Plant Slope Protection in Highway Engineering

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Abstract. With the rapid development of the economy, a large number of high grade highways have been built in Wuhai, China. Due to the special natural environment and the influence of human engineering practice, the geological disasters have occurred in recent years. Through the study of the failure mode of the slope and the protection of the ecological environment, the paper puts forward the method of adopting the plant supporting slope to achieve the stability in Wuhai highway, which focuses on the analysis of hydrology and mechanics of plant slope protection. The hydrological effects of plant slope protection mainly include rainfall interception of plant stems and leaves, weakening of splash erosion of raindrops, and inhibition of surface runoff; while the mechanical aspects include the reinforcement effect, the anchorage of the main root system and so on.

1. Introduction

Inner Mongolia is in arid and semi-arid area, and its mineral resources are abundant. Monsoon climate causes heavy rainfall in rainy season, which often leads to soil slope instability. With the implementation of the development of Western China, a large number of roads and railways have been built in Wuhai. Of course, a series of environmental problems are caused, which is mainly reflected in the destruction of the original vegetation in the local area and the formation of the bare slopes of different degrees. Of course, a series of environmental problems are caused.

There are many traditional ways to protect the slope, but with the requirements of environmental protection, the demands for environmental protection are becoming more and more important. As a new type of slope protected, plant slope protection has been paid more and more attention. A large number of research results have shown that the existence of plants plays an important role in effective prevention and control of slope soil erosion, shallow landslides, reducing the degree of slope soil mass cracking, reducing soil loss on the surface of the slope, and increasing the stability of the surface of the slope. Because of the important role of plant slope protection, more attention has been paid to the theory and application of plant slope protection [1].

Many researchers have done a lot of work. As early as 16 or 17 Century, plant soil consolidation revetment was applied to the reinforcement and protection of riverbank and the treatment of barren hills. However, its theoretical research and technical application began in the early twentieth Century. In order to cope with the serious environmental problems such as slope erosion, frequent landslides and avalanche, degenerated embankments and other serious environmental problems, the study of soil plant slope protection began in Europe at that time. The theory of plant slope protection developed initially in 1950s, but a relatively complete scientific system was formed, and only a few dozen
histories [2-3] were carried out according to the code. In China, there are also ecological projects of plant slope protection. The International Conference on the theory of plant slope protection for the first time was held in the United Kingdom in September 1994 after the industrial revolution. After that, the research on the theory of plant slope protection and related applications has entered a relatively rapid development period. It has promoted the development of this research field. The research on the mechanism of plant retaining and protecting slope is mainly shown in two aspects, namely, the hydrologic effect and the mechanical effect of the plant slope protected [4]. Among them, the mechanical effect includes the root reinforcement theory of soil shear strength [5-7] and the relationship between root and soil compounding stress [8-9]. Hydrological effects include slope vegetation cover and rainfall interception, slope vegetation types and throughfall, plant density and slope stability [10].

At present, the theoretical research and practice of plant slope protection have reached a high level. It has been very mature from the selection of vegetation, the formula of spray seeding matrix, the construction technology and the maintenance management. The three-dimensional greening with combination of trees, shrub and grass can not only guarantee the stability of the slope, but also beautify the environment and restore the original natural vegetation. The construction process mainly adopts hydraulic seeding combined with spraying principle.

In this paper, the applicability and feasibility of plant slope protection in this area are discussed in the light of the climatic and ecological characteristics of the arid areas and the existing methods of plant slope protection. The stability of plant slope protection was analyzed.

2. Plant slope protection project

2.1. Failure form of slope
In Wuhai, the climate is dry, some of the main highways in China pass through the city, and the highway geological disasters occur, which not only have large unstable slopes, but also have many small slopes. When building high-grade highways, the slope problems encountered are very complicated. For example, the construction of Rongwu expressway and Bao Yin expresswayway has encountered large and small slope problems. There will be a slope problem every few kilometers in severe sections. The problem of the onset of the rainy season is more prominent, and the erosion of the slope is slightly caused by the erosion of the slope, and the more serious is the whole or local destruction of the slope, such as sliding and collapse.

2.2. Traditional Slope Protection
According to the stability degree, the slope can be divided into two categories: one is the overall stability of the slope, and the other is the potential sliding surface. The whole stable slope only needs to take engineering protection measures for the surface or local deformation and failure, while the sliding surface needs to take the engineering protection measures to enhance the stability of the slope.

