WEP Warwick Evans Publishing

International Journal of Natural Resources and Environmental Studies

ISSN: 3006-2012 (Print), ISSN: 3006-0834 (Online) | Volume 5, Number 2, Year 2025
DOI: https://doi.org/10.62051/ijnres.v5n2.05
Journal homepage: https://wepub.org/index.php/IJNRES/index

Ecological Restoration and Key Technologies in High-Diving Mining Areas

Huifang Zhang

Henan Polytechnic University, Jiaozuo, China

ABSTRACT

Ecological management and environmental restoration of mines are the cornerstone of sustainable resource exploitation, and it is imperative to strengthen the ecological protection and restoration of mining areas. High-diving mining areas are often located in the hinterland of the plains, with high surface diving levels and proximity to urban areas, forming a unique ecosystem of land and water. Such mining areas are characterized by wide subsidence, widespread water accumulation, and challenging treatment technologies. Therefore, in view of the particularity of the high-diving mining area of Zhaogu No. 1 Mine, it is particularly important to adhere to the principle of "adapting measures to local conditions, agriculture if it is suitable for agriculture, fishing if it is suitable for fishing, and construction if it is suitable for construction". Through an in-depth analysis of the ecological and environmental problems exposed during the mining process of Zhaoguyi mine, we found that the mining area is currently facing six serious challenges: significant damage to the topography and landscape, extensive damage to natural vegetation, serious damage and illegal occupation of land resources, resulting in a sharp reduction in arable area, and unprecedented damage to the ground infrastructure. In order to solve the ecological and environmental problems left by Zhaogu No. 1 Mine, three core key technologies were studied: topography and landform remodeling technology, soil reconstruction and vegetation restoration technology, channel reengineering and road engineering technology. The synergy of these technical systems provides a comprehensive strategic planning and implementation plan for the geomorphological restoration, vegetation restoration and surface infrastructure reconstruction of the Zhaogu mining area. Through the on-site ecological restoration project of Zhaogu No. 1 Mine, this paper not only verifies the efficiency and applicability of the ecological restoration technology combined with specific terrain, ecological environment and surface facilities under the conditions of high diving mining area, but also highlights the great guiding significance of these research results for the ecological environment restoration work of Zhaogu No. 1 Mine and even similar mining areas, and sets a model for future ecological restoration practice.

KEYWORDS

High-Diving Mining Area; Subsidence of Stagnant Water; Terrain Remodeling; Ecological Restoration.

1. INTRODUCTION

As the core mineral resource in China's energy structure, coal occupies a pivotal position and is of irreplaceable importance for maintaining national energy security and economic development. Over the years, the proportion of coal resources has been in the highest position of energy in China, the proportion is as high as about 60%, and with the acceleration of industrialization, the increasing demand for resources, and the increasing expansion of mining activities, not only the ecological environment of the mining area has suffered serious damage and threat, but also has brought harm to the living environment and human health in the surrounding areas. Under the macro background of

promoting the construction of ecological civilization, the ecological restoration and management of mining areas has become an urgent topic that needs to be solved urgently and cannot be ignored in the field of environmental protection in China. How to effectively reduce the negative impact of mining activities on the ecological environment, restore and reconstruct the damaged ecosystem, and realize the sustainable use of natural resources and the harmonious coexistence of the ecological environment by taking scientific and reasonable ecological restoration measures has always been the unswerving and long-term goal and vision of China's mining area development.

In the mining operation of the mining area, the high-diving mining area is a unique and complex geological type, and its special condition poses a severe test to the regional ecological balance and sustainable development. Such mining areas are not only rich in mineral resources, but also mired in the quagmire of ecological crisis, such as rapid degradation of soil quality, frequent land subsidence, disorderly occupation of land, significant reduction of vegetation cover, heavy damage to the ecosystem, and large-scale coal mining subsidence and water accumulation areas formed due to mining activities, all of which constitute an ecological crisis that needs to be solved urgently in high-diving mining areas. Taking the Zhaogu No. 1 Mine as a whole, for example, its mining activities have formed a subsidence area of about 1,000 square kilometers, of which the area of water accumulation is as high as 500 square kilometers, accounting for between 60% and 70%, and the depth of water accumulation in some areas is as deep as 20 meters. To solve the flood disaster of subsidence of Zhaogu No. 1 Mine, it is urgent to take decisive action, and it is urgent to deal with and solve it.

