Landslides in Bhutan

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Abstract

Landslide poses real danger in the Himalayan Kingdom of Bhutan. Mountainous terrain forces construction of roads and other infrastructure up on the steep slopes that are mainly thrusted and folded and consequently fractured and weathered. This paper presents the overall view of the landslide problems, mitigation methods and the need to further the risk management plan. It also provides a glimpse of the social, economical and political situation of the Kingdom among others.

Introduction

Bhutan is a small kingdom covering an area of 46,500 square kilometers in the eastern part of the Himalayan Range between latitudes 26°40' and 28°20' north and longitude 88°45' and 92°7' east (Figure 1). It is surrounded by the Tibetan Plateau in the north, the Bengal and Assam Plains in the south, Arunachal Pradesh in the east and the Darjeeling and the Sikkim Himalaya in the west.

Figure 1. Map of Bhutan

Bhutan is mountainous with elevations ranging from 150 m up to 8,000 m. Three main ethnic groups live in Bhutan. Ngalops live in the north-western region. Sharchops inhabit eastern and central region and Lhotshampas in the southern foothill districts.

The economy, one of the world's smallest, is based on agriculture and forestry. About 70% of the population depends on agriculture for their livelihood. Agriculture consists mainly of subsistence farming and animal husbandry. Agriculture share to GDP is 36.4% in 2000. Bhutan's hydropower and tourism are key financial resources. The hydroelectricity power sector is the single biggest revenue earner of the Kingdom with hydro-electricity power potential of about 30,000 MW. Most of the rivers come from the glaciers and altitude difference provides huge potential for hydropower.

Rugged terrain makes building of roads and other infrastructure difficult and expensive. Each economic program takes into account the people's desire to protect the country's environment

and cultural traditions. Bhutan's economic growth climbed to 7.7% in 2002 from 6.6% the previous year.

Bhutan is ruled by a constitutional monarch. His Majesty King Jigme Singye Wangchuck governs with the support of National assembly and Council of Ministers. Since June 30, 2003, there are ten full fledged Ministers. Ministers are elected for a period of five years term. The prime ministerial post is rotated among the cabinet ministers on annual basis.

The National Assembly of Bhutan has 150 members of which 105 members (chimes) are elected by the heads of the households. Important decisions and laws are made during this Assembly.

The Kingdom is divided into 20 districts. The Dzongda or the District Governor is the head of the government in the district. He is responsible for implementation of the government policies, development projects besides maintaining law and order.

Bhutan is one of the least populated countries in South Asia. The population of Bhutan was estimated at 716, 423 and population growth was 2.4% in 2002.

Bhutan has a wide variety of climate conditions influenced by topography, elevation and rainfall patterns. In general, precipitation diminishes significantly from south to north. The winters are dry and rainfall is heavy during May - September. The climate is tropical in southern plains, cool winters and hot summers in central valleys, and severe winters and cool summers in northern Bhutan Himalayas.

Land use is influenced by the diversity of climate and topography related to altitude. More than 70% of the total land is under forest as per the central government policy. Major landforms consist of mountains and valleys. Agriculture is mainly practiced in the valleys and mountains are generally forested. Only less than 8% of the total land is fit for agriculture.

The regional geological setting of the Bhutan Himalaya has been described by Gansser (1983). Much of Bhutan is dominated by Higher Himalayan Crystalline Complex (HHC) which outcrops over a north-south width of about 60-100 km between South Tibetan Detachment (STD) along the northern border of Bhutan and the Main Central Thrust (MCT). To the south of the MCT is the Lesser Himalaya. The MCT dips to the north and separates the high grade gneiss of the HHC in the hanging wall, from the greenschist metamorphic rocks of the Lesser Himalaya. So an inverted metamorphic gradient is associated with this thrust. In general, the tectonic setting of Bhutan Himalayas shares similarities with Himalayas of Nepal and India. Major tectono-stratigraphic units and structures are Siwalik Group, the Main Boundary Thrust (MBT), the Lesser Himalayan Sequence (LHS), the Main Central Thrust (MCT), the Higher Himalayan Crystalline Complex (HHC), and the South Tibetan Detachment (STD).

Bhutan is a developing country. The problems of landslides are an important consideration in infrastructure planning and other developmental activities.

