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Research Article

The Key Technologies of Steep Rock Slope Protection

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Abstract: This study takes the steep slope of Qianlin Mountain in Beijing National Forest Park as an example. The job of engineering applications and comparative analysis are done as well as estimating the protection effect. Because of the complicated formation and geological conditions of the steep slope, accidents such as slope instability, collapsing are easier to happen. Therefore, the technology of the reinforcement and protection of steep slope are important. Even the methods are improper; it remains a significant security risk. Given the limitations of a variety of protection technologies, a new method called spray-anchor technology mixed flexible protection is proposed.

Keywords: Flexible protection, spray-anchor technology, steep slope

INTRODUCTION

In recent years, as the scale increasing of infrastructure in China, railways and highways construction continuously extend to the mountains, so more and more steep slope are aroused people's attention. Problems about a correct understanding, rational designing, appropriate management on slope, as well as reducing the breaking of slope losing stability must be considered (Yongmei *et al*., 2006). Qianlin Mountain in Beijing National Forest Park as an example, the job of engineering applications and comparative analysis are done as well as estimating the protection effect.

THE PRESENT SITUATION OF SLOPE MANAGEMENT

Slope stability analysis: Slope stability analysis is an important part in slope management. It has a history of more than 100 years and there are dozens of methods which analyze the stability of the slope from pressure, morph, capability or complex, including the limit equilibrium, elasticity-plastic analysis, determining deformation and breaking, damaging probability, force methods and so on Gongxian (2003).

The most frequently used method is limit equilibrium, including Swedish arc method, Bishop Slice, Janbu slice and unbalanced thrust transfer coefficient. Many methods based on the different mechanical model attract the attention of people because of the speed consideration and precision (Xianming *et al*., 2007). More and more new methods such as FLAC, back analysis, genetic evolution calculation, neural networks calculation, fuzzy measure theory, grey system theory and so on are used widely.

Various methods of slope stability analysis have developed rapidly in recent years. However, limitation also displays because of small deformation supposeed in finite element and boundary element. FLAC, a new numerical method, which exerts advantage as well as overcomes short coming, has developed rapidly.

Slope reinforcement and protection technology: Different slopes must utilize apposite reinforcement method according to actual situation, like geological conditions, thus to guarantee stability and practicality of the slope. Slope treatment measures, such as slowing, blocking (retaining wall, piles etc.), reinforcement and protection are used widely.

Usually, slowing slope is the first choose, with advantages such as the simple construction, economy, safety and reliability and disadvantages such as too many earthworks and demanding area. Retaining (retaining wall, piles, etc.) is the basic measure of slope treatment. For unstable rock and soil slope, it is a more reliable treatment with the advantage of a fundamental solution to slope stability problems and achieve the purpose of cure for poor stability of the slope, otherwise, it will result in material waste. Pressure grouting can be used to reinforce slopes when breaking and joints cracking progressively. Under pressure, grouting fluid, infiltrating surrounding through cracking joints cut around the borehole wall, cement broken rock and soil cement to form an integrated. Mortar columns bolt broke rock and soil,

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thus to achieve the purpose of improving the integrity and stability of the slope and deep reinforcement, etc. The pre-stressed cable is a better deep reinforcement means when the slope is high and the slope of the potential failure surface location maybe deeper (Nengpan *et al*., 2009). In the high slope reinforcement projects, pre-stressed anchor is gradually developing into a trend, accepted by an increasing number of people, but with shortcoming of higher costs and unpopular technology. Plant protection is a method that prevents soil erosion according to planting trees, vegetation, grass and other plants on the slope, which can stable the slope with low altitude and small angle.

For the steep slope, due to the special geological conditions and formations and rock composition, when subjected to the combined effect of environmental factors, tension cracks start up paralleling to the surface on the top of slope. It shows that the slope lose stability and collapse and block out on the top resulting seriously. Slope should be cut to shedding load and slowed down on the top as well as iincrease the reinforcement.

THE FEATURE OF THE SPRAY-ANCHOR TECHNOLOGY MIXED FLEXIBLE PROTECTION

Spray-anchor technology is a method that bolt insert deep into the rock through the anchoring holes, then the anchor in the hard rock uses the water mud in order to improve the shear strength of the rock. The process of injection is that the cement mortar mixed with quick-setting agent will mix high pressure water through concrete jet by using high-pressure air to spray into the surface of the rock. Then the cement mortar condenses rapidly, which can maintain a good bond with the rock as well as improve the stability of the rock.

