A Case Study of the Krishna Bhir Slope Failure Disaster: Past and Present Scenario at a Glance

Article · April 2016

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International Journal of Rock Engineering and Mechanics
Vol. 2: Issue 1
www.journalspub.com

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Abstract
The massive landslide disaster of Krishna bhir has been infamous for its dreadful consequences. This huge landslide in the region led to serious socio-economic and environmental disorders in the vicinity of the region, whose negative impacts were reflected soon in the capital city. In addition to the feeble geology, the blasting and drilling activities, rampant deforestation, heavy monsoon rain and the poor drainage are the engenders for weakening the natural slope resulting the perpetual slope failure of Krishna bhir. The concept of bio-engineering cum civil engineering was implemented by the Department of Road – Nepal to strengthen the hill slope and manage the mass movement. This has been a very effective solution, since it has managed to sustain the slope from more than past decade. However, Krishna bhir has managed to revert to its volatile state once again. Hence, this study investigates about the past and the present condition of the slope with the future recommendations to prevent the impending landslide.

Keywords: bio-engineering, geotechnical infrastructures, highway slope, Krishna bhir, landslide

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INTRODUCTION

Nepal is a poor country where most of the people live under the threshold of poverty. Therefore, the country has a very fragile base in terms of its trade and economy. Moreover, being an underdeveloped nation, roadways are the most efficient option for travel, trade and economy. So, the development of road networks is foremost mission to improve the trade and economy of the country.

Krishna bhir ('hill slope' termed as 'bhir' in Nepali) is located 83 km west from the capital city of Kathmandu in Dhading district and lies along the major highway of Nepal, the Prithivi highway. In 1974, this highway was made the major route for trade and commerce from India to the capital and other parts of the nation through the aid of Chinese government. This major highway, since its construction has contributed towards gradual rise in the economic condition of Nepal. By the time when this road network had already started to gain more attention, the natural hill slope along the Prithivi highway started to get affected by the dynamic and cyclic traffic loadings, and encroachment to the natural environment via deforestation. This ensued to the first minor-scale landslide in the upper two slopes of the terrain in the year 1999 AD, as presented in Figure 1. By the year May, 2000, deforestation and the heavy monsoon rain badly eroded the slope. The consequences was reflected in mid-scale landslide which led to 13 hours of road closer in the day and nearly 20 times of frequent road blockages in the month. By August, 2000, Krishna bhir reached to its saturation level after the heavy rainfall and poor drainage aggravated the slope. Eventually, the huge imminent landslide was inevitable. The eroded hill slope after the disaster of 2000 AD has been shown in Figure 2. The debris and boulders blocked the roadway for 11 consecutive days. In addition to the feeble geology (the steep slope and the loose material in general), the following were found to be the main reasons for perpetual slope failure in Krishna bhir:

(1) Blasting and digging activities along the slopes for road construction
(2) Hefty deforestation on the slope
(3) Heavy monsoon rain
(4) Very poor drainage system in the slope

Fig. 1. *Landslide of 1999 AD. Image Courtesy: S. Dwidevi (DWIDP).*

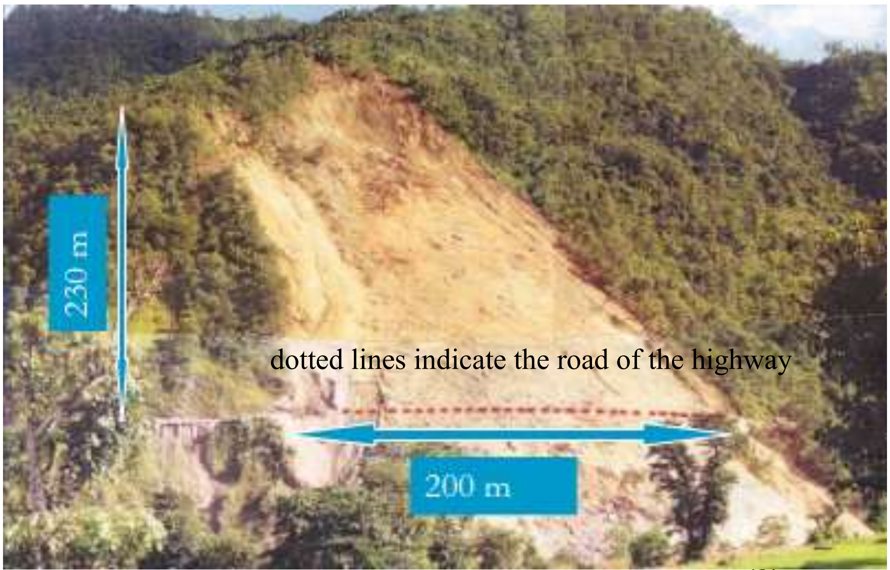

Fig. 2. *Krishna Bhir After Landslide of 2000 AD.*[2]