The traditional treatment can be summed up as follows: comprehensive drainage, in order to increase the shear strength of the slope strata and to prevent the erosion and erosion of the slope surface; to dig out the weak or potentially dangerous strata and so on.

2.3. Plant Slope Protection Methods
When constructing highways in arid mountainous area of Wuhai, it is inevitable to excavate and fill up, destroy original vegetation and expose a lot of soil slopes. While the traditional slope measures are mainly protective engineering, such as grouting and shotcrete, these protection forms can stabilize the slope and prevent soil erosion, but their shortcomings are also obvious. That is, geomorphic destruction, vegetation is difficult to recover, ecological destruction is hard to estimate, and the protective effect decreases with time, and there is no self-renewal ability.

With the importance of ecological environment in the western region, a new way of plant ecological support has emerged. The so-called plant slope protection is a kind of integrated
geotechnical engineering technology involving engineering geology, engineering mechanics, botany, ecology and other disciplines.

3. Type of plant slope protection
Slope plant support mainly through artificial planting grass and trees and provide a suitable growth environment for natural grass and trees, and finally achieve the restoration of ecology and coordinate with the natural environment. The protection of the slope is mainly reflected in the soil fixation of the plant roots, and the cover of the plant itself is used to prevent the erosion of water from erosion and wind erosion.

Common methods for ecological protection of soil slopes include planting grass, laying grass and comprehensive plant protection. Planting grass is directly sowing grass species on the slope to greening the slope as the main purpose, the construction is simple and the cost is low. The grass paving is first to dig the growing grass, and the suitable construction method is used to lay the slope on the protection. Comprehensive plant protection is a protective method for planting grass or lawn covering in the frame by means of concrete, slurry block, stone and so on.

There are several commonly used methods for plant protection of rock slopes.
1. Soil spray seeding
2. Spraying mixed planting grass
3. The technology of hydraulic spray seeding
4. The three-dimensional net spraying greening method
5. The vegetation concrete method

4. Plant slope protection principle
The technology of plant soil consolidation and slope protection has been applied in slope protection engineering. Research on plant slope protection and its related fields is of great theoretical and practical significance for deepening the theory of plant slope protection and effectively guiding the technology of plant slope protection and forming a more systematic theory.

4.1. Hydrologic effect of plant

4.1.1. Reducing pore water pressure of slope body. Rainfall is one of the important factors inducing slope instability. The instability of the slope is closely related to the size of the slope water pressure. According to the data, it is shown that the formation of the sliding of the shallow slope mainly depends on the shear strength of the soil. When the external factors, especially the rainfall, increase the water content of the soil, the shear strength of the soil is reduced and the soil decline force increases when the bulk density increases. According to the theory of static equilibrium, when the frictional resistance between soils is not enough to resist the sliding force of the soil, the slope will cause the phenomenon of sliding failure. By absorbing and transpiration water in the slope, plants absorb moisture in the soil continuously, reducing the water in the soil, reducing the pore water pressure, improving the shear strength of the soil, and is beneficial to the stability of the slope body.

4.1.2. Weaken the splash of raindrop and control the loss of soil. After passing through the aboveground parts of the plant, rainfall is roughly divided into three types: penetrating rain, stem flow and canopy interception. Penetrating rain refers to the rain that falls directly to the ground through the gap of plants, and the rainfall that falls on the ground with water droplets after contact with plants. The stem flow refers to the rainfall that flows through the upper part of the plant to the ground; Canopy interception refers to rainfall that eventually stays on the surface of plant stems and leaves after rain [11].

Under the impact of raindrops, the surface structure of the bare slope is destroyed, and the soil ruptures and spatter. There are plants on the slope that can be stopped by vegetation before reaching the slope, re-evaporating to the atmosphere or falling to the slope, thus reducing the infiltration of
rainwater. The plants can intercept the raindrops at high speed and weaken or even eliminate the splash of the raindrops through the buffering effect. The surface runoff can take away the soil particles that have been spattered and further cause the pitting and ditch erosion. The vegetation can obviously inhibit the surface runoff and control the soil erosion. In general, the loss of soil decreases exponentially with the increase of vegetation coverage.

