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Review of Ecological Slope Protection Technology Research

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Abstract

Along with the implementation of the national sustainable development strategy, the project construction has paid more and more attention to ecological protection. A large number of excavated or filled slopes have been formed in construction areas such as mines, highways, and water conservancy projects in the construction of foundation projects, which have destroyed the original ecological environment. The restoration of the slope ecosystem has promoted the research and innovation of ecological slope protection technology. This paper summarizes the research history of ecological slope protection at home and abroad, lists the research status of soil structure and indoor model test, and puts forward some problems existing in ecological slope protection technology at this stage, and looks forward to the long-term development and research of ecological slope protection technology.

Keywords

Ecological slope protection; Slope Protection; Soil structure; Indoor model test.

1. INTRODUCTION

The large-scale development of infrastructure has brought a high quality of life to human beings, but the development of engineering construction has also produced a large number of disturbed slopes. With the strengthening of human ecological awareness and the proposal of my country's environmental protection policies, the restoration of slope ecosystems has become an important problem that needs to be solved urgently [1-2]. Therefore, the concept of ecological slope protection has become an important answer to solve this problem. The ecological slope is different from the traditional reinforced concrete "gray" slope protection technology, but uses plant rooting and anchoring to stabilize the slope. On the one hand, the ecological slope protection enhances the anti-slip force of the slope through the gripping force of plant roots on the soil; on the other hand, plants use their own unique function of photosynthesis to absorb carbon dioxide in the air and convert it into oxygen, which greatly reduces the greenhouse gas carbon dioxide. content, purify the air, and realize the beautification of the ecological environment [3]. At present, researchers have developed a variety of new green slope protection technologies such as the planting roll method, the soil planting bag method, the fiber greening method, and the thick-layer substrate spray greening method. The vigorous development of ecological slope protection technology has pointed out the direction for slope protection.

2. RESEARCH STATUS OF ECOLOGICAL SLOPE PROTECTION

Ecological slope protection is a slope protection technology that integrates the basic knowledge of engineering mechanics, soil science, ecology and botany to support slopes or

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slopes and form a comprehensive slope protection system composed of plants or engineering and plants. After the excavation slope is formed, the surface layer of the slope is protected and reinforced by planting plants and using the interaction between plants, rock and soil (root anchorage), so that it can not only meet the requirements for the stability of the surface layer of the slope, but also The slope protection method to restore the destroyed natural ecological environment is an effective slope protection and slope fixing method [4].

Ecological slope protection is mostly defined abroad as: using plants alone or combining plants and civil engineering to reduce slope erosion and enhance slope stability [5-6]. Japan, the United Kingdom, Australia, the United States and other countries have carried out research work on rock slope vegetation restoration and landscape reconstruction earlier. Based on their own actual conditions, these countries have formed a suitable Theory and technical methods of ecological restoration according to the environmental conditions of the country. Among the above-mentioned countries, Japan is an international leader in the research on vegetation slope protection for rock slopes along highways and has a strong representation [7].

As early as the middle of the 20th century, Japan began to study related aspects of ecological slope protection. Since 1950, Japan has introduced and developed the emulsified asphalt technology invented in the United Kingdom [8-10].

In the 1950s, Japan invented the hydraulic spraying technology for vegetation slope protection.

In the early 1960s, Japan introduced spray seeding machines from the United States and realized the improvement of hydraulic spray seeding technology, which was widely used in highway embankment and slope greening.

In the 1970s, the technology of spraying slope protection for thick-layer substrates in Japan gradually matured, which overcomes the adverse effects of high pH value and poor water retention of substrates in the previous fiber-soil greening method.

In the 1980s, Japan introduced the continuous fiber reinforced geotechnical method from France, and combined it with the slope greening method to develop a continuous fiber greening method (TG greening method). With the continuous improvement of technology, continuous fiber greening technology has been widely used in various countries and regions [11-15].

At the end of the 20th century, Japan carried out a lot of research on the application of vegetation-based porous concrete, and at the beginning of the 21st century, Japan established the Greening Concrete Association, which promoted the development of vegetation-based ecological concrete.