Based on the analysis of the current situation of ecological and environmental damage in the waterlogged subsidence area of Zhaogu No. 1 mine, this paper advocates the concepts of adapting measures to local conditions, agriculture if it is suitable for agriculture, fishing if it is suitable for fishing, and construction if it is suitable for construction, and formulates appropriate restoration strategies and technical means according to the specific conditions of the mining area.

2. THE CURRENT SITUATION OF THE MINING AREA AND THE MAIN ECOLOGICAL AND ENVIRONMENTAL PROBLEMS

2.1. Current status of the mining area

Zhaogu mining area is located in the southwest plain area of Huixian City, the terrain is slightly inclined from northwest to southeast, the altitude range is between 75 and 100 meters, showing typical plain geographical characteristics, the climate of the region belongs to the warm temperate continental, the season changes clearly, the climate in spring and autumn is pleasant, the summer is warm and rainy, the winter is cold and dry, suitable for long-term residence and crop growth. The soil is mainly yellow tide soil, with good air permeability and fertilizer retention ability, mild soil quality, and easy to cultivate. The vegetation in the project area of Zhaogu No. 1 Mine is diverse, and agricultural vegetation occupies a dominant position. Among them, wheat, corn, vegetables and legumes are the main varieties of agricultural planting. In terms of green trees, poplars, willows and paulownia trees form the main body, and occasionally dotted with a small number of herbaceous plants and shrubs. The area belongs to the Weihe River system of the Haihe River Basin, with a well-developed water system, crisscrossed by major rivers such as the Yu River, the Huangshui River, the Shimen River and the Communist Canal, and the hydrogeological conditions are relatively simple and clear. Through field investigation, the land in the study area to be reclaimed is seriously waterlogged, with a cumulative damage area of 118.29 hm2, of which 75.70 hm2 is in the area with a subsidence depth greater than 3 m, and perennial water accumulation occurs, and the area of the area with a subsidence depth of 1-3 m is 24.98 hm2, with seasonal water accumulation.

2.2. Major ecological and environmental issues

The main ecological and environmental problems in Zhaogu mining area are manifested in five types: topography and landscape destruction, vegetation destruction, land damage and occupation, reduction of cultivated land area, and serious damage to ground facilities.

2.2.1. Destruction of topography and landform

The coal seam mining activities of Zhaogu No.1 Mine have led to ground subsidence and ground fissures, which have caused significant damage and impact on the original topography and landform. Since the official operation of Zhaogu No.1 Mine in 2009, it has formed a goaf area of 317.27hm2, resulting in surface goaf collapse, local surface undulation, and the formation of two subsidence and water accumulation areas of different scales. According to the numerical calculation of the field investigation and EIA report, the surface subsidence area of the study area to be reclaimed is about 118.29hm2. The flat land becomes a depression, which has a certain impact on agricultural planting, and has a great impact on the topography and landform, and the damage is serious. The extent of land damage is shown in Table 1 and Figure 1.

Table 1 The specific situation of the subsidence of Zhaogu No.1 mine

Grade	Depth of collapse (m)	Manifestations	Area（hm2）
Mild	＜1	No standing water	17.61hm2
Moderate	1~3	Accumulation of Water during the rainy season	24.98hm2
Severe	＞3	Perennial stagnant water	75.70hm2

Fig.1: Different levels of damage range

2.2.2. Vegetation destruction

The long-term coal mining activities of Zhaogu No. 1 Mine have had a profound impact on the mining area and the surrounding environment. This mining activity often causes significant damage to vegetation. The main reason is that mining requires large-scale excavation, blasting and excavation of the surface, which directly weakens the original vegetation coverage and significantly reduces the vegetation coverage of Zhaogu No. 1 Mine. All types of land within the mining area have been damaged to varying degrees, and the specific damaged area is shown in Table 2.

Table 2 Area damaged by different land types

Land type	Damaged area（hm2）
Garden	2.70
Woodland	27.14
Grassland	0.33
Other lands	10.45

2.2.3. Land damage and occupation

According to the detailed data statistics and analysis, it is known that in the long-term mining process, the Zhaogu No. 1 mine has caused different degrees of occupation and damage to about 41.98hm2 of land resources. Among them, the industrial site covers an area of about 37.26 hm2, and has gone through the land acquisition procedures, of which the production and living area is dominated by buildings and hardened ground, and the gangue dump is located on the west side of the industrial site, with a design area of 5.63 hm2, and the current gangue stacking area is 2.43 hm2, the pile height is about 16m, and the stacking volume is 144625m3. The Xifengjing Industrial Site covers an area of approximately 3.88hm2. Land destruction and occupation have led to a reduction in arable land and landless farming, affecting food security and farmers' livelihoods.

