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The Study of Paglajhora Landslide in the Darjeeling Hills, West Bengal, India

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Abstract

Landslides and their related phenomena are the most destructive geo-environmental hazard that claim many lives, livelihoods and property in the Darjeeling Hills during the monsoon almost every year. Earlier, especially in the pre-independence period landslides occurred mainly due to various physical factors like high inclination of rock beds, weak composition of the rocks, disturbed geological formation, precipitous slope with thin soil and vegetation cover, and etc. But after independence, as a result of rapid growth of population, settlement, urbanization and tourism coupled with rapid changes in landuse / land cover, the frequency and magnitude of landslides have increased significantly. The present article attempts to find out the exact mechanism by which the physical and anthropogenic factors have induced the Paglajhora slide which is observed to be still active and also investigates the present status of the landslide scar.

Introduction

On 16^{th} June, 2010 a devastating landslide occurred at the Paglajhora area of the Darjeeling Hills (Fig. 1) disrupting the Hill Cart road (part of NH 55) that connects the people of Darjeeling, Kurseong, etc with Siliguri and rest of India and the world. The landslide was the result of continuous heavy rain, coupled with a mild tremor caused by a passing heavy vehicle loaded with LPG cylinders. It was mainly a debris slide being associated with large amount of rock falls (diameters ranging from 0.5 – 4.0 m) (Plate– 1). The area has been a site of total natural destruction, making repair work for re-linking NH 55 very difficult. Till now, little progress has been made to restore this segment.

The landslide scar is still active because of the huge amount of talus produced from the slope failure remain at the critical instability threshold. Even the slightest movement by a group of passerby and vehicles near the slide area triggers slow movement of the materials. Understanding the severity of this slide, the author takes an attempt to find out the root causes of such devastation after careful consideration.

Area of Study

The location of this landslide (0.562 km^2) extends from 26°52'05” - 26°52'26”N and 88°18'05” - 88°18'56” E in the dissected central Hills of the Darjeeling Himalayas (Fig. 1 and 2).

Methodology

The methodology adopted for this study involves very careful survey of the landslide affected site with the help of a 'checklist' consisting of various physical and anthropogenic parameters and their magnitudes which act as causative factors for slope failure. The checklist has been prepared after the model of Cooke and Doornkamp (1974) and has been improvised further through customization in accordance with local factors and incorporation of human factors. The identification of the appropriate slide-provoking parameters has been done by means of a 'X' mark on the grooves provided against each category of the parameters. Finally, the parameters of each category with 4 as the highest rating value have been taken as the factors of slope failure (Table 1). The parameters related to slope instability can be grouped into major seven types such as relief, drainage, bed rock, regolith and soil, earthquake, legacies from the past and anthropogenic factors like man-made features including land use. The data of the above parameters, by putting X signs in the checklist, have been collected from direct field investigation by verifying various critical sites within the landslide area. A detailed analysis of this landslide has been done with modern equipment like GPS to identify the causes of such large failure of slope.

Analysis

The Paglajhora landslide (Fig. 2) is the largest landslide that occurred in 2010 in the Darjeeling Hills. The background of the origin of this slide is discussed below:

A. Physical Factors

(1) Physiography

Paglajhora is situated in the Darjeeling Himalayas having high amplitude of relief and dissected by by a large number of rivers with very steep valley side slopes (> 45°: Table 1, Plate – 2). A Digital Elevation Model of the slide area has been generated on GIS platform (Fig. 3) that clearly brings out the steepness of the slide surface (≥ 45°). The magnitude of valley depth is also very high. Being associated with other favourable factors, these terrain parameters trigger slope failure (Sarkar and Kanungo (2010), Ghosh *et. al.* (2009), Klubertanz. *et. al.* (2009), Kitutu. *et. al.* (2009), Vidar et. al. (2007), Evans, S. G. et. al. (2006), Seno and Thüring (2006), Shang *et. al.* (2003).

(2) Geological setup

Geologically the area is constituted by the Daling series of rocks of the oldest Dharwar System (mainly, phylites and slates) formed nearly 3787 million years back. It lies just above the Main Contact Thrust (MCT) line (Fig. 4) (Powde and Saha, 1976). Hence, the pushing force has made the constituent rocks very friable, weak and flaky in nature (Plate – 3). Moreover, the density of jointing of the bedrocks is very high with dominant direction towards sloping face. Hence, the shearing resistance of the rocks have low threshold value and thus high propensity for detachment and slope failure. Such characteristics facilitate slope failure when associated with steep gradient.