Extent of the landslide problem

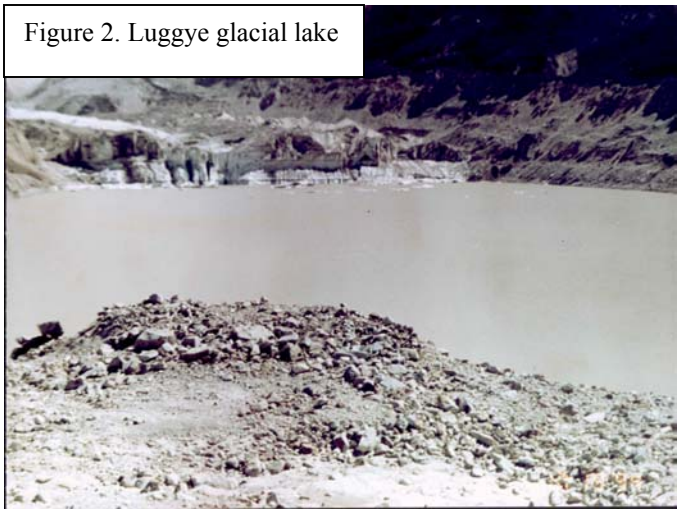
With the development activities taking place in the Himalayan regions a new focus has been shifted to the landslide problems. The geologic fragility of the Himalayan area has been highlighted and there has been an over emphasis on the macro scale in literature and very little on the micro scale. Due to the tectonics that have resulted the Himalayas, and Bhutan being part of

that region, it has always been recognized as an area prone to natural hazards including the landslides.

The entire northern part of Bhutan is covered by ice and snow, resulting in glaciers that are the sources of the rivers that traverse from north to the south. There are 667 glaciers and 2674 glacial lakes in Bhutan alone. Although these glaciers are perennial sources of water they are also potential for flood disasters. In total, 24 glacial lakes have been identified as potentially dangerous.

The criteria for identifying potentially dangerous glacial lakes are based on field observations, processes and records of past events, geomorphological and geotechnical characteristics of the lake and surroundings, and other physical conditions. Besides, the conditions of lakes, dams, associated mother glaciers, and topographic features around the lakes and glaciers are also studied for the hazard assessment of the glacial lakes.

Figure 2. Luggye glacial lake



Change in climate is resulting in melting of these glaciers. Consequently, the volume of the glacial lakes increases, thereby increasing the hydrostatic pressure on barrier dams (created by glacial debris), which give way causing catastrophic outburst. For instance, in 1994, Luggye glacial lake (Figure 2) outburst in Lunana flooded and damaged rice fields, bridges, houses and the dzongs (Figure 3), demonstrating Bhutan's vulnerability to such extreme events. GLOF and flash floods had also occurred in the same region earlier in 1950, 1960 and 1968.

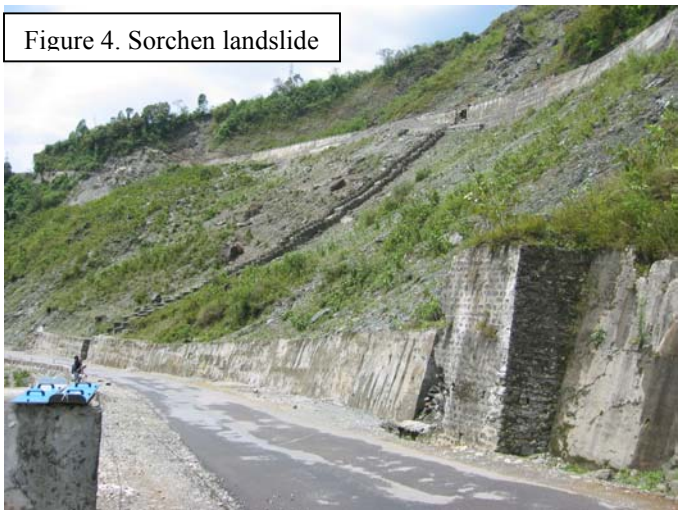
Figure 3. Punakha Dzong (partly destroyed by GLOF)

If the land in the north is highly prone to glaciers and related natural hazards then the area in the east and south are subjects to several landslides, especially in the rainy monsoon months. A lateral road runs from the west to east across Bhutan. Due to extreme Alpine terrain and deep valleys, landslides often block the way to the east.

Recently, on August 16, 2004 a flash flood struck eastern Bhutan (Tashigang, Mongar and Lhuentse). This flood and the consequent landslides claimed 11 lives. A total of 29 houses were washed away, about 26 collapsed and 107 were partially damaged. According to the Kuensel, the national newspaper 22 bridges had been damaged and 39 irrigation channels were either damaged or washed away. About 160 acres of wet land and 500 acres of dry land were damaged.

