
Bhedetar Landslide, Eastern Nepal: Aftermath of the Sikkim Earthquake (18th September 2011)

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Vishnu Dangol, Hiroshi Yagi and Daisuke Higaki

Abstract

The Bhedetar Landslide is one of the numerous landslides in Eastern Nepal that were triggered by the 18th September 2011 Sikkim earthquake (M: 6.9). The landslide is a rock avalanche type which caused serious damages to the 69+000 and 69+500 chainages of the Koshi Highway. Huge boulders were fallen down from the hill slope and rolled down hitting and sweeping the road surface at 69+000 chainage and damaging the road surface at 69+500 chainage located just below the 69+000 chainage. The road was fully blocked for the traffic movement and pedestrians for two and half days. Even at the time of our study (first week of April, 2012), the road sections at 69+000 and 69+500 chainages were single lane temporary track with earthen surface and huge rock blocks were in both sides of the road. This present paper describes the general condition of the Bhedetar Landslide and attempts to decipher causes of sliding besides the main trigger.

Keywords

Sikkim earthquake · Rock avalanche · Koshi highway · Eastern Nepal · Causes of landslide

V. Dangol (✉)
Department of Geology, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal
e-mail: vdangol@yahoo.com

H. Yagi
Faculty of Education, Art and Science, Yamagata
University, 1-4-12 Koshirakawa machi,
Yamagata 990-8560, Japan

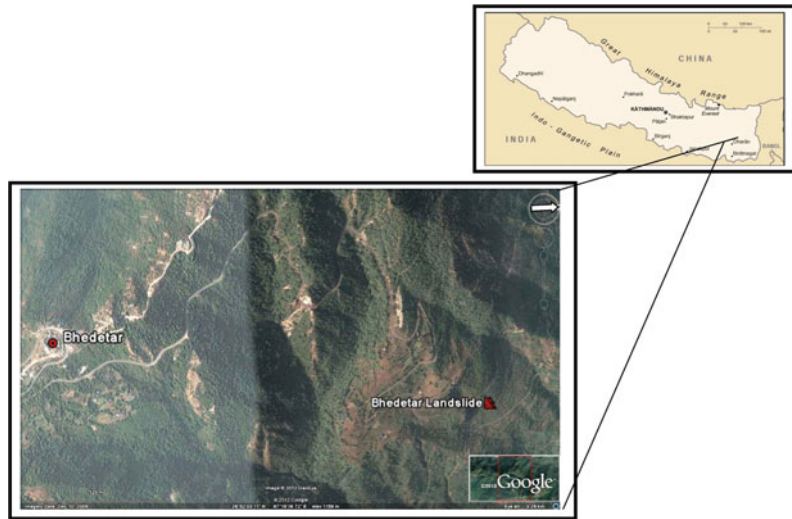
D. Higaki
Faculty of Agriculture and Life Science,
Hirosaki University, 1 Bunkyo-cho,
Hirosaki 036-8561, Japan

1 Introduction

Due to the 18th September 2011 Sikkim earthquake (M: 6.9), several “new” and “reactivated” landslides have occurred in Eastern Nepal and India right from the Himalayan foot-hill region up to the higher Himalayan range. The destructive earthquake caused serious damages on various civil structures in the eastern part of Nepal.

It is also pertinent to mention here that moderate to heavy monsoon rainfall prior to the occurrence of the earthquake, during and post

Fig. 4.1 Location map of Bhedetar landslide triggered by 18 September 2011 Sikkim earthquake



earthquake event is reported from the area. The rainfall contributed to some extent in lowering the shearing strengths of already-loosened (due to earthquake shaking) slope forming mass and ultimately triggered the landslide just immediately after the earthquake shock.

The road sections at 69+000 and 69+500 chainages of the Koshi Highway is completely destroyed by the earthquake induced Bhedetar Landslide. The landslide is a rock avalanche type and is located at approximately 6 km from Bhedetar along the Koshi Highway (Fig. 4.1). Huge boulders were fallen down from the hill slope and rolled down hitting and sweeping the road surface at 69+000 chainage and damaging the road surface at 69+500 chainage located just below the 69+000 chainage (Fig. 4.2).

The road was fully blocked for the traffic movement and pedestrians for two and half days. By concentrated efforts of the Department of Roads, District Administration Offices of Dhankuta and Sunsari, Nepal Army, Nepal Police, Armed police and all other concerned authorities, the highway was successful opened by 15:00 of 21st September, 2011. Due to various problems and emergency conditions, temporary tracks are made such that they are single lane with rough (earthen) surface. Original track at 69+000 chainage needs to be reconstructed by replacing the existing damaged retaining structures and that at 69+500 chainage is required to be rehabilitated by removing/

breaking the huge boulders on the road surface and maintaining it (DoR 2011).