Wire rope is the main feature components of the flexible protection system, which is composed of two basic types called covering (active protection system) and intercepting (passive protection system) to combat all kinds of geological disasters in the slope and blasting fly-rock, falling objects and other hazards. It is a systematic technique makes up component design and processing, system configuration designing and shaping, site design selection site layout and construction designing. Geocell grass revetment is a technology that improves the quality of the soil in the geocells started and fixed to the slope. Then hangs three-dimensional vegetation net through spraying construction in geocells. Geogrids provide a stable living environment for lawn plant growth, which green the barren slop as well as improve the drainage performance of the slope (Guoti, 2006). Hanging combined with geocell protection can not only avoid the harm caused by flying rocks but also beautify the slope.

Spray-anchor technology combined with flexibe protection, can solute the conflict of the slope protection and the environment and play their respective advantages. This ensures both the slope stability and the vegetation of the slope recovering rapidly, which achieves peaceful coexistence of human activities and natural environment.

The project management example and evaluation:

The overview of the project: Qianling mountain steep slope is located at the southwest suburb of Beijing, at the entrance to Qianling Mountain Forest Park, about 12 km Changxindian West in fengtai area, the junction of Fengtai, Shijingshan, Mentougou. The topographic elevation of Qianling mountain Forest Park is a larger part achieving to tens of meters and part slope steep because of the impact of artificial excavation. The overhead area of the slope is about 18154 m^2, which is composed of more moderate area of 8510 m^2 with gradient of 40~85º and more steep area of 9644 m^2 with gradient of 85~90º. Strata are mainly made up with archean thick layered slate and phyllite, orientation south west direction 20~30º. The development of the rock is perpendicular to the joints with few cracks clay filled mostly and little tectonic development in the area and nearby.

Programs and measures: The plan of the slope is shown in Fig. 1. The texture of the slope is mainly rock, less fallen. The design includes the following: In a relatively steep A, C, E, we will spray cement mortar for slope protection and fixed, then use 4~5 m long bolts to fix up like plum-shaped by 2×3 m for slope reinforcement, which is shown in Fig. 2. As for the more moderate of the B, D slope, we will plant