Among them, the vegetation concrete protection technology is developed on the basis of hydraulic spraying technology. This technology is mainly developed for the difficult ecological restoration of high and steep rock slopes along expressways and railways. The technology is to prepare concrete mixture by mixing soil (mainly sandy loam near the project area), cementitious material (mainly low alkalinity cement), water-retaining agent, herb and shrub seeds, and water in appropriate proportions. Its main advantages are a wide range of material sources, a porous structure similar to soil, a certain strength and erosion resistance, and a high degree of construction mechanization [16-17].

Also widely used in Europe and the United States is the thick-layer base material jetting slope protection technology, which is a new type of ecological protection technology developed with the difficulty of ecological restoration of road and mine rock slopes. The basic principle of the technology is to use a spraying system composed of an air compressor and a mixed spraying machine to spray the planting substrate mixed with suitable plant seeds onto the slope surface for ecological restoration. The planting matrix contains binders, and due to the binding effect of the binders and the reinforcement of the barbed wire and some plant roots, a vegetative layer

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that is both stable and suitable for plant growth can be formed on the slope. This technology has obvious advantages for ecological restoration of exposed rock slopes with difficult construction and management [18].

my country's ecological slope protection technology has a long history, but it started late. In the early days, ecological slope protection was called vegetation slope protection, slope ecology, and vegetation slope stabilization. It was only used for river bank protection and barren hill greening. The technical methods were relatively simple, and they were not widely studied and developed.

Before the 1990s, my country had been using methods such as hole sowing, sowing grass seeds, planting grass on a rubble skeleton, and laying turf for slope protection [19]. In 1989, Guangdong Water Conservancy and Hydropower Technology Research Institute introduced the first hydraulic seeding machine from Hong Kong and carried out the practice and research of hydraulic spraying technology in South China. From 1990 to 1991, China Zhishan Technical Training Center cooperated with relevant Japanese institutions to conduct experimental research on hydraulic spraying technology on the Loess Plateau. In 1993, China introduced geotechnical materials for planting grass and slope protection, and developed a variety of geosynthetics, such as three-dimensional vegetation nets, geogrids, geocells, etc. [20-22] The combination of materials and technologies is widely used in railways, highways, water conservancy It has been applied in the slopes of other projects one after another. In 1995, Chen Zhensheng used the planting bag method to deal with the greening problem of mudstone slopes. In 1998, the Chongqing Academy of Jiaotong Science put forward the composite nutrient soil spraying vegetation technology for the greening construction of weathered and broken rock slopes. In the same year, Liu Guinian used the planting of kudzu and pine to deal with the ecological protection of soft rock slopes [23].

Beginning in the 21st century, the research on vegetation greening on rocky slopes has been officially launched in my country. With the accumulation and continuous development of engineering application experience, the technical team of ecological slope protection in my country has gradually grown.

Beginning with the spraying technology of foreign soil introduced by Li Xuguang at the beginning, many scholars [24-29] introduced the technology in detail and carried out research. Soil spraying technology, also known as mud spraying greening method or high-order pellet spraying technology, it mainly mixes plant seeds, water, fiber mulch, adhesive, fertilizer, nutrient soil (foreign soil), soil stabilization After stirring and mixing in a certain proportion, high-pressure spraying machinery is used to spray evenly on the slope surface that has been anchored by hanging nets to form a substrate suitable for plant growth [30].

Since 2000, Zhang Junyun [31-33] has studied and carried out a series of experiments on the sprayed planting base of thick substrate for rock slope vegetation protection. factor.

In 2001, Guan Jiexiong proposed the application of three-dimensional vegetation net combined with spraying and planting to protect slopes with high, steep and broken quartz schist. In the same year, Three Gorges University conducted a series of studies on the issue of rock slope greening construction, developed the greening substrate spray anchor slope protection technology and successfully applied it to the ecological protection of rock slopes.

