Study on the Application of Vegetation Protection and Ecological Restoration Technology in Stone Slope

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Abstract. Taking the vegetation protection and greening project of the slopes of Yunan and Jigang quarry in Shenzhen as an example, the ecological restoration effect of the slope vegetation protection is evaluated through the application of vegetation greening protection technology of different soil quality and grade slope as well as the results of slope runoff sand content test and vegetation coverage rate survey. The result shows that: (1) Net planting grasses by spraying sowing technology has an excellent effect on the green protection and ecological restoration of steep soil slope and gentle rock slope, and the vegetation coverage rate is as high as 96%; Geocell external-soil spraying seeding technology has a very good effect on the green protection and ecological restoration of gentle soil slope, and the vegetation coverage rate is up to 99%; The planting slot technology is suitable for green protection and ecological restoration of high and steep rock slope in the quarry, and the vegetation coverage rate is up to 80%. (2) The runoff sand content decreases significantly after the slope is afforested, and the vegetation afforestation reduces the soil erosion by intercepting rain water and fixing soil by roots. (3) Drip-irrigation system is used in slope vegetation protection to achieve the purpose of energy saving, environmental protection and natural landscape integration.

1. Introduction

In the construction of the project many exposed slopes are formed by digging mountains for stones, resulting in landslides, soil erosion and other phenomena, which not only damage the ecological environment but also cause potential geological disasters. Therefore, the ecological reconstruction and restoration of quarry has been paid much attention[1-3]. After 2000, the slope protection and environment coordination and beautification were emphasized in the urban slope design. For example, Shenzhen has made remarkable achievements in the investigation and re-greening treatment of the quarry in the whole city. Yang Haijun and others[4] summarize the main technologies such as seed injection, plant bag and plant block used in the process of vegetation restoration of expressway slope and quarry in Shenzhen in recent years; The technology of planting basin, net planting grasses by spraying sowing and so on have been widely applied in the slope of Shenzhen mining farm[5]; The exposed slope of Dongxin quarry of Yantian port’s waterhole, adopted the measures of net planting grasses by spraying sowing, planting tank and other ecological greening[6].

In the practice of slope protection engineering in the past 20 years, Shenzhen mainly applies the experience of foreign countries or the slope vegetation greening engineering in the middle and lower reaches of the Yangtze river. There are some problems such as the single, growth advantage of vegetation species is not strong and vegetation is easy to degenerate. In terms of the selection of vegetation varieties, grass species could not adapt to the climate characteristics of clear dry rainy season
and heavy rain, and the survival rate is low after planting for one to two years, and there is still soil erosion. This paper aims at the above problems, based on a certain quarry slope vegetation protection technology of field test and monitoring test, verified the validity of the various vegetation protection ecological restoration technology, applicability, and studied which is suitable for the region to different slope mass slope greening technology measures and construction method. To achieve the result of slope quickly turns green and landscape restoration, the treatment of similar bare mountain gap in China will play an effective reference role.

2. Project Profile
Yunan quarry and Jigang quarry are located in water path of Buji Street office, Longgang District Street, Shenzhen City, the stone yard group. The slope foot of Yunan quarry is the health treatment plant of Shenzhen sanitation department, and the slope foot of Jigang quarry is the waste treatment plant of Shenzhen. The quarry is close to the west of Qingping expressway, with a total construction area of 350,000 m², and it stopped in 2004. The high and steep rock slope and irregular mining area formed by large area of quarry left over from the site have serious potential safety risks of soil and water loss, which affect the natural landscape and need to be treated urgently. The whole renovation project includes the slope surface, bridleway and other slope main body of the re-greening, but also including Yunan and Jigang two quarry slopes connected to the exposed mountain and the foot of slope. The quantities is large, engineering’s difficulty is high.

3. Comparison and selection of schemes
According to the slope type, rock and soil conditions, rainfall and natural environment conditions and other factors, several vegetation protection technology schemes suitable for the slope are compared and selected, as shown in Table 1.

| Vegetation greening protection technology | Construction method | Mechanical operation | Construction speed | Place of material acquisition | Ease of maintenance | Comprehensive Unit price of greening (Yuan/per square meter) |
|------------------------------------------|---------------------|----------------------|-------------------|-----------------------------|-------------------|-----------------------------------------------|
| Three-dimension vegetative net for planting grasses by spraying sowing | easy | A bit complicated | A little bit fast | local or foreign | intermediate | 25 |
| Vegetative net, Vegetative blanket, Vegetative mat | easy | simple | slow | local or foreign | intermediate | 35 |
| Vegetative bag | easy | simple | fast | local or foreign | easy | 10 |
| Organic spray-seeding | difficult | complicated | intermediate | foreign | intermediate | 120 |

