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Some Problems on the Slope Handling in the Highway Construction in China
(Beberapa Masalah dalam Pengendalian Cerun dalam Pembinaan Lebuh Raya di China)

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ABSTRACT

In western China, with plenty of transportation infrastructures being constructed, many man-made slopes have been formed in the highway constructions along the highway routes. Fortunately, most of these man-made slopes were in middle or small scales. However, in the procedure of slope design as well as potential landslides controlling, there are many problems and error viewpoints, such as slope angle is determined mainly on the basis of designers' experience without considering the lifetime of control projects, calculating slope satiability and optionally choosing remedial measurements. If not well resolved, these problems will affect not only the safety of highway operation, but also project investment. Based on the experiences in the highway engineering, these problems have been summarized in detailed and discussed in this paper. Some advices have also been put forward, which could be beneficial to the highway construction and operation.

Keywords: Highway engineering; landslides; safe handling; slope project

ABSTRAK

Di kawasan barat China terdapat banyak infrastruktur pengangkutan yang dibina, banyak cerun buatan manusia yang telah terbentuk dalam pembinaan lebuh raya sepanjang laluan lebuh raya. Mujur, kebanyakan cerun buatan muatan adalah dalam skala tengah atau kecil. Walau bagaimanapun, dalam prosedur mereka bentuk cerun serta kawalan tanah runtuh yang berpotensi berlaku, terdapat banyak masalah dan sudut pandangan ralat, seperti sudut cerun yang ditentukan hanya berdasarkan pengalaman pereka tanpa mempertimbangkan jangka hayat projek kawalan, pengiraan kebolehnampakan cerun dan memilih ukuran pemilihan secara pilihan. Sekiranya tidak dapat diselesaikan dengan baik, masalah ini akan memberikan kesan bukan sahaja kepada keselamatan operasi lebuh raya, tetapi juga kepada pelaburan projek. Berdasarkan pengalaman dalam kejuruteraan lebuh raya, masalah ini diringkaskan secara terperinci dan dibincangkan dalam kajian ini. Beberapa nasihat juga telah dikemukakan yang boleh memberi manfaat kepada pembinaan dan operasi lebuh raya.

Kata kunci: Kejuruteraan lebuh raya; pengendalian yang selamat; projek cerun; tanah runtuh

Introduction

In the campaign of Western Great Development, transportation infrastructure construction must precede for the development of the western regions of China. Billions of Yuan (RMB) per year has been invested into the infrastructure construction of west provinces of China, and the most are for highway constructions, such as, the Chong-wan highway (from Chongqing to Wanxian County) and the Cheng-yu highway (from Chengdu to Chongqing city) (Waters 1997; Yeung & Shen 2004). The natural geographic conditions in the west China's regions, especially for the three provinces (Sichuan, Guizhou, Yunnan) and a municipality (Chongqing) in Southwest China, are very special. Southwestern China is a mountainous and high-rainfall area (Huang & Li 2011). Not only is the complex geographic conditions with many high and steep mountains and plain lands, but also the conditions of engineering geology are rather tough. Some unfavorable geological structures have developed unexpectedly and seriously, including fault zone, broken zone, joints and cracks (Choo et al. 2014; Li et al. 2009; Nian et al. 2014; Yang et al. 2014; Yu et al. 2014). Therefore, the rock mass presents very poor stability after engineering disturbance which leads to a large number of natural disasters including landslides (Liu et al. 2004, 2003).

It is known that developments in infrastructure and large-scale engineering projects have considerably disturbed the natural landscapes in that area (Ji & Liao 2014). According to Chinese governmental statistical data, Chongqing city had 29896 crags and landslides in 1998 (Wu & Qi 2013). Total volume of these crags and landslides reached 50×10^6 m^3 (Kwong et al. 2004; Li 1995), which distinctly illustrated the toughness of natural conditions in these areas. In addition, some natural conditions such as mountains, gorges and canyons would inevitably be encountered in the procedure of highway construction in western China. Solutions to those problems mentioned above are to build bridges over rivers, gorges and canyons and cut slopes or construct tunnels through mountains (Lai et al. 2017). Generally, more attention has been paid to the plan, design and construction of these projects like bridges and tunnels to make sure of their stabilities and safeties as well as reaching the quality requirement by special laws and technological regulations. However, the man-made slopes cut or backfilled for passing through mountains or slopes, rarely attracted close attention (Gao 2007; Huang 2009; Xu et al. 2010; Yin et al. 2001), which results in many safe problems during highway construction, and will affect the safety of highway traffic. Based on the literature review and published case records (Kwong et al. 2004; Tang et al. 2002; Wang et al. 2004; Wu et al. 2005), the common problems have been summarized and discussed in detail in this paper. Some beneficial advices have been put forward to help the highway construction and operation.