3. ECOLOGICAL SLOPE PROTECTION SOIL STRUCTURE

The wide application of ecological slope protection technology at home and abroad has prompted the development of ecological slope protection in the direction of combining plant engineering and civil engineering [34-36]. Ecological slope protection project mainly refers to taking certain greening and slope protection engineering measures for a large number of exposed slopes in the construction of industrial and civil buildings, urban roads, railways,

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highways, water conservancy and other projects, and ecological greening and slope protection. deal with. The interaction between plant roots and soil is used to protect and reinforce the shallow layer of the slope to achieve the stability of the slope, prevent soil erosion, purify the air and beautify the environment. The premise of the successful ecological slope protection project is that the foreign soil on the slope can be stably attached to the slope surface, especially the high and steep rock slope with poor site conditions [37-42].

The form of slope protection has gone through such a process both at home and abroad, from "less protection or no protection, to the protection of tall masonry concrete or masonry projects, to the combination of rigid and flexible structures, multi-layer protection and ecological vegetation protection. With the evolution of ", the protection system is becoming more and more perfect [43-44]. The solid soil structure is the basic unit of slope protection, and the evolution of its structural form also reflects the evolutionary history of slope protection research.

The plant skeleton slope protection structure is one of the typical soil-reinforcement structures combined with plant protection and engineering protection in the early research in my country. Among them, the engineering protection is only a relatively small skeleton. One of the functions of the skeleton is to divide a large area of slope into small pieces. The smaller the soil area, the smaller the mutual traction between the soils, and the smaller the probability of large-area and deep soil collapse. Another function of the skeleton is to support the soil above the skeleton, constrain the deformation and displacement of the soil, and thus ensure the stability of the entire soil [45]. In 2012, Li Long et al. used the Mohr-Coulomb model to discuss the protective effect of the skeleton slope protection on the expansive soil cutting slope, and proved that the skeleton slope protection structure is a complete solid soil structure, and the skeleton and the slope soil are an organic whole. The stability of the framework itself and the stability of the slope soil are equally important. Nie Yihua, Tang Saiqian et al. conducted loading tests by constructing a small-scale prefabricated block surface skeleton slope protection structure at the bottom of mortar masonry scree to build an indoor scale model. The conclusion of the skeleton slope protection structure of the small prefabricated block (buckle seam) surface.

Three-dimensional geonet pad grass planting slope protection is a new type of ecological slope protection and soil structure that has developed rapidly in recent years. On the one hand, the three-dimensional geonet pad can form a complex mechanical mosaic system with soil and plant roots, which can well protect the soil from rainwater splashing and runoff scouring. On the other hand, this solid soil structure can beautify the environment. It is beneficial to the restoration of the slope ecological environment [46-47]. In 1993, my country introduced the technology of three-dimensional geonet pads for planting grass and slope protection. Through the cooperation between the civil engineering community and plastic product manufacturers, various forms of geonet products have been developed, such as geogrids, geocells and geonet pads. These products have been put into use one after another. It can be used in engineering slope applications such as railways, highways and water conservancy. With the wide application of the three-dimensional geonet pad ecological slope protection soil structure, people have done a lot of research on the anti-erosion characteristic test and anti-scour mechanism of the slope protection effect and engineering application after the vegetation has grown. More importantly, important research has also been carried out on the stability of the slope protection system in the initial stage of this soil-reinforcement structure and the stability of the three-dimensional geonet pad for slope protection and slope design optimization.

The composite bolt-geonet mat spray-seeded ecological slope protection structure is a new type of rock high and steep slope soil-reinforcing structure proposed by Shi Wei et al. Fix the geonet pad, and spray the planting base material in the geonet pad. After the vegetation grows, the greening effect of the slope surface is achieved. The root system of the vegetation is

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embedded in the shallow rock mass to enhance the effect of shallow slope protection, and the greening protection of the slope surface is combined with the deep slope solidification. The organic combination makes the rock slope stable as a whole [48-50]. The composite anchor rod-geonet mat spraying ecological slope protection structure organically combines the deep stability and shallow stability of the slope, and the stability of the vegetation layer on the slope surface and the stability of the slope body are unified through the spatial reinforcement of the anchor rod, which is suitable for unstable rock. High and steep slopes.

