# Landslide Challenges Due to Widening of Road Section Between Udhampur and Chenani Along National Highway-44, Jammu and Kashmir, India

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## Abstract

*Widening of 295 km National Highway-44 in Jammu and Kashmir is an important developmental project. The highway passes through Outer Himalayan and Higher Himalayan sequences of rocks and is frequently affected by landslides at various places. The paper deals with 22 km Udhampur-Chenani section of the highway within the Siwalik sedimentary sequence. The area is prone to landslides on account of fragile geological, topographic and hydrological conditions. The study area has high rainfall intensity and numerous old landslides zones. At the project feasibility stage, project authority has identified the landslide-prone area and suggested precautionary measures but during the construction work, various unpredicted landslide and ground sinking events happened which given trouble in road construction cost and project completion time. In this paper, the challenges faced due to landslide and ground failure as failure of old slide adjutant to road construction, agriculture and residential ground failure at a higher altitude due to road construction, the collapse of high tension towers in cut slopes; its impact on construction activities and project completion time; are discussed with mitigation measures for unidentified landslide related challenges.*

**Keywords:** Landslide, Geological and hydrological factors, Colluvium deposits, Mitigation measures

## Introduction

Jammu and Kashmir (J&K) is northern most state of India and 90 per cent of geographical area falling under Himalayan range. J&K state is very important in view of political, defence, tourism and spiritual purpose. Jammu to Srinagar National Highway-44 (NH-

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44; earlier NH-1A) is only one connecting road to Kashmir valley and Leh-Ladakh region. Jammu-Srinagar national highway NH-44 is lifeline for everyone. This road is passing through Outer Himalaya to Higher Himalayan range with very complex and landslide prone area. NH-44 is frequently closed during the rainy season, which cut off the Kashmir valley to remaining India. For smooth connectivity, road widening work is under progress.

Study area, Udhampur- Chenani road section(road chainage Ch 67.00 km to 89.00 km from South to North) is part of Jammu- Srinagar National Highway -44 which is 22 km long and widening work was awarded to GECPL in the year 2015 (Fig. 8.1).

Topographically area has highly variation; road elevation varies from 327 mean sea level (msl) to 2400 msl (Jammu to Patnitop). Road blockage due to landslide and snowfall is normal event along the highway. Climatically, the area belongs to temperate to subtropical region. Selected road section received rainfall twice in year i.e. 40-50 mm per month from January to March, and very heavy rainfall occurs between July and September, reaching up to 650 mm of rain. The annual rainfall in the temperate region varies from 600-900 mm with snowfall. River Tawi is Major River flowing along this section of road.

The Geomorphology of the road section is characterised by moderate to steep valleys. Presence of narrow river valley and numerous small perpendicular tributaries, mild to steep hill slopes and colluvium deposits at the toe of the slopes, are the main geomorphologic features of the project area. The slopes on both sides of river valley are varying generally from 30° to 70°. The geomorphology of the area seems highly erosion-prone due to presence of weathered rock mass on the slopes, loose rock blocks, old landslide debris and rock slide debris deposits all along the slopes. The major valleys being longitudinal and are aligned in WNW-ESE direction.

Geologically, study area belongs to Outer Himalayan range, consisting of Murree formation which is overlying the buried surface of the northern fringe of the Indian shield. Lithologically, these sediments constitute semi-consolidated to consolidated sandstones, siltstone, mudstone, shales, conglomerates and clay beds. Structurally these rocks display broad anticlines and synclines. A series of thrust is a characteristic tectonic feature in the nearby study area. The most prominent among them are Main Boundary Fault (MBF) from the Outer Himalayan strata.

The Outer Himalayan rock mass is highly disturbed having a general dip of approximately 30° at the higher levels and 70° at the lower levels on either side in folded strata with NNW-SSE strike. There are three major sets of joints: bedding joints, cross joints and micro joints dipping 20° to 80°. Steeply dipping joints predominate over gently