(3) Soil / Surface Material

Soil is coarse textured, and thin with maximum depth as 30 cm (Plate – 4). Sand fraction exceeds 80% which indicates that the compactness of soil over this area is very low for which micro pores have greater ability to be filled by water when soil is over-saturated. This rapidly increases the pore water pressure that enhances shearing stress and lessens soil coherence (Plate 5). It has a very steep angle of rest for which gravitational pulling of soil is quite natural. The liquidity index being very high along with very high degree of saturation and volume of expansion (not less than 71.26% and 8.51% respectively) during monsoon, detachment of soil from in situ position is easily possible.

The surface materials on the present landslides comprise huge debris in distinct lobes along with chunks of rocks of variable sizes ranging from 0.5m - 4 m diameter. Often there are big chunks of rocks on the slide surface at a very high and critical angle of repose (Plate - 4) for which movement of materials on the slide surface is continuous. Hence, the slide is still alive wherever surface materials exceed the threshold size.

(4) Vegetal Cover

Since the pre-independence period, forest depletion through increasing human activities has been rampant in the entire Darjeeling Hills region; the level is far below the recommended amount (i.e. 33%) prescribed by National Forest Policy 1952 (Bhattacharya, 1998, 2009). The area around the slide is mostly covered by scattered trees interspersed with agricultural lands (Plate – 6). True forest is found only at the bottom of the slide scar

(Fig. 2). The poor vegetal cover on precipitous slope cannot hold back the soil material that often comes down under the pull of gravity. As a result, development of soil horizons along with their thickness are seriously hindered. Had the area been covered with dense forest the severity of this landslide would have been much less.

5) Rainfall

The average annual rainfall in this region has been estimated to be 4248 mm from 25 years data (Bhattacharya, 2011). In June, July and August when landslides mainly occur, the respective monthly averages are 807.7mm, 1215.9mm and 798.1mm (Table – 2). Monsoon rain is associated with wet spells of 2 - 4 days alternated with a dry spell of several days (Bhattacharya, 2009).

The high intensity precipitation enhances the detachment of the materials on the steep slopes. The entire Darjeeling Hills is subjected to severe alteration of its natural setup through indiscriminate deforestation (Bhattacharya, 1998, 2009), sprawling of settlements on vulnerable slopes and anthropogenic overuse of land like construction of high rises, renovation of the damaged roads by concretes, unscientific mining, and dumping of domestic wastes on slopes (Bhattacharya 1999, 2002). All these physical factors have made the area susceptible and landslide-prone.

B. Anthropogenic Factors

(1) Deforestation and Unplanned Agriculture

The site of the slide is devoid of true forest cover (except at the bottom which is inaccessible). It is mostly covered with scattered trees with poor undergrowth, and thin soil cover. On the northern side of the slide scar there are cultivated lands where poor agriculture is practised on slopes. Although there is a tea garden in the northern side, it has become sick with poor bush and poor maintenance.

(2) Unscientific Constructions

Landslide controls are attempted by the geotechnical engineers in most of the cases over this area by building huge concrete constructions without considering the weight of the materials. For construction of damaged roads or filling up the subsided roads the same procedure is applied. This causes weight induced shattering on steep slopes (Plate – 7), subsequent slumping and sliding.

Moreover, in the masonry constructions like retention wall or sausage wall, little care is taken in making weep holes so that during monsoon these become incapable of letting water pass at high pressures during heavy discharges and the construction gives in (Plate - 8) setting the stage ready for subsequent sliding and slumping. It also facilitates old scars to recur in the same spot year after year. Such incidences are common in the Paglajhora area, specially at 14 Mile spot.

(3) Heavy vehicle induced tremor

Earlier, trucks with load less than 80 ton used to ply through the Hill Cart road or NH 55, but with an ever increasing population pressure, the demand for more commodities has resulted in larger trucks / road liners (of above 80 ton capacity) ferrying goods along this road and their passage often produces mild tremors which facilitates slides during the monsoon when persistent rain has already lubricated the weathered slope materials.

The Paglajhora slide which occurred on 16th June 2010 was the result of such a tremor from a LPG Cylinder- loaded truck which incidentally was recorded by an individual and posted in the internet (http://www.youtube.com/watch?v=7tXHhqLkGBE). The truck itself rolled down the slope due to the caving in of the road.

Conclusion

Thus, it is not the rainfall alone that triggered the landslide but it is also the tectonic and geologic fragility of the lithological matrix of the area (*developed by the physical and anthropogenic factors*) that induced the slide. The severity and vigour of a landslide is certainly a function of human activities. It is high time for considering the proper usage of the hill slopes in one hand and the expertise required for treating degraded slopes on the other so that living in the hills does not bring down trails of sorrow frequently.