2 Geology of the Study Area

The study area falls within the Lesser Himalayan region. Regionally, the area belongs to the Midland Group of Precambrian age (PEPP 2009), which is further subdivided into four formations, namely Dubbidanda Formation (Dbd), Sulikot Formation (Sl), Chiuribas Formation (Cb) and Bhedetar Formation (Bl). The Dubidanda Formation is represented by greenish grey quartzite with chloritic phyllite and augen gneiss. The Sulikot Formation (Sl) is composed of fine- to medium-grained grey quartzite and grey phyllite, whereas the Chiuribas Formation (Cb) contains green phyllite with grey, purple slate and grey quartzite. The Bhedetar Formation is made up of pink quartzite with purple slate and grey quartzite. The Bhedetar Landslide lies within the Dubbidanda Formation (Dbd).

3 Earthquake Event

The **2011 Sikkim earthquake** (Event ID usc0005wg6) was a magnitude 6.9 (M_w) earthquake centered within the Kanchenjunga Conservation Area (27.723°N, 88.064°E), near



Fig. 4.2 An overview of Bhedetar landslide

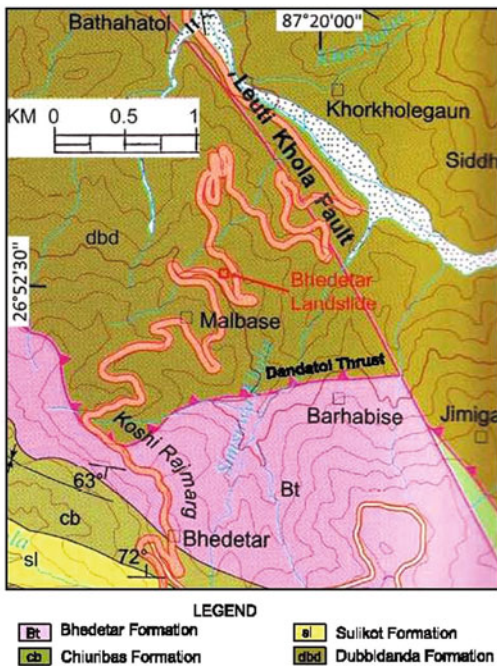






Fig. 4.3 Geological map of study area (modified after PEPP 2009)

the border of Nepal and the Indian state of Sikkim, at 18:10 IST (12:40 UTC) on Sunday, 18th September 2011 (<http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0005wg6>.

Table 4.1 Casualties by country (http://en.wikipedia.org/wiki/2011_Sikkim_earthquake)

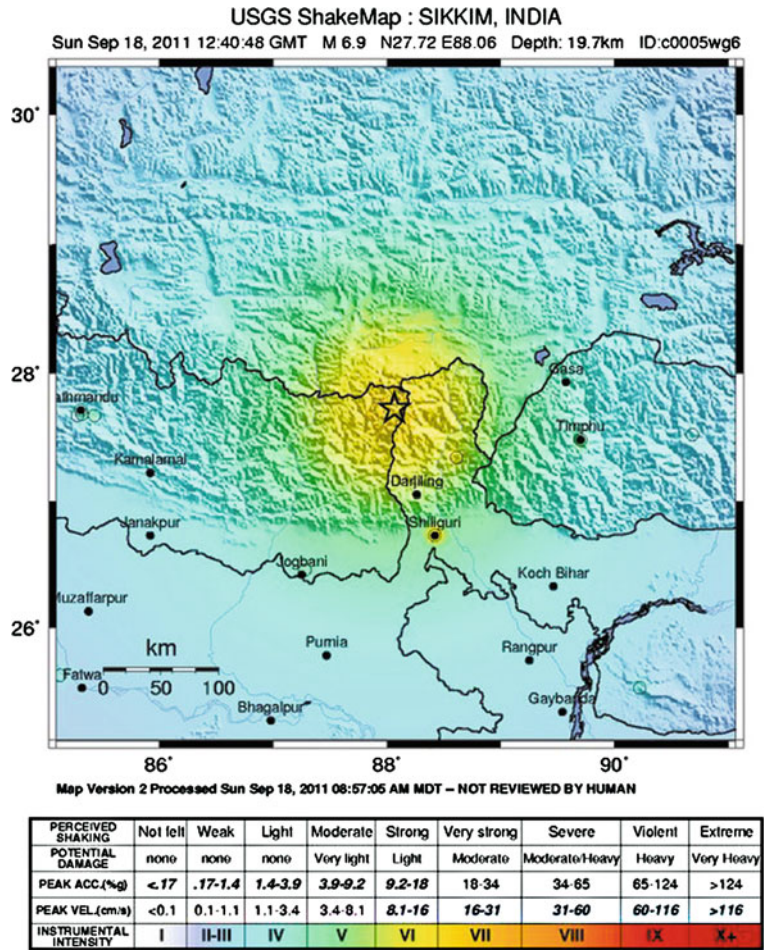
Country	Deaths
 India	97
 China	7
 Nepal	6
 Bhutan	1
 Bangladesh	0
Total	111

([php](#)) The earthquake was felt across northeastern India, Nepal, Bhutan, Bangladesh and southern Tibet.

The earthquake struck near a mountainous, albeit very populous region near the Sikkim–Nepal border; most of the structures were reported to be highly vulnerable to earthquake shaking. Upon impact, tens of thousands of residents evacuated their homes, and many areas suffered from communication and power outages. The strong shaking caused significant building collapse and mudslides; at least 111 people were confirmed killed by the effects of the earthquake, and hundreds of others sustained injuries. As the earthquake occurred in the monsoon season, heavy rain and landslides rendered rescue work more difficult (Fig. 4.3).

