Road widening along National Highway-58, Uttarakhand, India

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In the perilous Himalayan region, the roadway network serves as arteries for transportation. The terrain is susceptible to potential landslides due to its inherent geology which is reflected in its weak rocks. Anthropogenic intervention for developmental activities is continuously aggravating and deteriorating the geo-environmental condition of the region. One such intervention is the widening of roads being performed on fragile slopes. Here, the issues pertaining to improper excavation for road widening along National Highway-58, Uttarakhand, India have been discussed. The surface and subsurface drainage treatment is the foremost measure that needs to be undertaken. Excavation at steep angle should be avoided. Some preventive measures like steel mesh should be used to retain potential falling blocks along with flexible barriers to reduce kinetic energy of these blocks. Proper execution of remedial measures will strengthen the safety along the highway. The excavated muck should be dumped by constructing well-planned and scientific dumping sites. Rock shed construction is proposed for rockfall-prone sections.

The Himalayan orogeny has manifested multiple phases of deformation due to which the rocks are extensively deformed and sheared. These weak and deformed rocks are prone to slope instability-related issues and invite small to large landslides. The intervention of anthropogenic activities with the natural slope of the Himalaya has been a major cause for landslide disasters. Consequently, multitude casualties and loss to infrastructure are being reported from distinct parts of the Himalayan region, especially along the transportation corridors like national highways and state highways. In eco-sensitive terrains like the Himalaya, railway connectivity and airfield network are limited and sparse. Under such scenario, the roadway network serves as arteries for swift and hassle-free progression of transportation and communication activities of the region. Uttarakhand, India is the land of several holy shrines, fascinating landscapes and ecosystem leading to substantial inflow of tourists and pilgrims. The Central Government has announced a project to develop the Char Dham route heading towards the holy shrines of Badrinath, Kedarnath, Yamunotri and Gangotri. The total budget for the project is approximately Rs 11,997 crores, which includes civil construction, land acquisition and forest clearance. The prime focus of the project is widening of the pre-existing roads. Excavation for the project has started in discrete patches along National Highway (NH)-58 in late 2017. The roads in such perilous terrain are under significant stress. Any disruption in equilibrium conditions due to large-scale excavations may trigger catastrophic disasters in near future. Massive death toll has been reported in the region by several by researchers and organizations[1–3].

Slope instability issues along NH-58

During preliminary observations, many faulty executions were witnessed along innumerable sections of the highway. The inadequately performed excavation without proper consideration of eco-sensitive terrain conditions is detrimental and leads to tragic hazards. Most of the excavated cut slopes are sub-vertical to vertical, with large overhangs. The road-cut slopes should be gentle, particularly in those sections which are dissected by geological discontinuities. In order to complete the Char Dham Mahamarg Vikas Pari Yojana (Char Dham Highway Development Project) project the scientific studies/reports which ought to be given topmost priority have been ignored.

The construction of appropriate dumping sites is also a major issue along the highway. The excavated materials, including massive rock blocks, soil and debris have been dumped in hairpin bends along the road. Such faulty practices in ecologically fragile terrain may lead to catastrophic events as witnessed during the Kedarnath disaster. These dumps are interrupting the natural channel of many ephemeral streams and may give rise to an alarming situation in subsequent monsoon seasons. Besides ephemeral streams, the major perennial stream, including the holy river Ganga may witness such critical issues. Such adverse practices are unendurable and violation of rules and regulations of the river ecosystem needs to be assessed. Such unscientific acts will not result in any development; rather they would trigger fatal events in the state. Similar activities in the upper reaches of Uttarakhand will cause siltation problem in major hydroelectric projects. Apart from problems pertaining to landslides and river ecosystem, the unique canopy of the region is also being affected. Such adversely executed activities are deteriorating the aesthetic environment of Uttarakhand. It was observed during a traverse along NH-58, from Rishikesh to Devprayag, that no preventive and stabilization measures were undertaken after excavation. However, in a few road-cut sections, gabion walls have been constructed for stabilization; but these walls are deformed due to inadequate stabilization measures and maintenance (Figure 1).

Water is one the crucial factors causing instability to the slopes. Hence it needs to be channellized properly to avoid the build-up of pore pressure and

Figure 1. Deformed gabion wall along National Highway-58 near Rishikesh, Uttarakhand, India.

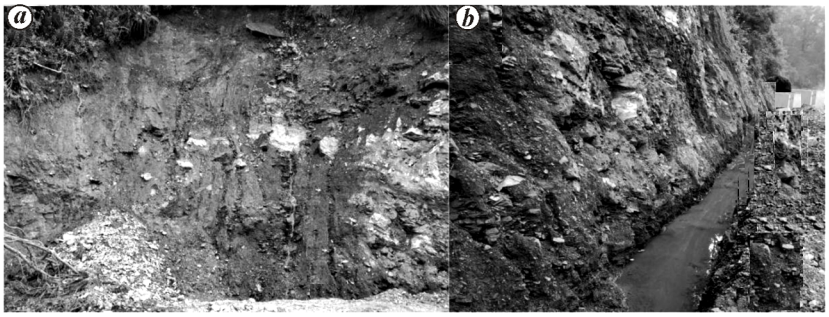

Figure 2. Photographs depicting adverse conditions along NH-58 near Rishikesh. ***a***, Panoramic view showing continuous outflow of water. ***b***, Cross-sectional view of cut slope showing stagnant water in the ditch hampering stability of the slope.