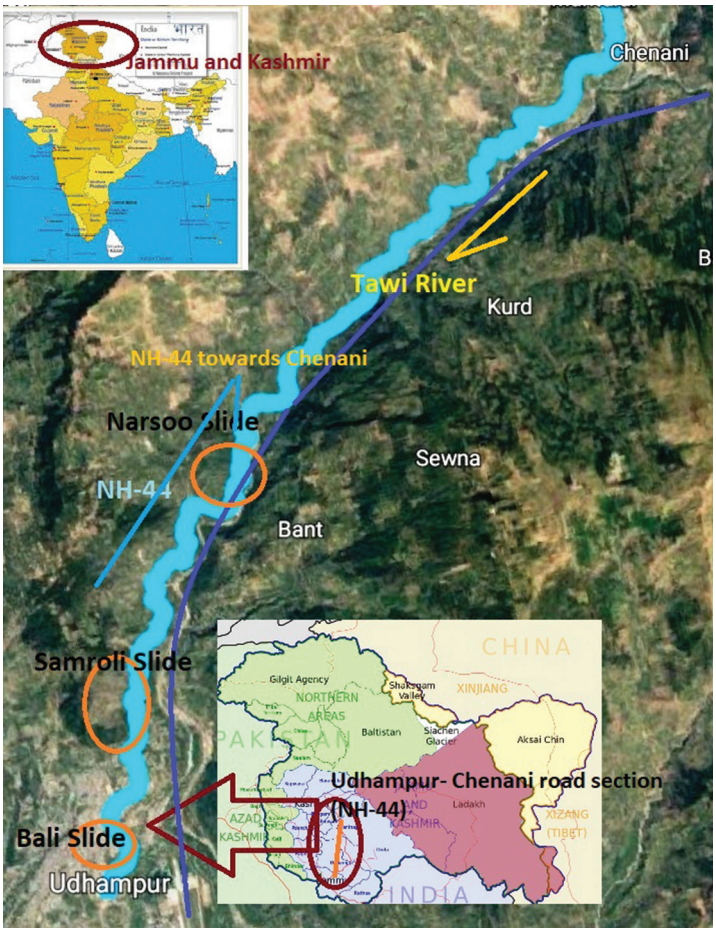
dipping joints. However, change in the strike and dip direction observed at localise place that is due to the folded nature of the rock. Earthquake history, microseismicity and the presence of longitudinal and transverse thrust faults in the region, it is concluded that the study area is quite vulnerable to earthquakes. The Jammu and Kashmir partial comes under Seismic Zone IV and partial in zone V.

As per approved design and provided ROW (Right to Work), GECPL had started the hill excavation but due to poor geology; faced various slope and ground failure which disturbed the unidentified problems such as collapse and cracks in residential building, agriculture land, high tension electricity tower and usually identified landslide. GECPL had faced losses in form of manpower, machineries, precious project time and project cost. Challenges due to unidentified landslide/ground failure issue have been discussed in this paper with probable causes and mitigation measures, which will beneficial in other projects also and government bodies should take care in an upcoming project for saving the project time and project cost burden on civil contractor.

## Landslide Zones and Probable Causes

A landslide along the NH-44 is normal phenomena. Several old landslide zones have observed along the existing highway. Landslide is the result of a wide variety of processes, a combination of one or more factors which include geological, geomorphological, geotechnical, hydro-meteorological factors such as rainfall and snow; and the reduction of shear parameter due to an increase of pore water pressure by saturation during spells of torrential precipitation and undercutting/toe erosion by water bodies. Rockfalls occur along closely spaced and steeply dipping joints, while planar and wedge failures occur due to the intersection of adversely-oriented joint planes. Slides on the thick colluvium deposits have also observed. Colluvium deposit had made up of cobbles, boulders and Silty sand and clay-sand soil which increase the chances of liquefaction in presence of water. Main landslide areas are Bali landslide, Samroli landslide and Narsoo landslide which were observed by various researchers such as Bhat et al. (2002); Chingkhei et al. (2013); Pandey (2018); Singh (2006), slope stability report (2016); Verma (1966).

**Map 1: Location Map of study area with major landslide zones along NH-44 (Udhampur -Chenani Section), J&K**




Causes of landslides in the studied area are divided into three factors, discussed below

- Geological and topographical factors: Geologically area is made up of weak rocks with four to six sets of joints and covered with overburden materials consist of boulders and soil. Slope angle (45° to 70°), alternate bands of weak rocks and valley side natural slope have increases the frequency of landslide.
- Hydrological factors: As the area is made up of loose overburden material with weak rock and unfavourable joint orientation, nominal rainfall causes the erosion/sludge flow and as rainfall varies 600-900 mm annually with twice in a year; water percolated in between the joints and causes liquefaction, which is one of the causes of a landslide

in this area. Frequency of Cloud burst event in higher ridges is increasing and causes the flash flood and brings boulders and sludge and blocks the road.

- Human and construction activities: For fulfil the daily basis needs, the local public had made the agriculture land after cutting the natural vegetation as well as diverted the water for irrigation and drinking purpose through small drains. During diversion of water, water percolated underneath the soil which causes the slope failure in some area. Excavation along the road or in loose strata, disturbed the natural slope and sinking or sliding of the area observed in some locations.