2.2.4. (The area of cultivated land decreases

After the mining of high-diving mines, a huge subsidence area is formed, which destroys a large amount of arable land, and the mining site needs to occupy a large area of land, resulting in part of the arable land being converted into a mining area, thus reducing the area of land available for agricultural production. Zhaogu No. 1 Mine is under the jurisdiction of Jitun and Zhaogu Townships of Huixian City, involving about 6,089 farmers and a total population of more than 24,400 people. The region is rich in food crops, such as wheat, corn and sweet potatoes, while cash crops are represented by tobacco, peanuts, cotton and medicinal herbs, and agricultural production is very diversified. However, the mining activities of Zhaogu No. 1 Mine have caused a large amount of cultivated land to be damaged, accounting for the main part of the total damaged area, about 81.58%.

2.2.5. Ground facilities are seriously damaged

In mining operations, the movement and destruction of underground rock formations inevitably lead to surface subsidence, which in turn causes serious damage to various facilities on the ground, and infrastructure such as residential houses, traffic roads, and farmland water conservancy systems have been damaged and affected to varying degrees.

3. ECOLOGICAL RESTORATION AND GOVERNANCE IDEAS

This governance adheres to the principle of "adapting measures to local conditions and implementing policies by classification", and flexibly chooses the appropriate development direction of agriculture, fishery or construction according to the actual conditions of Zhaogu No. 1 Mine. Use system thinking to combine the ecological restoration of the mining area with the improvement of the living environment, strictly follow the established planning concept, and promote the sustainable development of the mining area. At the same time, based on the current situation of the ecological environment in the region, according to the living environment, hydrological conditions and geological conditions around the mining area, according to the ecological governance idea of "environmental governance, ecological conservation, and increasing natural capital for harmonious coexistence with man and nature" and "land subsidence treatment, land subsidence restoration, terrain remodeling, and landscape restoration". Engineering governance ideas. The ecological restoration of the waterlogged area should be closely integrated with the long-term development of the local social economy. Scientifically plan the spatial layout of the subsidence area to realize the efficient use of land resources and the harmonious coexistence of the ecological environment. While restoring the structure and function of the ecosystem, we should increase the space for public activities, make up for the shortcomings of urban and rural green infrastructure, achieve benign social and economic development, and form a modernization of harmonious coexistence between man and nature. After comprehensively considering the scale and existing ecological and environmental problems of Zhaogu No. 1 Mine, a series of scientific and targeted technical measures were adopted in accordance with the overall plan and the general idea of differentiated design of different deep and shallow areas, including topography and landform remodeling technology, soil reconstruction and vegetation

restoration technology, channel reconstruction and road engineering technology. Comprehensively address the environmental damage caused by mining activities. Realize the comprehensive management of the ecological environment of Zhaogu No. 1 mine.

4. MAIN ENGINEERING TECHNOLOGY

In the practice of ecological environment restoration and governance of Zhaogu No. 1 Mine, in view of the six ecological and environmental problems caused by the development of Zhaogu No. 1 Mine, the ecological environment of Zhaogu No. 1 Mine was effectively restored by comprehensively using topography and landform remodeling technology, soil reconstruction and vegetation restoration technology, channel reengineering and road engineering technology.

4.1. Topography and landform remodeling technology

Topography and geomorphology remodeling technology can enhance the stability and safety of mining areas, which is the basic work of ecological environment restoration in high-diving mining areas. Combined with the actual situation of the Zhaogu mining area, the topographic remodeling project needs to achieve the following objectives: (1) leveling and shaping the land surface, and restoring the surface cover and vegetation. (2) Adjust the morphology and landform of the surface of the mining area to make it suitable for other purposes such as agriculture, forestry, and fishery. (3) Realize the sustainable use of land in the mining area and improve the ecological environment. In order to achieve the above goals, the topsoil stripping technology, the excavation and shallow technology and the land leveling technology were mainly used to remediate the terrain of the Zhaogu mining area. According to the governance objectives and economic costs, the governance and zoning are planned, and the project content and restoration are shown in the table.

