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Geological, Geomorphological and Kinematic Study of the Martam Landslide, East Sikkim, India

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Abstract
The incidents of landslide and mass movement along NH10 in Sikkim is very frequent and hazardous. One of them is Martam landslide that is very big and active landslide which is located at Lat 27°15'34.4''N, Long. 88°33'02.2''E on NH10 near the Martam village. The landslide location is about 9 km from Ranipool on NH-10 towards Singtam. It is a debris fall type of mass movement causes by the heavy rainfall which result in erosion of loose and unstable material, rising of water table and decrease the cohesiveness of the soil. Geology of the area, slope, rainfall, climate and other factors also played important role in frequent occurring of this slide. This slide has been reactivating every year particularly during the monsoon season causing obstruction to vehicular traffic along the national highway NH-10. As a result of investigations, some remedial measures have also been suggested to control further slope movement to save life and properties.

Key Words- *Landslide, NH-10, Martam, Kinematic analysis, Geological investigation.*

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I. Introduction:

Landslides are one of the critical natural phenomena that frequently lead to serious problems in hilly areas, resulting to loss of human life and irreparable losses to properties and infrastructure (Rahamana, et al., 2014). Overuse of natural resources, quick changes in land use and land cover, unscrupulous mining and deforestation, climate changes, traffic congestion caused by expanding urbanization, and widening of roadways all contributed to the disastrous landslides (Nadim *et al.* 2006; Hoyois, *et al.* 2007; Schuster 1996). The Martam landslide on NH10 near Martam village in east Sikkim district is a very big landslide which affect the people and transportation of the area. The rocks exposed in the study area is Interbanded chlorite-sericite schist / phyllite and quartzite also very prone to landslide and play important role in Mass movement. The study area is tectonically active and having so many lineaments and joints which plays important role in this landslide. Kinematic analysis also performed to understand the role of joints in the Martam landslide.

Study Area

The Martam landslide falls on the Survey of India Toposheet No. 78A/11 on NH10 near the Martam village, East District, Sikkim. The geographical coordinates of Martam landslide is Lat 27°15'34.4''N, Long. 88°33'02.2''E. The landslide location is about 9 km from Ranipool on NH-10 towards Singtam.

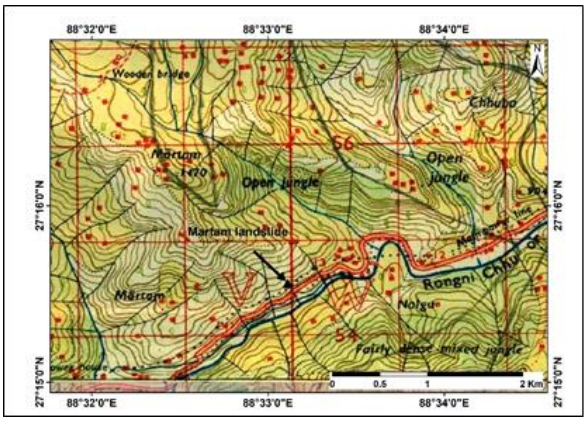


Fig.1: Location of the Martam slide along NH-10, falling in parts of Toposheet no. 78A/11.

II. Geology & Geomorphology of the study area

From a regional perspective, the study area forms a part of Sikkim-Darjeeling Himalayas located between the Himalayan Kingdom of Nepal in the west and Bhutan in the east. Tectonically, the Sikkim-Darjeeling Himalayas have been divided transversely into four tectonic belts each having characteristic lithological and structural attributes (GSI, 2012). In Sikkim, the Gondwana Supergroup is represented by two Formations Rangit pebble slate overlain by Damuda Formation exposed in the Rangit window zone, where these are surrounded by Daling Group of rocks (Acharyya, 1989, 1992). The Daling Group representing the Lesser Himalayan domain in Darjeeling-Sikkim Himalaya has been distinguished into three regional litho-tectonic assemblages i.e. the Gorubathan Formation, Reyang Formation and the Buxa Formation (Acharyya, 1989). Since a major part of the study area is overburden covered, the rock exposures are available at places only, along the road section. The rocks exposed in major part of the study area are of Proterozoic (undifferentiated) age and include Interbanded chlorite-sericite schist / phyllite and quartzite {Fig.2. (a)} belonging to Gorubathan Formation of Daling Group. The Lingtse Granite Gneiss of Meso Proterozoic age is also exposed in some parts of the study area. The lithological unit comprising dominantly of greenish to grey colour Interbanded chlorite sericite schist /phyllite and quartzite exposed in the study area. Geomorphologically, the affected area is a part of moderately dissected hill slope{Fig.2. (b)}. The slopes are steep (>45°).