## Discussions

During the Detailed project investigation (DPR) stage, old landslide zones have been identified and provided the protection work such as Breast wall, Retaining wall, Concrete Cladding and others. Minor soil failures were taking care but some slide zone was activated due to natural slope failure, geological and hydrological factors. In the Udhampur- Chenani road section, various slope/ground failure issues have been faced during construction activities which were not identified earlier. Due to the sudden ground and slope failure, happened in the form of activated old landslide zone, damages of houses, agriculture and forest land, high tension tower collapse or in critical condition. Due to these unpredicted sudden ground failures events adversely impacted the project. Mainly three patterns of failures are observed:

- Failure of active old slides adjutant to road construction
- Agriculture and residential ground failure due to road construction at higher altitude
- Collapse of High tension towers above the cut slopes

**I. Failure of active old slides adjutant to road construction**

Ch. 68 + 900 km to Ch. 69 + 300 km, Ch. 75 + 600 km to Ch. 76 + 400 km and Ch. 84 + 500 km to Ch. 84 + 700 km are covered with thick colluvium material.Geologically synclinal structure Mudstone, Claystone and Siltstone are evidently. At the above locations, namely Bali, Samroli and Chenani, landslides respectively have occurred in recent past.

These areas show the wedge and planner failures due to an increase of pore water pressure and sometimes undercutting/toe erosion by rivers/water bodies which are activated during the rainy season.

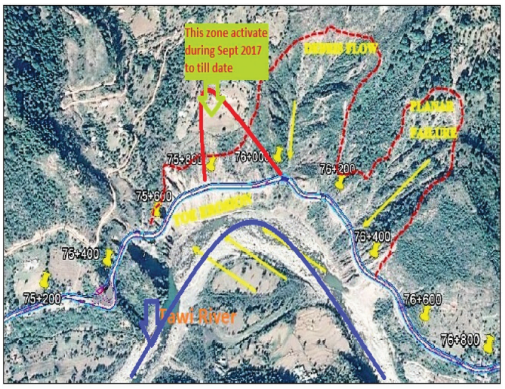
The road widening work is started in the year 2015. River Tawi is flowing parallel to this road section. The area having 40°-50° topographical slope and various small water bodies. Following landslide failures have been faced by GECPL:

- Bali Landslide zone: Bali landslide zone is made up of colluvium material with 12-18 per cent water content, 25-41 per cent liquid limit, 17-20 per cent plastic limit,

having Slity sand (SM) in nature. These sliding activated during the monsoon, due to liquefaction. In this section minor bridge was proposed to avoid the landslide disturbance. GECPL has permanently deputed the machineries for 3-4 months during monsoon season. Google earth image (Map 2) shows steep topography and colluvium materials in this landslide zone.

**Map 2: Google Earth Image of Bali Slide**


**Map 3: Google Earth Image of Samroli Slide**




- Samroli Landslide zone: This slide is in between Ch. 75 + 600 km and Ch. 76 + 400, differential and aggressive erosion of the Mudstone/shale layer in between the Sandstone layers. Soil properties are the same as the Bali landslide zone. Anticline and Syncline geological feature are well developed in between the Sandstones and Mudstone layer. The crested part of this syncline is dislocated along right limb by a dip-slip fault and along left limb by a tear fault. The Sandstone bands are fractured and blocky in nature and due to the joint orientation, a series of triangular troughs of erosion have been created in the weaker rock. During the rainy season the strata is water charged and lubricated along the joint planes and wedge failure and toe erosion beneath the Sandstone band; shown Samroli slide (Map 3).

  The bridge abutment in this location was constructed in the month of August 2017 but in the same year in the month of September, sliding started and completely blocked the NH -44 for one week. The bridge was also covered with sliding mass, about 200 m long and 70-80m high. More cracks were observed about 60-70 m away from the top of the slide area (Photo 1). The cracks width was 20-30 cm, 50-60 m long and depth up to 4-5 m and beyond (Photos 2 and 3). Cracks were developed in two high tension electricity tower foundation and agriculture land at the top of the landslide. Minor bridge abutment was cracked and settled due to this slide, which completely blocked

the NH-44 for single lane also (Photo 4). The Cracks were filled with Kanker, Sand, Cementaggregate. Drainage was also provided to avoid the surface water percolation inside the cracks.

