

## *Original Paper*

# Application Analysis of Ecological Slope Protection Technology for Mountain Highway Slope

Dong Tianxiong<sup>1</sup>, Deng Yuewen<sup>1</sup> & Qi Gaoyuan<sup>2</sup>

<sup>1</sup> China Merchants Chongqing Highway Engineering Testing Center Co., Ltd., Chongqing, 400067, China

<sup>2</sup> China Municipal Engineering Central South Design & Research Institute Co., Ltd, Wuhan, 430064, China

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### ***Abstract***

*With the standard of living in China is improved constantly, the construction of expressway in northeast Chongqing has also witnessed a rapid growth. The process of the construction of mountain road, the cuttings and embarkment of the road would definitely cause the distortion and movement of the high slope and create a large amount of lose sand, which seriously threat the safety of high slopes. Meanwhile, the engineering also causes destruction the original vegetation, which is hard to restore. Therefore, in the construction of expressway in mountainous areas, we should hold on to the idea of green development and adopt the combination of engineering protection and vegetational protection. The project should be revised constantly according to the situation and reduce its negative affect on ecological environment as much as possible.*

### ***Keywords***

*mountain road, slope, ecological protection, artificial grass planting, spray and plant grass*

## **1. The Advantage of Ecological Slope Protection**

Ecological protection is a combination of engineering slope protection and vegetational slope protection. It mainly includes sealing protection, masonry protection, and rock bolt protection etc. Sealing protection mainly uses lime mixture, cement mortar cement concrete and loses the slope through hammering the surface, plaster and injection. Slope protection by rock bolt is mainly used on noncontinuous layer of crushed soil, increasing the stability of side slope by conduct the engineering combining rock bolt technology and hanging net and guniting technology. Engineering slope protection can effectively protect the side slope from further sliding, moving or distortion of the side slope. The

effect is more obvious in the beginning period of side slope construction, but the durability is not as good and hard to be restored after destruction is done. Furthermore, the cost of engineering slope protection is relatively high, the engineering material would also make an irretrievable destruction on the environment. Planting and slope protection, however, stabilize and reinforce the side slope through stem hydraulic effect and root system mechanical effect. It can also ease the effect of the flow on slope and side slope shallow underground water on the stability of the slope. While ecological slope protection is applied, the actual geographical situation is needed to be taken into account. The ecological slope protection should be the guideline of the slope protection while the engineering slope protection should be taken as the subsidy, to maximize the effect of ecological slope protection.

## **2. The Choice of the Vegetation of Ecological Slope Protection**

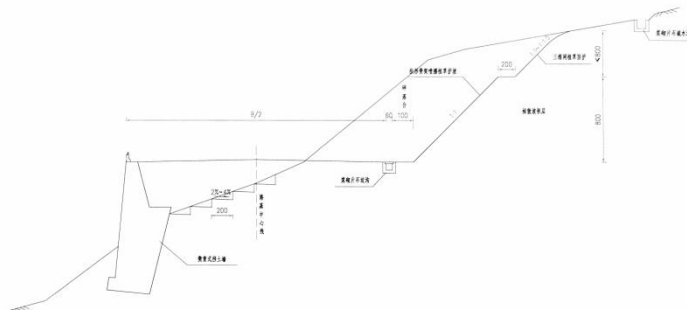
Ecological slope protection can absorb the particles and oxycarbide in automobile exhaust and consume the power of noise to reduce noise pollution and decompose the organic pollution around the slope, ameliorating the environment. The vegetation chosen to be used in ecological slope protection should be able to stabilize the slope and restore the ecological environment around the slope. The specific choice of the plants should be decided according to the specific situation of the slope and be planted appropriately. The landscape of the chosen plants should also be taken into account. In addition, because the engineering could cause ecological destruction and affect the growth of the plants, choosing local plant to protect the plant may not achieve the expected result. Therefore, when we choose to conduct vegetation slope protection, except choosing the local plants of where the construction site is, we can also introduce non-native plants with strong ability to adapt to the environment which spread fast. The plants should be chosen according to the following principles.

