Water and soil conservation technology of steep slope based on artificial vegetation restoration

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Abstract. The mountain steep slope is in serious soil erosion owing to the rain wash, and is prone to geological disasters. Restoring vegetation on steep slopes can effectively maintain water and soil, avoid disasters and protect the environment. The key point of restoring vegetation is to solve the difficulties of soil conservation on steep slopes and satisfy the basic needs of vegetation growth. Based on the design and discussion of vegetation species selection, growth hole design, substrate soil ratio and water and soil conservation facilities on steep slopes, a water and soil conservation technology based on artificial vegetation restoration is proposed. The results show that the soil with a certain thickness is successfully maintained on the steep slope and the artificial vegetation is restored.

1. Introduction
The mountain is destroyed by construction or geological disasters, forming steep slopes with high and steep slope. The steep slopes are washed by precipitation and the matrix covered on the slope surface is lost, which makes the vegetation difficult to grow. With the improvement of living standards, people's requirements for living environment are constantly higher. The soil conservation of wasteland has become a hot spot of concern and the focus of research [1]. There are two reasons make the steep slope cannot grow vegetation: First, there is no soil environment that required for vegetation growth, even if a small amount of soil parent material produced by rock weathering will be washed away by rain due to the steep gradient [2-4]; Secondly, there is no suitable moisture and no enough nutrients to provide for vegetation growth needed. Therefore, the key to vegetation restoration on steep slopes is to preserve a certain thickness of substrate soil on the slope to provide conditions for vegetation growth. This study mainly solves this problem from vegetation species selection, growth hole design, substrate soil ratio, three-dimensional barbed wire and retaining plate [5,6], and achieves the restoration of vegetation on the steep slope, so as to achieve the purpose of soil conservation.

2. Vegetation species screening and growth hole selection
2.1. Vegetation species screening
Different plants have different genetic characteristics and exhibit different adaptability to environmental conditions. For the native plants in the construction site, because of the principle of “survival of the fittest”, they have adapted to the local living environment through competition between different species. They are more adapted to the local climate than exotic plants [7-9].
However, the local plant seeds are not easy to collect, which is not conducive to the restoration of steep slope vegetation. Based on this, exotic herbaceous, turf and shrub species that are similar to the physiological and ecological characteristics of native plants and are easily available in large quantities are used as pioneer species. Firstly, construct exotic pioneer plant communities, and then develop them as native species plant community. Because of high altitude and steep slope, slope vegetation need to satisfy the following requirements: plant that can adapt to the climate and soil conditions in the area where the steep slope is located, has strong tolerance, developed root system, rapid growth speed, perennation characteristic, and can grow with extensive management. Under normal circumstances, the choice are mainly herbs, and supplemented by vines and shrubs, and the diversity of provenance tree species, so that different combinations can be adopted based on local conditions. According to the slope of different gradients, foreign scholars surveyed the growth of vegetation on different slopes. The results are shown in Table 1. Because most gradients of steep slopes are larger than 60°, herbs is not suitable, and shrubs and dwarf trees should be planted.

| Gradient | The growth of vegetation |
|----------|--------------------------|
| < 30°    | Shrubs and dwarf trees grow well, native plants are easy to invade after vegetation cover erosion. The growth and development of plants are vigorous. Under the shelving condition, the boundary slope of whether the surrounding plants can naturally invade and form a community is 35°. |
| 30°--35° | The plants grow well and can form a community of shrubs and herbs. |
| 35°--45° | Plants grow poor and can form low plants community of shrubs and herbs. Tall trees will cause slope instability. |
| 45°--60° | Plants growth are significantly poor, herbs easy early decline. |
| > 60°    | Plants growth are significantly poor, herbs easy early decline. |

2.2. Minimum depth selection of vegetation growth holes

Different plants have different requirements on the thickness and growth conditions of the growing soil. For general soils, the minimum soil thickness required for plants is shown in Table 2. However, since the substrate soil used in the soil conservation process is organic soil, it has stronger water retention and fertilizer retention ability than the general soil, and the soil thickness required for plant growth is thinner than that of the general soil.

Therefore, it can be considered that the steep soil slope has a soil preservation thickness of 60 cm, which can satisfy the living conditions of shrubs and low trees.

