

Discussion on Landscape Ecological Restoration Measures - A Case Study of Abandoned Mines

Danni Wu

College of Landscape Architecture, Zhejiang Agriculture and Forestry University, Hangzhou, China

ABSTRACT

Abandoned mines have caused many landscape ecological problems to urban development, This paper analyses the causes of the problems from the concepts related to mineral resources and mine wasteland, and briefly describes the concepts related to ecological restoration, combining with two cases of mine restoration, discusses the effective measures for the restoration of abandoned mines, which are mainly as follows: the management measures for slopes; the tailings management measures; the soil grassroots improvement; phytoremediation of heavy metal pollution in mines; restoration of water resources in mines and microbiological restoration measures.

KEYWORDS

Abandoned mines; Ecological restoration; Landscape measures.

1. INTRODUCTION

Mineral resources, also known as mineral resources, are valuable assets created by nature through the process of geological mineralisation, which are either deeply hidden in the earth's crust, buried under the earth's surface or directly exposed on the earth's surface, as an aggregate of useful elements in nature, its form is widely and varied, encompassing solid solid and stable, liquid flow and change, and even gaseous lightness and diffusion, and each of them contains a rich value for exploitation and use, and is a valuable resource given to mankind by nature. Each of these forms is rich in exploitation and utilisation value, and is a valuable resource given to mankind by nature. As a solid cornerstone for the rapid development of the national economy, mineral resources are of inestimable strategic significance in accelerating the pace of industrial and agricultural modernisation and ensuring national energy security.

However, influenced by historical factors, some regions in China, driven by the urgent pursuit of economic benefits, have adopted a non-scientific mode of mining mineral resources, leading to the abandonment of a large number of mines, which in turn has given rise to a series of serious ecological problems, greatly restricting the economic potential of the land resources and the restoration and enhancement of the ecological function.

The ecological restoration of abandoned mines has far-reaching significance beyond the surface. It can not only enhance the water conservation capacity, stabilise soil and water, significantly enhance the aesthetic value of the regional environment, and become an important initiative to beautify the natural landscape; it can substantially improve agricultural production conditions, promote the optimisation and adjustment of the structure of the agricultural industry, open up new ways for farmers to increase their income, and help revitalise the countryside.

Particularly important is the crucial role played by mine rehabilitation, which is not only an effective means of eliminating potential geological hazards, but also an indispensable key link in safeguarding

the lives and properties of the people. Through scientific and reasonable restoration measures, the risk of landslides, mudslides and other natural disasters triggered by mining activities can be effectively mitigated or eliminated, creating a safer and more stable production and living environment for the people.

2. OVERVIEW OF ECOLOGICAL REHABILITATION OF MINE WASTE LAND

2.1. Concepts related to mine wasteland

2.1.1. Abandoned land

Abandoned land, in short, is land that has ceased to be used and is unused. It is a broad category covering land resources that have not been effectively utilised in a wide range of areas such as industry, agriculture and urban construction. These lands may have lost their original function due to the closure of mines, the abandonment of industrial facilities, or landfills. These areas cover a wide range of types, including mine wastes, industrial wastes, and landfills. These sites not only occupy valuable land resources, but may also have an impact on the ecosystem.

2.1.2. Mine waste land

Mining wasteland refers to areas of land that have been damaged and occupied as a result of mining operations and have not been effectively treated to the extent that they can no longer be used in a normal manner. During mining activities, mining sites formed by open excavation, dumps where waste rock is piled up, tailings sites where tailings are stored, areas where the ground has collapsed as a result of mining, and land contaminated with heavy metals to the extent that it has lost its original value for economic use are all classified as mine wasteland [1].

2.1.3. Ecological restoration of mine waste land

Ecological restoration of abandoned mine lands is a systematic project that focuses on mine lands that have been abandoned due to the loss of their economic use value. Through the in-depth application of system ecology theory and methodology, it aims to protect and rationally utilise these lands and their surrounding natural resources. The core objective is to gradually restore and rebuild the damaged ecosystems in the abandoned mine lands, and to restore their self-regulation and balancing ability, so as to promote the abandoned mine lands to the path of sustainable development [2]. This process is not only about ecological recovery, but also an important contribution to the sustainable use of land resources.

2.1.4. Landscape design of mine wasteland

Landscape design for abandoned mine sites is the application of landscape planning techniques to aesthetically sublimate and reshape the reborn site on the basis of solid ecological restoration. The process is rooted in mining culture, blending natural beauty and deep history to give the abandoned land new vigour and unique value.

Abandoned lands can effectively address the many problems left behind by abandoned mines through innovative landscape design [3]. In this process, landscape designers cleverly use the topography of abandoned mines, leftover mining equipment, precious geological remains, deep pits, naturally occurring bodies of water and adaptive plants and other rich resources, combined with the principles of landscape ecology and advanced technology, to carry out careful design and planning for abandoned mines. Through these initiatives, abandoned land can be revitalised, and mining sites are transformed into green and environmentally friendly parks, adding a touch of unique scenery to the city [4]. This not only enhances the efficient use of land resources, but also brings significant socio-economic benefits and promotes sustainable economic and social development [5].

2.2. Analysis of the causes of mine waste land

China is facing a serious problem of land damaged by coal mining, the total amount of which is huge and widely distributed, and this problem has been intensifying year by year, while effective land reclamation measures seem to be stretched to the limit. This has not only led to the damage of the ecological environment in many aspects, but also profoundly affected the land resources, surface landscape, vegetation cover, water resources and the atmospheric environment, which in turn led to a series of complex social problems.