Based on the comprehensive consideration of various factors in Table 1 and combined with the soil quality, gradient and supporting structure of the slope, the technical scheme of vegetation greening protection shown in Table 2 is adopted.

| Slope          | Gradient | Greening plan                          | Landscape restoration measures                                      | Main application plant                  |
|----------------|----------|----------------------------------------|----------------------------------------------------------------------|----------------------------------------|
| Gentle slope   | ≤45°     | Geocell external soil spraying seeding technology | Cutting slope grade, Drill holes to plant trees and shrubs            | Partridgeberry, Cynodon dactylon       |
| Steep slope    | >45°     | Net planting grasses by spraying sowing | Artificial excavation of shrubs and trees                            | Leucaena, Cynodon dactylon             |
| Rock gentle slope | ≤45°   | Net planting grasses by spraying sowing | Artificial dig-hole, Planted by laying bricks and stones in a basin to plant trees and shrubs, vine | Cynodon dactylon, Bahia grass, aalii   |
4. Plan of Vegetation Green and Protective Technique

4.1. Technical Scheme of Vegetation Protection on Steep Rock Slope
The protection technology scheme of planting slot vegetation on the slope of rock field is adopted, then the main construction technology are as following:

4.1.1. Slope trimming and reinforcement. Clean up the floating stone, floating soil and other debris on the slope, and make simple repairs to the slope to ensure the stability of the slope.

4.1.2. Digging holes. Due to the steep slope, a 45 degree anchor hole is drilled on the slope surface under safe condition.

4.1.3. Build a planting slot. The reinforced concrete prefabricated trough plate is hoisted to the slope surface, align the anchor hole into the prefabricated plate, forming a row of planting groove.

4.1.4. Fixed planting slot. Using high-grade cement mortar to fill the gap between the precast trough plate and the slope surface, and casting and sealing the exposed part of the anchor rod to ensure the stability and durability of the planting trough.

4.1.5. Bedding planting soil. Fill each row of planting slot with planting soil that takes up 3/4 of the volume of the slot. The planting soil is composed of loam, compound fertilizer, water-retaining agent and peat soil to ensure the nutrients needed for plant growth.

4.1.6. Planting trees, bushes and vines such as white Tephrosia, leucaena, lantana, boston ivy

4.2. technical scheme for vegetation greening protection of gentle rock slope and steep soil slope
The technical scheme of vegetation protection for gentle rock slope and steep soil slope by net planting grasses by spraying sowing. The main construction process and technical requirements are as follows:

4.2.1. Clearing debris and trimming slopes. For particularly convex slope surface repair with tools to ensure slope stability and mesh operability.

4.2.2. Hanging net, drilling holes, anchors. The wire mesh along the slope laid down, wire mesh selection machine woven galvanized. When laying, the net should be pulled tight, after being smoothed, and fixed with long anchor rod and short anchor rod from top to bottom. Use a drill to punch holes in the slope, then use a bolt or anchor to secure the wire mesh. When the slope is large (50°~70°), the anchor diameter is φ =10~20mm. Staggered arrangement of long and short bolts, long anchor l=0.6~1m, short anchor l=0.3~0.5m, the vertical and horizontal spacing is about 1m. At the top of the slope, the barbed wire should extend 30cm from the top of the slope and be buried under the soil with anchor bolts. As the long bolt has the double function of slope consolidation and network hanging, the number of the long bolt is properly encrypted at the place where the dangerous rocks and joints and fissures are developed which cannot be cleared in advance.
4.2.3. **Spray organic layer.** The reasonable proportion of organic material is determined according to the rock quality, and after mixing evenly, the dry material of organic material is added with water-retaining agent, PH buffer agent and water are sprayed evenly on the rock surface. The injection should be uniform, with an average thickness of 10–15 cm.

4.2.4. **Spray organic wood surface layer and seeds.** After the spraying of the organic layer, the organic material surface layer is sprayed with the thickness of 3–4 cm, and the seeds are added. The thickness of organic material on the wire mesh is not less than 5 cm, forming the basal layer of plant growth and development, local concave gentle slope to build planting basin trees and shrubs.

4.2.5. **Covered non-woven.** In order to ensure the germination rate of seeds, 13 g/m² non-woven cloth is used to cover the seeds from top to bottom, and fix it with bamboo stick or u-shaped nail to keep lap joint. Non-woven fabrics play a role in water and heat preservation and can prevent rain water from scouring the slope during germination, to be removed after the emergence of the seedlings.

4.2.6. **Maintenance.** During the period of grass seed germination, planting and seedling rooting recovery, the site should be inspected every day to keep the substrate layer wet, and the amount of watering should be controlled according to the weather conditions. After the grass seedlings grow into a lawn and the seedlings grow normally (about three months), gradually reduce the number of watering times, training the plant's adaptability.