Table 3 The content and implementation effect of the topographic and landform remodeling project

Serial number	Governance partitions	Area	Project content
1	Restoration of cultivated areas	750.9	The area with a subsidence value greater than 3m was dug deep to form a fish pond area, and the excavated soil was filled into the area with a subsidence value of 1m-3m to form a cultivated land restoration area and a vegetation regreening area.
2	Surrounding the lake and building pond area	582.9	
3	Vegetation regreening area	263.25	

4.2. Topsoil stripping technology

4.2.1. Topsoil stripping

Soil quality directly determines food yield. As the core of soil quality, topsoil is rich in essential nutrients for plants, such as organic matter, nitrogen, phosphorus, potassium, etc., which can efficiently assist plant growth. Therefore, proper protection and management of topsoil is the key to maintaining the health of soil ecosystems, promoting sustainable agricultural development and protecting the ecological environment. The treatment area of Zhaogu No. 1 Mine has taken measures to strip and store the topsoil to ensure that the land productivity can be quickly restored after the subsequent topsoil backfilling. Generally speaking, the fertile soil of the surface layer of the land is distributed at 30-50cm of the surface, and the stripping depth can be appropriately increased for the soil with fertile soil and deep soil layer, while the amount of earthwork with poor soil and thin soil layer can be reduced, so as to strip the most fertile soil as much as possible under the premise of controlling the total amount.

4.2.2. Storage and protection of topsoil

Centralized preservation and protection of stripped topsoil. Four storage sites were selected around the Zhaogu No. 1 mine, which required flat terrain, good drainage, convenient transportation and distance from pollution sources. The combination of mechanical stripping and manual assistance was used to reduce the damage to the soil structure during the collection of topsoil. The surface of the storage site is covered with a layer of dust net to reduce the damage of wind and water erosion to the topsoil.

4.2.3. Measurement of topsoil stripping and storage engineering

It is estimated that the topsoil stripping area of Zhaoguyi Mine is 101.23 hectares, the average stripping thickness is 30cm, and the topsoil stripping engineering amount is 30.37 m3. The stripped topsoil is stored in the dump of the main project, and the earthwork is stacked with straw bags around it, with a total amount of 2323.6m3.

4.3. Digging deep and shallow technology

Digging deep pads are often used for terrain remodeling, often for high-diving areas that are deep in stagnant water. In this method, the soil is extracted by digging deep into the waterlogged area, filling in the shallow depression area and reclaiming it as cultivated land, and transforming the deep excavation area into a fish pond to achieve comprehensive land use and ecological restoration.

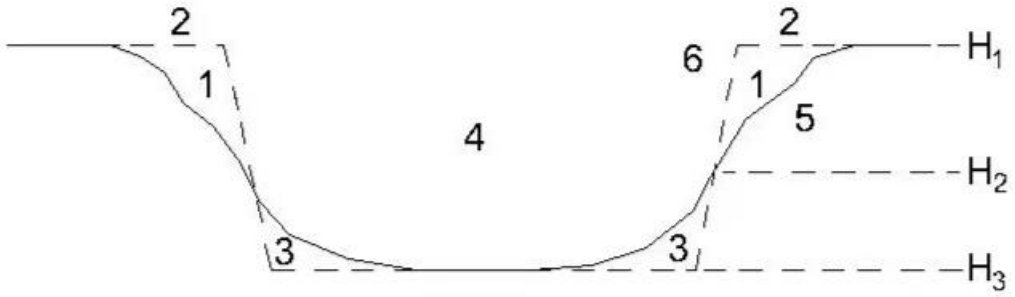

Fig.2: Schematic diagram of the shallow layout of the excavation pad

4.4. Ditch Rehabilitation and Road Engineering Technology

When the Zhaogu No. 1 mine was not mined, the original internal ditches and road systems remained intact, but the mining behavior caused surface subsidence and damage to ground facilities. Based on this situation, it is particularly urgent and important to construct a new ditch and road system to ensure the smooth and safe operation of the Zhaogu No. 1 Mine.