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Table – 1: Factors influencing Paglajhora Landslide

Relief	1. Valley depth 2. Slope steepness 3. Clieff face having >40° 4. Valley side shape	: very Large, 500 m : very large >45° : present : deep cove
Drainage	1. Slope undercutting by drainage 2. Concentrated seepage flow 3. Pore water pressure	: very severe : Present : very high
Bedrock	1. Jointing density 2. Direction of major joints 3. Steepness of joints 4. Degree of weathering 5. Coherence of beds	: very high : towards steepest slope : very high 25° – 30° : large : very low
Soil	1. Angle of rest 2. Shear strength 3. Porosity, Permeability 4. Degree of saturation 5. Volume of expansion	: very steep > 25° : very low (field method) : very high (= 55%) : very high (above or =71%) : very high (above or =8.5%)
Earthquake	1. Tremor felt	: many / frequent
Legacies	1. Previous landslides	: many
Man-Made Features	1. Excavations- depth 2. Drainage diversion across hillsides 3. Loading of upper valley sides 4. Deforestation 5. Retention wall weep holes 6. Broken down contructions 7. Construction load	: large : present : large : high : very blocked : present : very high

Source: Compiled by the author

Table – 2: Mean Monthly Rainfall and Temperature (Darjeeling Hills)

Mean Annul Rainfall = 4248.00 mm from 25 years' data												
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Rainfall (mm)	15.5	26.3	45.1	206.1	293.3	807.7	1215.9	798.1	619.4	183.3	20.3	16.8
Mean Monthly Temperature=18.60 °C from 20 years' data												
Mean Temperature (°C)	11.4	12.9	17.8	20.5	21.2	22.2	22.4	22.8	22.1	20.6	16.2	12.5

Source: Comiled by the author

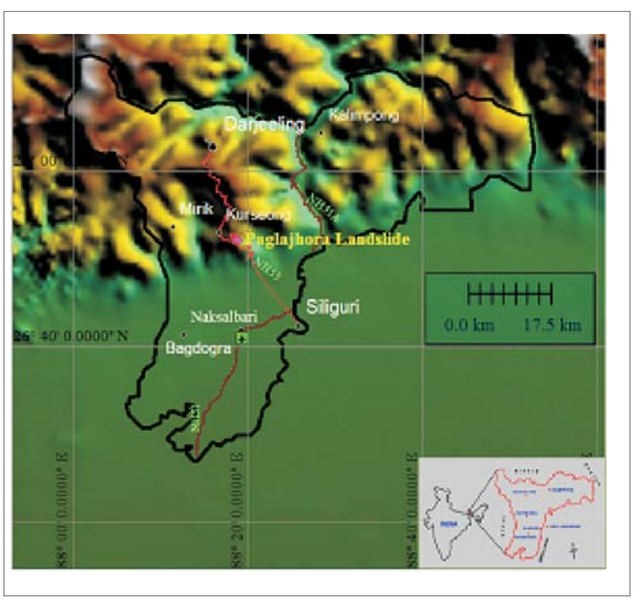
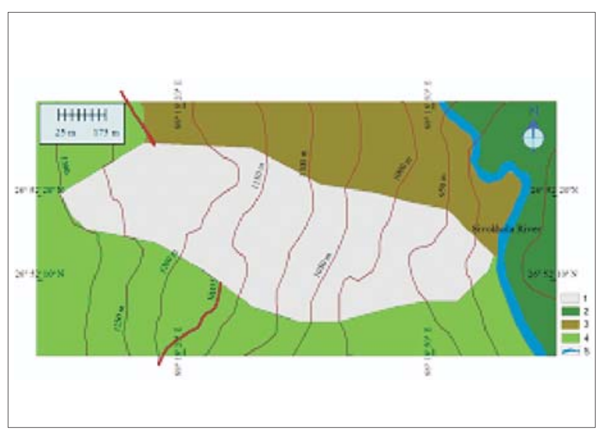


Fig. 1. Location of the Study Area



1: Landslide Scars, 2: Dense Forest,
3: Scattered Trees/Agricultural Lands,
4: Scattered Trees/Thin Cover
5: River