- Chenani Landslide Zone: Chenani landslide zone has colluvium material with 12-18 per cent water content, 25-41 per cent liquid limit, 17-20 per cent plastic limit, having Slity sand (SM) in nature above the rock. This area is about 150 m wide along with the existing road level. It is largely a combination of slump and flow of surface material. The slide material is composed of mainly rock fragments in a matrix of brownish-grey Silty sand. The maximum thickness of the colluvium is more than 10-20 m. The existing road had been affected by the slide several times. This slide was activated during the monsoon, due to abrupt floods.

**Photo 1: Samroli Landslide with dimension and cracks marked, during Sept 2017 event.**

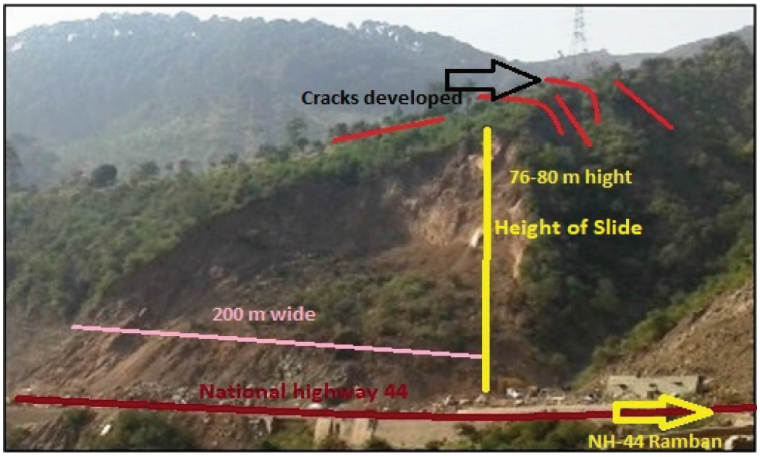



**Photo 2 and 3: Cracks developed at top of Samroli Slide during September 2017 event.**

**Photo 4: Settlement of bridge and Cracks in bridge abutment A2.**


**II. Agriculture and residential ground failure due to road construction at higher altitude**

Along the hill top, the houses and agriculture land were developed. Due to thick cover of colluvium and debris material as well as poor strength rock and toe erosion, several areas near the slide zone, grounds started sinking at Bali village (Ch 70 km to Ch 73 km), Toldi village (near Ch 78 km) and Narsoo village (Ch 81 km to 82 km), were affected:

- Bali Village: Maximum numbers of houses damage were reported in this area. Geologically the area is made up of thick colluvium materials- Silty soil with big boulders, slope are gentle with the medium cover of vegetation. Google Earth image is showing that areas forming spoon shape (Landslide prone area) due to hydrological and man-made activities in this area. Rock present at a deep level and slope angle are also high. Geomorphological, hydrological and geologically area have landslide favorable zone and old landslide zone. Presence of water, good agricultural soil had attracted humans for settlement in this area. Strength of colluvium materials would be very less and due to water percolation in subsurface lubrication form at contact plane of rock and colluvium, the landslide has been started at a huge level as shown in Photos 5-7.
- Toldi Village: Only one number of house damage was reported in this area. House is very near the ROW of the project. Geologically the area is made of thin colluvium materials 3-4 m before the Siltstone interbedded with sandstone rock, dipping gentle towards valley side, refer Photo 8.
- Narsoo Village: Three number of house damage complains were reported in this area. Houses are about 150 m far from the ROW provided to GECPL. Geologically the area is made of thick colluvium materials (3-4 m) and Siltstone interbedded with sandstone rock, dipping gentle towards valley side. Rock present at shallow depth and slope angle is high with valley side and increasing the probability of landslide refer in Photos 9-10.

**Photo 5: Geological strata from Ch 70 + 600 km to 71 + 200 km, Bali Village**

**Photo 6: Geological strata from Ch 70 + 600 km to 71 + 200 km, Bali Village**

**Photo 7: Geological strata from Ch 73 + 400 km to 73 + 600 km, Bali Village**

**Photo 8: Geological strata at Ch 78 + 500 km, Toldi Village**

**Photo 9: Geological strata at Ch 81 km, Narsoo village**

**Photo 10: Geological strata at Ch 82 km, Narsoo Village**

**III. Collapse of High tension towers above the cut slopes**

High tension electricity tower at Ch 71 + 300 km passing near the ROW were suddenly collapsed in the afternoon (60 m away from ROW) due to ground sinking at Bali slide zone. Study based on geological strata and slope failure prediction and importance of issues identified 28 numbers of towers in critical condition in which 26 numbers were suggested to be protected by micro piles, rock anchors and cladding wall as per site condition and 2 towers suggested shifting. Another tower (32.70 m from ROW) at same chainage was also collapsed within one month of collapsing of the first tower. Some tower photographs are given below (Photos 11-16):

