Ecological Protection for Rocky Side Slope in Excavation

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Abstract: To plant the vegetation on rocky side slope is even difficult, but can be realized by spraying a layer of guest earth with special organic matrix and choosing appropriate plant variety. The vegetation measures, called as ecological protection, behaviors two kinds of the forms such as the whole vegetation protection and vegetation protection with the structural frame. Because of the advantage over the other traditional measures in the aspects of safety, beauty and economy, the ecological protection as a new technique is increasingly attached importance to engineering. On the basis of some properties of ecological protection, the stability for two kinds of the ecological protection has been analyzed in this paper. Furthermore, spraying of guest earth, plant variety and constructing processes were also stated briefly. Finally, by applying successfully to several expressways, it is suggested that the ecological protecting measures may be popularized to rocky side slope protection in expressway, hydraulic engineering etc.

Keywords: ecological protection, rocky side slope, vegetation, stability

1 Introduction

As a science concerned with life system and environmental system, ecology has changed gradually from the traditional discipline into the inter-discipline combined with modern theory and high technology since the 1980s, and has been increasingly applied to expressway, hydraulic engineering, railway and so on. Recently, with the construction of many projects, the corresponding environmental problems due to the excavation of mountainous land have not been effectively resolved. For example, the destroyed vegetation in the surrounding of the projects cannot be recovered, because of traditional side slope protection such as grouted retaining wall, stone pitching, armoring wall etc., as well as water and soil loss becomes seriously. On the other hand, in view of the utilization of plenty of stone, many ecological problems and negative effects, such as lack of stone resources, worse outward appearance, no-unity scenery and expensive investment, will be brought. As a result, to replace traditional measures by ecological protection suited for rocky side slope in excavation becomes the important environmental subject concerned by engineers and experts.

Since June1996, by absorbing foreign advanced experiences, we have been devoted to research and develop a new ecological technique for rocky side slope protection, and have made some preliminary achievements. A part of the results will be introduced in the later section, which has practical significance for rocky side slope protection in excavation to change from traditional measures into ecological measures.

2 Properties of ecological protection

In our country, the traditional measures used for rocky side slope protection, called hard protection too, mainly include grouted retaining wall, stone pitching, armoring wall, shotconcrete wall and so on, which exist some problems too. Firstly, because of damage of landform and difficulty of vegetation recovery, water and soil loss becomes more seriously, and run off by plenty of rainwater directly; Secondly, the utilization of many stone materials enough leads to the lack of local resources and increasing of expensive investment. Thirdly, the traditional measures not only behavior worse outward appearance and scenery, but also pollute the surrounding environment to the certain extent.

Unlike the traditional protecting measures, the ecological protection as a flexible armoring wall may be regarded to be the combination of both hard and soft protecting measures, which is divided into two kinds of protecting forms such as the whole vegetation protection and vegetation protection with the

structural frame.

In comparison with the above traditional protecting measures, the merits of the ecological protection may be concluded as follows, stabilizing slope; supplement of hard and soft measures each other; beauty, economy etc. Because of spraying a layer of guest earth with special organic matrix on rocky side slope and the adoption of both grass and tree, the vegetation on rocky side slope in excavation can be recovered effectively and unify with the surrounding nature in the long duration.

3 Stability analysis for ecological protection

3.1 The whole vegetation protection

The various flexible protection planting on the whole surface of rocky side slope, defined as whole vegetation protection, consists of three large parts such as vegetation sheet with various grass and tree seeds, guest earth with special organic materials, and metal net with the diameter of 2mm which can not only be prevented from slope failure in the thin surface layer, but also provide the basis for spraying guest earth.

As for guest earth block, the shear stress to resist the sliding of guest earth block may be expressed as

$$\tau = c' + W\cos\alpha \cdot \tan\phi' \tag{1}$$

and sliding force is

$$T = W \cdot \sin\alpha \tag{2}$$

In which, W is weight of guest earth block; α is incline angle of side slope; c' is sticking force; ϕ' is inner frictional angle of guest earth particle.

