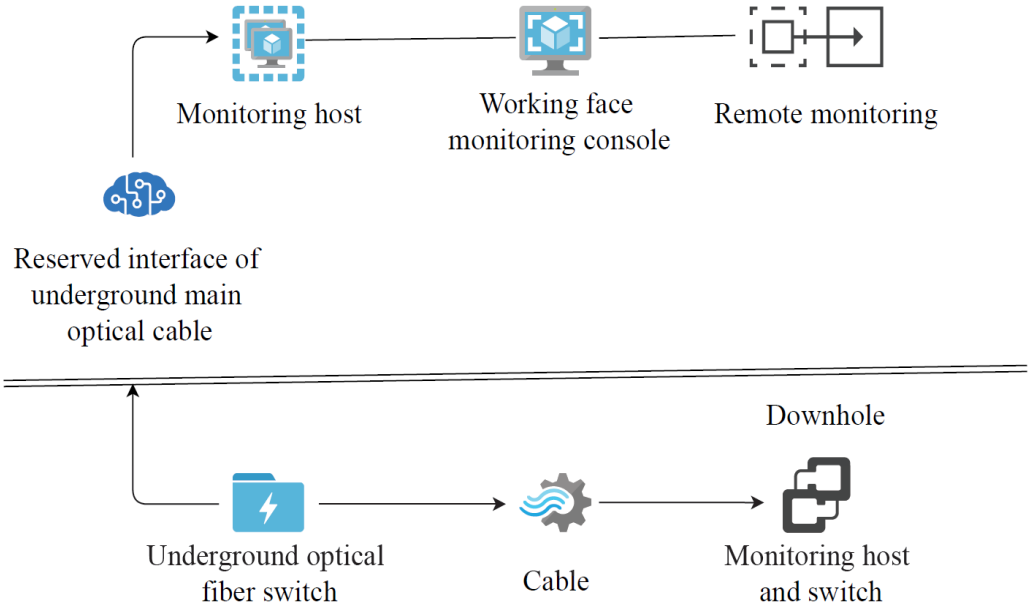


Figure 1. Stress online real-time monitoring and early warning system

According to the occurrence conditions of ore bodies, sublevel open stoping method is adopted for mining. The ore body is divided into several ore blocks along its strike. The designed ore block is 28 m long, and the width of the ore room and pillar is 14 m. The width of the ore block is the thickness of the ore body, and the height is 50 m. According to the specific conditions of mine geology, ore-rock characteristics, mining technology, etc., the online real-time stress monitoring and early-warning system uses analytical method to analyze the self-stabilization ability of surrounding rock and the

bearing capacity of pillar. To control the environmental pollution in mining areas and transform the ecological environment in mining areas in a benign direction, we must first understand the present situation of environmental damage in mining areas in China, make a scientific and objective evaluation of the current situation, and make a reasonable plan on this basis, and adopt feasible technical means to control pollution through the stress online real-time monitoring and early warning system, so as to improve the quality of ecological environment in mining areas.

2.2. Micro-seismic monitoring system

The goaf collapse in the area is located in the steep mountain area. The rock mass is broken and the active fractures are developed, resulting in the goaf collapse caused by mining; At the same time, it is very easy to cause ground fissures, collapse and other secondary disasters, forming a mine geological disaster group. There is still a long way to go to meet the requirements of the environmental monitoring and forecasting system in the mining area. We cannot timely and accurately conduct large-scale, continuous and dynamic monitoring of the environmental pollution and ecological damage in the mining area that is urgently needed by the country, and it is also difficult to comprehensively, timely and accurately reflect the environmental quality of the mining area [7]. Therefore, it is necessary to build a microseismic monitoring system to improve the current situation. The structure of the microseismic monitoring system is shown in Figure 2. The geophone installed in the monitoring area receives the vibration signal and transmits it to the microseismic monitoring substation. The monitoring substation converts the electrical signal into an optical signal and transmits it to the monitoring master station via optical fiber, and then transmits the data to the host computer through the internal switch for positioning analysis and display of microseismic events.