EXİSTİNG PROBLEMS İN THE HİGHWAY CONSTRUCTİONS

Compared with ordinary roads, stricter and higher requirement for both of the technology and quality of highway construction has to be met during the highway constructions in the western regions of China. Furthermore, its route selection is required to be even more careful and stricter to avoid the terrain prone to landslides due to anthropogenic activities and natural triggers (Huang 2015). The highway construction still stays at primary stage in China, especially in the western regions. All kind of difficulties and problems are inevitable to be encountered, especially in the construction of tunnels, bridges and slope projects (Zhang 2007). Bridges and tunnels in the design and construction are always paid much more attention. In engineering application, there are various technical standards, technologies as well as rich experiences for bridge and tunnel constructions; therefore, less problems have been confronted in bridge and tunnel construction. However, it is quite different in slope construction. Despite of numerous achievements already gained on landslip disposal, there still exist many problems which will affect the safety of highway traffic

Based on the review of literature and published case records, the common problems were summarized as follows:

The understanding of the dangers of highway slope is not enough, which leads to randomly determination of the slope parameters without stability calculations. Most of slopes on the highway construction are in small scale,

FIGURE 1. A landslide at Yu-Wan highway after completion

therefore some slope parameters, such as the slope angle, are usually determined through experiences or directly based on the technical standards. It may be permitted to do so in the past because the technologies were poor and backward at that time (Kamsani et al. 2017). But now the relevant theories have already been quite mature and the computation technology has been also advanced. To do something just by experiences is out of date and cannot meet the requirement of project, even causing very dangerous results, as shown in Figure 1.

Firstly, to select parameters like this is very blind and unreliable. It is not easy to estimate the stability factors of slope in different conditions, because the designers did not know accurate data of a slope.

Secondly, if only according to the standards, the slope designers usually prefer to select larger parameters for the economical factors. However, the difference in parameter between the lowest and the largest is 33% - 50% as shown in Table 1.

Finally, if based on the experience, the classification of rock mass will appear greatly different with the different technical staffs, which will lead to great difference in dealing with a slope.

Additionally, during the highway construction, the earthquakes coming from blasting for excavation will weaken the strength of rock mass. However, in determining a slope angle, the impacts of these factors were not fully considered by engineers (Hoek et al. 2002). Hence, after the highway projects finishing, many landslides varying in size continually occurred along the highway route. Especially in the rainy season, the situation is more serious.

TABLE 1. Advanced angle values of cut rock slope by the standard

Rock classifications	degree of weathered	Slope height (m)	
		< 20	20- 30
All kinds of magmatic rock, hard limestone, conglomerate, sandstone, gneiss , quartzite	lightly weathered weak weathered	1:0.1- 1:0.3	1:0.2-1:0.5
	highly weathered completely weathered	1:0.5-1:1.0	1:0.5-1:1.25
All kinds of shale, mudstone and schist	lightly weathered weak weathered	1:0.25-1:0.75	1:0.5-1:1.0
	highly weathered completely weathered	1:0.5-1:1.25	1:0.75-1:1.5

In order to control existing and potential landslides induced by excavation, the remedial measurements are casually selected during the highway construction, even without basic geological profiles of the reinforced slope for saving investment. Before implementing the remedial measurements, field geotechnical investigation which includes boreholes, various tests have not been performed. For example, a part of a highway, which is 5.367 km long, has a total of seven man-made slopes which are about 20 m high (Huang et al. 2009). All of these slopes need to be dealt with to be more stabilized. However, four of them had been remedial by the construction company without doing any field geotechnical investigation, which leads to three slopes appeared various degrees of collapse after three months (Tang et al. 2002).

In addition, the lifetime of reinforced projects is not clear. It is well known that the lifetime of brick-concrete house is 50 years according to national regulations. However, there is no standard related to the slope handling, which results in that landslides of some handled slopes still reoccur, as shown as in Figure 2.

FIGURE 2. A collapse occurred at a handled slope

There are some error viewpoints to the landslide disasters on the highway construction. Generally, once the slope failure occurred on the highway construction, the remedial measurements are to cut the landslide mass or reinforce it. Compared with other types of slope failure such as open-pit slope failure, the slope failure on the highway does not result in tremendous losses of life and property. However, it is still unacceptable for the economy consideration, because the cost and difficulty of dealing with these landslides may be higher. After a slope failure occurred, the shear strength of rock mass is reduced to the residual shear strength which is less than the original strength (Skempton 1985). Moreover, once a failure of slope occurred, the progress highway construction could be affected and delayed. For example, during the Chong-wan highway construction, there was one landslide occurred which led to work stoppage for nearly 5 months.

Additionally, fallen rocks are usually failed to be considered in highway construction. Therefore, there are many disasters occurred during the highway operation, as shown in (FIGURE 3).

FIGURE 3. A rock fallen from a slope hits a bus

FIGURE 4. A collapse of backfilled slope

The stability of backfilled slope is often ignored. The engineers usually pay more attention to the stability of cut slope, but they always ignore the stability of backfilled slope. These because many backfilled slopes collapse in varying scale in rainy season, as shown in (FIGURE 4), which badly influences the normal traffic.