- (1) To realize fast afforestation and solidification of the road slope, herbs should be planted first.
- (2) Shrub seeds and flower seeds should be sprayed together by spray seeding. Every slope should be planted with at least three kinds of shrub seeds and flower seeds each to preserve biodiversity.
- (3) The local climate and seedtime should be emphasized.
- (4) The chosen seeds should be resistant to drought, have strong vitality and easy to survive.
- (5) The sowing rate of shrub seeds should be between  $10\text{g}\sim 20\text{g}/\text{m}^2$ , the coverage rate should be above 65% after a while.
- (6) An appropriate quantity of vegetation should be planted on the slope without loading the slope and cause the sliding power of the slope increase and affect the stability of the slope.
- (7) Because every different plant has its own different speed of growth and growth characteristic, so we should pay attention on both the short-term and long-term landscape of the plant.

### 3. Application

#### 3.1 General Introduction

This article mainly uses a case of highway engineering in northeast Chongqing as the to conduct the analysis. The total length of this highway is 48.69km. It adapts four-lane double way standard. The design road speed is 80km/h and uses separated subgrade with the width of 12.75 km. The side slope of highway is located in mountainous areas and the surrounding ecological environment was destructed to a certain degree because of the engineering. The quality of the shallow soil of side slope is fine while some parts on the surface of the slope are rather barren. The engineering prevention has 8 levels of side slope in total. The slope ratio of first to the third level of the side slope is 1:1.25, and the fourth to eighth is 1:1.5. All levels of side slopes adapts rock bolt lattice beam. The height of every level is 8.0m, the width of the second, fifth and seventh level is 5m, the other is 2m. Drainage are placed on every platform, interceptings dike are the brim of side slopes. The space between the top of the side slope and the intercepting is hardened with plain concrete. The first, third and fifth side slopes are placed with a row of diagonal dales. The intervals between the dales are 12m. A row of spuds for antislip are set on platform on the second level, which are 1.5m wide and 2.0m tall. The length of the spud is 15m. Its elevation is the same as the elevation of the platform of the side slope. The intervals are 5.0m each. The platform on the second level is placed with 38 spuds for antislip. The inside of rock blot frame on the first to the eight levels are all closed by M7.5 masonry MU30 cleft stone of 30 cm. The cross-section profile of the side slope shown as followed.



**Figure 1. Cross-Section Profile of the Side Slope**

#### 3.2 The Geological Condition of Side Slope

To see from the geological condition, this part of side slope belongs to tectonic denudation low hill, slope accumulation geomorphologic region. Its main formation lithology is the quaternary system comprehensive cause crushed stone combined with secondary floury clay. The middle of the slope is a layer of quaternary system comprehensive cause noncontinuous floury clay combined with 25% crushed shale of the thickness of 1.50~8.50m, with a layer of quaternary system comprehensive cause crushed stone. The drill can go deepest to 67.30m down into the detritus soil without seeing the bedrock. According to the geological cross-section profile of the side slope, the front edge of the

congeries is of great thickness, the geotechnical boundary is flat. The geotechnical boundary is at the toe of the hill excavated and can't be unsupported. The anti-slope sections in the front are much bigger than the pushing section in the back. There is still a lot of space left after the sloping of the through cut at the anti-slope sections in the front. Therefore, the chance that the congeries slides holistically through the geotechnical boundary after the through cut is drained is small.

### 3.3 The Application of Ecological Protection

The measures of ecological prevention on side slope are based on completed engineering prevention. It mainly adapts the combination of artificial grass planting and slope protection and spray planting and slope protection. The artificial grass planting and slope protection protects the side slope by sowing grass seeds and laying turf. The spray planting and slope protection uses native soil spray planting and slope protection, hydraulic spray planting and three-dimensional net spraying and slope protection.

#### 3.3.1 Artificial Grass Planting and Slope Protection

All the preventions of artificial grass planting and slope protection conducted by human. This is the simplest and the most original type of prevention. The engineering of artificial grass planting and slope protection is easy and has a relative low cost. It doesn't need a lot of mechanical equipment and the preventions take effect fast. There are two forms of artificial grass planting and slope protection used on this side slope: sowing seeds and laying turf. Sowing seeds can be applied to shorter and slower slopes. When we protect the slope by sowing seeds, we need primarily considerate the habitat and choose the plants that are suitable for growing on this side slope. Laying turf is transplanting the plants that are already grown, the application is wider than sowing seeds. It can not only apply to soil side slopes, but also to air-slake rock slopes.

##### (1) Sowing seeds

The pros and cons of sowing seeds are very obvious: the advantage of it is that the duration is short, the cost is low, and the technique is easy. The disadvantage of it is that the survive rate of grass seeds are hard to maintain, the sowed seeds are easily brought away by the sheet flow caused by the rain, and it can't be applied to rock side slopes. The specific steps are as followed:

① Cleaning the slope. Clean the remains and weeds of the construction conducted before to make it meet the standards of the initial stage of construction. Then, loosen the soil on the side slope about 20~30cm, or laying planting soil about 10cm on the surface of side slope to make it suitable for growing plants.

