Study of the stability of Sancun slope and bio-controlling methods at a reservoir in China

SHI-YUAN ZHANG[1] JI-LIANG ZHU[2] YAN-YUN LUO[3]

[1]School of Life Sciences, Sichuan University, 29 Wangjiang Street Jiuyanqiao, Chengdu, Sichuan, 610064, China; email shiyuan79530@163.com

[2] Guangxi Electric Power Industry Investigation Design and Research Institute; email: zjl16@163.com

[3] School of Life Sciences, Sichuan University. 29 Wangjiang Street Jiuyanqiao, Chengdu, Sichuan, 610064, China; email: luoyanyun3966@163.com

Abstract: A hydroelectric station lies in the lower reaches of Dahewan, on the Yalong River. This hydroelectric station is connected to the biggest capacity reservoir in the Yalong River. One of the slopes of the reservoir is very steep. If this slope fails it will harm thousands of people who live up slope. Calculations of the slope's stability using three methods indicates that the slope is safe under natural conditions, although under unusual weather conditions it is thought that it could partially fail. In order to ensure the stability of the slope bio-controlling measures have been implemented to reduce any effects that adverse conditions could have on the slopes stability.

Résumé: Une centrale hydraulique à construir localise à l'amont du fleuve Yalong. La capacité du réservoir de la centrale hydraulique est la plus grande sur le fleuve Yalong. Le glissement de terrain se trouve à la rampe abrupte à gauche du fleuve. On a utilisé trois méthodes de l'équilibre limité pour calculer sa stabilité. Le résultst montre : dans le cas normal, le corps du glissemnt de terrain est stable. Quand l'orage, il est impossible de perdre sa stabilité du corps de glissement de terrain. Mais il est possible de perdre sa stabilité partielle. Pour le corps de la rampe se trouvant en état de stabilisation, sauf la mesure de traitement habituelle des travaux, il est néccessaire de prendre la mesure de protection biologique de la rampe.

Keywords: engineering geology, soil erosion, slope stability, protection, dams, landslides

INTRODUCTION

A hydroelectric station with a very large reservoir capacity lies on Yalong River (Zhuoyuan Zhang, Shi-tian Wang, Lan-sheng Wang, 1994). The designed height of the dam for the reservoir is 305m. A 300m high slope (the Sancun slope) lies on the left bank of the dam site upstream of the dam. If this slope suffers large scale deformation or failure, it maybe not only induces a river surge and dam collapse or failure, but it will also harm the thousands of people who live upslope. Therefore its stability is a major concern.

THE ENGINEERING GEOLOGICAL CONDITIONS OF THE SLOPE

The Yalong River lies in a "V" shaped valley. The bank slopes are steep with angles of 35°-40°on the left bank, and 40°-50° on the right bank.

Sancun Slope Configuration

The slope lies on the left bank of the River Yalong and is 'dustpan' shape in plan (figure 1) with its base at 1660m, although it is about 6m lower during low water, and the top is about 2020m. The difference of elevation between the base and top is 460m. Its length is about 1000m, its width is about 570m, and its area is about 0.57 km^2. The thickness of the potential slide mass is about 64~120m, averaging 80m giving a volume is about 15×106m^3.

There are three flat segments in the slope (Zhuoyuan Zhang, Shi-tian Wang, Lan-sheng Wang, 1994). The first one is 'dumbbell' shaped, partly eroded by a gully, and it lies between 1775m and 1880m with an average slope of 18°. The others lie between 1875m and 1925m, and between 2040m and 2125m, with slopes of 18~26° and 23° respectively.