Specifically, the erosion and destruction of soil caused by coal mining activities have directly reduced the quantity and quality of surface organisms, weakened the service function of the original ecosystem in the mining area and, in extreme cases, may lead to the complete disintegration of the ecosystem, resulting in profound damage to ecological integrity. At the same time, the surface landscape has been severely damaged by mining, and the original natural geomorphological features have been replaced by large-scale trauma, and the surface has become desolate and lost its aesthetics, which contrasts sharply with the neighbouring unmined areas, and makes a great impact on the visual environment. The destruction of vegetation and land degradation cannot be ignored. The reduction of vegetation cover and the degradation of land quality have made it difficult for these areas to support normal plant growth, further exacerbating ecological degradation. In addition, acid mine wastewater has become a source of pollution of surface and groundwater resources, while the release of toxic gases and dust poses a threat to the atmospheric environment, affecting air quality and the health of residents. What is particularly serious is that coal mining activities often induce a series of geological disasters such as landslides, avalanches, subsidence, earth fissures and mudslides, which pose a major threat to the safety of the mining area and its surrounding areas. These disasters not only affect the normal industrial and agricultural production, but also directly threaten the safety of residents' lives and properties, which in turn leads to a series of complex social problems, such as the relocation of residents, economic compensation, social stability, etc. [6].

2.3. Ecological restoration concepts

Ecological restoration is a comprehensive environmental management strategy, which is deeply rooted in the principles of ecology, with bioremediation as the core, while cleverly integrating physical and chemical restoration methods and advanced engineering technology. Through careful design and optimal combination, it strives to achieve the best restoration effect while minimising resource consumption. Broadly speaking, ecological restoration aims to restore the biological and environmental elements of degraded or damaged ecosystems through the synergistic effect of human regulation and natural ecosystem resilience in order to restore their original ecological functions [7]. In this process, ecological restoration and ecological reconstruction have different focuses, but they go in the same direction. Ecological restoration pays more attention to utilising the power of natural succession to guide the ecosystem towards a healthier and more stable state, while ecological reconstruction emphasises the dominant role of human regulation and accelerates the process of ecosystem transformation through active intervention. Either way, the ultimate goal is the same, i.e. to promote the sustainable development of degraded or damaged ecosystems and to provide a harmonious and symbiotic living environment for humans and other organisms [8].

2.4. Ecological restoration features

2.4.1. Ecological restoration: based on the principles of cyclic regeneration, harmonious coexistence, overall optimisation and regional differentiation

Recycling principle.The principle of cyclic regeneration describes a fundamental cyclic process within ecosystems, whereby living components synthesise new substances from non-living components (e.g. water, air, minerals, etc.) while at the same time progressively degrading these new

substances to their original, simpler counterparts, and ultimately returning these substances to the non-living environment. This process ensures that substances in the ecosystem can be continuously recycled and reused, maintaining the stability and balance of the ecosystem.

Principle of harmonious coexistence.The principle of harmonious symbiosis plays a crucial role in ecological restoration systems. It emphasises the harmonious relationship of interdependence and mutual promotion between various biological components (including restoration plants, microbial populations, animal populations, etc.) and between these organisms and the environment of the treatment system during the restoration process. Specifically, this principle is embodied in the following aspects: interaction between organisms, transformation and degradation of pollutants, promotion of plant growth and development, environmental improvement and ecological balance. The reduction of pollutants, the increase of nutrients and the enhancement of biodiversity together contribute to the restoration and maintenance of ecological balance.

Overall optimisation principles.The principle of holistic optimisation occupies a central position in ecological restoration technology, which emphasises the need to consider the interconnections and dependencies of each link in the restoration process to ensure the efficient and synergistic operation of the entire restoration system. Specifically, the principle of holistic optimisation includes the following aspects: close linkage, mutual indispensability, system synergy, dynamic adjustment and optimisation. In the process of restoration, the changes of various indicators should be closely watched, and problems should be detected in time and corresponding measures should be taken to make adjustments. At the same time, the restoration programme should be optimised in accordance with the restoration effect and environmental changes to ensure that the restoration objectives are achieved.

Principle of regional differentiation.The principle of regional differentiation reveals that in different geographical areas or between different sections of the same geographical area, the processes of migration, transformation and degradation of pollutants in the ecosystem will show obvious regional characteristics due to significant differences in natural environmental factors. Specifically, the principle of regional differentiation is embodied in the following aspects: diversity of natural environmental factors, differences in biological populations, regional differentiation of ecological behaviours of pollutants, and local adaptation of remediation strategies. For the specific conditions of different regions or lots, appropriate remediation technologies, remediation plants and microbial species are selected to ensure optimal and sustainable remediation results.

2.4.2. Ecological restoration: integrated consideration of microbial and plant life activities

Ecological remediation is a complex and delicate task, which is achieved mainly through the life activities of microorganisms, plants and other organisms. These organisms play a crucial role in the remediation process by absorbing, transforming and degrading pollutants to facilitate the recovery and reconstruction of ecosystems. However, various factors affecting the life of these organisms, such as climatic conditions, soil types, hydrological conditions, biodiversity, and human activities, will directly or indirectly influence the effect and process of ecological restoration. Therefore, ecological restoration is characterised by many and complex influencing factors, and requires comprehensive consideration of the interactions and impacts of various factors in order to formulate a scientific and reasonable restoration programme to ensure the effectiveness and sustainability of restoration work.