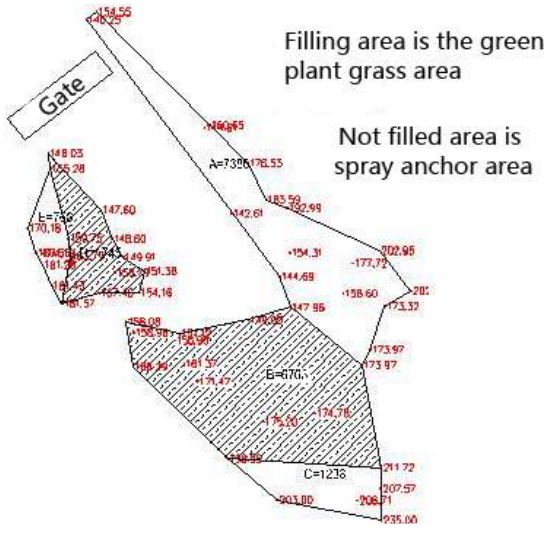

Fig. 1: The plan of Qianling mountain slope

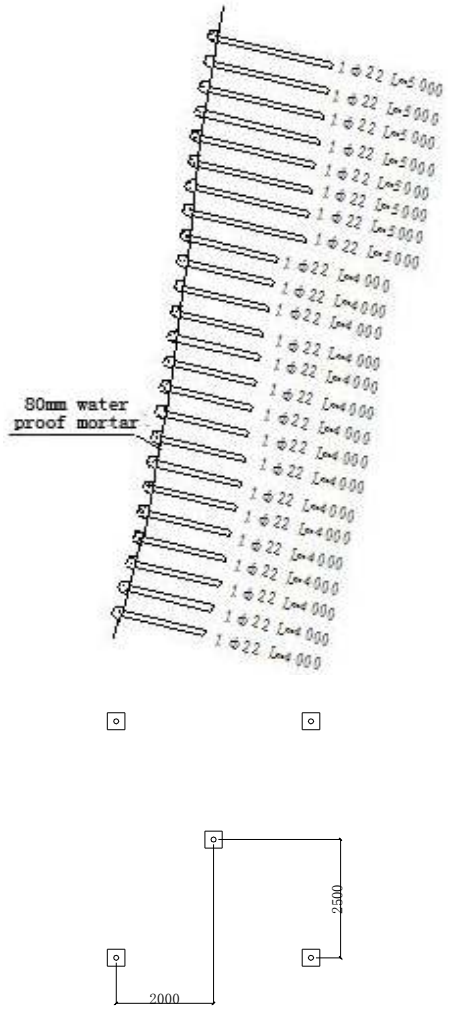

Fig. 2: The side view of the bolts layout and the detailed layout of the bolts (unit: mm)

protective vegetation. Then, the surface of the whole slope will be covered with 10×10 cm of steel mesh and ribs to prevent falling rock. During the construction, requirements of reinforced protective layer thickness is not less than 2 cm. Bolts must be anchored safely. And it is significant to set drainage holes and deformation. Colored concrete can be used during the construction to design into the corresponding pattern to achieve specific artistic effect.

EXPECTED RESULTS

Results are obtained by the calculation of mechanical models which are established by FLAC according to the spray-anchor plus flexible protection of the slope. It shows that parameters such as the maximum displacement, the first, second and third principal stress and maximum shear in all directions are up to specification requirements. The safety factor of Qianling mountain slope is 2.0 according to the analysis result based on numerical calculation by FLAC (Fig. 3), which descripts that the reinforcement of the spray-anchor maxed with flexible protection can reinforce the side slope effectively. In this project, we choose protective measures reasonable according to the slope angle and height, hydro-geological conditions and degree of slope hazard, which improve the shear strength of the weak structural surface formation and the potential slip plane and other mechanical properties as well as reinforce dangerous rocks. Structure and ground form a common work system to improve the stability of the slope. The technology of the spray-anchor mixed flexible protection can not only achieve stable results but also build a landscape combined with the surrounding environment.

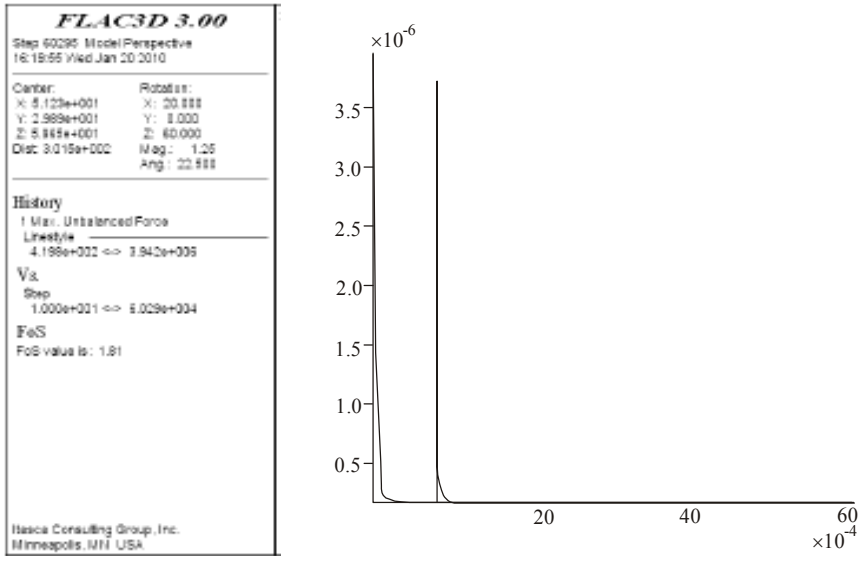

Fig. 3: The maximum unbalanced force and safety factor after protection

CONCLUSION

The application of the spray-anchor mixed flexible protection in the management of this slope can solve the difficult problems that existed in the traditional protection measures of the slope, which meet the requirements of stability as well as environment protection. During the construction process, protective methods like shotcrete, hanging net, bolts protection, grass are used to ensure the stability of the slope. The spray-anchor mixed flexible protection is a promising method for the management of slope because of the technical and economic advantage, such as the reliable security, the quick standardization of the construction and it is conductive to environmental protection, together with the new and ingenious concepts and design.

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