From eq.(1) and eq.(2), in order to keep guest earth block not to slide down, the resistance τ must be more than sliding force T. In other words, the frictional force between guest earth and rock surface should be raised, of which the specific approaches are to decrease incline angle α and to increase c' and ϕ'.

3.2 The vegetation protection with the structural frame

For the representative ABCD analyzing element in the check structural frame shown in Fig.1, supposing that the frame specification of $L\times L$(L=2m—3m), beam specification of $B\times B$(B=30cm—40cm), thickness h(h=2cm—20cm) of guest earth, length L_s of the frame node anchor rod, shear stress between frame and rock surface may be expressed as

$$\tau = c' + \sigma \cdot \tan\phi' = c' + \gamma_s \cdot L_s \cdot \cos\alpha \tan\phi' \tag{3}$$

And the effective horizontal force exerted on node anchor is

$$H = W\left(\sin\alpha - f \cdot \cos\alpha\right)\cos\alpha \tag{4}$$

To make the frame stabilize, the safety factor of the frame must be more than F=1.0, i.e.,

$$\tau > \frac{H}{DL} = \frac{\sin\alpha \cdot H}{L_s \cdot L} \tag{5}$$

$$L_s > \frac{\sqrt{c'^2 L^2 + 2\gamma_s L \cdot H \cdot \tan\phi' \cdot \sin 2\alpha} - c'L}{2\gamma_s L \cdot \cos\alpha \tan\phi'} \tag{6}$$

Several constants may be given as γ_s=26.5kN/m; $c' = 0$; $f = \tan\phi_B = \tan\phi = 0.6$.

In addition, total weight of both frame and guest earth is

$$W = B^2 \cdot \gamma_t\left(2L - B\right) + \gamma_W\left(L - B\right)^2 \cdot h$$

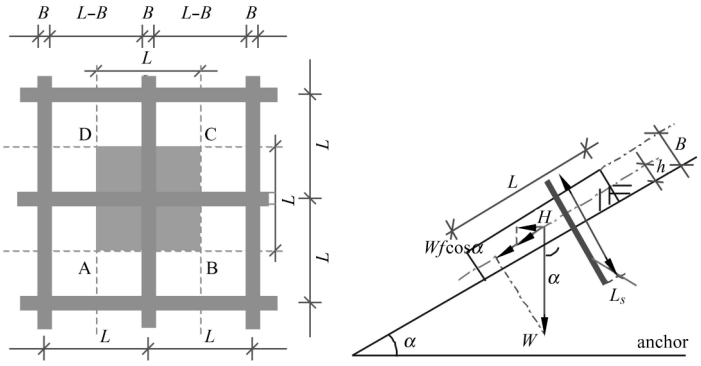

Fig.1 Structure and force analysis for frame

where, γ_t and γ_w are respectively specific weight of the frame concrete and guest earth (γ_W = 18.0 kN/m^3).

It is very important for stability design of vegetation protection with the structural frame to calculate the minimum anchoring length $L_{\min}$ of the node anchor rod by eq.(6).

4 Technique for ecological protection

4.1 Spraying of guest earth

Guest earth sprayed on rocky side slope mainly contains organic matrix, soil, fiber, fertilizer, preserve water dose, binder and stabilizing agent. These components can be met the basic demand of plant growth such as basic soil thickness, acid-base value, air voids, nutrition composition, moisture and their duration. These indexes are related to not only the specific geologic conditions but also local climate conditions. Therefore, it is necessary to establish the specific proportion of every component by testing in field.

In order to ensure the vegetation successfully planting on rocky side slope, the content of organic matrix in guest earth should exceed to 60 percent generally. According to some analysis and practical experiences, the relationship between hardness number of side slope and thickness of spraying guest earth under various pH value has established preliminarily, as shown in Table 1, which may provide the reference for the actual application.