In order to satisfy the vegetation survival requirement of the substrate soil on the steep slope, the thickness of the substrate soil is only 200mm. Therefore, it is necessary to make a vegetation growth hole on the slope surface, the diameter is 100 mm, the depth is 400 mm, and the hole spacing is 500 mm. There is a plum-shaped distribution between the holes with 4 holes per square meter, the maximum amount of soil is:

\[
4 \times \pi \times (0.05)^2 \times 0.4 = 0.0126 \text{m}^3
\]  

(1)

The thickness of the substrate soil per square meter is 0.2m, and the amount of substrate soil is:

\[
1 \times 0.2 = 0.2 \text{m}^3
\]  

(2)

The vegetation growth pores maximum retain soil rate is:

\[
0.0126 \div 0.2 = 6.3\% 
\]  

(3)

Therefore, the growth hole diameter of the steep slope is 100mm and the depth is 400mm, which can save 6.3% of the soil and provides the necessary conditions for the survival of shrubs and dwarf trees.
Table 2. The minimum soil thickness required for plants to survive and grow.

| Classification          | Herbaceous | Large shrub | Under shrub | Shallow-rooted trees | Deep root tree |
|-------------------------|------------|-------------|-------------|----------------------|---------------|
| Minimum soil thickness for survival (cm) | 15         | 45          | 30          | 60                   | 90            |
| Minimum soil thickness for growth (cm)   | 30         | 60          | 45          | 90                   | 150           |

3. Determination of substrate soil ratio

The steep slope substrate soil is composed of greening substrate, cultivated soil and fiber [10]. The greening substrate is composed of organic matter, fertilizer, water retaining agent, binder, agglomerate, pH adjuster and so on. The greening substrate ensures the stability of the slope substrate mixture, improves the substrate soil structure, and provides the required balance nutrients and moisture for vegetation growth. Cultivated soil refers to the soil suitable for cultivation around steep slopes, which is dried, pulverized and sieved. The particle size is less than 8mm×8mm and the humidity is less than 30%. The cultivated soil provides a suitable growth environment for the vegetation, and promotes the formation of the substrate soil aggregate structure together with the greening substrate. The fibers are generally pulverized materials such as straws and branches having a size of 10 mm to 15 mm. It can avoid the over-tight of the slope substrate soil, enhance the inter-linkage between the substrate soils, and improve the strength and corrosion resistance of the substrate soil.

The substrate soil of steep slopes needs to meet the vegetation growth of shrubs and trees, and is resistant to rain erosion. Prof. Zhou Peide from Southwest Jiaotong University conducted detailed research on the three distributions of substrate mixture, water constant and agglomeration degree, and obtained the mixture ratio of substrate mixture (as shown in Table 3). On this basis, the study determined the ratio of the substrate soil of the steep slope, which was adjusted by engineering test. When the slope ratio is larger than 1:0.3, the amount of binder used increased by 20%. The basic configuration is shown in Table 4. The substrate soil formed under the basic ratio satisfies the minimum conditions for vegetation survival and lays an important foundation for the restoration of vegetation on steep slopes.

Table 3. The mixture ratio of substrate mixture (volume ratio).

| Greening substrate (%) | Fiber (%) | Planting soil (%) |
|------------------------|-----------|-------------------|
| 20                     | 40        | 40                |

Table 4. Main materials and their dosage (The area is 10m² and the thickness is 20cm).

| Category          | Name                | Quantity | Remark                               |
|-------------------|---------------------|----------|--------------------------------------|
| Cultivated soil   | Cultivated soil     | 1000kg   | The matrix principal                 |
| Greening substrate| Peanut shell         | 10kg     | Increase matrix permeability and improve structure |
|                   | Adhesion agent      | 100g     | Increase soil and matrix binders     |
|                   | pH regulators       | Moderation | Adjust the pH of the substrate to 6.5-7.5 |
|                   | Compound fertilizer | 750g     | N: P₂O₅: K₂O=8:10:7, 300 times       |
|                   | Water preserving agent | 40g    |                                       |
|                   | Aggregate agent     | 45g      | Promote the formation of aggregates  |
| Fiber             | Saw dust            | 10kg     | Improve structure and enhance organic matter |
|                   | Straw               | 20kg     | Reinforcement interconnection        |

4. Steep slope water and soil conservation facilities

4.1. Three-dimensional wire mesh

Due to the steep gradient of the hard rock slope, the soil is hard to store. Therefore, it is an indispensable measure to cover the surface of hard rock slope with barbed wire for soil conservation.
In addition to measures such as adding a binder to the matrix ratio and punching holes on the slope, it is necessary to use a three-dimensional wire mesh to connect the sprayed nutrient soil with the steep slope to provide conditions for vegetation restoration. In addition, the barbed wire is fixed with the anchor rod, and the anchor rod is fixed with the rock. The formed structure plays the role of bearing the substrate soil and the weight of the vegetation, and ensures that the steep slope soil layer does not collapse. The durable years of the wire mesh is the main basis for selection. The wire mesh used in the study was a 14-gauge galvanized mesh (mesh size: 60 mm × 60 mm), and the anchor bolt was a φ14 bolt (length is 50 cm and anchored with mortar).