Slope monitoring work is not considered after the highway projects finishing. It is well known that bridges and houses should be monitored unceasingly for two years or even longer after finishing according to the national laws, slope monitoring work are completely ignored.

Analysis the Problem Causes

The slope is an important part of highway, and belongs to one of the three key projects (bridge, tunnel and slope/ soft foundation) of the highway construction. Logically, it should be as important as the bridge and house project. But the reality is very unsatisfactory. The reasons are summarized as follows:

There are some error viewpoints for the understanding of slope engineering. Project owners, project designers or project contractors usually consider that the highway slopes are in middle or small size. Compared with bridge and tunnel projects, the slope risk is considered to be neglected. Also, it is generally considered that the slope does not belong to the project scope like house and bridge (Wei & Yu 2001). In addition, once a landslide occurred, it is difficult to indentify responsibility. Landslip causes are always attributed to natural factors. Up to now, along the highways there have been many landslides occurred, but no person has been punished for these accidents.

There exist some limitations in the previous technical standards. The previous technical standards for highway slope handling are very fuzzy (Huang et al 2009). For example, based on the Specification for Design of Highway Subgrades (JTGD30-2004) which is the main technical code for highway design at present in China. Slope angle can be determined according to slope height, as shown in Table 1.

However, there are many factors which would affect the slope stability (Wang et al. 2000). Therefore, it is not reasonable to determine the slope angle only based on the value of slope height. Moreover, no guidelines are presented for cut slopes at which the slope height exceeds 30 meters, The code for investigation of geotechnical engineering (GB50021-94), shown in Table 2, has the same problem. In practice, this makes no guide to operate for project owners, project designers and project contractors. Therefore, engineers have to adopt engineering experience to design slopes with height more than 30 m.

TABLE 2. Advanced values of slope angle by the standard

Rock classifications	Degree of weathered	Permitted slope value (height ratio)			
		8 m high	8 - 15 m high	15 - 30 m high	30 - 40 m high
Hard rock	lightly weathered moderately weathered highly weathered	1:0.10- 1:0.20 1:0.2- 1:0.35 1:0.35- 1:0.50	1:0.20- 1:0.35 1:0.35- 1:0.50 1:0.50- 1:0.75	1:0.30- 1:0.50 1:0.50- 1:0.75 1:0.75- 1:1.00	1:0.45- 1:0.75 1:0.75- 1:1.00 1:1.00- 1:1.50
Soft rock	lightly weathered moderately weathered highly weathered	1:0.35- 1:0.50 1:0.50- 1:0.75 1:0.75- 1:1.00	1:0.50- 1:0.75 1:0.75- 1:1.00 1:1.00- 1:1.25	1:0.75- 1:1.00 1:1.00- 1:1.50	
Detritus	Dense Mid-dense slight dense	Less than 5 m high. 1:0.35-1:0.50 1:0.50-1:0.75 1:0.75-1:1.25		5 – 10 m high. 1:0.50-1:0.75 1:0.75-1:1.00 1:1.00-1:1.25	
Gummy soil and pulverous soil	Hard Hard plastic	1:0.75-1:1.00 1:1.00-1:1.25		1:1.00-1:1.25 1:1.25-1:1.50	

Conclusion

The existing problems in handling slope are very serious, such as slope angle is determined mainly on the basis of designers' experience without considering the lifetime of control projects, calculating slope satiability, and optionally choosing remedial measurements. If these problems are not resolved, lots of traffic disasters on the highway will happen. How to effectively solve these problems? Two recommendations are stated as follows. To deal with the highway slope, project owners, project designers and project contractors should establish a correct viewpoint and have a good understanding to the slope project.

First of all, highway slope handling is as important as bridge and tunnel projects. Secondly, the highway slope handling must be done in strict accordance with technical standards. Every highway slope has its own characteristic which means that one slope is different with another in the terrain, rock component and characteristics. There are even great differences among some slopes. Field geotechnical investigation and stability calculation for the analysis and control design of landslides should be carried out by professional companies. Thirdly, the monitoring and prediction of slopes should be performed. It is possible to select some new methods for large scale landslide prevention design, such as integrated intelligent methodology. A dynamic comprehensive method is also excellent for landslide control (Wei et al. 2006).

Improve the technical standards continually. With the continual development and evolvement of science and technicality, many new methods, new technicalities and new equipments are also put forward in highway construction. To consider the validity and realistic objectivity, the technical standards should be improved and revised correspondingly, which can provide a good technical guide for project owners, project designers and project contractors in handling highway slopes.

With the Western Great Development, more and more highways are under construction. At the same time, highway slope projects will also increase. The problems mentioned above should be correctly resolved so that the safety of highway traffic can be really guaranteed.

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