② Sowing seeds. Sow the seeds after mixing them according to the designed ratio. Set a working section in every 20m and sow the seeds horizontally. Pay attention to the density of the seeds, make sure that the seeds are sprayed evenly. After working on a section, adhesive bonded fabric should be covered on the slope to prevent the seeds to be taken away by the sheet flow or the wind, and pat on the surface.

③ Maintenance. After the whole sloped is sowed, maintain it by spraying water. The interval should be set according to the growth condition of the seeds. Meanwhile, desensitization is also needed to

secure the survive rate of the seeds. If the growth condition of the seeds is unsatisfactory or sections that are too scarce are found in the process of maintaining the slope, then the grass seeds should be supplanted in time.

## (2) Laying turf

The size of the turf used this time is 20cm×20cm, it is a mixture of bluegrass 40%+ Tall Fescue 40%+ cynodon 20%. Laying turf can do the isolation and cover the whole slope and make the loosen soil particle on the slope hard to be washed away, hence reduce the rain's erosion on the slope and decrease the air-slake effect at the same time. And finally increase the stability of the soil mass on the slope. Comparing to the traditional way of sowing seeds, laying turf are not affected by season. It covers a much bigger area, and the duration is also shorter. However, the cost is higher than sowing seeds. The turf laid on the sloped should be covered with various types of plants to prevent to be despoiled by the plant diseases and insect pests. The post maintenance of turfs laid is difficult is hard. As long as the turf is damaged, it is very easily to be washed away by the rain<sup>[10]</sup> and lost the protecting function. So, the post maintenance should keep up in time.

① Laying soil. A layer of fertile soil of 10cm should be placed on where the turf will be placed on. And this layer of soil is needed to be leveled.

② Laying the turf. Take the toe of the side slope as the starting point, placing the turfs horizontally from the bottom to the top in staggered joints. The turfs should cover more than 95% of the surface. If the vegetation is needed to grow fast, then we can increase the density of big grass blocks and leave no seams between them.

③ Fixation. After covering a section, compact and water the turf on the corresponded area and fix it with bamboo nail or wood stake. Make it paste firmly on the slope and secure the quality of the construction.

### 3.3.2 Spray Planting and Slope Protection

#### (1) Native soil spray planting and slope protection

Native soil spray planting and slope protection can be applied on side slopes unsuitable for sowing seed or laying turfs which has infertile, loose soil or uneven or complicated condition. When the quality of engineering protection is relatively high, pray planting and slope protection can be applied on steep side slopes. However, it is not suitable for sides slopes that are seriously scoured, effected seriously by water damage, or have poor stability. The layer of native soil sprayed on the side slope provides an environment for the growth of the plant community including trees and scrubs. The root system can go deep in the layer of soil and reinforce and anchor the side slope. So, a durable and sustainable porous soil structure can be formed and suppress the air-slake of shallow soil on the side slope and increase the erosion influence against runoff of the slope in order to maximum the effect of the treatment and improve the landscape of the slope. The depth of the layer should be decided by the rock on the slope: when the rock is strong-weathered rock, the depth of the layer should be 6~8cm; when it is moderate-weathered rock, the depth of the layer should be 8~10cm; when it is weak-weathered rock,

the depth of the layer should be 10~12cm. Meanwhile, the gradient of the side slope also has a direct influence on the choice of the depth of the native soil layer on the side slope. When the falling gradient is 1:1.0 or 1:1.2, the depth of the native soil layer should be 3~6cm; when it is 1:0.8~1:0.6 the depth should be 4~10cm. The Native soil spray planting and slope protection's construction period is short and is of high quality. The productivity of spraying is dozens of times the productivity of artificial grass planting and slope protection.