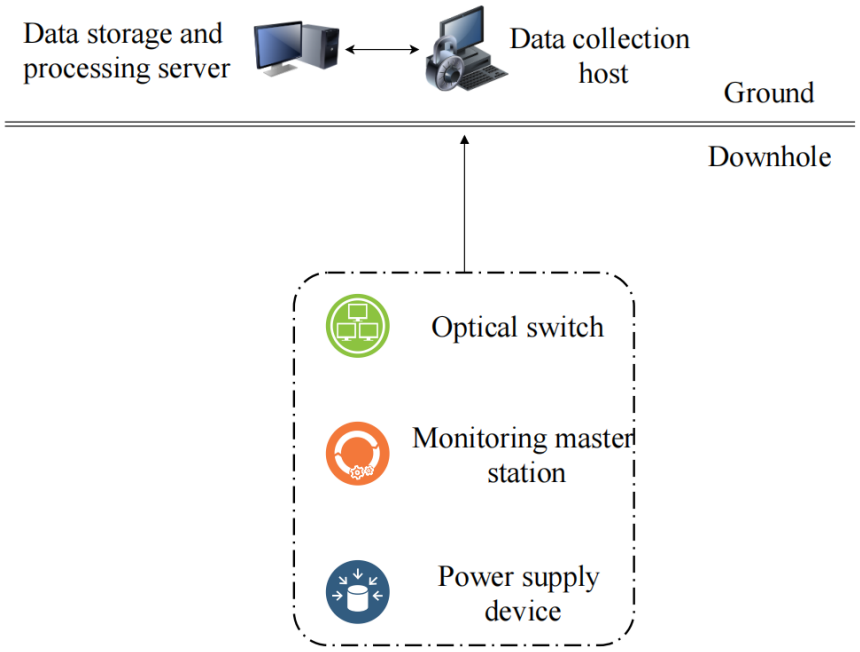


Figure 2. Microseismic Monitoring System

The microseismic monitoring system is a high-precision microseismic monitoring system, which can monitor the vibration events with a vibration energy of more than 100J, a frequency of less than 1500Hz and less than 110dB. In the process of ore body mining, both the pillar and stope roof are ores. After mining, the roof rocks are mainly altered diorite and skarn. Because skarn only exists in local sections, altered diorite is selected as the evaluation rock mass, and the lowest strength of altered diorite is taken as the saturated uniaxial compressive strength [8-9].

3. Application of Remote Sensing Image in Environmental Monitoring of Mining Area

3.1. Remote sensing image processing of environmental monitoring in mining area

Use medium-resolution remote sensing images to conduct a large-scale census to delineate areas with concentrated mine development and relatively serious environmental damage; Secondly, the high-resolution remote sensing images are used to monitor the large-scale environmental damage and geological disasters in the delineated area, and the areas with the most serious environmental damage are pointed out. The subsidence right above the goaf is the largest, forming a concave shape; The farther the roof is from the goal in the horizontal direction, the smaller the settlement is, and it gradually approaches the stable state, and the stability is getting better and better. This point is just at the bottom of the depression formed by the roof of the goaf [10]. Therefore, according to different requirements of image interpretation, different bands in remote sensing images can be selected for combination, redundant information of images can be removed, and image processing speed, image interpretation quality and accuracy can be improved. The calculated continuous deformation time of mined-out subsidence area after stopping mining in coal mines of different scales is shown in Table 1.

Table 1. Duration of collapse deformation caused by stopping mining in coal mines of different scales

Serial number	Mining scale	Mining depth /m	Deformation time /a
1	Large-scale	700~930	4.3~5.8
2	Medium-sized	400~700	2.2~4.3
3	Small-sized	100~400	1.1~2.1

Based on the remote sensing image, the farther away from the goaf, the settlement value will decrease, and the roof of the goaf will be more stable. The plane grid diagram used to generate the three-dimensional model on the basis of the profile of the exploration line along the ore body strike, with the height of the middle section of 50m, and the width of the ore room and pillar according to the design of large ore room and small pillar [11].

Two-dimensional quadrilateral isoperimetric element is used as the main element, and the local element can be degenerated into triangular element after automatic optimization by computer. The maximum settlement value of the 62m middle roof is smaller than that of the +126 m middle roof. It shows that the depth of mined-out area is inversely proportional to the settlement, and the subsidence value is large when the mined-out area is close to the surface, otherwise it is small. The principal stress is tensile stress, which is located at the acute angle of the footwall of the goaf. The peak value of the tensile stress is 47. 637 MPa, which is generally higher than the tensile strength of the surrounding rock of the footwall. This phenomenon is closely related to the excessive exposed area of the roof of the goaf and the excessive mining depth. The location of stress concentration is related to the shape of mined-out area, dip angle of ore body, etc. Remote sensing image is the true reflection of the surface of the study area, which contains the texture features of ground objects. Digital elevation model represents the surface topography discretely by digital matrix, and the combination of them can generate a virtual three-dimensional image map of a certain area.

3.2. Remote sensing evaluation of environmental quality in mining area

Select evaluation indicators, analyze and establish appropriate evaluation model to evaluate the ecological environment quality of the mining area. The commonly used environmental quality assessment indicators mainly include vegetation coverage, dust pollution rate, water pollution rate, water and soil loss rate and geological disaster occurrence rate. The extraction of evaluation indicators is usually obtained through interpretation of remote sensing images. The change of the number, scale and status of underground mining points of coal mines can affect the change of the development trend of goaf collapse area. The change of the occupied area of coal mines is being used to reflect the

difference of mining intensity, which is also related to the change trend of goaf collapse area. The deformation trend of goaf collapse area can be inferred from the change of the mining status of coal mines. Due to the continuous mining of large and medium-sized coal mines in the mining area, the deformation of the existing goaf collapse area will continue to occur, and there is a possibility of new goaf collapse deformation. Therefore, environmental quality assessment occupies a non-important position. The environmental quality assessment method is a scientific method to assess and predict the environmental quality of a specific area based on certain standards. Determine the evaluation object, scope and purpose, and determine the evaluation accuracy accordingly.