2.4.3. Ecological restoration: multidisciplinary and integrated practice and response to challenges

The successful implementation of ecological restoration is a highly integrated project, which profoundly reflects the necessity and importance of multidisciplinary intersections within the scientific field. In this process, ecology, as the basic theoretical framework, provides a deep understanding of the structure, function and dynamics of ecosystems, which provides a scientific basis for the design of remediation programmes. At the same time, the participation of physics and

chemistry helps us to analyse the nature of pollutants, migration and transformation laws and their interaction mechanisms with the environment, providing technical support for the precise formulation of pollutant removal strategies. Botany and microbiology play an indispensable role in ecological restoration. Plants are involved in pollutant removal and soil improvement through physiological processes such as root absorption and leaf transpiration, while microorganisms, with their strong metabolic capacity and genetic diversity, show unique advantages in pollutant degradation, nutrient cycling, and soil microenvironment regulation. The development of molecular biology has opened up new avenues for in-depth research on the interaction mechanism between microorganisms and plants, and genetic improvement to enhance remediation efficiency. In addition, the knowledge of cultivation science and environmental engineering also provides important support for ecological restoration practice. Cultivation focuses on plant planting, maintenance, pest control and other techniques to ensure that remediated plants can grow healthily and perform the best remediation effect; while environmental engineering involves the investigation and assessment of contaminated sites, the design and implementation of remediation processes, and the monitoring and evaluation of remediation effects, which provides a comprehensive guarantee for the smooth implementation of ecological remediation projects.

2.5. Basic approaches to ecological restoration

Based on the multi-dimensional principle of ecological restoration, we can subdivide the restoration methods into the following three categories: bioremediation, physical and chemical restoration, and phytoremediation. Each of these approaches has its own characteristics, and together they constitute a comprehensive solution for ecological restoration.

2.5.1. Bioremediation: a central cornerstone of ecological restoration

Bioremediation, as the basis and core of ecological remediation, relies mainly on the metabolic activities of living organisms, especially microorganisms, to degrade or transform organic pollutants in the environment. This process can be either controlled or spontaneous. The success of bioremediation hinges on three core elements: the activity and type of microorganisms, the chemical nature and structure of the pollutants, and the suitability of the environmental conditions. By optimising these factors, the efficiency and effectiveness of bioremediation can be significantly improved.

2.5.2. Physical and chemical restoration: a powerful aid to ecological restoration

Physical and chemical remediation, as an important part of ecological remediation, focuses on the use of physical means (e.g., light, heat, electricity, magnetism, etc.) and chemical principles (e.g., redox, adsorption and desorption, precipitation and dissolution, etc.) to directly treat or transform pollutants in the environment. These methods can quickly and effectively remove or reduce the concentration and toxicity of pollutants and create more favourable environmental conditions for bioremediation. In practice, physical and chemical remediation is often used as a pre-treatment stage of bioremediation, laying the foundation for the successful implementation of bioremediation by reducing the pollutant load and improving the nature of the environmental medium.

2.5.3. Phytoremediation: the green messenger of ecological restoration

Phytoremediation, as the basic form and visual embodiment of ecological remediation, absorbs, transforms or fixes pollutants in soil and water by planting specific plants. In this process, plants not only absorb the pollutants directly, but also through root secretion, inter-root microbial community and inter-root soil physicochemical changes and other mechanisms, to achieve the comprehensive remediation of the polluted environment. The advantage of phytoremediation is that it is economical, environmentally friendly and easy to promote, and can achieve the dual goals of environmental management and ecological restoration at the same time. Therefore, phytoremediation has a wide range of application prospects and important practical value in the field of ecological restoration.

3. EXISTING PROBLEMS OF ABANDONED MINES

3.1. Shortcomings in laws and regulations: Inadequate systems in the field of ecological restoration

Overall, affected by multiple factors such as historical legacy problems, China is still deficient in the construction of mine environmental protection and rehabilitation systems, and the specific shortcomings are reflected in the following key aspects:

3.1.1. Inadequate financial reserves

At present, enterprises undertaking mine development and operation generally fail to fully set aside special funds for subsequent ecological restoration work, resulting in the restoration process often being hindered by a lack of funds.

3.1.2. Fragmentation of the regulatory system

Ecological restoration of abandoned mines often crosses the responsibilities of multiple government departments, but most regions have not yet built a unified cross-sectoral regulatory system, resulting in regulatory gaps and overlaps that affect restoration efficiency.

3.1.3. Vague definition of responsibilities

At present, geological environmental protection and ecological environment restoration in mining areas have not yet been formally incorporated into the daily operation system of mining enterprises, resulting in a vague definition of the responsibility for managing the impacts on the land surrounding the mining area. At the same time, the lack of awareness of environmental protection among government regulators and the management of mining enterprises has increased the complexity and challenge of responsibility implementation.

3.1.4. Inadequate regulations, standards and regulatory approval mechanisms

The legal and regulatory system for ecological restoration of mines is not yet perfect, and relevant standards are missing or lagging behind, making it difficult to effectively guide practice. At the same time, there are also deficiencies in the regulatory approval process, making it difficult to ensure the scientific, rational and effective nature of restoration projects.

3.2. Weak financial and tax support: ecological restoration funding bottleneck to be solved

At present, in the face of widespread and complex abandoned mine sites and the serious ecological problems they cause, the existing scale of funding is particularly stretched to meet the demand for comprehensive and in-depth restoration. What is more serious is that in some areas, special funds have been misappropriated, which undoubtedly adds to the already tight funding situation [9]. Such irregularities in the use of funds not only directly weaken the strength and effect of ecological restoration work, but also constitute a new obstacle to the sustainable improvement of the ecological environment in mining areas.

3.3. Shortcomings in scientific and technological inputs: bottlenecks restricting the efficiency and quality of mine ecological restoration

In the context of the global strategy of "carbon neutrality", scientific and technological support has become an indispensable key factor in ensuring the effectiveness and efficiency of mine rehabilitation. With the increasing demand for the capacity of natural carbon sink systems such as soil carbon pools and forest carbon pools to sequester carbon and increase sinks, mine ecological restoration has been given a more important mission and more severe challenges.