4.4.1. Branch ditch and dry ditch engineering technology

In order to ensure that the cultivated land of Zhaogu No. 1 Mine can quickly drain excess water after heavy rainfall in the rainy season, a two-stage drainage ditch system was designed, namely a dry ditch and a branch ditch. The system is designed to prevent the risk of crop drowning due to water accumulation on farmland, thereby protecting the healthy growth of crops, ensuring stable agricultural yields and avoiding sharp declines in yields due to catastrophic weather.

First-class drainage ditch - branch ditch. The primary drainage of cultivated land is mainly carried out, and the location is set in a relatively low place around the cultivated land to ensure that the excess water inside the cultivated land can be quickly collected and flowed to these drainage ditches. The design is a drainage ditch with a lower bottom of 0.10 meters, an upper bottom of 0.46 meters, a height of 0.12 meters, a slope ratio of 1:1.5, and a total length of 2618.56 meters. The detailed design scheme and parameters are shown in Figure 3.

Secondary drainage ditch - dry ditch. It is mainly responsible for directing the flow of water collected by the branch ditch into the water collection facility. The location is set downstream of the branch ditch and connected to the branch ditch to build a new drainage system. The design is a drainage ditch with a lower bottom of 0.15 meters, an upper bottom of 0.66 meters, a height of 0.17 meters, a slope ratio of 1:1.5, and a total length of 2538.44 meters. The detailed design scheme and parameters are shown in Figure 4.

The dry ditch and the branch ditch are all plain soil.

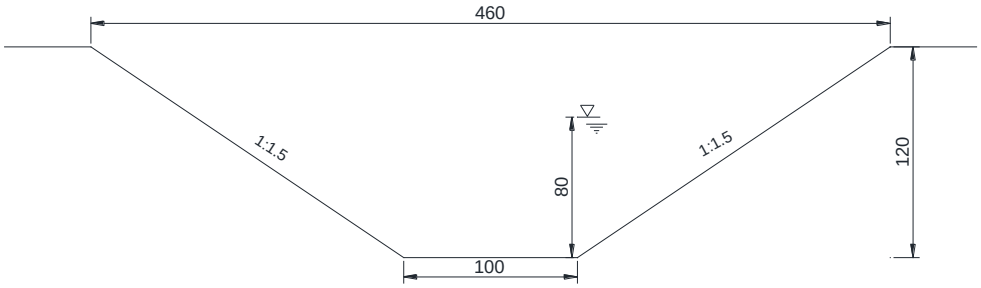

Fig.3: Illustrated analysis of branch ditch section

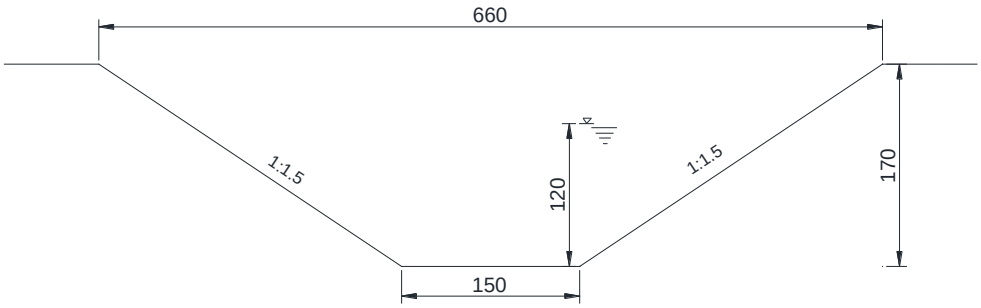

Fig.4: Diagram analysis of dry ditch section

4.4.2. Branch canal and trunk canal engineering technology

In order to ensure that the cultivated land of Zhaogu No. 1 Mine can be fully irrigated, a two-stage irrigation canal system was designed, namely the main canal and the branch canal. The aim of this system is to improve the efficiency of arable land irrigation and meet the needs of crop growth, thereby increasing the yield and quality of crops.

Primary irrigation canals - branch canals. Branch canals are branches of the main canal that penetrate deep into the plot to ensure that each cultivated area can be irrigated. The design is an irrigation canal with a lower bottom of 0.10 meters, an upper bottom of 0.60 meters, a height of 0.167 meters, a slope ratio of 1:1.5, and a total length of 3032.60m. The detailed design scheme and parameters are shown in Figure 5.