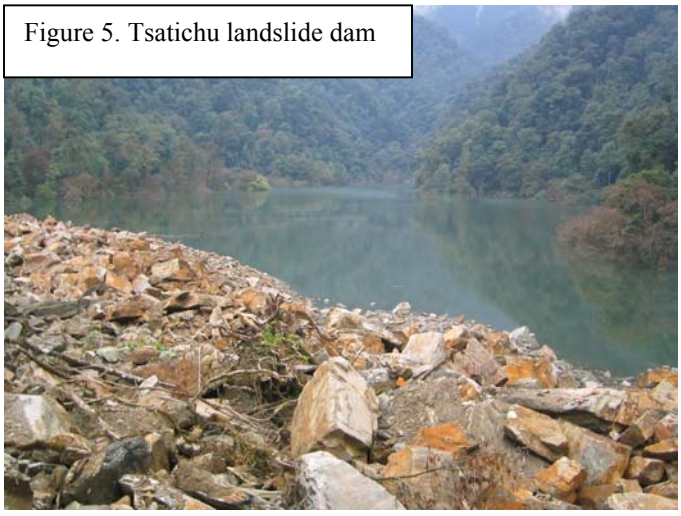
The landslides triggered by road cutting are quite common in Bhutan. During the rainy months of May-September, landslides crop up at various places blocking the roads. The life line of Bhutan, the road from Phuntsholing to Thimphu often gets blocked by landslide debris. This is the road that brings in the consumer goods from India. When this road gets blocked, the capital city, Thimphu gets cut of from India, the single most important partner of trade for Bhutan. Sorchen landslide (Figure 2) is a very popular slide for which a risk treatment has not been found for several years. This is a deep seated slide in rocks of moderate to highly weathered phyllites. Just two years ago, the Government has decided to totally do away with this landslide and built an alternative route as an avoidance strategy.

Figure 4. Sorchen landslide



Landslide-dams occur in the steep, narrow valleys of the high rugged mountains of Bhutan as these valleys only require relatively small amounts of material to form blockages. This is extremely dangerous for Bhutan because the country relies heavily on its hydro-electricity powers, which are built on these rivers. For example, on the morning of September 10, 2003 a huge combination of rock and earth slump occurred in Tsatichhu River blocking it and forming a dam (Figure 5). A lake started to form immediately behind the dam. The height of this landslide dam was 140 m over the original river bottom. The discharge into this lake was estimated to be 0.5 m^3/sec in dry season and 5 m^3/sec in monsoons. Bursting of this lake could damage Kurichu Hydro Power project, one of the most important undertakings of the Kingdom. Therefore, landslides have a huge adverse impact on development activities of the country.

Figure 5. Tsatichu landslide dam



Causative factors

In the Himalayan region of which Bhutan is a part of, the landslides are scale-dependent, ranging from the magnitude of mountain ranges, through lateral spreading, to the smallest slope failures. The morphology of the slopes consequent to slope failures are complex and controlled by many factors, such as lithology, rock-mass strength and other physical properties.

Based on the field study carried out on a micro scale in the Himalayas, the causes of the landslides are due to both natural geological activities as well as possible human related causes. The natural causes include tectonic activities that have formed the region into high relief thrusted and folded mountains. Unpredictable precipitation levels during summer monsoon months and the steepness of the slopes, undercutting of the banks by deeply incised rivers are some of the causes of landslides. Although so far the disasters from the earthquake have been

rare, Bhutan should prepare for earthquake as it lies in a seismically active zone (4-5 on Richter scale).

In the Bhutan Himalaya, landslides are often triggered by toe cutting of the slope for road construction. Intensive deforestation for agriculture leaves the land vulnerable to landslides. The possible human impact could well be the result of construction of road and other infrastructure on these slopes without proper planning. Blasting is also one of the main triggers for landslides. With the growth of population and subsequent pressure on natural resources, the landslide problem can only be expected to escalate.

Rainfall induced slope failure is the most common geo-environment hazard in Bhutan. Saturation of soil not also increases the pore water pressure but also degrades soil strength parameters. There is a direct correlation between the amount of rainfall and the incidence of landslides. The areas that are most prone to rainfall induced failures are heavily fractured and weathered rocks of phyllites, slates and schists that contain high amounts of clay minerals. The southern part of Bhutan which forms part of Lesser Himalayas is such an area. The risk from such slope failure will only increase as more roads are cut into the hills and mountains.

Unpredictable monsoon rainfall is also one main cause of flash floods in the southern parts of Bhutan. In 2000, a flash flood washed away major parts of Phuntsholing (the second biggest town after the capital city, Thimphu) destroying several houses, bridges and lives.

Hazard Zonation

The Department of Geology and Mines has been involved in preparing hazard maps by applying risk principles. This involves preparation of maps summarizing observations on geology, geomorphology, and in particular the distribution of landslide processes including use of local records, interpretations of aerial photographs and field observations. But this has been done only along some of the existing highways and important sites of new towns and projects due to manpower and other resources constraints.