4. INDOOR MODEL TEST OF ECOLOGICAL SLOPE PROTECTION

As a slope protection unit, the solid soil structure also provides the possibility for indoor model tests. Through the study of the basic unit of the soil-retention structure, the characteristics and influencing factors of each slope protection structure can be quantitatively analyzed, which is the basis of the indoor slope model research.

The laboratory test method is mainly to simulate the influence of the actual natural environment on the slope stability, such as gravity factors, rain erosion and infiltration, wind erosion and earthquake. The key to the indoor test lies in the design of the indoor slope model. Model selection and production are the basis for obtaining good test results. By analyzing the indoor slope models designed by various scholars, the design and development of new indoor slope test models can be multiplied with less effort.

In order to study the influence of the stability of the foreign soil under the gravity factor, Yang Junjie [51] designed a simple indoor slope model. The experimental model is to lift one end of the model manually, so that the model and the ground form a certain angle, that is, the slope angle. Then carry out the corresponding experimental research; Lu Kunlin [52] designed a slope model groove that can be lifted, and the slope angle can be adjusted by the screw lifting device, but the slope model can only achieve 30°, 45° and The transformation of three angles of 60°.

Taking into account the factors of rain erosion, Yang Xiaohua [53] designed a slope model composed of steel troughs and upper and lower water systems and conducted loess embankment slope erosion tests, considering the geocell size as the influencing factor and obtained the geocell size It is concluded that the amount of soil erosion can be reduced; Cheng Ye [54] designed the indoor erosion resistance test of the ecological slope with reference to the slope model design diagram of Li Jun [55] and others, considering the area requirements for the growth of plant samples. The model is used to compare the scour resistance of different plants and different geotechnical materials. The model plate is fixed at an angle by connecting a baffle with a support rod, and the surface of the plate is polished and then covered with a layer of fine stone concrete.

In terms of water seepage, Huang Tao [56] used a pressure cell to test the thrust on the sliding surface during rainfall in his indoor seepage test, and studied and analyzed the influence of four seepage models on the slope stability. The water pressure was measured, and drilling was carried out on both sides of the slope model; Qian Jiyun [57] designed a centrifugal field simulating rainfall equipment, combined the centrifuge technology with artificial rainfall, and tested the edge during the rainfall process. Slope displacement and failure form.

In terms of wind erosion, experts and scholars [58-60] designed indoor model tests and conducted field wind erosion resistance tests to provide a basis for the prevention and control of wind erosion slopes.

In considering seismic factors, Liu Hanxiang [61] used a large-scale shaking table to simulate earthquake action; Yang Qinghua [62] used centrifugal sand pile model test to simulate the dynamic characteristics of sand piles under different seismic intensities, which is the most important part of the loose soil slope. Shockproof design provides reference.

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5. ISSUES AND PROSPECTS

Ecological slope protection takes into account the two aspects of slope protection and slope greening, and mechanical balance and ecological balance have always belonged to two different disciplines. Therefore, the research on ecological slope protection technology often has a separation phenomenon. Hope to optimize and improve the following problems.

(1) In the selection of materials for the construction of ecological slope protection technical engineering, in order to increase the stability of the slope, reinforced concrete lattice beams with high cost and high pollution are often used for slope protection. It will also cause environmental pollution and loss of vegetation while causing waste of resources. Therefore, the new ecological slope protection technology should pay more attention to the use of environmental protection materials and the construction of ecological systems.

(2) Ecological slope protection technology When designing the thickness of the base material layer of the protection system, the design thickness often does not meet the needs of plants to grow and take root, and it is impossible to build a real long-term slope protection system. It is hoped that the new ecological slope protection technology can start from the ecological point of view, and consider the cooperation between slope protection technology and plant development.

(3) When the ecological slope protection technology is verified by the indoor model test, the test conditions and test materials cannot be close to the conditions in the real field construction, and can only be simplified accordingly, and the verification of the protection effect is also different. For the research and development and innovation of ecological technology, indoor model tests that are closer to natural conditions should be used to simulate and test.

With the advancement and improvement of traditional slope protection technology, ecological slope protection technology has entered a stage of continuous innovation. With the enhancement of human's awareness of ecological and environmental protection, ecological slope protection technology will achieve long-term development and research.

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