Secondary irrigation canals – trunk canals. Responsible for the introduction of water to cultivated land. It is usually designed to be spacious enough to carry sufficient water flow to ensure that the cultivated land is adequately irrigated. The design is an irrigation canal with a lower bottom of 0.15 meters, an upper bottom of 0.90 meters, a height of 0.25 meters, a slope ratio of 1:1.5, and a total length of 1577.40m. The detailed design scheme and parameters are shown in Figure 6.

The main canals and branch canals are made of cement.

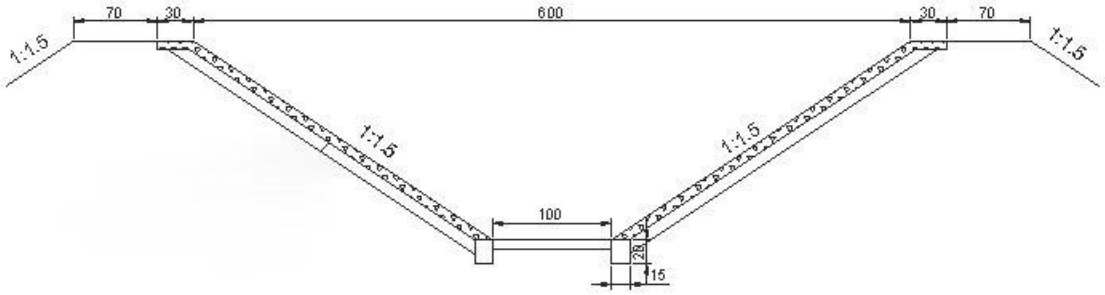

Fig.5: Illustration analysis of branch canal section

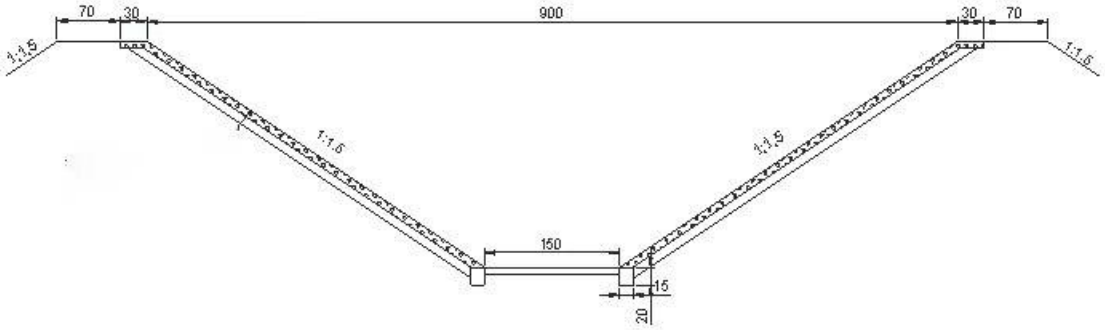

Fig.6: Diagram analysis of the trunk canal section

4.4.3. Road Engineering Technology

The road project needs to design the field road network according to the topography and surrounding conditions of Zhaogu No. 1 Mine, so as to maintain the transportation of Zhaogu No. 1 Mine. The field road network mainly includes production roads, field roads, and asphalt roads. The construction of roads enables tractors, harvesters and other large agricultural machinery to smoothly enter the field, improving the convenience of large-scale agricultural operations; At the same time, the traffic conditions have been improved, and travel is more convenient. The layout of the field road network should be adapted to local conditions, which should not only meet the production and living needs of farmers, but also coordinate with the surrounding landscape.

The production road is usually set on the long side of the field, and its core function is to serve all aspects of field production and field management, and carry the basic needs of agricultural production. The road is designed to be 2 meters wide, 0.3 meters high, and has a slope ratio of 1:1. The detailed design scheme and parameters are shown in Figure 7.

Field roads are the arteries for the transportation of agricultural materials and agricultural products, ensuring that machinery can be transferred to the field to support all aspects of agricultural production, which can be called the "lifeline" of agricultural production. The design pavement width is 4 meters and the height is 05 meters with a 1:1 slope ratio. At the same time, trees are planted on both sides of the road to beautify the environment, prevent wind and sand fixation, and protect the ecology of farmland. The detailed design scheme and parameters are shown in Figure 8.