Figure 3. Talus-type slide along NH-58, Shivpuri. ***a***, Pre-failure scenario in July 2017. ***b***, (Inset) Image showing tension crack near crown portion. ***c***, Post-failure condition in September 2017.

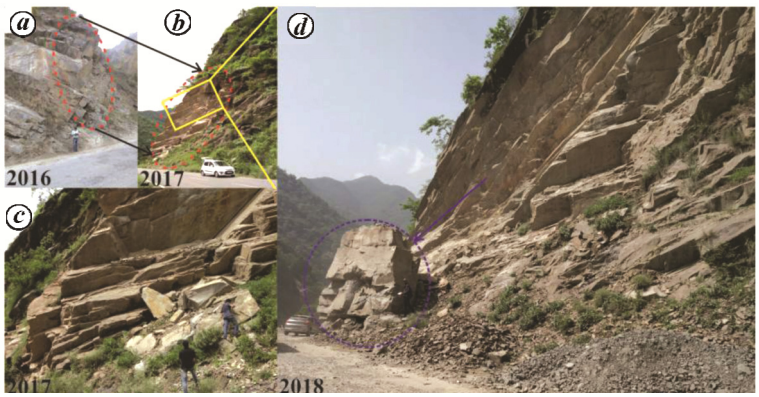

Figure 4. Recurring structurally controlled failure along NH-58 near Kaudiyala, Uttarakhand. ***a***, Rock mass prone to planar and wedge failure. ***b***, Block failure that occurred in 2017. ***c***, (Inset) View of the failure depicting size of the block. ***d***, Recurrent mass failure that occurred in 2018.

to enhance stability. Proper drainage outlets are efficient and cost-effective means to deal with such issues. During road-widening phase along NH-58 near Rishikesh, however, the discharged water from the slope was observed to be collected in a roadside ditch (Figure 2). Such careless practices are continuously hampering and endangering the health of slopes and may give rise to large-scale landslides. In the monsoon season of 2017, a talus-type of landslide was witnessed along NH-58 near Shivpuri (Figure 3). The landslide was triggered by the percolation of water through tension cracks between the debris and bedrock interface near the crown portion of the slope. The stagnant water on the slope may cause disturbance in the equilibrium conditions by increasing pore pressure and reducing shear strength of the material, thereby hampering stability to a great extent. So, proper outlet channels need to be constructed along the cut slopes.

NH-58 is hazardous due to frequent landslides. By employing different proxies, studies have been undertaken to assess the geotechnical behaviour of the road-cut slopes along the highway[4–9]. Thirty-five critical slopes from Rishikesh to Devprayag were evaluated by employing rock mass classification schemes and remedial measures have been suggested[5]. These critical slopes should be excavated at an angle of 65°–70° with benches of 10 m height and 5 m span. As excavation is ongoing, the suggested precautionary measure will play a crucial role in attaining safer and economically functional design along the highway. Similarly, optimization for rockfall threat was conducted near Saknidhar township[9]. In the same patch, eight vulnerable debris slopes were examined[5]. In blocky rock mass, steel wire mesh of individual mesh smaller than the size of the block should be fixed. Such detailed geotechnical appraisal should be considered in the fragile and eco-sensitive Himalayan slope conditions. The probability of anthropogenic landslides increases when excavation for road-widening is performed without proper consideration of complex geological and geotechnical aspects of the region. Inadequate blasting and improper excavation techniques induce ground vibrations, and consequently additional fractures and avenues for further landslides are generated. Sati *et al.*[10] also highlighted several issues pertaining to road widening-induced landslides along NH-58, but appropriate steps for improvement have hardly been taken. Recurrent slope failure due to several exogenic and endogenic factors is common along the highway. One such failure has been evidenced near Kaudiyala, Uttarakhand (Figure 4). Inherent adverse conditions and increased human intervention by large-scale excavation may activate and trigger several landslides.

The Geotechnical Engineering Office, Government of Hong Kong has developed an automated system to monitor surface deformations (using surface-mounted crack method, multipoint translation rotation and settlement sensors and differential global positioning system) and subsurface deformations (using inclinometers and time domain reflectometry[11]. Moreover, groundwater and rainfall monitoring support the data acquired for monitoring of geomaterials. Such practices can also be adopted in the Himalayan orogeny, particularly along the critical road-cut sections and slopes in proximity to densely populated areas. A study was conducted in Alberta, Canada for highway improvement in landslide-prone terrain, and relocating or realignment of highly prone sections was suggested[12]. The tampering and excavation for road-widening purpose in highly landslide-prone sections needs a thorough scientific investigations. To cope with recurrent nature of slides along NH-58, realignment of road may be undertaken. The impact of road widening was assessed in Peradeniya, Sri Lanka[13]. The safety factors were determined and certain precautionary measures (proper land-use planning, installation of warning system, management of drainage and irrigation system) were suggested.

Conclusion

For sustainable development, the authorities and stakeholders must ensure proper execution of the Char Dham Highway Development project and work should be monitored by a committee of experts from distinct domains. To attain safer design during pre- and post-construction stages, efforts should be undertaken for better prediction of extreme rainfall events and accordingly planning needs to be made. The real-time monitoring of slope movements should be done along highly vulnerable and risk sections. Due to huge muck of debris, there will be degradation in river ecosystem and quality of water flowing downstream. In rockfall-prone sections, rock shed may be designed to overcome accidents and frequent blockage of the highway.

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