Since the anchor is continuously corroded during use, it is considered that the anchor loses its effect when the cross section of the anchor is lost by 60%. According to the estimation of the maximum corrosion rate of steel specimens in China in the soil of 3.2g/dm² per year, the service life of the bolts is:

\[
\frac{7800 \times 60\% \times 3.2}{2 \times 0.06} = 51.2Y
\]

The estimated life of the galvanized wire mesh is based on the corrosion age of the galvanized layer and the durable years of the wire. The thickness of the 14th wire mesh galvanized layer is larger than 70μm, the density is 6800g/dm³, the average corrosion rate of zinc in the mountain is 0.06g/dm² per year. The diameter of the wire is 2mm, and the corrosion rate also takes the maximum corrosion rate 3.2g/dm² per year of the steel specimen in the soil for estimation. So, the corrosion years of galvanized layer and wire mesh are as shown in equations (5) and (6) respectively, and the service life of 14th wire mesh is the sum of these two, as shown in formula (7).

\[
6800 \times 70 \times 10^{-3} \div 0.06 = 79.3Y
\]

\[
\frac{1}{1 \times 7800 \times 60\% \times 3.2} = 7.3Y
\]

\[
79.3 + 7.3 = 86.6Y
\]

Since the years of anchors and galvanized wire mesh are more than 50 years, it can be considered as permanent in architecture, and can be used for soil conservation and vegetation restoration on steep slopes.

4.2. Retaining plate

The retaining plate can block the soil on the steep slope, increase the soil preservation capacity, reduce soil loss, increase soil stability, and is more conducive to soil conservation. Considering the material's plasticity, environmental resistance and cost performance, ultra-high molecular weight polyethylene sheets were used as materials for the retaining plates in the study. The row of retaining plates installed during the construction process has a spacing of 2.0 m, a board width of 200 mm, a thickness of 8 mm, a length of 1200 mm, a distance of 100 mm from both ends, and two round holes of 10 mm in diameter from the side 30 mm. During the installation of the retaining plate, it is only necessary to align the hole with the fixed anchor and connect the anchor to the retaining plate with a wire (as shown in Figure 1). The designed retaining plate is simple and firm in the construction process, which greatly reduces the soil loss of steep slopes and promotes the growth and restoration of vegetation.

![Figure 1. Connecting diagram of retaining plates.](image)

5. Vegetation restoration and soil conservation application in steep slopes

The gradient of the steep slope selected by vegetation restoration and soil conservation test is about 85°, and the mixed substrate soil is sprayed on the slope surface where the growth hole is drilled. After
2 years of vegetation growth and soil conservation verification, the method used has played a good role. The specific construction process and vegetation growth process are shown in Figure 2. The sprayed vegetation grows vigorously on the steep slope, covering the exposed surface of the steep slope, and the roots of the vegetation firmly lock the soil to prevent the soil loss.

Figure 2. The specific construction process of steep slopes and vegetation growth process.

6. Conclusion
Through the analysis and screening of vegetation types and growth hole depths on steep slopes, the adjustment of substrate soil ratio, the three-dimensional barbed wire and retaining plate facilities design and preparation, the determined test plan was finally applied to the actual situation to prevent soil erosion and provide a safe environment for vegetation restoration, and the following conclusions were drawn:

(1) By screening the suitable growing vegetation types on the steep slope and analyzing the growth hole depth, the shrubs and dwarf trees can be grown on the steep slope after construction, which is the foundation of vegetation restoration and soil conservation on the steep slope.

(2) There are many components in the proportionally determined substrate soil, which not only provide nutrients for the growth of vegetation, but also increase the bonding force between the soil and the rock and stabilize the growth of vegetation on the slope.

(3) Three-dimensional barbed wire and retaining plate facilities can effectively achieve the purpose of soil conservation, and provide a reliable guarantee for the safe growth of vegetation.

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