4.2. Mechanical effects of plant
The mechanical effect of plant slope protection is manifested in the reinforcement effect of the shallow root system on the soil, the anchorage of the deep root to the soil and the traction effect of the horizontal root to the soil. The root system can effectively enhance the shear strength of the slope soil and form a root soil complex with the surrounding soil. The compressive strength of the soil is relatively strong and the shear capacity is relatively weak. Compared with the soil, the tensile strength of the plant roots is relatively strong and the compressive strength is low. Therefore, the root soil composite can give full play to the advantages of two materials, root and soil. The increase of shear strength provided by plant roots depends on the number of roots that pass through the potential shear surface, the distribution of root and its strength, the angle between the root and the rupture surface, the elastic modulus of the root system, the initial water content of the soil and the root system. In the soil layer, the plant roots enhance the stability of the slope by means of reinforcement and anchorage.

4.2.1. Surface reinforcement effect of shallow root. The shallow roots of plants are intertwined in the soil layer of the slope, making the soil mass of the slope become an organic composite layer in the extension area. The mechanism is similar to the reinforcement in reinforced concrete, which mainly plays the role of shear resistance and tensile strength. The reinforcement effect of the root system increases the cohesive force C of the soil layer on the one hand, according to \( \tau = \sigma \tan \phi + C \), in the formula: \( \sigma \) is the normal pressure, \( \phi \) is the internal friction angle, \( C \) is the cohesive force. It can be seen that the increase of \( C \) increases the shear strength of the soil, and on the other hand, the tensile force of the root limits the deformation of the soil or rock. It can prevent the occurrence of surface tension cracks and prevent the slope failure caused by the infiltration of rainwater and the extension of tensile cracks.

4.2.2. Anchorage effect of vertical deep roots. The vertical roots of woody plants can be deeply embedded in the soil. When the main root is perpendicular to the weak or sliding surface of the slope, the effect of the root system is similar to the effect of soil nailing or anchor, and it is anchored to the slope to reinforce the slope. The main roots of gramineaceae, leguminous plants and some small shrubs have obvious reinforcement effect on the soil layer of 0.75 ~ 1.5 m underground, and the root of the tree can affect the deeper layer of rock soil. The test shows that the thinner the diameter of the root, the higher the tensile strength, the relative formula is \( T = nDm \), in the formula: \( T \) is the tensile strength of the root; \( D \) is the diameter of the tree root; \( N, M \) is the empirical constant of the given tree species. For the roots with diameter of 2~5 mm, the tensile strength of \( T \) is 8~80 MPa.

4.3. Negative effects of plants on slope
Plant slope protection has its limitations, and slope plants will also have negative effects. For example, the extension of the vegetation root causes the crevice of the soil, which leads to the increase of the permeability of the upper layer, and the pore water pressure of the soil. The luxuriant vegetation increases the anti-slip force and the sliding force of the slope, and increases the instability of the slope, and the deep root anchorage of the plant can not extend to the stable rock soil, and the effect is not obvious. The other explants can play a more important role in the deep sliding of the slope.

5. Conclusion and Prospect
Based on the above research situation of plant slope protection and its application area, the future research in this field is mainly manifested in the following aspects.
The soil moisture of the slope has an important influence on the plant growth and the stability of the slope. The research on the hydrologic effect of the plant solid soil protection mainly focuses on the rainfall interception, the suppression of surface runoff and the erosion of the splash erosion in the slope plant, and the interaction between the roots of the slope plants and the soil. The mechanical effect of action and its influence on slope stability need to be further discussed.

The effect of plant soil consolidation and slope protection is the result of the interaction of plant stem and leaf hydrologic effect and root mechanical effect, that is, the result of the superposition of the mechanical effect and the hydrologic effect. In the previous study of hydrology effect and mechanical effect, the hydrology effect and mechanical effect were analyzed separately, which made the conclusion incompleteness, Therefore, in the future research, we will further combine the hydrological effect and the mechanical effect, so as to show the comprehensive effect of plant soil consolidation and slope protection.

The plant slope has the advantages of low cost, low maintenance cost, strong self-repairing ability and strong adaptability of native plants, but the slope also has a relatively slow effect, and the plant growth is affected by various factors such as climate and environment, which makes plants not easy to survive, to a certain extent, limits the ability of the plant to protect the soil slope protection ability and so on. In most cases, a good vegetation slope is more stable than the bare slope.

Considering the positive and negative two aspects of the plant to the slope, the slope plants have the same function as the anchor, but it is not necessary to simply compare the mechanical enhancement effect of the slope plants with the reinforcement effect of the anchor or pile. Plant is a living life body, and its interaction with the slope body is mutual.

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