To judge, evaluate and predict the environmental quality, the common methods for environmental quality evaluation include environmental comprehensive index method, analytic hierarchy process and fuzzy mathematics method. It is suggested that the mine management department should severely crack down on all kinds of illegal mining activities in the name of mine environmental management, strictly regulate the mining activities of gangue and shale brick plants, encourage the use of abandoned coal gangue in the process of coal production, and prohibit the mining and utilization of naturally occurring coal gangue to avoid creating new ecological environment damage. The underground mining areas of large and medium-sized coal mines belong to potential unstable areas. The time required for the goaf collapse area to become stable can be calculated by remote sensing evaluation of the service life and mining depth of the mine and the environmental quality of the mining area.

4. Conclusion

Based on remote sensing images, this paper analyzes the present situation of ground pressure development in mined-out areas, effectively monitors the mined-out areas through reasonable selection of monitoring methods, studies the development and deformation law of ground pressure in mined-out areas according to the monitoring results, and summarizes the critical conditions for instability of mined-out areas with weak strata in this mine. The detailed detection results of unknown mined-out areas are analyzed, the basic characteristics of mined-out areas below 1202m level in this mining area are summarized, the occurrence law of ground pressure disasters in this mine in recent years is analyzed, the ground pressure monitoring methods suitable for the characteristics of this mine are put forward, and the key areas of ground pressure monitoring are determined. Through the microseismic monitoring results during the mine production and shutdown period, it is found that blasting vibration has a great influence on microseismic events in goaf. Under the influence of blasting vibration, rocks inside the roof of goaf are more likely to break, resulting in the release of energy inside the roof, easily causing roof collapse and other events. The stability analysis of stope shows that the rock mass quality and the self-stabilization ability of surrounding rock are good. In general, the safety factor of pillar bearing capacity is greater than, but there should be enough thick protective pillars when encountering faults and fracture zones. Collapse still threatens the safety of production and life, so it is necessary to fill the existing clear collapsed areas for plugging, curtain grouting to prevent soil erosion, and increase the recharge of surface water to aquifers. Based on remote sensing images, geophysical methods should be used to find out the location and scope of coal mine goaf, and corresponding measures should be taken.

References

[1] Fei Z, Dong W. A Numerical Study on Critical Factors Influencing Small Coal Mine Goaf Stability [J]. Chinese Journal of Underground Space and Engineering, 2018, 14 (2): 9 - 17.

[2] Bhattacharya A. Coal Mine Fire: Monitoring Through Thermal Remote Sensing Technique [J]. Indian Journal of Geosciences, 2020, 28 (3): 74 - 79.

[3] Wang X W. Stability Analysis and Engineering Treatment of Highway Landslide in Goaf of Xiyu Coal Mine [J]. Construction & Design for Engineering, 2019, 39 (10): 25 - 38.

[4] Cheng G, Han J, Lu X. Remote Sensing Image Scene Classification: Benchmark and State of the Art [J]. arXiv e-prints, 2017, 45 (12): 25 - 43.

[5] Miao X X, Zhang H Q, Yu W, et al. Nondestructive testing of bolt support quality and stability control of coal mine roadways – ScienceDirect [J]. Advances in Coal Mine Ground Control, 2017, 55 (20): 227 - 268.

[6] Hui S, Wang Q. Integrated Evaluation on Site Stability of Goaf of a Coal Mine [J]. Modern Mining, 2018, 38 (9): 9 - 24.

[7] Liu J K. Remote Sensing Monitoring and Analysis of Mine Geological Mining Based on Geophysical Prospecting Technology [J]. World Nonferrous Metals, 2018, 18 (3): 5 - 16.

[8] Gao L, Zhang S. Application of UAV Remote Sensing Technology in Ground Collapse Monitoring of Coal Mining [J]. Microcomputer Applications, 2019, 33 (11): 20 - 28.

[9] Vinoth, L, Ajay, et al. Experimental Study on Monitoring of Slope Stability Using High Resolution Microseismic System in an Indian Opencast Coal Mine [J]. The Indian mining & engineering journal, 2017, 56 (1): 24 - 28.

[10] Wang X, Amp A. Discussion on application of satellite remote sensing technology in coal resource exploration and exploitation [J]. Mine Surveying, 2017, 20 (5): 10 - 18.

[11] Luo J H. Application of GNSS system to geological disaster monitoring in mine goaf [J]. World Nonferrous Metals, 2018, 36 (8): 42 - 36.