Firstly, scientific and technological inputs play a central role in enhancing restoration efficiency. Through the introduction of advanced ecological restoration technologies and management modes, it is possible to accelerate the process of vegetation restoration, soil improvement and ecological reconstruction of mine wasteland, thereby achieving significant improvements in the ecological environment in a relatively short period of time. Secondly, scientific and technological innovation is crucial for enhancing the capacity of carbon sequestration and sink enhancement. In the process of mine restoration, emphasis should be placed on adopting technologies and methods that can promote soil carbon storage and enhance the capacity of forest carbon sinks. In addition, strengthening scientific and technological research and development and the transformation of results is also an important direction to promote the ecological restoration of mines. Support for scientific and technological research and development in the field of mine restoration should be increased, and scientific research institutions and enterprises should be encouraged to carry out joint research and break through key technological bottlenecks. At the same time, to strengthen the promotion and application of scientific and technological achievements and demonstration leadership, advanced scientific and technological achievements into actual productivity, for mine ecological restoration to provide strong technical support.

4. RECOMMENDATIONS AND MEASURES FOR ECOLOGICAL REHABILITATION OF MINES

In view of the problems faced by abandoned mines, solutions can be explored from multiple dimensions, the key lies in the following aspects: firstly, strengthening the policy orientation and providing clear direction and support for ecological restoration of mines by deepening the policy leadership; secondly, defining the main responsibility of the government, ensuring the synergy of various departments, and forming an effective supervision and governance system; Thirdly, increase the investment in science and technology, relying on scientific and technological progress to improve the technical level and implementation effect of mine ecological restoration; fourth, continuously improve the professional capacity of mine ecological restoration, to ensure that the restoration of high-quality work to promote; and finally, the construction of a perfect market mechanism to actively attract and encourage social capital to participate in mine ecological restoration projects, the formation of a diversified and sustainable capital investment system.

After clarifying the above core solution direction, a series of ecological restoration measures can be implemented in a targeted manner: formulate scientific and reasonable restoration planning to ensure the scientificity, feasibility and relevance of the restoration programme; introduce advanced ecological restoration techniques and methods, such as vegetation restoration, soil improvement and ecological engineering technology, to accelerate the recovery and reconstruction of the ecological environment in the mining area; strengthen the monitoring and evaluation of abandoned mines to Strengthen the monitoring and evaluation of abandoned mines to grasp the effect of restoration in a timely manner and provide data support for the follow-up work; at the same time, pay attention to the participation and coordination of interests of the communities around the mines, so as to ensure that the ecological restoration work receives broad social recognition and support.

The following are some of the ecological restoration measures regarding the mine:

4.1. Core elements of slope management measures

The core of slope management is to ensure its stability, a process that includes two key tasks: firstly, the clearance of dangerous rocks and slope modification, and secondly, ecological re-greening and long term stabilisation. Firstly, by removing the loose dangerous rocks on the slope and adopting the slope reduction and cutting technology, the steep and stepless cliffs are gradually transformed into multi-level horizontal steps, which aims to fundamentally reduce the slope gradient to within the

safety range, thus effectively eliminating the potential safety hazards such as collapses. This step is the foundation of slope management and the prerequisite to ensure that the subsequent work can be carried out smoothly. Secondly, after completing the stabilisation of the slope structure, further ecological re-greening measures should be implemented. Through the planting of suitable vegetation, not only can beautify the environment, more importantly, can use the root system of the vegetation to fix the soil, further enhance the stability of the slope, prevent soil erosion and the occurrence of secondary landslides.

4.2. Optimisation strategies for tailings management measures

In response to the problem of tailings occupying a large amount of land resources, active measures should be taken to promote the secondary development and comprehensive utilisation of tailings. The first task is to improve the comprehensive utilisation rate of tailings, through technological innovation and market expansion, develop tailings products with high demand, low cost and wide marketability, realise large-scale operation and diversified development, and transform tailings resources into commodities with economic value, so as to truly realise "turning waste into treasure". At the same time, strengthening the tailings dam wastewater treatment is crucial. We must ensure that the wastewater treatment meets the national standards, realise the effective purification and comprehensive reuse of flotation wastewater, and strive to achieve the goal of zero wastewater discharge to protect the surrounding water environment from pollution. In addition, for the untreated mining legacy issues such as empty areas, waste roadways and chambers, innovative ways of utilisation can be explored, such as using the underground mining area as a discharge site for tailings. This initiative not only solves the problem of tailings storage, but also makes effective use of the underground space of mines, achieving a win-win situation in terms of maximising the use of resources and environmental protection.

4.3. Soil Subgrade Improvement Strategies

Mining activities often lead to severe land degradation, centred on significant changes in soil factors, including deterioration of physical and chemical properties, loss of nutrients and accumulation of toxic and hazardous substances. In view of this, soil improvement has become a key and indispensable part of the ecological restoration of mine wasteland. Several specific improvement strategies are described below:

4.3.1. Off-site soil transplantation and ecological restoration

Under the premise of strictly protecting the integrity of off-site soil resources, high-quality soil is carefully collected and precisely placed in the most severely damaged areas of the mine. Subsequently, carefully selected plants are planted to gradually improve the quality of the damaged soil and stimulate the natural recovery process of the soil ecosystem by relying on their powerful ecological restoration capabilities, including absorption, volatilisation, root filtration, degradation and stabilisation.

4.3.2. Construction of artificial water barriers

Prior to topsoil modification, advanced engineering techniques, such as grouting, are used so that the slurry tightly coats the surface of the waste residue to form an effective protective layer. Subsequently, a layer of clay is laid down and compacted to build up an artificial water barrier. This measure is aimed at reducing the seepage of surface water, effectively blocking the release of highly toxic elements in the slag, and safeguarding the safety of groundwater and the gradual improvement of the soil environment.

