**Extended Abstract** **DOI: https://doi.org/10.64862/ajeg.2025.2sp.71.195** **Open Access**

# Geotechnical Challenges and Adaptive Solutions in the Nagdhunga Tunnel Construction Project

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*Received: August 18, 2025, Accepted: September 25, 2025*

**Abstract: The Nagdhunga Tunnel Construction Project in Nepal encountered a range of substantial geotechnical challenges, primarily due to the Himalayan region's complex and unpredictable geological conditions. Constructed using the New Austrian Tunneling Method (NATM), the project required significant adaptations to contend with collapses and sidewall deformation observed during excavation. Nepal's geology, dominated by ongoing tectonic activity thrust faults, and high-pressure metamorphic rocks, posing risks specific to accretionary prism formed by plate collision. This experience highlights critical considerations for future underground infrastructure projects in Nepal and similar geologically active zones, particularly concerning geological complexity and logistical constraints related to material procurement.**

**Keywords:** ***Accretionary prism, NATM, Deformation, Himalayan range.***

## Introduction

The Nagdhunga Tunnel Construction Project, planned at the western edge of the Kathmandu valley, is Nepal's first road tunnel, funded by a Japanese ODA loan. This project involves constructing a 5,560 m bypass, including a 2,688 m long tunnel on the main national highway connecting the capital Kathmandu with major cities such as Pokhara. The planned tunnel site, the Nagdhunga Pass, is a section where frequent landslides occur during the rainy season and the road's longitudinal gradient is steep, exceeding 10%, leading to severe traffic congestion due to vehicle breakdowns and accidents. The project location is shown in Figure 1.

Construction commenced in November 2019, with excavation proceeding from four faces for both the main tunnel and the evacuation tunnel. The evacuation tunnel achieved breakthrough in August 2023, and the main tunnel achieved breakthrough in April 2024.

## Geology based on excavation records

Excavation revealed relatively, at the boundary between the Sopyang formation and the Tistung formation on the west side, thrust faults with a north-south strike and a westward dip repeatedly appeared. Moreover, in the central section of the tunnel, the geology was primarily composed of black schist to phyllite interbedded, and fracture zones fragmented into flaky pieces a few millimeters wide were observed. The schistosity plane of the black schist was concentrated with mica, exhibiting a glossy dark black color and scaly cleavage. The face condition where the fracture zone was distributed is shown in Figure 2 and the geological map reviewed based on excavation is shown in Figure 3.

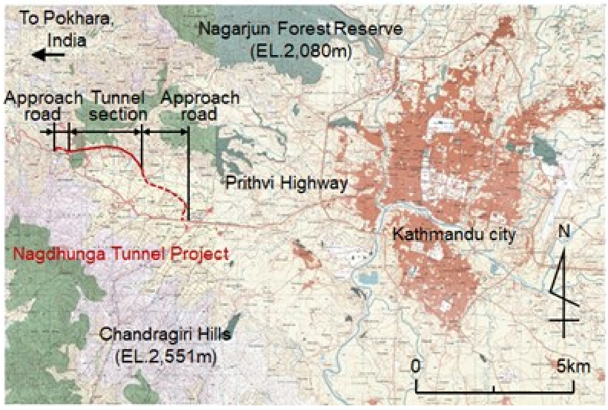

*Figure 1, Project location map.*

*Figure 2, Fractured layer at 1+951.*

## Deformation and countermeasures

As excavation advanced toward the center of the tunnel, horizontal displacement increased, and large-scale deformations, such as rock bolt rupture, steel rib deformation, and buckling occurred continuously in the Main Tunnel. The characteristics and factors of the deformation are summarized below:

- Horizontal movement was dominant, and the displacement velocity was large (maximum 1,060 mm).

- The displacement was correlated with excavation progress, and the increase in displacement ceased during periods when excavation was suspended.