The novel concept of bio-engineering and tradition civil engineering methods were implemented by the Department of Road – Nepal aiming to strengthen the slope and manage the mass movement as shown in Figure 3. This has been a very effective solution since, this approach has sustained the slope from more than past decade. However, Krishna bhir has managed to revert to its volatile state once again. Hence, this study investigates about the past and the present condition of the slope with future recommendations to prevent the impending landslide.

Fig. 3. *Prithivi Highway and Krishna Bhir at Present (View From the Highway).*

SITE GEOLOGY

The site lies in the Lesser Himalayan Zone of the central Nepal. On northern side, the region is surrounded by Main Central Thrust (MCT) and the Main Boundary Thrust (MBT) on the southern side. Stratigraphically, the site falls in upper Nuwakot group of Nuwakot Complex at Benighat formation with Jhiku Carbonate beds, Malekhu Limestone, Robang Phyllite with Dunga Quartzite and Raduwa Schist.[1]

Lithologically, at the upper and middle part of the area, alternative beds of highly fractured phyllitic slate and carboneous slate are present. But, at the lower middle part of the slope, a thin band of quartzite and thick beds of limestone are present which are sandwiched between slaty phyllite and slate with quartz veins. In addition, thin bands of highly fractured Slates were observed within the limestone beds.

These rocks are highly weathered and have very poor strength. Colluvium deposits were also seen in the mid reason, which are very liable to slide and erode.[2]

AFTERMATH OF THE DISASTER

The landslide of Krishna bhir has been infamous for creating a pathway for many secondary disasters in the region and the capital. Krishna bhir landslide was declared as one of the massive landslides in Asia and has also achieved an international concern. As Prithivi highway is the only transportation artery to support logistics from India and China to the country, the landslide in Krishna bhir had created a dreadful situation for thousands of people travelling along route. This large-scale landslide blocked the traffic for nearly 2 weeks which created the obstruction of the supplies to Kathmandu and adjoining areas from its trade logistic partners mainly, India and China. It also led to shortage of daily commodities in the capital.

The blockage of the highway by debris and boulders brought the economic crisis for the several weeks. The disturbance gave rise to many disorders in the capital such as fuel shortage, political instability for the period and the riots in the city. These activities ultimately created psychological imbalance among the denizens of the capital. However, the concrete economic data are not made transparent to the people by the government.

As per one of the staple tasks of this study, the interaction was made with the local people of the area with different professions such as farmers, shopkeepers, animal rearing farmers, local business men and also the school goers. As reported by the people of the area, the massive landslide swallowed their agricultural areas and stopped their supplies for wood, flowers and fruits (as told by Mrs. Binita Nepal and Mrs. Mithu Chatkuli, local farmers). Selling woods, flowers and fruits obtained from the hill to the neighbouring places and the capital were the major source of income generation. Moreover, the annihilation of agricultural land stopped the supplies of fresh grasses to the cattle. The problem of dust was very disturbing that caused severe air pollution in the area. The houses used to be layered with coatings of dust (as told by Mr. Hari Basnet, a local denizen). The livestock suffered from illness due to air pollution (as told by Mr. Daya Ram, a cattle rearing farmer).

The pollution also effected the health of elderly people in the region. Air pollution in the region also lowered the local Indian travellers who frequently stayed at the motel. The disaster's commotion led to theft and robbery from the shops (as told by Mrs. Thir Kumari Nepal, a shopkeeper).

These actions had the adverse effect on the revenue of the local people of respective professions. The impact of the disaster was also reflected among the school goers, as the students could not make their way to the schools due to the road blockage. The people were unable to visit the health post for their check-up and the ladies for their pregnancy delivery.