4.3.3. Soil Fertilisation and Physico-chemical Improvement

Fertiliser enhancement measures are taken to address the problem of soil nutrient deficiency and deterioration of physico-chemical properties. By adding organic matter, mineral fertilisers and other effective substances to the soil, not only can soil nutrients be supplemented, but also the physico-chemical properties of the soil can be significantly improved. This process helps to shorten the natural succession cycle of vegetation, accelerate the process of vegetation restoration and ecological reconstruction of mine wasteland, and ultimately achieve comprehensive ecological restoration and sustainable development of wasteland.

4.4. Phytoremediation techniques for heavy metal pollution in mines

In the ecological rehabilitation of mines, phytoremediation techniques have attracted much attention because of their unique advantages in addressing the problem of heavy metal pollution. The core of such technologies lies in the use of heavy metal-tolerant plants, which are not only able to survive heavy metal contamination, but also adapt to the poor soil and poor structure of the waste land. Critically, some of these tolerant plants have demonstrated excellent enrichment capabilities, absorbing and accumulating high concentrations of heavy metals, making them a key force in the treatment of heavy metal-contaminated land.

4.5. Integrated rehabilitation strategies for mine water resources

The impact of mining activities on water resources is far-reaching and is mainly reflected in the double damage to surface water and groundwater. In response to this complex problem, we need to adopt a comprehensive remediation strategy to restore the health of mine water resources.

Firstly, the construction of artificial wetlands is an effective means of treatment for surface water and groundwater pollution problems. By simulating the natural wetland ecosystem, artificial wetlands can make use of the tolerant plants and microbial communities in them to absorb, degrade and transform pollutants in the water body, so as to achieve the purpose of purifying water quality. This ecological restoration method is not only inexpensive and easy to operate, but also has significant environmental benefits. Secondly, we need to implement scientific water diversion and storage measures to deal with the lack of surface water and the decline of groundwater level due to over-exploitation of water. Through rational planning and design of water diversion projects, external water sources are introduced into the mining area to replenish the surface water and groundwater reserves. At the same time, construct a perfect water storage system, such as building cisterns and rainwater collection systems, in order to collect and store rainwater, wastewater and other water resources, so as to realise the recycling and saving of water resources. These measures will help alleviate the pressure of water shortage in mining areas and restore and maintain the ecological balance of water resources in mining areas.

4.6. Microbial remediation: the key to building healthy ecosystems

In the ecological restoration of mine wastes, it is not enough to focus only on the restoration of soil and vegetation. It is also essential to re-establish microbial communities, which are the cornerstone for improving ecosystem function and ensuring that the restored ecosystems are naturally sustained. The core of microbial remediation is the restoration and enhancement of the original microbial community at the site, as well as the introduction of exogenous microorganisms that are capable of specific degradation of the contaminants. This process not only aims to rebuild the microbial diversity of the ecosystem, but also effectively removes or reduces pollutants in the soil, such as heavy metals and organic matter, through the biochemical action of microorganisms. These microorganisms reduce the pressure on the ecosystem by converting hazardous substances into harmless or low-toxicity forms through a variety of mechanisms such as adsorption, degradation, and transformation. In addition, the

health status of microbial communities directly affects soil fertility, plant growth and the stability of the entire ecosystem.

5. MINE REHABILITATION CASE STUDIES

5.1. Nanjing Tangshan Mining Pit Park

5.1.1. Project background

The Nanjing Tangshan Pit Park is located north of the scenic Tangshan Hot Springs Tourist Resort in Nanjing, Jiangsu Province, adjacent to the Tangshan Mountain, a land that was once renowned for its "imperial hot springs" distinction. However, after the founding of New China, in view of the rich limestone resources in the area, the area was transformed into the Longquan Quarry, which began a mining process that lasted for more than ten years (1990-2004). During this period, the development of pit resources did inject vitality into the city's economy, but what followed was the crisis of resource depletion, serious damage to the ecological environment, and a gradual loss of economic development momentum. Years and years of mining activities in Tangshan left four shocking huge pits (shown in Figure 1), they are like scars of the earth, not only led to the collapse of the site, the topography of the landscape has changed dramatically, but also the original mountain vegetation completely destroyed, production waste scattered around, the whole area shrouded in a barren and decay. Especially serious is that these abandoned pits happen to be located in the picturesque Tangshan tourist attractions, seriously undermining the overall beauty and ecological balance of the scenic area. The four pits are independent, with different shapes, and the vertical height difference from the bottom of the pits to the top of the mountain is significant, ranging from 30 metres to 100 metres, which makes it difficult to form a coherent overall landscape among each other. In addition, the continuous washing of rainwater on the exposed mountains has intensified soil erosion and nutrient loss, causing plants and animals to lose the basis for survival, ecosystems to suffer heavy damage, and the gradual disintegration of the biological chain, making the road to ecological restoration particularly difficult [10].

One of the landmark projects completed (or in the process of being partially completed) by Zhang Tang Landscape Architecture to date is the magnificent transformation of the Nanjing Tangshan Pit Park, which boasts an ambitious 40-hectare design scope. The development and construction of the project was carefully planned and led by the Nanjing Tangshan Hot Springs Tourism Administrative Committee, with the aim of transforming the former abandoned site into a new landmark for ecology and tourism. In the new round of urban planning, Southeast University drew a grand blueprint for Tangshan Hot Spring Town, and the pit park, as a bright pearl, was given the important mission of attracting future tourist and holiday makers, and leading a new style of leisure. With the gradual implementation and completion of the project, Tangshan Pit Park will not only repair the damaged ecological environment, but also become a comprehensive tourist destination integrating natural scenery, leisure and entertainment, culture and education, bringing a brand-new tourist experience to the visitors in Nanjing and the neighbouring areas, and further promoting the development and prosperity of the tourism industry of Tangshan Hot Spring.