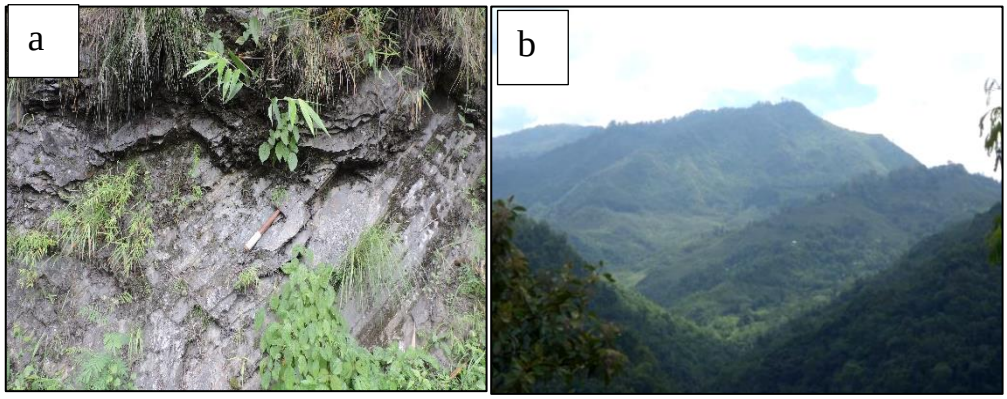


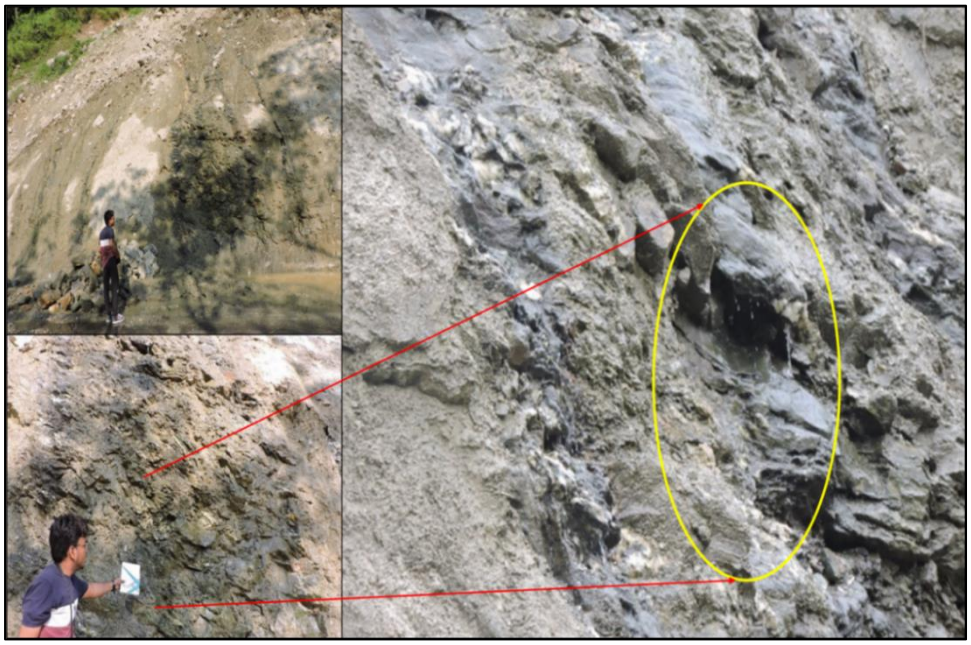
Fig.2. (a) Interbanded phyllite and quartzite (b) Moderately dissected hill slope