The material and equipment of spraying is the key facture which decides the quality of native soil spray planting and slope protection. Normal cynodon is the substrate grass seeds, the dosage is 15~25g per square meter. The scrub seeds are cassia bicapsularis and dodonaea viscosa seeds mixed by 1:1. The dosage is 30g per square. It should be planted after mixed evenly with organic material, long-term compound fertilizer, rubber powder and SAP. The hydroseeder must be at least 20 meters away from the slope, the specific steps are as followed:

- ① Cleaning the slope and spray native soil: Even the side slope after cleaning various sundries and humus and gravel on the slope. Then clean pest on the slope with antiseptic and spray the prepared native soil on the slope evenly. Adjust the depth of the native soil according to the actual situation.
- ② Hydro Seeding. Spray the seeds by hydro seeding after the native soil is dried. Make sure the vegetation coverage is no less than 85%. Drainage facilities like drainage ditches and chute can be set during the hydro seeding, to lower the influence of sheet flow.
- ③ Management: After hydro seeding adhesive bonded fabric should be covered on the slope for maintenance. Spray the potion periodically to prevent the pests. Weeding and topdressing at regular time are also needed.

## (2) Hydraulic spray planting and slope protection

Hydraulic spray planting and slope protection is mixing seeds, SAP and fertilizers in proportion in site and inject the mixture with high-pressure pump in time. It can be applied to any slope lower than 10m or completely decomposed rock slope. It can also be applied on higher or steeper slope by remote injection. The seeds used in hydraulic spray planting and slope protection have higher survive rate, they can cover a wider size of slop and grow more rapidly. Its cost is also lower than native soil spray planting and slope protection.

The seeds chosen this time is cynodon seeds and teff seeds, the dosage is 15 g/m<sup>2</sup>. The dosage of erosion control agent is 3g/m<sup>2</sup>, and the dosage of compound fertilizer is 100g/m<sup>2</sup>. Before the formal spraying, seeds should be sprouted to promote the survive rate of the seeds. Seeds can only be sprayed on the slope after the shallow layer of soil is water and the slope is stabilized. Maintenance should be conducted after spray planting; the method is the same with that of native soil spray planting and slope protection.

## (3) Three-dimensional net spraying and slope protection

Three-dimensional net spraying and slope protection combines the plastic geonet and protection with plants, it applicable to slopes lower than 20m, with slope rate lower than 1:1.5 soil or strong-weathered

rock slopes. The function of three-dimensional net and net patch is vital in the protection. Three-dimensional net plays the role of isolation on the slope and protect the shallow soil particle from being washed away by rain and protect the seeds and the fertilizer. Three-dimensional net can also entwine with the plants' root system and reinforce the slope; The net patch can not only increase the erosion influence of the slope and can also moisturize the slope, hence provide a suitable growing condition for the vegetation.

*Paspalum notatum* is used as the vegetation material this time, the dosage is  $20\text{g/m}^2$ , the dosage of SAP is  $6\text{g/m}^2$ , the dosage additive is  $2\text{g/m}^2$ , the dosage of organic mulch is  $300\text{g/m}^2$ , the dosage of compound fertilizers is  $100\text{g/m}^2$ . The specific steps are as followed:

- (1) Cleaning the slope. The same as the cleaning method of Hydraulic spray planting and slope protection.
- (2) Placing three-dimensional net and anchor the net. Poke the rod out of the net patch as the mark, the net patch should overlap each other on the sides and use U-shaped nails to fix it. The net patch should be placed at a cool place with shade and stick tightly on the slope without pleats.
- (3) Backfill. If the condition on the slope is not suitable for the vegetation to grow and needs to backfill a layer of native soil on the slope before spray planting. The soil should cover the net patch evenly and depth of the soil should be about to cover the net patch and the three-dimensional patch under soil. The soil should be maintained by spraying water after backfilling. And the spray planting should be conducted after the slope is stabilized.
- (4) Spraying seeds. Spray the seeds mixing with other components with injector on the slope. Rain proof should be prepared during the injection.
- (5) Maintenance. After the spray planting, maintain the slope. The method of maintenance is the same as hydraulic spray planting and slope protection.

#### *3.4 Result*

After 7 days of ecological protection engineering, the seeds already sprout according to observation; the vegetation is basically fully grown after 30 days; the coverage of vegetation is 75% after 70 days and more than 90% after 180 days. This ecological slope protection engineering not only increase the stability of the slope, but also improve the landscape and the surrounding environment of the slope.

#### **4. Conclusion**

Highway engineering in mountainous areas will definitely cause the destruction of ecological environment. Ecological prevention can not only improve the stability of the erosion influence and stability of the side slope but also improve the landscape and the surrounding environment of the slope. While applying ecological slope protection, we should considerate the actual situation around the slope and the long-term and short-term profits, combine artificial grass planting and slope protection and spray planting and slope protection and apply the suitable type of vegetation and technique.

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