ANALYSIS OF THE STABILITY

Obtaining Parameters

In order to properly evaluate its stability, we did direct shear tests on site and recovered 11 samples for laboratory testing. The parameters obtained were as follows (table 1):

Table 1. Material parameters established for the Sancun slope

	Natural density (kg/m^3)	Saturated density (kg/m^3)	Cohesion(KPa)		Friction angle (°)	
			Natural	Saturated	Natural	Saturated
Sliding body	2200	2250	60	50	34	30
Sliding zone	1630	1680	30.9	21.29	29	25
Bedrock	2700	2750	65	55	38	36

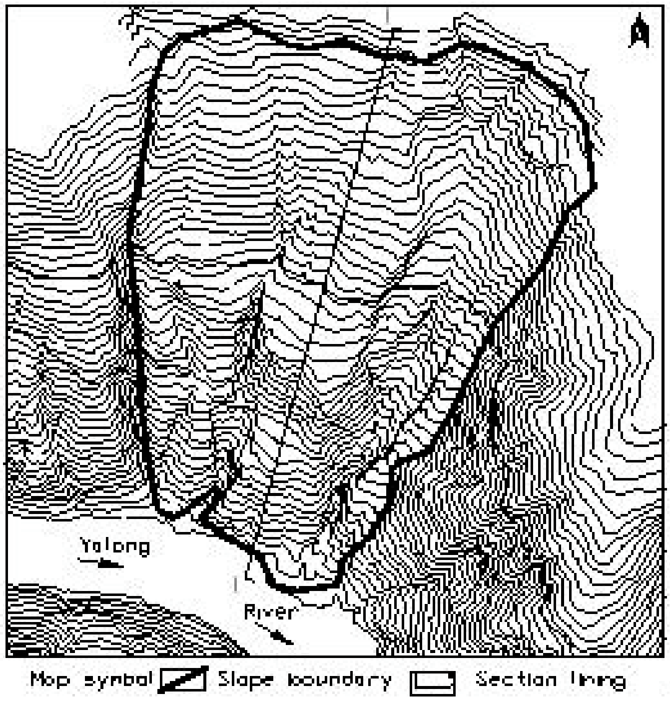

Figure 1. Plan of Sancun slope

We selected a representative section and calculated stability coefficient of the I-I cross section (Figures 1 and 2) that included three potential sliding surfaces, that is, the main one, the first-order one and the second-order one.

Calculation of the slope stability under natural conditions and unusual weather conditions was undertaken using three methods: general slices method, Bishop Method, and transfer coefficient method. The Factor of Safety calculated using the different methods and water conditions are presented in table 2):

Stability Evaluation

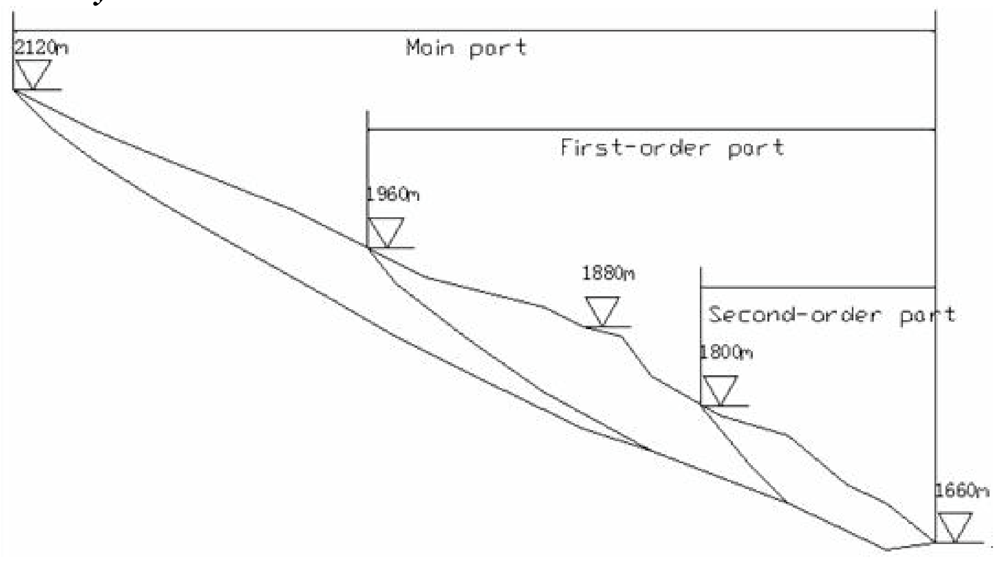

Figure 2. Ⅰ-Ⅰ Cross Section of Sancun Slope

Table 2 Factors of Safety obtained from the Sancun Slope Stability Analyses

	natural conditions			unusual weather conditions		
	general slicing method	Bishop method	transfer coefficient method	general slicing method	Bishop method	transfer coefficient method
Main part	1.163	1.168	1.200	1.015	1.020	1.044
First-order part	1.091	1.098	1.150	0.952	0.959	0.997
Second-order part	1.029	1.048	1.132	0.896	0.912	0.981

The Factor of Safety calculations indicate that the slope is safe under natural conditions, although under unusual weather conditions it is thought that it could partially fail.