III. Landslide description

The Martam landslide has been reactivating every year particularly during the monsoon season causing obstruction to vehicular traffic along the national highway NH-10. The affected zone consists of debris material. The preliminary field observations show huge amount of debris material piled over the distressed slope (Photograph 1). Free fall of boulders from upper portion of the slide is common whenever the slide reactivates after continuous heavy rainfall. The crown portion of the slide lies at an elevation of about 750 m. The estimated dimension of this landslide is length-152 m, width-75 m and height-140 m. The affected part of the slope is mainly covered with debris, however, jointed rocks on the exposed outcrops can be seen near the crown portion. Many seepage points were observed in the lower portion of the slide (Photograph 2). The slopes on either side of the distressed zone are covered with >6m thick overburden comprising older well compact debris. The crown portion of the slide has exposed jointed phyllites interbedded with quartzite of Gorubathan Formation (Daling Group). Some rock exposure in the distressed zone shows N250°/42°-NW foliation trend with four joint set: J1-N110°/22°-NE, J2- N40°/52°-SW, J3- N65°/62°-SE and J4- N128°/42°-NE. The affected area is a part of moderately dissected hill slope (> 45°) with moderated forest cover. From the preliminary field observations, it is evident that the slide which presumably initiated long back, is being intermittently reactivated and the old slide debris material over the slope is subsequently getting destabilized due to action of surface and subsurface water contributed by one first order stream in the vicinity of the affected slope. The head-ward erosion along the same is increasing instability of the rocks exposed along the crown portion of the slide.

The seepage points present within/on the slope during intense rainfall, saturate the debris mass leading to development of pore pressure. An increase in the pore water pressure decreasing the shear strength of the debris material, which finally triggers its down slope movement along the steep slope.

Photograph 1: (a) & (c) showing the side view of the Martam landslide along NH-10, (b) showing panoramic view of Martam landslide (Source: Google-earth image).



Photograph 2: showing the seepage water flowing over the slope covered with loose debris in Martam landslide.

IV. Kinematic Study:

Kinematic analysis is a method used to analyze the potential for the various modes of failure in rocky slope governed by presence of unfavourable orientation of the discontinuity planes. This analysis is carried out based on Markland's test (Hoek and Bray, 2005) with the help of Dips software using collected structural data. The kinematic analysis has been carried out assuming the internal friction angle of 15° for Interbanded chlorite sericite schist/phyllite (Hoek & Bray, 2005). Kinematic analysis at Location (27°15' 35''N, 88°33' 02''E) (Fig. 3) represent the structural condition at Martam landslide. At Martam slide, data from a very small rock outcrops exposed within the distress zone (covered with debris) slightly above the road bench, shows possibility of wedge failure due to intersection of J4 & J3 joints.

Table 1- Joint orientation details

Sl. No.	Joint no.	Dip (°)	Dip direction (°)
1	J1	22	N 20
2	J2	52	N 308
3	J3	62	N 155
4	J4	42	N 38
5	Slope	53	N 140