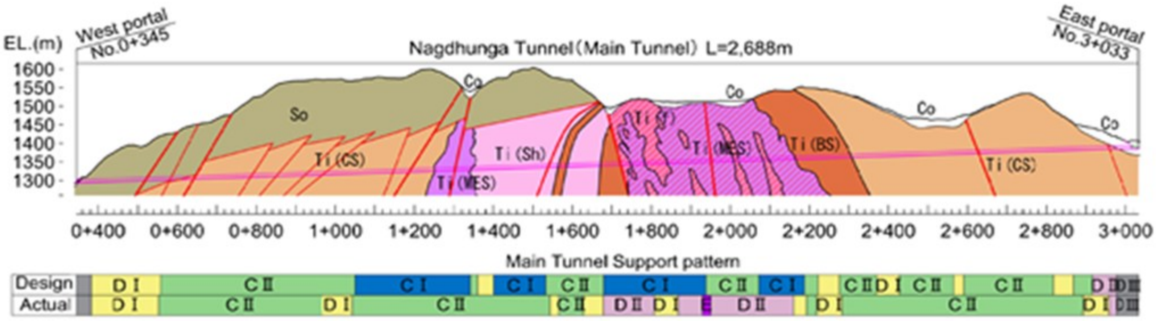

Figure 3, Geological profile (review based on excavation).

- In sections with large displacement, the strike of the rock mass is parallel to the tunnel alignment.
- Rock identification confirmed the absence of swelling clay minerals and no slaking property.

From these factors, it is considered that the superposition of multiple causes led to the progression of stress relief along the cleavage planes deep into the rock mass immediately after excavation. This resulted in the load acting in the horizontal direction, causing significant deformation

## The largest displacement section

At station No. 1+951, a collapse occurred in the crown to the right shoulder. The collapse recurred intermittently, and the face was buried by the collapsed soil. Immediately after the collapse, the shotcrete on the crown spalled off, and the heads of the sidewall rock bolts shot out horizontally with a snapping sound. Furthermore, the steel ribs installed at 50 cm intervals were destroyed by buckling and rupture at the crown. Given this situation, it was deemed dangerous to attempt collapse countermeasures at the face, so it was decided to begin the re-installation of the destroyed supports from 60 m behind.

Since a significantly vulnerable fault clay was distributed in this section, there was a concern that the support rigidity might be insufficient even if re-excavation was performed with the DII pattern. Therefore, a FEM analysis was conducted based on the results of the convergence measurements to calculate the stress acting on the support members. The results showed that the DII pattern lacked sufficient load-bearing capacity, so the E pattern (H-200 steel ribs, shotcrete thickness t=250 mm) was adopted. The condition of the re-excavation is shown in Figure 4.

Nevertheless, even displacements exceeding 1 m were confirmed to converge upon the completion of all ground excavation, including invert excavation and re-excavation after the breakthrough. This ground behavior is considered a particularly important characteristic for examining the deformation mechanism during tunnel excavation in Nepal. The measurement results at station No. 1+948, where the E pattern using H-200 was applied, are shown in Figure 5.

Figure 4 Re-excavation due to increased displacement.

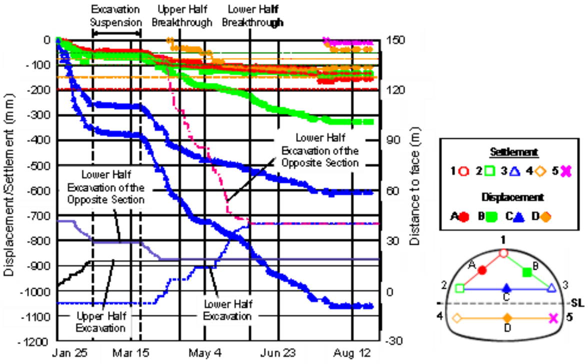

Figure 5, Example of convergence measurement.

## Conclusion

Because the initial rock stress was high and cracks had been tightly closed before tunnel excavation, the seismic wave velocity in the preliminary survey was high. As a result, for approximately 19% of the main and evacuation tunnel, support structures were designed that were two to three ranks lighter than the support structures required.

These are the result of the technical limitations of geological surveys, and it is highly likely that similar phenomena will occur in future tunnels planned in Nepal.