Asphalt roads are mainly made of moderately viscous asphalt mixed with mineral materials, which are mixed to form a strong and durable mixture. Asphalt roads are subjected to repeated impacts from the loads of moving vehicles and are also resistant to long-term erosion by environmental factors such as climate change. The road is designed with a width of 6 meters, a height of 0.5 meters, and a slope ratio of 1:1 to ensure its stability and durability. The detailed design scheme and parameters are shown in Figure 9.

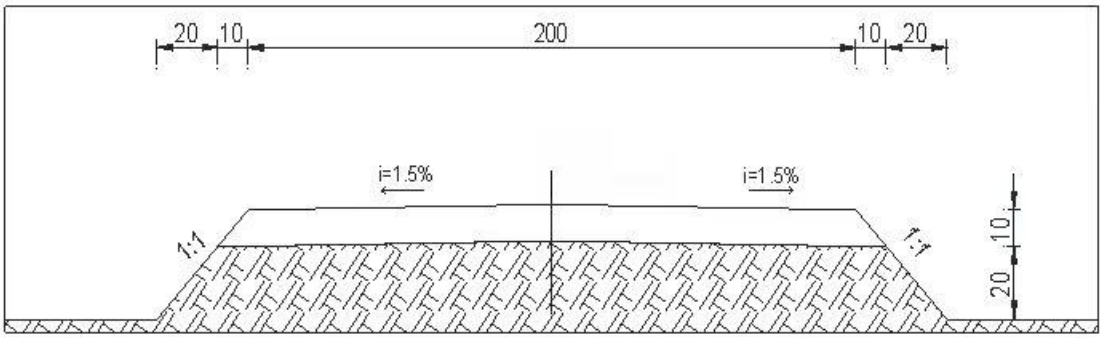

Fig.7: Illustration of the cross-sectional diagram of the production road

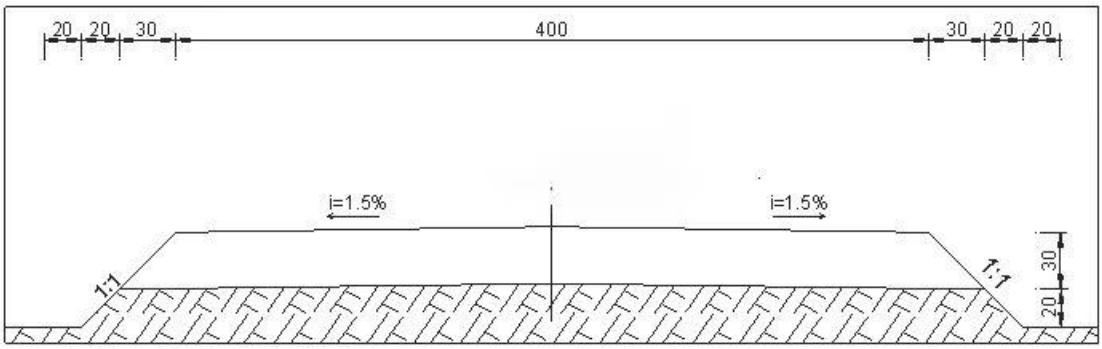

Fig.8: Illustration of the cross-sectional diagram of the field road

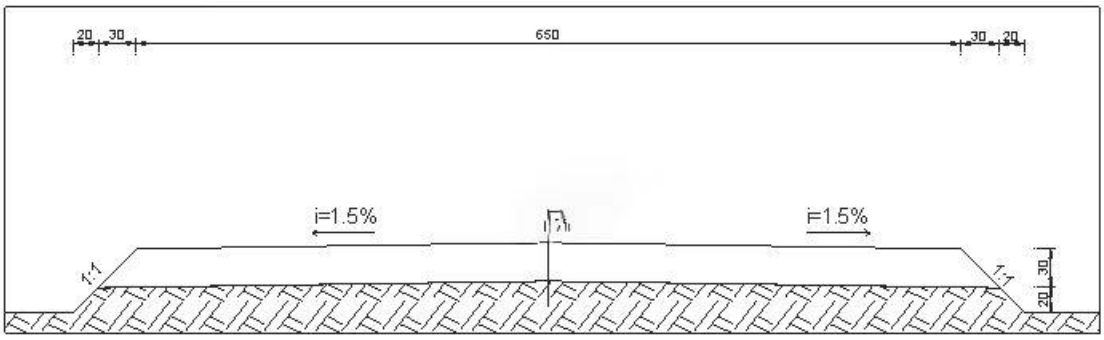

Fig.9: Analysis of the cross-sectional diagram of the asphalt road

5. CONCLUSION

(1) In the process of mining mineral resources, the ecological environment of Zhaogu No. 1 Mine has suffered many challenges. The ecological and environmental problems in the mining area are significant, covering six major aspects, mainly including six types: terrain and landform landscape damage, vegetation destruction, land damage and occupation, reduction of cultivated land area, and serious damage to ground facilities. It is urgent to take effective measures to restore and improve the ecological balance and ensure sustainable development.