During the month of January 2004, a geo-hazard map has been prepared for the road connecting Phuntsholing, (a border town) with Tala, a site for Bhutan's largest hydro-power project. This stretch was chosen for zoning because the area is geologically weak marked my several shear zones as well as weathered and folded phyllite rocks turning into clay. A geo-hazard map was also prepared for the highway connecting Sarbang with Chirang. This is a 62 km stretch in the southern part of the country, where the geology is most prone to landslides. Similarly, the Department is in the process of preparing hazard zonations maps for the other critical highways and new towns.

Often the hazard information is plotted on 1:50,000 scale contour maps since they are readily available. However, such maps are inadequate for detailed study of a small project site. Recently, the use of aerial photographs for hazard zonation has become popular. With such photos the mountainous terrain can be mapped quite easily though not exactly. These photos are available on 1:10,000 scales. The above two methods are aided by geophysical methods (Figure 6) to further investigate and understand subsurface geology.

Mitigation strategy

Figure 6. Geophysical survey (GPR)

The national development policies incorporate the problem of landslide. For every important project, be it the construction of a hydropower project or infrastructure development, the land stability is assessed first. Realizing the vulnerability of the terrain to landslides, generally the construction of buildings, bridges and other important infrastructure can begin only after the site has been approved for stability by the engineering geologists. Besides the Department of Geology and Mines, the Department of Road is also involved in mitigation of the landslide problems. Recently, every new road alignment is first thoroughly studied by the engineering geologists and landslide experts before the actual cuttings begin and in some places even environmental friendly roads have been constructed despite the huge cost. This was not done in the past. The advice of the concerned organizations are sought with regard to the geotechnical aspects. The Department of Geology and Mines caters geotechnical services to the other government and private agencies.

Landslide mitigation strategies are applied to different types of landslides related to different geologic settings. These strategies include avoidance, stabilization, prevention and no action (live with recurring maintenance from landslide). Some of the common strategies to stabilize, control or prevent landslides include surface drainage and subsurface drainage as water is one of the main culprits of instability. Other strategies, especially for the roads and construction of infrastructure on the slopes include increase of resisting forces by retaining walls, soil reinforced earth and bioengineering of the disturbed slopes.

Mitigation interventions

Whenever a landslide or any other natural disasters struck a place, the Department of Geology is called up to assess the hazard and suggest mitigation measures. When the impact of the potential disaster (for example bursting of a landslide dam that can destroy a hydro-power project) is potentially too large, then the concerned authorities are called upon for a joint study team. The local community that is directly impacted by the natural disaster is usually informed of the impending danger. However, at present the community based initiative ends with informing the local authority of the likely hazard by the community members. The local authority in turn informs the central government for action leading up to the mitigation works.

Capacity building and experience sharing

At present the society at large is not fully aware of the landslides or other natural hazards. The concerned organization, particularly the Department of Geology and Mines alone seems

responsible for the mitigation of landslides. Therefore, there is a need to educate the public at different levels about the dangers of landslides. There needs a strategy that envisions a society that is fully aware of landslide hazards and routinely takes action to reduce both the risks and costs associated with those hazards. A comprehensive landslide hazard mitigation strategy that provides and encourages the use of scientific information, maps, methodology, and guidance for emergency management and land-use planning to reduce losses from landslides and other ground failure hazards nationwide needs to be developed. Geologists, engineers and decision-makers should be further trained in this regard.

The Department of Geology and Mines works closely with International Institute for Geo-Information Science and Earth Observation (ITC, Enschede and Delft, the Netherlands) and Norwegian Geotechnical Institute (NGI) regarding slope stability and environmental analysis. At present two long term experts from ITC, Delft are attachment with the Department and a joint project on geotechnical engineering is going on with NGI.

With regard to the glaciers in the northern parts of Bhutan, in the past the Department has work with International Centre for Integrated Development ICIMOD, Nepal on the dangers of Glacial Lake Outburst Floods (GLOF). Subsequently, a joint expedition venture was formed with the University of Vienna, Austria to monitor the potentially dangerous glacial lakes in Lunana. At present the glaciologist of the Department presently has a joint venture project with a team from the University of Kyoto, Japan and these glaciers and glacial lakes are monitored annually by field expeditions.

Recommendations

For effective land risk management, the potential landslide prone areas should be identified. In this light, the first thing that has to be done is to delineate susceptible areas and different types of landslides hazards at a scale useful for planning and decision making. At present the hazard prone areas are mapped on 1:50,000 scale, which is not really useful for micro-scale infrastructure development.

Further guidance and training ought to be provided regarding landslides not only to the geologists and engineers but also the decision-makers. The loss assessment from the landslide related hazards of the country and the economic impacts should be conducted to highlight the importance of such study. Public awareness and education with regard to the landslides is also of utmost importance.

Improper land use, for example quarrying for construction material without considering the conditions of the terrain, agriculture practices on steep slopes, irrigation on steep and vulnerable slopes, etc. should be avoided.

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