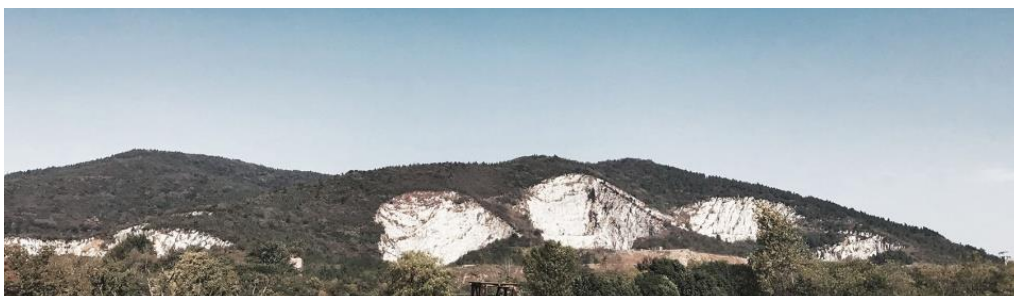


Figure 1. The site's original appearance

5.1.2. Project description

A few kilometres away, the abandoned dangs of the Longquan quarry are visible, and as the largest pit site in Tangshan in the past, they have witnessed the vicissitudes of time. The Zhangtang Landscape Project was created to rejuvenate these scarred pits and transform them into a fascinating tourist and leisure destination. Despite their mottled appearance, the interior of the pits display a striking beauty, with natural vegetation growing tenaciously between the cracks in the rocks, weaving a vivid picture of nature together with the cold stone walls (shown in Figure 2).



Figure 2. The beautiful stone textures combined with newly sprout plants from cracks

Knowing that the road to natural restoration is long and complex, Zhang Tang has taken a cautious approach to the artificial greening process, striving to avoid any ecological imbalance. Through fine terrain combing and hydrological planning, the project team cleverly constructed a series of diversified experience zones on top of the ruins, such as a hot spring hotel to enjoy tranquillity, a watery waterfall to feel the watery charm, and a sky corridor to appreciate the beauty of the sky, etc. At the same time, the project team has fully respected and preserved the unique features of the mountain quarry pits, and tailored a different functional positioning for each dangang [11].

The landscape design is a brilliantly creative, subtle blend of the site's topographical and hydrological features, and a series of intriguing, layered experiential spaces have been carefully carved out of the shattered natural remnants of the past. The four ingenious dangling designs - the hot spring hotel, the gurgling water of the Zizi Waterfall, the beauty of the sky corridor, and the natural wilderness of the accompanying mountain campsite - mirror the splendour of the Qianlian Flower Stream, the fun exploration of the Mining Wild, and the serenity of the Three Stacks Lake, and together they weave a vivid picture of tourism and recreation. In addition, the intimate restaurant tea room and other ancillary facilities, but also for tourists to provide a full range of comfortable experience.

In response to the independent and disconnected quarry pits on the mountain, the design team demonstrated extraordinary creativity and insight, tailoring a unique functional positioning for each of the dangs. The deep and secretive pit on the east side is cleverly transformed into a quiet extension of the hot spring hotel, providing visitors with a resting place away from the hustle and bustle; while the open site on the west side is transformed into a bustling public activity space, where music festivals, camping and caravanning experiences are staged, bringing endless joy and excitement to visitors. The two dangs in the middle, with their unique natural scenery and rich experience programmes, have become a must-visit place for visitors to explore the park and get close to nature.

The design team showed a high sense of responsibility and professionalism in the face of the potential safety hazards posed by the rock walls of the mountain after the quarrying damage. Under the rigorous assessment and guidance of geological experts, they carefully planned the tour route to ensure that tourists can enjoy the beautiful scenery and at the same time get adequate safety protection. In particular, the introduction of the "Time Tunnel" not only brought visitors a wonderful experience of

travelling through time and space, but also cleverly solved the problem of entering the bottom of the dangkou. Subsequently, through the well-designed ladder-type ascending path, tourists can experience the rough and steep beauty of the quarry, and finally arrive at a wide-view, picturesque viewing platform (shown in Figure 3). This place, once a pile of abandoned slag, is now an excellent location for viewing the park's panoramic view, which makes people wonder at the ingenuity of nature and the wisdom of mankind's creation.



Figure 3. Unique landscape combined with the design

The renovation of the Quarry playground is a perfect blend of ecological restoration and fun experience (shown in Figure 4). On this former waste dump, the design team not only restored the hydrological ecology and reinforced the hillside, but also cleverly integrated a variety of amusement facilities such as climbing, slides, swings and trampolines. These facilities not only satisfy visitors' pursuit of excitement and fun, but also allow them to feel the unique charm of nature and history while having fun. The completion of the Mining Wild Gleaning Paradise has undoubtedly added a splash of colour to the entire tourist and leisure resort, allowing tourists to enjoy the beauty of nature while also reaping a wealth of joy and memories.

