Study on the selection of vegetation for ecological restoration of residual soil slopes in South China

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Abstract. Vegetation selection is one of the key contents of slope ecological restoration, based on the characteristics of climate and soil in South China and the principle of local conditions, this paper studies the selection of vegetation in the ecological restoration project of the residual soil slope. The typical herbs, shrubs and trees suitable for the area are determined by theoretical analysis. At the same time, through field tests, the growth and development of vegetation after the spraying are monitored for a long time, and the interaction relationship between vegetation community after multiple vegetation mix-ups is analyzed. The results show that plant selection should avoid the choice of a single plant, and should try to achieve complementary coordination between species. At the same time, when taking a variety of plant mixing spray, the configuration ratio of different plants should be determined according to the growth cycle of different plants and the results of indoor ratio test, so as to avoid mutual interference.

1 Introduction

The construction of mountainous highway is often accompanied by a large number of high filling and deep excavation due to topography, forming many exposed engineering slopes. Because of the one-sided pursuit of economic benefits or technical limitations in the early engineering construction projects, most of the above exposed slopes were not treated with ecological restoration works, so that the original ecological system where the project is located has been damaged, and even lead to a large area of ecological degradation and aggravated soil erosion on the surface at the same time.

Since the 1990s, Chinese engineers have gradually realized the above-mentioned problems, and have successively introduced and independently developed a variety of slope ecological restoration technologies from abroad and applied them to domestic road construction projects, such as hydraulic spraying technique, external-soil spray seeding technique and vegetation-growing concrete technique, etc.[1]. The so-called slope ecological restoration technology refers to the artificial means to create a suitable substrate for vegetation growth on the slope surface, build a vegetation community adapted to the environment, and slowly restore the slope vegetation. On the one hand, the slope ecological restoration technology uses the hydrological effect of vegetation to greatly reduce the soil erosion of the slope. On the other hand, it can restrain the expansion of the ecologically degraded area and avoid a greater ecological crisis. In addition, it can also improve the landscape image along the highway.

Vegetation selection is one of the core contents of the slope ecological restoration work, and its purpose is to build a long-term stable ecological community on the slope through the selection and matching of suitable vegetation species. Zhang and Zhou[5] proposed 7 principles for the selection of slope protection vegetation. At the same time, in terms of plant screening methods, it is mainly based on empirical induction[6], analytic hierarchy process(AHP)[4] and other methods to comprehensively screen slope protection vegetation, such as Chen[7], Xie[6], Liu[7] pointed out that grass species such as Eragrostis, Bermuda grass, Bahia grass and ryegrass are ideal grass species suitable for local site conditions. Wei[9], Guo[9], Wu[10] screened tall fescue, bluegrass, ryegrass, lespedea and other vegetation species suitable for ecological restoration in the subtropical region of southwest China. At present, the vegetation community configuration models explored and applied to slope ecological restoration at home and abroad mainly include: (1) herb mixed sowing; (2) herb and shrub mixed sowing; (3) arbor and legume mixed sowing; (4) arbor, shrub and herb mixed sowing[11-13].

There are a large number of highways in the mountainous areas of South China. For this area, it has its own unique climate, soil and vegetation conditions. When selecting vegetation types, it is necessary to carry out targeted research based on the principle of "adapting measures to local conditions". Based on the investigation

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of the climatic and soil conditions in South China, this paper conducts a comprehensive analysis of the optimal vegetation for the ecological restoration of the residual soil slope in the area. At the same time, it conducts field experiments to study the restoration of the vegetation community under natural conditions. The selection of vegetation types in the ecological restoration of residual soil slopes has certain reference value.

2 Climate and soil conditions in South China

2.1 Climatic conditions

The mountainous area of South China is a subtropical semi-humid climate zone, with a mild and humid climate and plenty of sunshine. Such as Guangzhou, the area is rich in precipitation and concentrated in April to September. The annual average precipitation is about 1500mm, the annual maximum precipitation is above 2000mm, the annual minimum precipitation is about 900mm. And the annual average evaporation is about 1400mm.

At the same time, there are frequent typhoons in this area, with the maximum instantaneous wind speed reaching 17m/s.

2.2 Topography

The northern mountainous area of Guangzhou belongs to the Nanling mountain system. The terrain is complex and the canyons are developed. The main areas are tectonic denudation and erosion of low mountains and hilly landforms in South China. The terrain is generally high in the middle and low at both ends, and the elevation is between 27m and 492m. Regional landforms can be roughly divided into alluvial-proluvial accumulation landform units and structural denudation and erosion hilly landform units according to their genesis, as shown in Fig.1.