Fig. 2. Map of the Paglajhora Slide

Fig. 3. Original 3D View

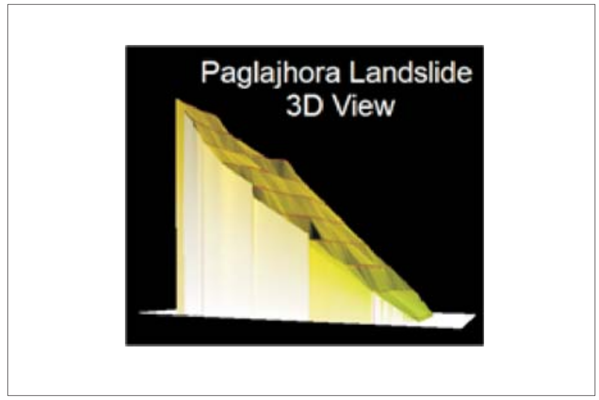


Fig. 4. Turned 3D View

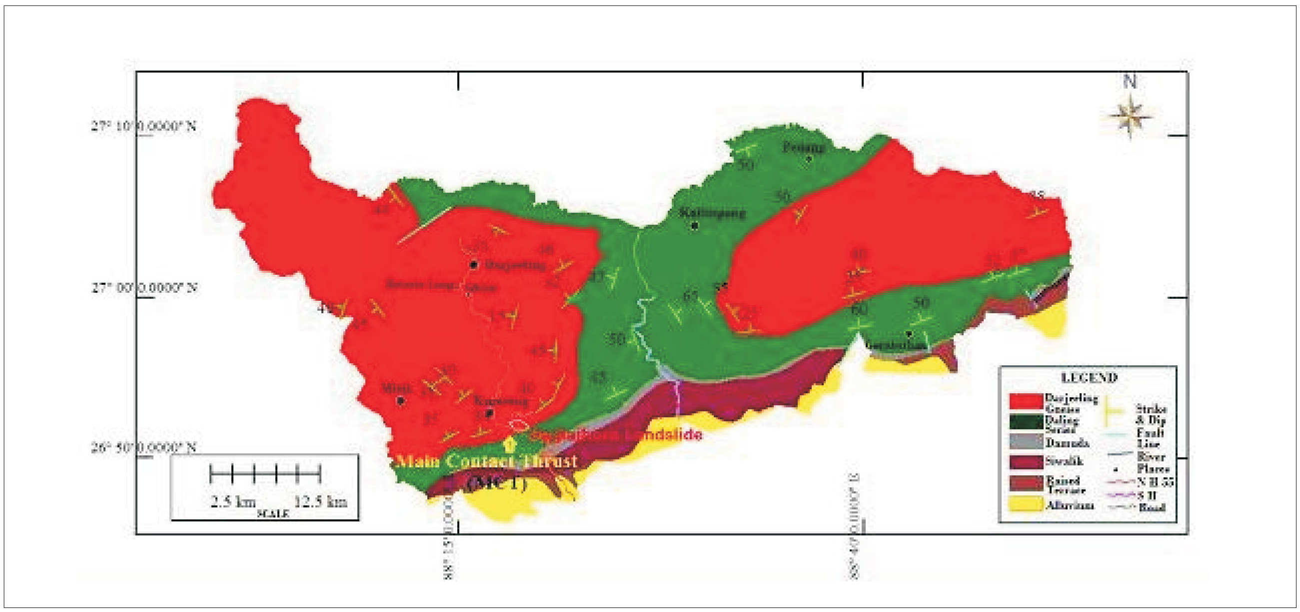


Fig. 5: Geological Map of the Darjeeling Hills

Fig. 6. Rock Chunks on the Slide

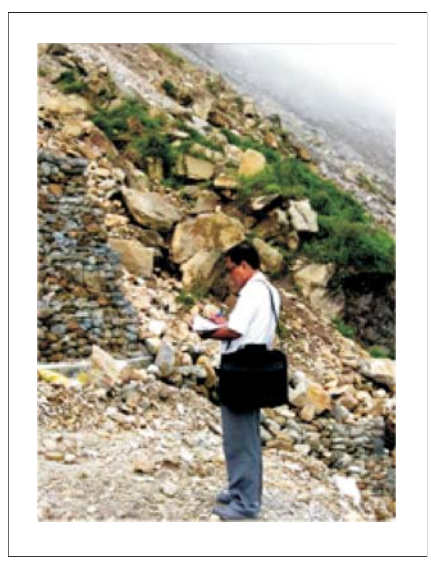


Fig. 7. Steep Slide Surface

Fig. 8. Flaky Phyllites

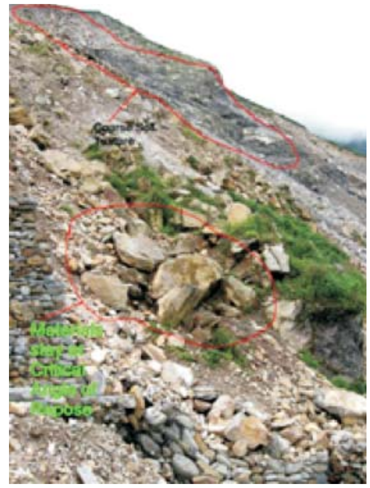


Fig. 9. Soil and Surface Materials

Fig. 10. Hollow formed by Hydraulic Pressure

Fig. 11. Scattered Tree / Thin Cover

Fig. 12. Weight-inducd Shattering in Constructions

Fig. 13. Blockage of Weep Holes