The daily commuters on the hilly expressway had also faced the problems up to the tangible extent. The drivers used their vehicle as a temporary shelter for several weeks due to the blockage. Some of the drivers faced hefty loss in their business as they were stuck in the road with the sacks full of commodities from India.

Some of the vehicles were trapped inside the debris which gave a huge loss to the drivers.

STRENGTHENING AND MANAGEMENT OF THE MASS MOVEMENT OF KRISHNA BHIR AT PRESENT

Krishna bhir landslide was becoming a major mayhem for the transportation system of the nation. In 2004, Department of Road – Nepal (DOR) under to expert supervision of Er. N. M. Shakya carried out their wise management measure to minimize the perpetual slope failure disaster. DOR purposed a method that combined civil engineering technique and bio engineering technique. In depth procedures and methodology of the work initiated are beyond the scope of this research. Due to a very huge area of the slope, the movement of the mass (soil and rock) was controlled by civil engineering structure and slope protection was carried out by the bio-engineering technique. The debris flow at the midst and lower portions of the slope were managed by civil engineering approach and the lower parts were strengthen by bio-engineering technique. Figures 4 and 5 show the civil engineering structures constructed and bio-engineering vegetation planted to stabilize the slope. It could have been highly uneconomical and daunting effort to construct the civil engineering structures in the uphill zone. Hence, at toe portion of the hill, structures like the gabion wall and stone masonry wall are built. The steel reinforced gabion walls provided sufficient ductility for the active soil pressure. Simultaneously, the areas with very steep slopes were armoured with vegetation. The reinforced concrete cascades are also provided to change the direction of mass flow away from the road below. This structure also aid in collection of wasted rock and soil mass thus, dissipating the energy and velocity of the landslide. Furthermore, it also acts as a natural or artificial drain (provided with pipes) for water flow. The artificial drains are also installed at some parts in the slope by using perforated plastic pipes.

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(a) Stone Masonry Wall with Weep Holes for Drainage

(b) Artificial Drain Pipes in the Gabion Walls

(c) Cascade Structure

(d) Culvert

(e) Gabion Wall

Fig. 4. *Civil Engineering Structures Built to Manage the Landslide.*

Fig. 5. *Bio-engineering (Vegetation Plantation) in Krishna Bhir Slope.*

The top areas of the slope is strengthened by the bio-engineering technique. The species used with their applied functions are clearly illustrated in Table 1. Once the vegetative structures have been established, it is expected to take over the entire support function, since, with time, relative strength of civil engineering structures decreased whereas, that of vegetative structures increases.[3] Random grass and Bhujetro were planted in the area of weathered rock mass having a severe problem of erosion. They help in armoring and binding the loose soil material and also allowed to flow the water from their surface. Bamboos also absorbed significant volume of water which helped to make the surface and subsurface flow inactive in the slope. These were some of the techniques how the slopes were given an artificial shear strength through root of plants and draining the slope surface.

Table 1. *Vegetation Used to Strengthen Krishna Bhir With Their Respective Functions*

Categories	Vegetation	Functions
Trees	Bakaino (*Melia azedarach*)	• Roots of the trees helped in gripping and armoring the soil mass • Trees planted behind the structural walls provided the auxiliary support to the engineering structures
	Khayer (*Acacia catechu*)	
	Epil	
Shrub	Bhujetro (*Butea minor*)	• Shurbs helped in armoring and binding the loose soil material • Bhujetro can even grow in rocky surfaces. Apart from strengthening the slopes, their broad leaves prevented the percolation of rainfall water to soil by allowing to flow the water over their leaves • It prevented the slope surfaces against plucking soil particles out of the slope surface due to the high impact of raindrops • It acted as a wall to catch debris
	Simali (*Vitex negundo*)	
Grass	Kans (*Saccharum spontaneous)*	• Grasses can retain, reinforce small loose debris • Kans and Babiyo have very strong fibres and they can grow even in harsh, stony and dry condition. Therefore, these grasses armoured and reinforced the slope surface • Bamboos strengthen the slope and take the large amount seeped water thus, reducing the active water flow
	Babiyo (*Eulaliopis binate*)	
	Amliso (*Thysanolaena maxima)*	
	Bamboo	

SYMPTOMS OF THE MASS MOVEMENT AND THE CONDITIONS OF THE STRUCTURES AT PRESENT

After the thorough investigation by the author in the year 2014, Krishna bhir was found to be triggering once again. As seen in Figure 6(a), the slope is weathered and exposed of Slate in the lower part which makes it highly vulnerable to erosion during the rainy season. The slopes in the upper region are still active indicated by running of loose debris along the steep slope. The symptoms of active mass movement at the midst of the slope can also be viewed from the inclined trees and highly yielded gabion walls in Figure 6(b).