THE BIO-CONTROLLING MEASURES

The results of the stability calculations show that a rainstorm is important to the stability of the slope, so besides making essential measures to drain the slope body, it was deemed necessary to undertake bio-controlling measures. The engineering works for the drainage installation will destroy the indigenous vegetation, aggravating the erosion of the slope . The fluctuation of the reservoir level and wave washing the bank slope will easily result in destabilization of the slope. Accordingly, it is important to restore the ecological environment, strengthen soil and water conservation as soon as possible for the stability of the slope to be maintained.

Function and Mechanism of the Bio-controlling Measures

When it rains, the rain hits the slope, some water infiltrates, some water forms flows on the surface of the slope. It will engender shearing force on the surface of the soil. When the force is larger than the erosion-resistance, the soil granule will be taken away by the runoff, so water loss and soil erosion will easily occur (Chang-jun Zhou. 2003). Vegetation can protect the stability of the slope by preventing water loss and soil erosion. The canopy of vegetation can keep out rainwater, it can reduce infiltration of water into the slope, and the rhizome can take-up water and transpire. This dries out the soil and lowers the water table. At the same time vegetation can retard surface runoff and surface erosion by water. The rhizome can also reinforce the soil, increasing its shearing strength. The rhizome may embed bedrock, which could help anchor the soil body. According to the different conditions of the slope, we will take some corresponding bio-controlling measures, such as planting arbuscles and lawn and other plants, to prevent water loss and soil erosion.

The Technology of Slope Protection

Under the impounded water level, it's difficult for land and aquatic plant to grow. About ten metres under the impounded level, water loss and soil erosion is serious because the water level elevates and subsides. Therefore, in this zone it is best to choose amphibious plants. According to the research of Yuan-xiao Jing, Vetiveria zizanioides can live submerged for 5 months, and these plants can normally grow after the impounded water level falls. Under the submersion condition, the growth and development are the same as those under terrestrial condition, demonstrating Vetiveria zizanioides is an amphibious plant (Jing Yuan-xiao, Chen Zhao-ping, Yang Dan-jing. 2001).

Sancun slope is potentially unstable and consists of fragmented rock and soil. Gully erosion and landsliding can easily occur in the superficial layer. Vetiveria zizanioides are a herbaceous perennial graminaceous plants that are adaptable, have large biomass and are extensively grown. They are the optimum plants for both the steep slopes and flat areas. Their merits are as following.

1. The root systems are strong. The tensile strength is 75MPa and shear strength is 25MPa, which can help prevent slope erosion and landsliding in the superficial layer.
2. The rate of growth is fast, capability of interception is powerful, so it can reduce surface runoff about 73% from naked surface soil, and intercept silt about 98%. It is able to endure submersion by water (it can survive 120 days of complete submersion). The anchoring soil and water-holding capacities are strong, and its washing resistance is more powerful.
3. The leaves have high transpiration rates that can rapidly reduce the saturation water of the soil (Feng Zi-yuan, Zhang Li-ping. 2003) and thus enhance the stability of the slope.
4. It reproduces asexually, so the ruderals will not be born among them.
5. The construction cost is moderate, and the execution of works are not effected by the seasons.
6. Moreover, Vetiveria zizanioides can be made into fuel, knitting artwork, spice and paper manufacture etc. So it is the best plant of slope protection, and it has wide application values (Cheng Hong, 1998).

