Geotechnical Investigation of Landslide at km 104+700 along Mechi Highway (H07), Eastern Nepal

Dangol V.[1], Adhikari T.L.[2], Shrestha J.N.S.[3], Pant S.R.[4], Chamalagain D. [1], Bhandary A.N.[5], Paudel S.[5] and Thapa M.K[5]

[1]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*ITECO Nepal (P) Ltd., 96 Sri Panchakanya Marg, Minbhawan, New Baneshwor, Kathmandu, Nepal*
[3]*BDA Nepal, Baluwatar, Kathmandu, Nepal*
[4] *Geophysical Research and Consultancy Service (P) Ltd., Lalitpur, Nepal*
[5]*ICGS Pvt. Ltd., Minbhawan, New Baneshwor, Kathmandu, Nepal*

* Correspondence to: Vishnu Dangol, P.O. Box 21897,
Department of Geology, Tribhvuan University, Tri-Chandra Campus, Ghataghar, Kathmandu, Nepal
Cell: +977-9841223086;
E-mail: vdangoll@yahoo.com

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1 Introduction

The Mechi Highway (H07) is 268 kilometers in length and is one of the busiest roads of the country. The highway connects Terai to Taplejung and is the most important road for transport of foods and all daily necessary goods. The hill slopes with its fragile geology, extreme high concentration of precipitation in a short time period, steep slopes, and seasonal streams are physical constraints in maintenance of this highway.

Every year the harsh monsoon rainfall causes enormous damages to many sections of the Mechi Highway. Especially the landslide at Ch. 104+700 hinders the smooth traffic for several days in a year. Routine maintenance was insufficient for coping this problem.

This paper presents the results of detail geotechnical investigation carried out at Km 104+700 of the Mechi Highway to develop an action plan for effective management of landslide disaster at this road section. The investigation included topographical survey, engineering geological mapping, Multi Channel Analysis of Surface Waves (MASW), rotary core drilling and in-situ tests.

2 Study area

The study area lies in the Ilam District of Eastern Nepal and is bounded by the latitudes 26° 53' 15" N and 26° 54' 45" N and longitudes 87° 56" 30" E and 87° 57' 30" E (Dangol and Chamlagain, 2013). The landslide is located on the right slope of the Mai Khola, about 150 m upstream from the bridge over the Mai Khola.

The elevation of the landslide ranges from 438 m to 540 m. The average total annual precipitation of the study area is 2108 (Chamlagain and Dangol, 2002). The landslide is mostly covered by 5 to 15 m deep soil cover consisting mainly of colluvium. Its toe lies at river. The length of the slide is 180 m and the width of slide is 120 m at the toe part. The direction of failure surface is SE and the slope is about 30°.

3 Works carried out

1. Preparation of topographical map at 1:1,000 scale of approx. 5 ha area with contour interval of 2 m,
2. Assessment of slope conditions,
3. Preparation of land use map
4. Identification of causes and mechanism of landslide
5. Rotary core drilling
6. Standard penetration tests on soil mass
7. Permeability test of overburden and bedrock
8. Multi-channel analysis of the surface waves (MASW) using active and passive sources

4 Results and conclusions

1. The engineering geological map was prepared at a scale of 1:1000 based on data collection in field. The mapping was carried out in a larger area including the surrounding of the unstable area.

   During the topographic survey of landslide, engineering geological parameters i.e. major landslide boundary, spring/seepage zones, gullies, forest boundary and big boulders were defined on the survey drawings and produced on 1:1000 scale, which was used as base map for geological investigation in the field. Many spring / seepage zones, rock, soil type and their contacts, land use, exploration pits, bore holes, tension cracks, small landslides in the vicinity and other field observations were plotted on the engineering geological map.

   The findings from the engineering geological study show that the main unstable area has thick colluvium with bedrock underneath. The thickness of the colluvium is about 11.5m. Bed rocks are visible in outcrops in the nearby stream as well as culvert outfall near road head to Puwa Khola hydropower site.