Fig.1. Typical topographic and geomorphic units in the mountains of South China

2.3 Granite residual soil

The granite residual soil is widely distributed in the mountainous areas of South China, and some low hills are exposed directly or under the thin slope soil. The thickness is not high, generally 3-10m. Granite residual soil can generally be divided into cohesive soil, sandy cohesive soil, and gravel cohesive soil from top to bottom, and its physical and mechanical characteristics are quite different in the vertical direction. Indoor geotechnical tests are carried out on typical granite residual soil samples in this area, and the basic physical index parameters are shown in Table 1.

| Area       | Specific gravity | Liquid limit (%) | Plastic limit (%) | Dry density (g/cm³) | Moisture content (%) |
|------------|------------------|------------------|------------------|--------------------|---------------------|
| South China| 2.74             | 33               | 25               | 2.6                | 18.8                |

3 Selection of ecological restoration vegetation

3.1 Principles of vegetation selection

Based on the special topography and climatic soil conditions of the mountainous area of South China, such as hilly landforms, high temperature and rain, frequent typhoons, etc., combined with the characteristics of the engineering slopes in this area, this paper determines the basic principles of vegetation selection in this area as follows:

(1) Plants need to adapt to the climate of the area;
(2) Plants need to be resistant to barrenness and extensive management;
(3) Plants have a long green period and are perennial, which can make full use of hydrothermal conditions;
(4) Plant seeds germinate quickly and can form a developed root system in the early stage;
(5) The plant root system has strong resistance to pulling out, and the windward area of the canopy should not be too large;
(6) In combination with local vegetation survey, try to choose native plants that adapt to the local environment.

3.2 Optional vegetation for ecological restoration

Herbaceous plants are pioneer plants for slope protection. They have the advantage of rapid growth and coverage. They can form a more comprehensive protection for the slope in the early stage of the slope restoration project, and greatly reduce the hydraulic erosion and soil erosion of the residual soil slope.

Combining the characteristics of high temperature and humidity in the mountainous areas of South China, the herbaceous vegetation for ecological restoration in this area should be mainly perennial herbaceous plants that love warmth, tolerate flooding, tolerate barrenness, and have strong adaptability, such as Bermudagrass, Zoysia japonica, Fake grass, Bahia grass and so on. In addition, the above-mentioned vegetation can form an intricate root system network within a depth of 30 cm, and the multi-surface slope soil forms a reinforcement effect, which
greatly reduces the probability of the surface residual soil slipping after being softened by water. At the same time, engineering experience shows that the ecological restoration of slopes based on a single vegetation is imperfect, and it is prone to degradation in the later growth process.

Compared with herbaceous plants, shrub and arbor plants have longer root systems, and their root tips can extend to the soil parent material and weathered layer, forming a good reinforcement for shallow soils. At the same time, shrub and arbor vegetation has a good advantage of drought resistance, wind sand prevention, dust reduction, fast growth, barren tolerance, and low environmental requirements. Therefore, the ecological restoration of the slope should also be matched with certain shrubs and arbor. The selected shrubs are mainly tropical and subtropical plants that like sunlight, warm and humid climate, and are resistant to water and humidity, such as Oleander, Albizia julibrissin, Schefflera. At the same time, considering the frequent typhoons in summer and autumn in this region, the choice of trees should avoid choosing tall and large perennial trees with a large canopy windward area.

In summary, according to the vegetation survey and literature research in this area, combined with the characteristics of South China, the main ecological restoration plants in this area are determined as shown in Table 2.

| Category | Family name | Scientific name |
|----------|-------------|-----------------|
| Herbs    | Gramineae   | Cynodon dactylon, Zozizia japonica, Eremochloa ophiuroides, Paspalum notatum, Eragrostis curvula, Vetiveria zizanioides, Melinis minutiflora |
|          | Leguminosae | Crotalaria pallida, Melilotus officinalis, Medicago sativa |
|          |              | Lespedeza bicolor, Magnolia multiflora, Cajanus cajan |
| Shrub    |_leguminosae | Nerium oleander |
|          | Leguminosae | Rhododendron ovalum |
|          | Rosaceae    | Rosa multiflora, Rosa laevigata |
|          | Araliaceae  | Schefflera octophylla |
|          | Sapindus    | Dodonaea viscosa |
| Trees    | Leguminosae | Leucaena leucocephala |
|          | Lyrithraceae | Lagrsinosenia indica |
|          | Anacardiaceae | Rhus chinensis |

4 Field test of vegetation selection

4.1 Overview of the test area

The field test is carried out based on the Kaichun Expressway project. The annual rainfall in the area of the project reaches 2400mm, and the area where the project is located is affected by typhoons throughout the year. Heavy rains are frequent, the slope of the project is severely eroded, and the problem of soil erosion has become a more prominent problem in the project.

The test was carried out on the K5 slope which is protected by concrete lattice, and has a slope of 40°~60°. The slope is excavated in three levels, and the test area is the first level slope, as shown in Figure 2. The area within the red line in the figure is the test area, with a total area of about 3000m².

During the 9-month construction period of the on-site spraying, the temperature and precipitation on the site were monitored, as shown in Fig. 3 and Fig.4, respectively. The area where the project is located has a typical subtropical monsoon climate. The dry season is from December to April of the following year, with low precipitation. During the rest of the year, precipitation is abundant, and the frequency of heavy rain and heavy rain events is high. The maximum daily rainfall reaches 280mm.