Initial analyses suggest the earthquake was complex, likely a result of two events occurring close together in time at depths of 19.7 km beneath the Earth’s surface. At the latitude of the September 18 earthquake, the India plate converges with Eurasia at a rate of approximately 46 mm/year towards the north-northeast. The broad convergence between these two plates has resulted in the uplift of the Himalayas, the world’s tallest mountain range. The preliminary focal mechanism of the earthquake suggests strike slip faulting, and thus an intraplate source within the upper Eurasian plate or the underlying India plate, rather than occurring on the thrust interface plate boundary between the two.

Fig. 4.4 2011-Sikkim earthquake Shakemap (<http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0005wg6.php>)



At least 111 people were killed in the earthquake (Table 4.1). Most of the deaths occurred in Sikkim, with reports of fatalities in and near Singtam in the East Sikkim district (http://en.wikipedia.org/wiki/2011_Sikkim_earthquake). Several buildings collapsed in Gangtok. Eleven are reported dead in Nepal, including three killed when a wall collapsed in the British Embassy in Kathmandu. Elsewhere, structural damage occurred in Bangladesh, Bhutan, and across Tibet; another seven fatalities were confirmed in the latter region.

Sikkim experienced three aftershocks since the earthquake, occurring at magnitudes of 5.7, 5.1, and 4.6 (M_w) within 30 min of the initial earthquake. Kathmandu experienced two aftershocks that both had a magnitude of 4.8 M_w . The aftershocks had no serious impact in the region. At least

20 aftershocks back-to-back throughout the night created panic in the Gangtok. On 19th September, tremors shook some parts of Maharashtra measuring 3.9 (M_w) at around 06:30 IST including Latur, Osmanabad and Solapur districts. However, no loss of life or property was reported (Fig. 4.4).

4 Bhedetar Landslide

The Bhedetar Landslide is located at approximately 6 km from Bhedetar along the Koshi Highway (Latitude: N 26° 52' 33", Longitude: E 87° 19' 31"). It is one of the numerous landslides in Eastern Nepal that were triggered by the 18th September 2011 Sikkim earthquake (M: 6.9). The landslide is a rock avalanche type which



Fig. 4.5 Slicken side planes on quartzite with stations

completely destroyed the road sections at 69+000 and 69+500 chainages of the Koshi Highway. Huge boulders were fallen down from the hill slope and rolled down hitting and sweeping the road surface at 69+000 chainage and damaging the road surface at 69+500 chainage located just below the 69+000 chainage.

The landslide zone from crown to toe is almost bare and is covered by debris. Around the landslide zone, the slopes are covered by small trees and bushes. Some of the boulders are fairly large (more than 8 m in length) with striation marks on slicken side planes (Fig. 4.5). The average size of boulders is 1.5 m.

The length of Bhedetar Landslide is nearly 150 m and the width is approximately 40 m. The width is less than 30 m at 69+000 chainage, whereas it is more than 50 m at 69+500 chainage. The natural slope at the landslide zone is N 65° E, which is also the movement direction of the masses detached from hill side. Towards the hill side the slope is steeper ($\sim 60^\circ$) than on the valley side ($\sim 40^\circ$).

The rock in the landslide zone is represented by light grey to white quartzite belonging to the Dubbidanda Formation (Dbd) of Precambrian Midland Group. The rock is massive, but with open cracks/joints. The discontinuity planes especially the foliation planes are iron stained indicating good water movement. They are slightly to moderately weathered.

The landslide (rock avalanche) was triggered by the 18th September 2011 Sikkim earthquake (M: 6.9). The main causes of the avalanche was open

joints and cracks along the discontinuity planes, some of which probably had infilling materials. At the same time the joint planes exposed at surface were weakened by weathering. There was moderate to heavy monsoon rainfall prior to the occurrence of the earthquake, during and post earthquake event. The rainfall also contributed to some extent in lowering the shearing strengths of already-loosened (due to earthquake shaking) slope forming mass and ultimately triggered the just immediately after the earthquake shock.

5 Conclusions

1. The Bhedetar Landslide triggered by the 18th September 2011 Sikkim earthquake (M: 6.9) is a rock avalanche. The hill side slope of the landslide is steeper ($\sim 60^\circ$) than the valley side slope ($\sim 40^\circ$).
2. Huge boulders averaging in length of 1.5 m (some more than 8 m in length) were fallen down from the hill side and rolled down sweeping the road surface and destroying retaining structures at 69+000 chainage and blocking the road at 69+000 and 69+500 chainages. The road was completely blocked for two and half days.
3. The moderate to heavy monsoon rainfall prior to and during the occurrence of the earthquake might have lowered the strength of slope forming mass, making it easy to slide down.
4. Besides the major triggering factor, i.e. 18th September 2011 Sikkim earthquake, rock structures, weathering and infilling materials in open discontinuities are underlying causes of the landslide.

References

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- http://en.wikipedia.org/wiki/2011_Sikkim_earthquake