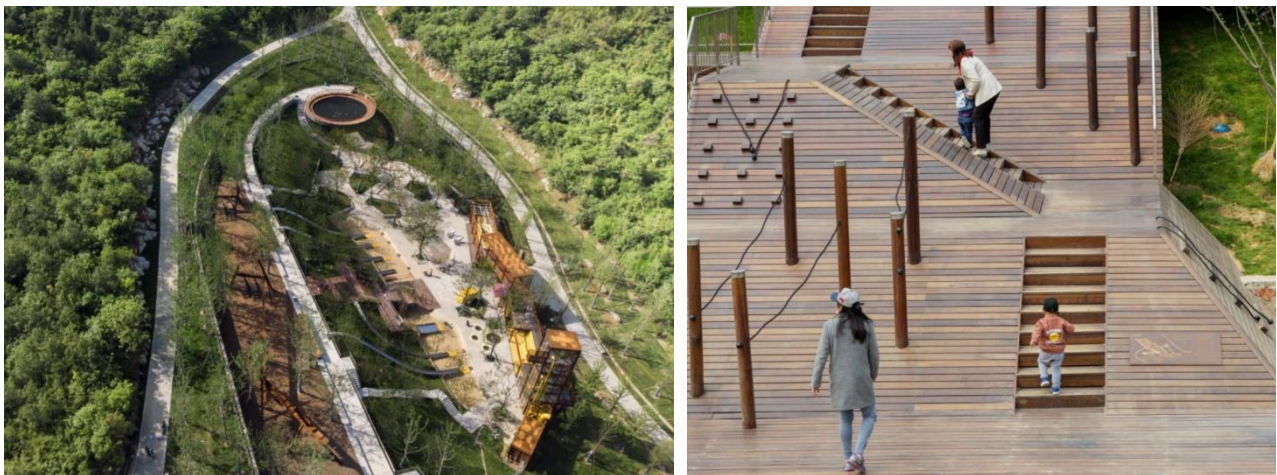


Figure 4. Quarry playground

5.1.3. Summary

In summary, the design team, adhering to the original intention of revitalising the abandoned pit, implemented the ecological design concept in depth and carried out a comprehensive and detailed landscape design for the pit, closely relying on the existing conditions of the site. During the implementation of the project, the team not only focused on ecological restoration measures for slope management, but also cleverly integrated the uniqueness of the site with the design concept, and innovatively constructed a curved air corridor, which not only added a sense of hierarchy to the landscape, but also ensured the safety experience of visitors. At the same time, by reinforcing the

slopes and designing wetland meadows, the team effectively restored the mine's water resources and further enhanced the quality of the overall ecological environment.

When designing the development mode of natural restoration of the mining environment, the design team has a deep insight that, for those mining scenic spots with ecological restoration potential, the use of vertical greening technology to cover the rock wall of the mining pit can significantly increase the proportion of vegetation cover on the mountain, thus accelerating the ecosystem's self-recovery process, and promoting the realisation of ecological balance. This strategy not only demonstrates ecological wisdom, but also provides strong support for the green transformation of the mining environment. During the planning and implementation of this development model, the team strictly controlled the natural conditions of soil and rock layers, flexibly applied advanced construction techniques such as thick substrates and re-greening technology, and meticulously restored the green vegetation of the mining landscape, in an effort to create an ecological picture of vibrant and harmonious coexistence [12].

5.2. Ecological Rehabilitation of Lianhuashan Mine in Danzhou City, Hainan Province

5.2.1. Project Background

Hainan Lotus Hill (shown in Figure 5), which is embedded in Danzhou City, Lanyang Town, the bright pearl, only 11 kilometres away from the city, since ancient times is the "blessed" culture of the deep bearing place, enjoys the "thousand years of Danzhou Ancient City, ten thousand blessings convergence of the Lotus Hill," the reputation. However, the wheel of time into the 1950s, due to social production and the urgent needs of the people's lives, Hainan Agricultural Reclamation Group's Lanyang Farm in this land to open the lime mining, leaving six shocking quarry pits and ponds, the local natural environment has caused serious damage - forest vegetation damage, soil erosion is serious, the ecosystem is gradually being destroyed. Forest cover was destroyed, soil erosion was severe, and the ecosystem gradually declined, which in turn affected the safety and well-being of the local residents.

In the face of this serious challenge, since 2018, Hainan Nongken Tourism Group has resolutely embarked on the road of ecological restoration and cultural tourism integration and development, through the implementation of pit restoration, environmental management, cultural implantation and industrial upgrading of the "four-in-one" strategy, which has brought about an unprecedented metamorphosis of Lotus Hill. The former scarred abandoned mine pit, in the careful planning and management, and gradually revitalised, not only the ecological environment has been significantly improved, but also into the rich cultural elements, has become a collection of natural scenery, cultural heritage and industrial vitality in one of the 4A-level tourist attractions, and won the "second batch of the National Forest Recreation Demonstration Base and won the honour of "the second batch of national forest recreation demonstration base".

This road of transformation is not only a profound redemption of the natural environment, but also a positive exploration of the integration of traditional culture and modern industry. Lotus Hill has not only restored the appearance of green water and mountains, but also driven the green growth of the regional economy and raised the income level of local residents through the prosperous development of the cultural tourism industry, realising the harmonious unity of economic, social and ecological benefits. With its unique model, it provides valuable experience and inspiration for ecological environment restoration and sustainable development in other regions.



Figure 5. Aerial view

5.2.2. Project description

In concrete implementation, Haiken Tourism Group has taken the following series of innovative and pragmatic initiatives, successfully transforming Lotus Hill from an abandoned mine pit into an ecological and cultural tourist attraction:

Scientific planning, precise policy implementation and strengthening of ecological restoration and management. In order to ensure the scientific and effective ecological restoration work, the Group has specially prepared a detailed "Lotus Hill Ecological Restoration and Cultural Scenic Area Construction Plan". On the premise of not increasing the burden of construction land, strictly protecting the existing forest resources, and resolutely resisting real estate development, the Group has initiated a "four-wheel drive" strategy of ecological restoration, environmental management, cultural heritage and industrial drive. Through the rational use of abandoned pits and exposed mountains, the Group has carefully laid out six functional zones, each of which is centred on the themes of inheritance of blessed culture and forest hot springs and recreation. During the restoration process, we strictly followed the principle of "safety first, ecology first, and landscape in mind", and adopted advanced riveting technology to stabilise the four broken mountains, with a treatment area of more than 40,000 square metres, effectively eliminating potential geological hazards. At the same time, the mine pit and the surrounding rubbish dumps were comprehensively cleaned up, the water conservation function of the natural ecosystem was gradually restored by backfilling with fertile soil, laying drip irrigation systems and other measures, and extensive planting of turf and shrubs in the slope area effectively curbed soil erosion.