4.2 Experimental vegetation

In combination with the actual climatic conditions of the project site, the experiment used 2 kinds of herbs (molasses, alfalfa), 2 kinds of shrubs (carberry, pigeon pea) and 1 small tree (Leucaena) for ecological restoration.
(1) Molasses
Molasses Grass is a perennial herb. It is often used as a pioneer plant on newly reclaimed land with a height of about 1 meter.

(2) Medicago Linn
Medicago Linn is an annual or perennial herb with a height of 30~100cm and strong roots. It is an important forage plant and is widely introduced and cultivated all over the world.

(3) Dodonaea viscosa
Dodonaea viscosa is a shrub or small tree with a height of 1-3 meters or higher. It is distributed in tropical and subtropical regions all over the world.

(4) Leucaena leucocephala
Leucaena leucocephala is a shrub or small tree with a height of 2-6 meters, which is produced in Fujian, Guangdong, and it is now widely distributed Various tropical regions.

(5) Cajanus cajan
Cajanus cajan is an upright shrub, 1-3 meters, produced in Yunnan, Sichuan, Jiangxi, Hunan, Guangxi, Guangdong, Hainan, Zhejiang, Fujian, Taiwan, Jiangsu. It is generally cultivated in subtropical regions and is extremely resistant to barren and drought.

4.3 Test procedure
The ecological restoration field test of the residual soil slope in South China is mainly composed of three stages: construction preparation phase, slope vegetation protection project construction and slope vegetation maintenance. The main steps of the test are: (1) Slope finishing, (2) Test and lofting, (3) Plant preparation, (4) Preparation of construction materials, (5) Hanging net, (6) Spray substrate mixture, (7) Heat preservation and moisturizing, (8) Slope vegetation maintenance.

4.4 Test results

4.4.1 Overall vegetation restoration
After the construction, the recovery status of the slope at different times is shown in Fig.5.

The vegetation on the slope began to sprout 15 days after the completion of the construction, and about 30 days after the completion of the construction, the herbaceous plants for the slope protection began to sprout, and the plant heights were mostly between 1 and 5 cm. About 150 days after the completion of the construction, the herb plants have basically grown and covered the slope with a high coverage. At the same time, there are scattered shrubs such as pigeon peas and mulberry among the various grids. But at this time, the germination rate and plant height of the shrub vegetation are low. Therefore, at this time, the slope vegetation is still dominated by vegetation such as alfalfa and molasses, while the shrub vegetation coverage rate is low. 210 days after the completion of the construction, it is obvious that the herbaceous vegetation has declined and its coverage has been greatly reduced. The height of the shrub vegetation has reached 20-50cm, and the growth status is good. Each frame of the lattice structure is basically distributed with 1 ~2 shrub vegetation.

4.4.2 Comparative analysis of growth and development of different vegetation
The change of the plant height of Molasses grass over time is shown in Fig.6. The plant height of Molasses grass reached about 2 cm after the completion of the construction, about 3.5 cm at 45 days, and about 15 cm after 90 days. Molasses grow densely and have a high coverage rate, and grow faster even on slopes where no functional materials are added.

![Fig.5 The vegetation restoration status on the slope at different times](image)

![Fig.6 Growth of molasses grass in different periods](image)

The change of the height of Medicago Linn with time is shown in Fig.7. The height reaches about 2.2cm in about 20days after construction, about 5.5cm in 45days, and about 12cm in 90days. Medicago Linn has a low coverage rate per plant, will not inhibit the growth of shrubs, and is conducive to long-term ecological protection.
In this region from other
45 days
bc Molasses Grass
about 20 days after the
s always low in the first,
and at the same time, it affects the slope surface due to the
herb plants absorbs a large amount of nutrients in the soil,
herb plants germinate and cover quickly. The growth of
proportion of herb seeds is relative high.
The reason for this phenomenon may be that the
growth rate in the first 200 days is only 0.09cm/d.
The growth of shrub vegetation is still going
maximum. The growth of shrub vegetation is still going
consistent and design of thick-layer substrate spraying
sheltering effect. The moisture and heat transfer in the soil
ultimately affect the germination and growth of Cajanus
cajan.

5 Conclusion
Based on the principle of local conditions, a study on
vegetation selection for ecological restoration of residual
soil slopes in South China has been carried out. The main
conclusions are as follows:
(1) The high-temperature and high-humidity
conditions in the mountainous areas of South China cause
differences in the selection of vegetation in the slope
ecological restoration project in this region from other
regions. The vegetation selection should be based on
warm-season vegetation that prefers warm and humid

(2) The main growth period of herbaceous plants is in
the early stage of the slope protection engineering, and its
growth stagnates in the middle and late stages. Adding
shrubs, small trees and other middle and later plants will
help further improve the erosion protection ability of the
slope in the middle and later stages.
(3) When using a mixed spray of multiple plants, the
proportion of different plants should be determined
according to the growth cycle of different plants and the
results of the indoor ratio test, so as to avoid the influence of
the shading effect that inhibits the growth of some
species.

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