Table 1 Guest earth thickness under the various slope types

Slope Types	Hardness Number	Thickness (cm)		
		pH<6.5	pH=6.5—7.0	pH>7.0
Soil slope	≤23	2	3	3—5
Strongly weathered rock slope	23—27	2—4	3—6	5—10
Middle weathered rock slope	27—30	4—6	6—10	10—15
Weakly weathered rock slope	≥30	6—15	10—15	15—20

4.2 The choice of plant variety

Ecological protection for rocky side slope differs from the ordinary planting grass on soil side slope. Besides spraying of guest earth, the synthetic scheme of the vegetation with the suitable grass and tree should be considered, so that the planting vegetation becomes more similar to the natively natural plant as far as possible. The mixing of plant variety is to realize the gradual process from grass to tree and long-term growth of the planting vegetation on rocky side slope, especially increasing reasonably the

proportion of tree. For this reason, the vegetation planting on rocky side slope is closer to the natural ecology, and can grow normally without the maintaining management.

4.3 Constructing processes

The main constructing processes of the whole vegetation protection are to clean the broken materials on slope surface, to drill anchoring hole, to spread out metal net, to spray guest earth and spread out vegetation sheet. The installation of anchor rod and metal net has two kinds of functions. The first one is protection function, which may be used in some unsteady side slope and stabilize side slope by increasing the depth of anchor rod. The second one is supporting function, to provide the supporting basis for spraying guest earth.

As for the vegetation protection with the structural frame, besides the construction of the structural frame must be increased, the other constructing orders are similar to the whole vegetation protection. In a word, the vegetation protection with the structural frame has two kinds of the functions such as the vegetation and prevention from landslide and slope failure.

5 Application and effects

The whole vegetation protection was applied to Jinghu expressway (Shandong Province) in 1999. The chosen rocky side slope has the geological structure with middle weathered argillaceous rock and gradient of 1∶0.75—1.00. The local rainfall amount is 500mm per a year. Thickness of spraying guest earth is 6cm—8cm, and planting scheme combined of grass and shrub was adopted.

On the other hand, the vegetation protection with the structural frame of the specification 230cm×230cm was applied to Tongshan expressway (Shandong Province) in 2000. The chosen rocky side slope has the geological structure with weak weathered shale and gradient of 1∶0.75. The local rainfall amount is 600mm per a year. Thickness of spraying guest earth is 10cm, and planting scheme combined of grass and shrub was adopted.

The common effects of the above two ecological measures may be described as follow, the covering area rate of the vegetation could reach about 60 percent one year later, and the plant variety of vegetation is mainly grass at that time. After that, the shrub seed started to sprout out, and cover gradually the whole side slope. After two years of finishing construction, the covering area rate of the vegetation may attain more than 90 percent, and main vegetation changes gradually from grass into shrub, so as to keep long-term vegetation effects. Therefore, the ecological protection for rocky side slope in excavation has the wider prospects applying to construction of hydraulic expressway, engineering, railway etc.

It has been indicated by the application that two kinds of the ecological protection had made the success basically.

6 Conclusions

(1) Ecological protection for rocky side slope, including two typical forms such as the whole vegetation protection and vegetation protection with the structural frame, has advantage over other traditional measures as following: environmental landscape, recovery nature, water and soil conservation, beauty and economy.

(2) According to stability analysis for ecological protection of rocky side slope, some important parameters of two kinds of ecological protection have been established, for example, the minimum length $L_{\min}$ of the node anchor rod in the structural frame.

(3) For the various side slope with the certain gradient and rock properties, the adjustment of both guest earth and vegetation scheme can be adapted to many specific conditions of local climate and geology.

(4) As the most important component of guest earth, the organic matrix has the perfect functions of preserving water and fertilizer and permeability and soil improvement, which may provide the basic condition for the long-term growth of vegetation.

(5) Because of the adoption of both grass and tree, especially increasing reasonably tree proportion, the vegetation on rocky side slope in excavation can be recovered effectively and unify with the surrounding nature in the long duration.

Along with the gradual maturity of ecological protecting technique for rocky side slope, it is believable that the ecological protection will be popularized increasingly in near future.

Reference

[1] Shin Y.S., Shu Anping *et al*., Design Approaches to Anchoring Projects with Concrete Frame, Japan Sankaidou Press, April 1996.