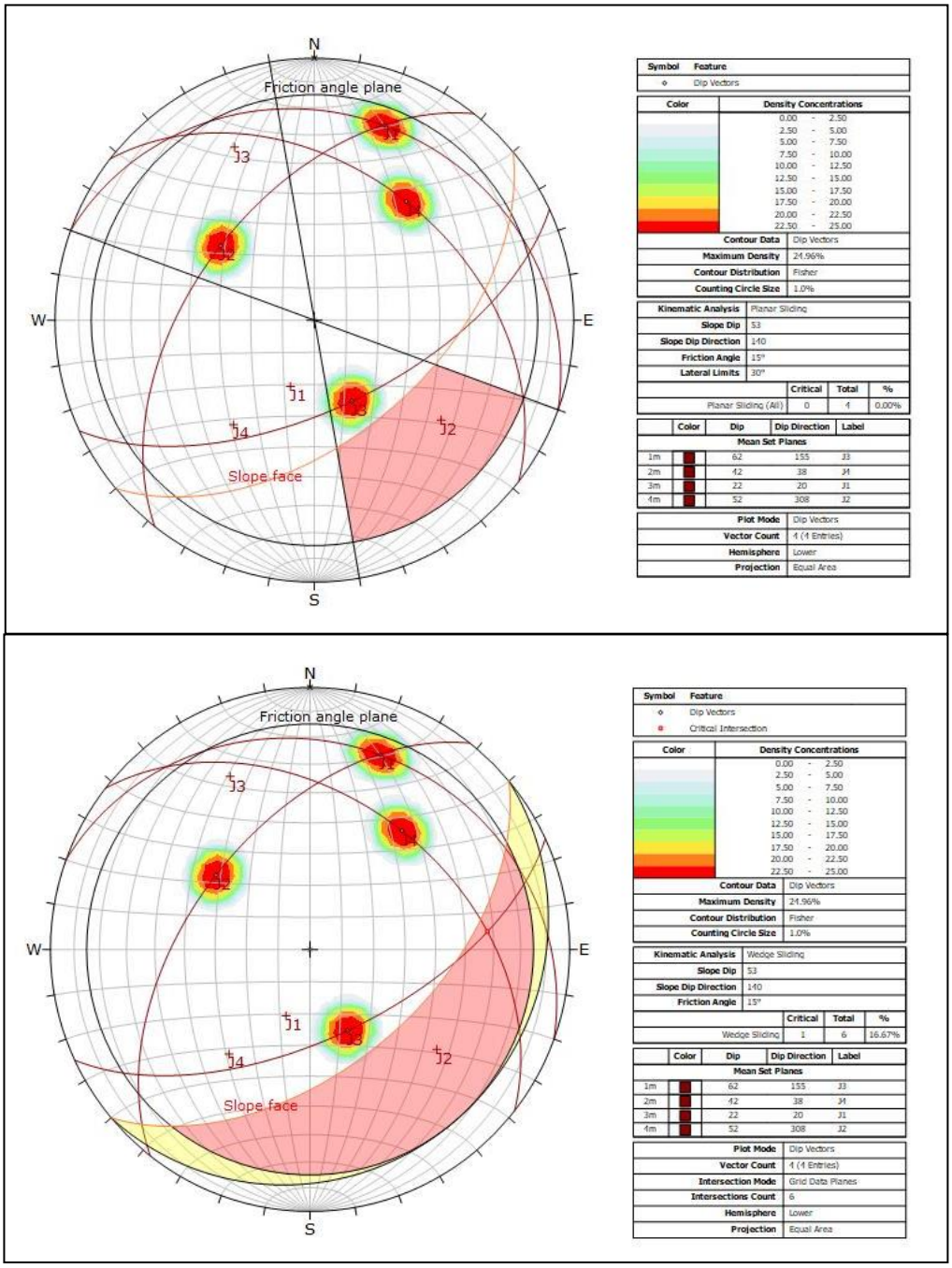


Fig.3. Kinematic analysis near Martam slide for Planar Sliding and Wedge Sliding

V. Remedial Measures

The slope failure seems to be due to the action of surface, subsurface water and head-ward erosion of the first order stream, based on the field observation preliminary remedial measures are suggested. For restricting the seepage of subsurface water, construction of contour drain is suggested. Breast wall of sufficient height with weep

holes can be constructed across the slope to restrain the downslope movement of the loose debris material. The breast wall should be placed with foundation over the competent bed rock, and suitable filter arrangement at the contact of the debris mass and the wall, so that no pore water pressure is developed at the contact of colluvial and alluvial material. The distressed part of the slope can be trained suitably and thereafter covered with anchored wire mesh, geo-net/geo-textile.

VI. Conclusions

NH-10 is a life line for Sikkim which connect Sikkim state from rest of the India. The Martam landslide is big threat on NH-10 between Singtam to Gangtok. Martam landslide is a shallow planar failure and reactivate every year during the monsoon season. The study suggests that the overburden covered slopes in the study area are most susceptible to slope failure especially during the monsoon season. Therefore, regulating surface run off, flowing across the slope and surface water that will seep into the soil is utmost important. This can be done by providing suitable drainage measures which will improve the stability of the overburden covered slopes. Kinematic study reveals that area is prone to wedge type of failure due to intersection of J3 & J4 joints. Proper drainage arrangement for seepage, construction of chute drain near the ridge, retaining wall and treatment of the distressed portion of the slope with a geo-net or geo-textile are the major remedies to control the mass movement in the study area.

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