4.3. **Technical Scheme for Afforestation Protection of Soil Vegetation on Gentle Slopes**

Gentle soil slope adopts vegetation afforestation protection technology of geocell external-soil spraying seeding, which is a composite slope plant protection measure integrating slope surface reinforcement and plant protection. The three-dimensional network is made of degradable material, which is laid from top to bottom of the slope. The lap length between the two nets is more than 10 cm. For the uneven slope with anchors fixed, so that the three-dimensional network close to the slope. Through the anchor and the connection of three-dimensional network, to stabilize the slope. Especially for the loose and broken rocky slope, in the early sowing to prevent erosion, to maintain the soil for grass seed germination, growth. Some mixed materials including the seeds, fertilizer, water retention agent, clay are sprayed into the net by using the injection machine, and the spray thickness is not less than 7 cm. After the spraying, the accumulated material in the jet and the feeding pipe is cleaned, and the slope surface is covered with non-woven fabric. Water should be sprayed regularly during the lawn maintenance management period.

5. **Site monitoring and testing**

5.1. **green conservation**

The quarry has a large area and some steep rock slope, which cause extremely difficulties on construction, replace with out-soil attached, plant growth and maintenance. During the maintenance of slope greening, the drip-irrigation system, reservoir and valve irrigation are placed on the top of the mountain, and the water supply pipeline is arranged according to the terrain. In the rainy season, natural water is used to store water, and part of the rainwater in the intercepting, falling water and drainage ditch is collected in the reservoir. After filtration, it is pumped to the platform of the bridleway and the pool on the top of the slope through cascade pumps; In the dry season, the gravitational potential energy of water is converted into kinetic energy to supplement the water requirement and nutrients of plants, so as to achieve the purpose of energy saving, environmental protection and natural landscape integration.

5.2. **Investigation on greening effect**

After 20 months of maintenance and monitoring and tracking investigation of vegetation growth process, the comparison of gentle soil slope before and after greening is shown in Figure 1. After 20 months of
construction, shrubs and vines grow luxuriantly, gradually restore the natural growth state, and completely achieve the purpose of slope regulation, soil and water conservation and ecological restoration. After construction, the results of soil sand content test and vegetation growth and coverage follow-up investigation are shown in Table 3. From Table 3, it can be seen that the change of runoff sand content is obvious before and after greening. For example, the runoff sand content of the rock steep slope with the lowest coverage (82%) decreases from 1820 mg/L before greening to 220 mg/L after greening, through afforestation, soil and water loss is reduced obviously, and the effect of soil and water conservation is remarkable. As can be seen from table 3, in the early stage of slope plant planting, due to the use of spray seeding, the substrate has more abundant nutrition and water is more sufficient after watering and maintenance, which shows the phenomenon of vigorous growth and high coverage of plants, the vegetation coverage rate of soil gentle slope is up to 99%, and the landscape effect is excellent.

![Figure 1.Contrast map before and after greening of gentle soil slope.](image)

| Slope                  | Gradient | Greening effect                                      | Runoff sand content |  |
|-----------------------|----------|-----------------------------------------------------|---------------------|---|
|                       |          | Before greening after greening                      |                     |   |
| Gentle slope          | ≤45°     | Coverage of 99%, with flowering landscape           | 3630 mg/L           | 160 mg/L |
| Steep slope           | >45°     | Coverage of 98%, good landscape effect              | 4160 mg/L           | 210 mg/L |
| Gentle rock slope     | ≤45°     | Coverage of 96%, the landscape effect is better     | 1380 mg/L           | 90 mg/L  |
| Steep rock slope      | 45°~75°  | Coverage of 96%, the landscape effect is better     | 1380 mg/L           | 90 mg/L  |
|                       | >75°     | Coverage of 80%, the landscape effect is better     | 1820 mg/L           | 220 mg/L |

### 6. Conclusions

The protection effect of slope vegetation greening is evaluated by field test of protection technology application of different rock and soil quality and grade slope vegetation greening in a quarry. The following main conclusions are drawn:

Net planting grasses by spraying sowing technology is applied to the green protection of the steep soil slope and gentle rock slope, and the vegetation coverage rate of the slope is as high as over 96%; Geocell external-soil spraying seeding technology is applied to the green protection of the gentle rock slope, the vegetation coverage rate of the slope is up to 99%. The above vegetation greening protection technology has a good protection effect. In the high and steep rock slope of quarry in Shenzhen area, it is more suitable to use the planting slot technology to afforest the slope, and the vegetation coverage rate of the slope reaches 80%.

The runoff sand content decreases significantly after the slope is afforested, and the vegetation afforestation reduces the soil erosion by intercepting rain water and fixing soil by roots. Drip-irrigation system is used in slope vegetation protection to achieve the purpose of energy saving, environmental protection and natural landscape integration.
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