The site condition at present indicated that the preventive maintenance and monitoring was lacking to a great extent. The existing condition of the structures has been illustrated by Figures 6(b) and (c). The artificial drains in the cascade are clogged by vegetation and debris. The path of the cascades is blocked by heavy boulders and high amount of sediments due to rock fall and landslides in the upper region. One of the cascades is damaged and failed seriously by impact of heavy rock fall and debris flow. The levity in maintenance can be visualized with failed cascades, clogged drain pipes in masonry walls and flushed artificial drains pipes along the slopes. The slopes around the vicinity of Krishna bhir were quite stable which might be due to the difference in constituent of the material in other part of the slope. These symptoms clearly show liveliness of slope with time.

(a) *Exposed Krishna Bhir at Present*

(b). Signs of Active Slope

(c). Present Condition of Cascades

(d) Washed Away Drain Pipe

Fig. 6. *The Present Condition Krishna Bhir and Stabilizing Structures.*

PROPOSED RECOMMENDATIONS

In order to stop the present triggering slope failure monitoring and corrective maintenance are the first steps to be initiated. In the active and exposed areas, more plantation of Babiyo should be done due to its nature to grow in rocky base. In the steeper areas of the slope, construction of civil engineering structures are quite difficult so, the replantation option should be selected. It was also seen that in the crown of the slope, no sort of preventive measures were adopted.

Cress-cross gabion wall or masonry wall can also be built in the near crown area accompanied with some plantation. The fallen debris and soil-rock masses should be stabilized in the same area with some degree of trimming, because, the same material can help in stabilization by bio engineering. This might help in prevention of soil – rock mass movement. Furthermore, on the steeper slopes, it would be better to choose bio engineering armoring stabilization rather that civil engineering walls because of their dead weight. Finally, the monitoring is absent in the area and preventive maintenance should be carried as soon as possible. Cleaning the clogged drain pipes, removal of debris and boulders from the cascade, repair of impaired structures and more plantation of vegetation in the naked areas should be the first steps of maintenance.

CONCLUSIONS

The landslide of Krishna bhir was classified as one of the large scale landslides ever happened. In regards to the scale, this landslide along the highway led to numerous secondary disasters in the region and the capital. It adversely affected the socio-economic and environmental condition of the region and the capital as a whole. Civil engineering construction was applied to manage the mass movement at the mid and the lower portions of the slope while bio-engineering method was applied at the top.

The bio-engineering method proved to be very effective and economical for reinforcing the Krishna bhir. The villagers reported, to have realized their faults of deforestation and have already been involved in planting more vegetation. The lush vegetation also created a pollution free environment, generated optimum source of revenue for the local people. This sustainable method proved to be a lucrative solution in consideration to the large are of the slope.

From this study it can be reported that, Krishna bhir has again returned to its volatile situation. The hill is seen to be active gradually with the time. Monitoring is lacking in the area and the preventive maintenance should be implemented very soon.

Cleaning the clogged drain pipes, removal of debris and boulders in cascade, repair of impaired structures and more plantation of vegetation in the naked areas should be the first step to be initiated. As done in Niigata prefecture of Japan, number of survey stations should be established for accurate determination of ground surface.

Lastly, it will be better to invest certain percentage of the capital by the government in monitoring and maintenance of Krishna bhir rather than investing a huge sum for the corrective maintenance after the disaster.

ACKNOWLEDGEMENTS

The author would like to acknowledge Mr. N. M. Shakya (Senior Divisional Engineer in Department of Road, Nepal) for lending his valuable time for the interview session regarding the past issues of Krishna bhir landslide.

I am also very thankful to Er. A. Basnet and Mr. B. Silwal for their cooperation in the field work and sharing their knowledge and experience regaring the study for this research. This work has been partially supported by the Inter-Graduate School Program for Sustainable Development and Survivable Societies, Kyoto University. This support is gratefully acknowledged. My sincere thanks to Prof. P. N. Maskey for his encouragement and management.

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