The land use of the unstable area and its surrounding is mostly cultivated with thin forest with isolated trees. Heavy infiltration from the irrigated paddy fields recharges the perched water table at the interface of soil and rock.

The bed rock is gneiss of good quality showing high core recovery and rock quality designation. The attitudes of the bed rock show that some planar and wedge failures are likely at some sections of the unstable area. However, no significant failures are observed at the available outcrops.

2. Geophysical exploration was carried out to study the subsurface of the landslide under a separate program. To make the detail coverage of the Multi Channel Analysis of Surface Waves (MASW) was used to obtain information related to water table, depth to bedrock and different material type in the overburden, and different rock masses.

   The MASW survey shows presence of thick colluvium material (up to 11.5m) in the investigated area. These materials are dominated by sandy gravel and boulders. The general impression of the subsoil section is that the area has layers of lower and higher permeability. There could be presence of perched water table which was not recorded during the drilling operations conducted during driest period of the year. However, elevated levels of perched water tables are anticipated during monsoon months.

   The depths to the bedrock in the landslide are variable. The detail of the bedrock depths can be obtained directly from the MASW sections and tables.

   From the closer look of the profiles it has become evident that the present reactivation of the landslide is limited to moderate (about 11.5m) depth. The depth of bedrock at the concerned section is at a depth below 11.5m.

3. A geotechnical team had undertaken the geotechnical investigation for the landslide km 104+700 of Mechi Highway under a separate assignment. The investigation comprised of confirmatory core drilling and in-situ tests DCPT, permeability and Lugeon values.

   The core drilling was carried out in 2 boreholes along the most representative cross section of the landslide. Dynamic cone penetration test (DCPT) was performed at 1.5m intervals in each of the drill holes. Besides, permeability test was conducted at 5m intervals in overburden material and Lugeon test was conducted at 3m intervals within the bed rock.

   Gneissic bedrock is encountered in both boreholes at a depth of 11.5m to 12.0m. In general upper layers about 0m to 4.5 m consist of loose silty medium to fine sandy soil with or without cobble and boulders with higher permeability. Below which follows predominantly fine to coarse sandy material with gneissic cobble and boulder having lower permeability. Probable slip surfaces are found to be at soil-rock interface.

The ground water table and depth to rock were measured in the two bore holes during drilling period. The results were as follows:

BH - 1: Total depth 16.15 m, rock depth 13.50 m, water table 10.70 m

BH - 2: Total depth 19.50 m, rock depth 13.50 m, water table 19.30 m

The DCPT had been carried out as per applicable standards. The summary of results is shown in Table 1.

Table 1 Summary of SPT Results

Depth (m)	BH-1	Depth (m)	BH-2
4.00	60	1.5	14
5.50	17	3.0	10
7.00	89	5.7	77
8.50	56		

4. Soil properties were derived out from field observation and testing. The pertinent soil properties include unit weight, internal friction angle, cohesion etc. for limit equilibrium methods of slope stability analysis.

   The subsoil has been generalized into three distinct layers (loose soil, firm soil and bedrock) based on lithology obtained from the bore holes and test pits.

   The USCS classification of the soil is GP or SP with indicative unit weights ranging from 16.5 to 22 kN/m^3 and friction angles ranging from 36° to 38°. Based on the SPT values, the strength parameters are adopted as 30° and 34° respectively. The cohesion of loose soil layer is assumed to be zero, while that for dense layer is assumed to be 10 kPa.

5 Recommendations

1. Draingae Works: Three categories of drainage woks are suggested to improve drainage condition:
   - Surface water drainage
   - Near surface water drainage
   - Deep drainage
2. Structural Works: The passive anchors of 22-25 m long along with retaining structures are recommended with inclinations at angles of 15 deg and 25 deg below horizontal and horizontal divergence angle of 10 deg from the perpendicular to the wall face.
3. Bioengineering Measures: Bioenigneering measures consist of shrub and grass plantation, brush layers, edge trimming, stone arches etc. in integrity with other drainage and structural measures. The measures are proposed to cover the entire reactivated landslide areas and areas of cut and fill.

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