**Photo 11: High Tension Tower Ch 68 + 041 km**

**Photo 12: High Tension Tower Ch 69 + 115 km**

**Photo 13: High Tension Tower Ch 83 + 020 km**

**Photo 14: High Tension Tower Ch 84 + 797 km**

**Photo 15: High Tension Tower Ch 87 + 505 km**

**Photo 16: High Tension Tower Ch 87 + 886 km**

## Mitigation Measures for Landslide Zones

Precautionary measures for landslide zones, situated along the NH-44, are different due to various causes. Based on the pattern of failure in the studied area, selected for mitigation measures, mitigate the landslide due to road excavation needs excavation in flat angle, stepwise excavation, construct the supporting structures (retaining/breast/cladding wall as required) and for old landslide zone such as Bali, Samroli and Chenani area proper slope protection measures such as rock net, anchoring, shotcrete, rockfall barrier, Bio-engineering methods with a drainage hole for avoiding the pore water pressure are applied.

It is proposed to have the safety of agriculture and residential ground to be taken care on high priority and measure through geotechnical instrumentation (crack meter, settlement markers, deep settlement markers, etc.) and protection of toe would be the high priority through slope protection structures.

For the protection of High tension tower nearby the ROW land, retaining wall with a drainage hole and for tower having considerable distance from project boundary and protected through micro pilling and rock anchor.

Apart from above-discussed mitigation measures; three stages of landslide mitigation measures need to be adopted during the planning stage to the operation stage of the project.

1. **Project feasibility stage mitigation plan:** During the study of the project feasibility stage, following points needs to be taking care:
   - Old landslide and probable landslide zones to be identified properly and avoid such zones for construction activities. If not feasible to avoid, natural slope

protection measures to be suggested as well as recommend a bridge, tunnel as per site feasibility.

- A separate report needs to be prepared on geological, geomorphological, geotechnical, hydrological factors to be studied properly for impact on construction activity on landslide or natural slope throughout the project section.
- It is essential and mandatory that the landslide zonation mapping work of project affecting areas to be conveyed to local public and administrative body for avoiding such area for urbanization and physically mark such area. No financial funding or other facilities to be provided, if construction activities are done in that demarcated area.
- ROW for the project to be fixed as per the slope protection required land by authorities. Less land acquisition is cheaper during the initial stage of the project but challenges faced during the construction and operational stage of the project become much higher.

**2. During construction activities:**

- Stabilized the slope by preparing the benches with retaining wall after the removal the loose colluvium materials and Bio-engineering methods to be adopted.
- Giving proper drainage for avoiding ground failure. Catch water drain, drainage hole/ weep holes and diversion of water to be properly designed for a free flow of pore water.
- All the site representatives must know the slope hazard zone and suggested mitigation/precaution measures.
- Project approving agency must issue slope protection work as separate head to avoid incumbent financial and time load to the construction contractor for smooth tackle the slope protection work.
- As much as possible, avoid hazard-prone zone for disturbing the natural slope and if disturbing is essential then excavation to be done with all precautionary measures.
- ROW if not adequate and slope heights are more, the mitigation measures are to be judiciously provided.

**3. During the operation stage:**

- All slope protection works to be done.
- Instrumentation to be fixed at critical zones for daily monitoring of ground stability and issue warning at appropriate stages.
- Inputs from public awareness are always beneficial to identify the upcoming ground failure.

## Conclusion

Based on the types of landslides and related impacts in Udhampur-Chenani road section, it is concluded that area is covered with thick debris materials with a steep slope (angle = $>60^0$) and water bodies (rainfall, nallas and rivers). Natural features such as geology of area, geomorphology of steep disturbed slope and hydrological factors of subsurface water percolation are predominantly present in the area of study. The combined effect of these natural features mainly causes a landslide and related challenges during excavation.

Landslide study during the project feasibility stage is highly recommended with mitigation measures as per modern engineering solutions. Stepwise slope protection measures, protection from Wedge and planner failure and drainage are appropriate for safety aspect from landslide hazard. Funds also be allotted in infrastructure project for slope protection measures, that would save the project completion time as well as project cost escalation.

The mitigation measures need for Himalayan projects for smooth construction and long term performance. The impact of hill cutting and filling needs to approximate protection measures to be recommended as per modern engineering solutions.

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