(2) In the process of promoting the ecological restoration and governance of Zhaogu No. 1 Mine, we should always follow the planning concept of "adapting measures to local conditions, agriculture if it is suitable for agriculture, fishing if it is suitable for fishing, and construction if it is suitable for construction", so as to maximize the regional natural endowment and realize the harmonious coexistence of efficient utilization of resources and environment. Based on the starting point of "ecological priority, overall coordination, green development, and landscape integration", and in accordance with the ecological governance ideas of "environmental governance, ecological conservation, increasing natural capital and harmonious coexistence between man and nature" and the engineering governance ideas of "terrain remodeling, vegetation landscape restoration, and

facility restoration", the ecological restoration and governance system of high-diving mining areas has been established, and three key governance technologies have been formed: terrain and landform remodeling technology, soil improvement and vegetation restoration technology, ditch reengineering and road engineering technology.

(3) In the practice of ecological environment restoration and treatment of Zhaogu No. 1 Mine, the topography and landform remodeling technology, soil improvement and vegetation restoration technology, ditch reengineering and road engineering technology were comprehensively used to effectively solve the problem of ecological environment damage in Zhaogu No. 1 Mine, and achieved good treatment results, and provided a reference for ecological restoration and management of high-diving mining areas. However, there are still many problems to be solved in the ecological restoration of Zhaogu No. 1 Mine, and it is still necessary to increase the research on the ecological reconstruction model of Zhaogu No. 1 Mine, and strive to build a harmonious ecology of the life community of mountains, rivers, forests, fields, lakes and grasses, so as to ensure that coal mining activities are carried out under the premise of respecting the environment and promoting social harmony, so as to achieve sustainable and coordinated development among the three.

REFERENCES

[1] Du Jianping, Shao Jing'an, Zhou Chunrong, etal. Research on concave and convex landform remodeling technology of temporary construction land of coal mine: A case study of Mulang Coal Mine in Chongqing[J]. Journal of Southwest University(Natural Science Edition), 2018, 40(06): 140-148.

[2] Wang Yifei. Study on the impact of ecological restoration on surface water quality in high-diving coal mining subsidence area[D]. China University of Mining and Technology, 2022.

[3] Liu Hui, Zhu Xiaojun, Cheng Hua, etal. Key technologies for human settlements and ecological reconstruction in high-diving coal mining subsidence area: A case study of Lujin Lake in Huaibei, Anhui Province[J]. Journal of China Coal Society, 2021, 46(12): 4021-4032.

[4] Hu Bingnan, Guo Wenyan. Coal Science and Technology, 2022, 50(05): 21-29.

[5] Hu Haifeng, Lian Xugang, Cai Yinfei, etal. Coal Science and Technology, 2020, 48(04): 70-79.

[6] Wang Tong, Du Bin, Li Congcong, etal. Journal of China Coal Society, 2021, 46(01): 230-244.

[7] Li Fengming, Ding Xinpin, Bai Guoliang, etal. Journal of China Coal Society, 2021, 46(12): 4033-4044.

[8] Li Shuzhi, Li Xueliang, Men Leilei, etal. Coal Science and Technology, 2020, 48(04): 60-69.

[9] Zhang Yanbin, Li Jingfang, Li Dehai. Coal Mine Safety, 2015, 46(08): 128-130+134.

[10] Yang Long, Wang Xiangchun, Qin Fei, etal. Research on ecological restoration technology system in high-diving coal mining subsidence area[J]. Environmental Science and Management, 2021, 46(06): 160-164.

[11] Tang Hao. Research on ecological environment landscape restoration in coal mining subsidence area based on high diving level in plain[D]. Nanjing University, 2011.

[12] Fang Shenzhu. Ecological restoration technology and application in coal mining subsidence area of Lujin Lake in Huaibei Province[D]. Hefei University of Technology, 2022.