Integrate culture and craftsmanship to create special tourist attractions. Haiken Tourism Group has invested a total of 150 million yuan, and has successfully leveraged 430 million yuan of social capital, which has been jointly invested in the ecological restoration of Lotus Hill and the construction of tourist attractions. The accessibility and convenience of the scenic spot has been greatly enhanced through the widening of rural roads, the construction of excursion trails and road networks connecting various functional areas, as well as the addition of motorway interchanges. In the planning and construction of the scenic spot, the local culture of praying for blessings and the historical allusions of Su Dongpo were deeply excavated and integrated, and a series of attractions with rich cultural connotations, such as Five Blessings at the Gate and Exclusive Ao Tou, etc., were created with the core concept of "ecological restoration of blessings and blessings on the mountain", which not only enriched the tourism experience, but also carried forward the traditional Chinese culture.

Resource transformation and industrial upgrading to maximise ecological value. The Group has cleverly integrated the ecological restoration and resource development of Lotus Hill into the tourism industry planning, constructed the whole industrial chain of "culture, recreation, tourism, food, accommodation and transportation", and realised the benign interaction between ecological

protection, business operation and regional development. Relying on rich geothermal resources, the Group has introduced the "national medical grade mineral spring" Hot Radon Spring, and innovatively combined it with hot springs physiotherapy, forest recreation, tree house lodging and other tourism products, which provides tourists with unique and high value-added recreation experience. In addition, the Group also made full use of the resources of the abandoned mine pit, transformed it into a mine pit theatre, and launched the "Ancient Rhythm Danzhou, Water Lotus" light and shadow show, which has become a new highlight to attract tourists. Meanwhile, a series of creative cultural products have been developed through the introduction of natural heritage such as fossilised wood, further enriching the tourism industry and enhancing the cultural connotation and attractiveness of the scenic spot.

5.2.3. Summary

The case has achieved significant results in the realisation of the value of ecological products in the following key areas:

Effective ecological restoration and significant increase in ecological benefits. The Lotus Hill Ecological Restoration Project has achieved remarkable results, successfully restoring an area of over 600 acres of abandoned rock pits, restoring more than 400 acres of ecological water surfaces, planting a total of more than 60,000 trees and 200,000 clumps of bamboo, and laying nearly 300,000 square metres of turf and flowers, which has greatly contributed to the ecological restoration of the surrounding nearly 3,000 acres of forested land. This series of initiatives not only restored the integrity of the ecosystem of mountains, water, forests, fields, lakes and grasses, but also significantly improved the quality of surface water, forest coverage and air quality in the region, providing a high-quality ecological environment and a wealth of ecological products for the neighbouring residents and tourists.

Ecotourism is booming and economic benefits are steadily increasing. With the deepening of ecological restoration and scenic area construction work, the Lotus Hill 4A scenic area has rapidly emerged as a popular tourist destination. Since its opening more than a year ago, the scenic spot has attracted as many as 700,000 tourists, with direct and indirect economic benefits totalling more than 100 million yuan, contributing more than 10 million yuan in tax revenue to the local treasury, significantly enhancing the value of the scenic spot's assets, and ensuring the steady growth and preservation of the value of state-owned assets .

Significant industrial linkage effect and comprehensive social benefits. The success of Lotus Hill's ecological restoration and scenic area construction has also brought about significant industrial linkage effects and social benefits. More than 40 farmers in the surrounding villages have successfully transformed from traditional rubber cutting to catering and retailing, and their annual per capita income has increased significantly. More than 200 shops in the scenic area, priority to provide to the nearby poor households to rent free of charge for one year, the annual income of each household has reached more than 30,000 yuan, and effectively led to nearly a hundred poor households of stable employment and poverty alleviation and enrichment. In addition, Hainan Nongken Tourism Group and the aboriginal close co-operation, invested heavily in the transformation of abandoned homes for the scenic bed and breakfast, not only for more than 200 villagers to provide employment opportunities, but also promote the further improvement of the scenic environment and the booming development of the region's bed and breakfast industry, to achieve from the ecological "restoration" to ecological It has achieved a magnificent turn from ecological "restoration" to ecological "welfare", and set a model for rural revitalisation and sustainable development.

6. SUMMARY

In recent years, the comprehensive creation of pit parks has become a mainstream trend in the ecological restoration of abandoned pits in urban planning areas [13]. This initiative not only responds

to the urgent needs of the times for green development, but is also a concrete practice of the concept of "dual urban repair". The concept of "double repair of the city" emphasises a two-pronged approach: on the one hand, through the refinement of urban repair work, reshaping the regional characteristics of the landscape, and enhance the city's cultural identity and sense of belonging; on the other hand, committed to ecological restoration, efforts to improve the quality of the urban ecological environment, and to promote the harmony of human beings and nature coexistence.

During the construction of the pit park, the designers cleverly used a low-intervention landscape design approach [14], aiming to build a bridge of harmony between man and nature, and to transform the pit resource, which was originally regarded as a disadvantage, into an attractive cultural landmark and ecological landscape [15]. This process not only demonstrates the clever combination of human wisdom and natural forces, but also vividly interprets the development concept of "green water and green mountains are golden silver mountains" [16].

Therefore, when promoting the ecological restoration and re-greening design of abandoned mine sites, we need to grasp the natural law of landscape development and regional characteristics, and strive to restore the original appearance of abandoned sites while reasonably retaining and making use of their historical buildings and equipment, giving them new life and meaning. In this way, we can not only fully explore and show the unique cultural value of the mining landscape, but also maximise its inherent ecological advantages, and realise the win-win situation of economic benefits, social benefits and ecological benefits.

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