Based on the evaluation of the slope, we will take the measures shown in figure 3. On the part between the first-order sliding surface and the upper of the slope, Vetiveria zizanioides will be planted along the contours. The row spacing will be 100cm to 120cm, the cluster spacing 10cm, and each cluster comprises 5 stems of a plant. Other plants, such as Paspalum notatum Flugge, Cynodon dactylon and Wedelia chinensis, will be planted that have the features of tolerance to heat, tolerance to drought and flood resistantce. On the other areas, that is, on the part between the first-order sliding surface and the lower part of the slope, object tree species and pioneer tree species can be planted with Vetiveria zizanioides. At the same time, the planting densities of Vetiveria zizanioides and mixed herbaceous will be augmented, that is, the row spacing will be 20cm and each cluster will comprise 4 stems of a plant.

The object tree species and the pioneer tree species will be sown as seeds. Plants grown from seed have better root networks, higher stretching resistance, and the capability of resisting natural disasters than those planted in a more mature condition.. During the early stages, Vetiveria zizanioides are the major plants. During the medium-term, the pioneer tree species begin to function. During the later phase, the object tree species form a natural community, and then they can finally restore the ecological balances of the slope. Furthermore, tall trees should not be planted on the slope, because their weight and wind resistance will be a disadvantage to the stability.

CONCLUSIONS

Sancun slope consists of three potential level sliding surfaces. The top of these are located at 2040~2125m for the main one, 1875~1925m for the first-order one, and 1775~1800m for the second-order one. The slope is safe under nornal conditions, although under unusual weather conditions it is thought that it could partially fail. .In order to ensure the stability of the slope bio-controlling measures have been implemented to reduce any effects that adverse conditions could have on the slope's stability.

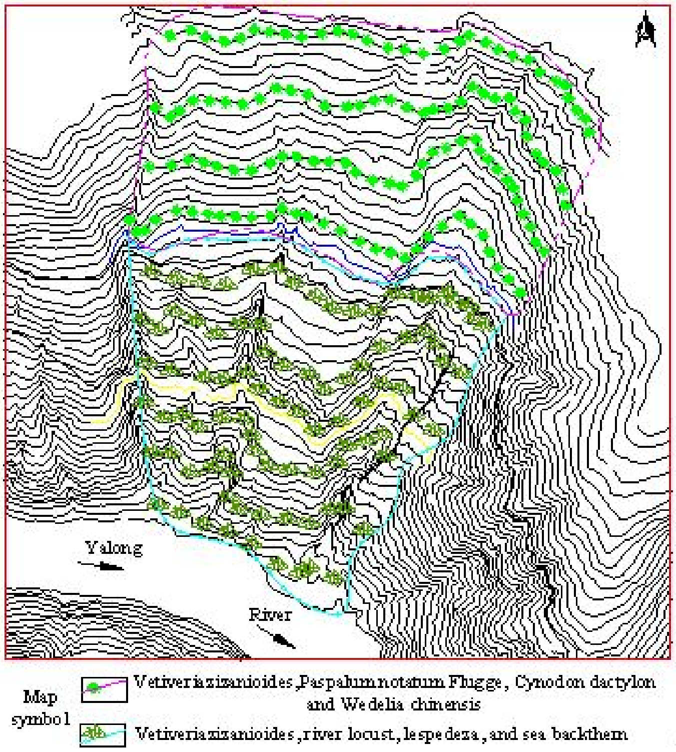

Figure 3. Plan of Bio-controlling measures

REFERENCES

Chang-jun Zhou. 2003. The Prevention of Slope in Highway Apply to Bio-technique. The traffic Technique in Heilongjiang Province, issue 113

Cheng Hong. 1998. An Overview of Vetiver Grass Utilization and Research in China. Bulletin of Soil and Water Conservation, **18**(3),

Feng Zi-yuan, Zhang Li-ping. 2003. The Technology of Vetiveria zizanioides Apply to Prevention of River Slope in Baise Hydraulic Engineering, Pearl River,(4)

Jing Yuan-xiao, Chen Zhao-ping, Yang Dan-jing. 2001. Preliminary Studies on Responses and Adaptations of Vetiveria zizanioides to Flooding. Journal of South China Normal University (Natural Science Edition), 4.

Run-qiu Huang, Shi-tian Wang, Yu-sheng Li et al. 1998. Study on Jinping hydroelectric Station Yalangjiang Important Engineering Geology 168-180

Zhuoyuan Zhang, Shi-tian Wang, Lan-sheng Wang, 1994. Principles of Engineering Geology Analysis, 2nd edition.