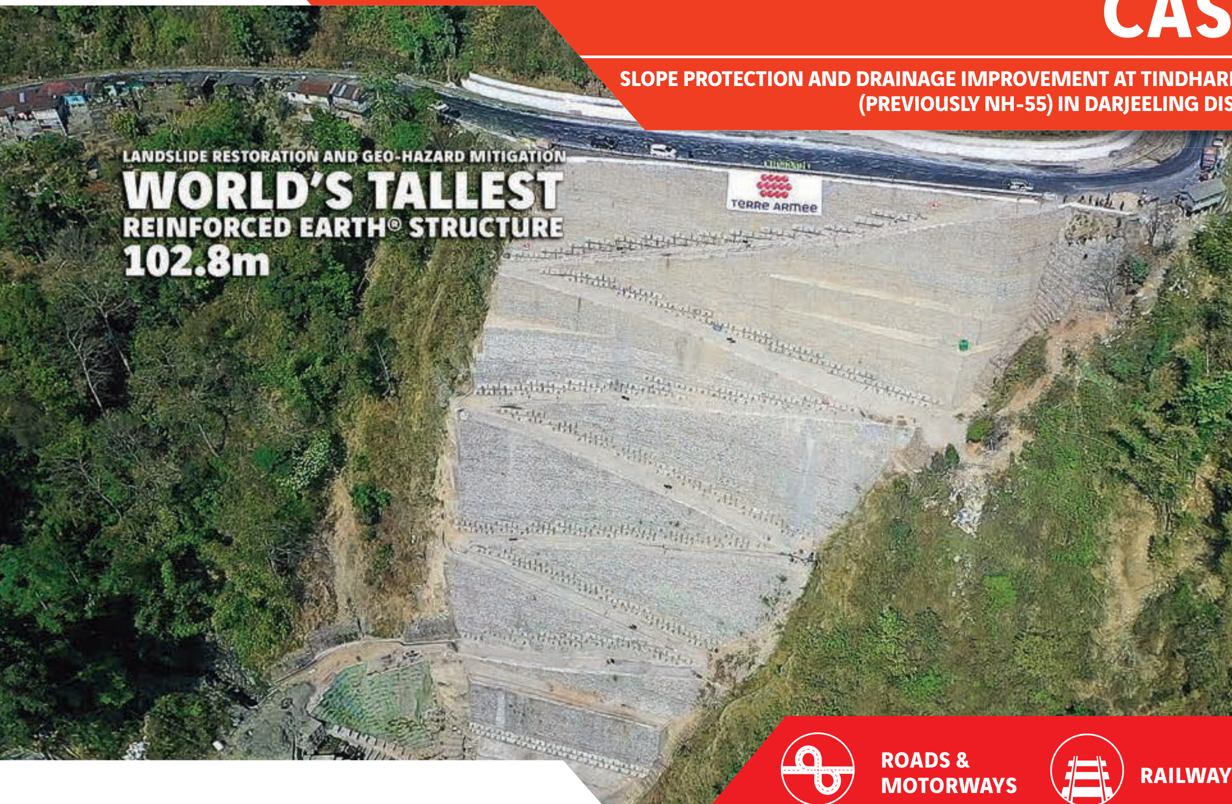
CASE STUDY

SLOPE PROTECTION AND DRAINAGE IMPROVEMENT AT TINDHARIA ON NATIONAL HIGHWAY 110 (PREVIOUSLY NH-55) IN DARJEELING DISTRICT OF WEST BENGAL, INDIA



ROADS & MOTORWAYS | RAILWAYS | DISASTER MANAGEMENT

Background

In September 2011, Tindharia, a picturesque town located on the historic Siliguri-Darjeeling hill cart road, NH-110 (previously NH–55) in West Bengal, India experienced massive landslide following an earthquake of 6.9 magnitude and heavy rainfall. The landslide significantly affected three locations - S1 (Height 34.9m), S2 (Height 102.8m) and S3 (Height 38.7m) on this road - resulting in the collapse of a section of roadway on the valley side of the mountain. Part of the Darjeeling Himalayan Railway (DHR), a UNESCO World Heritage Site that runs through Tindharia, was also cut-off due to this landslide. There was severe socio-economic impact on the residents along the NH-110 (previously NH–55) due to stoppage of vehicular movements and shortage of key supplies. The Ministry of Road Transport & Highways, Government of India in collaboration with the Public Works (Roads) Directorate, NH Circle - III, P. W. (Roads)

Rehabilitation of landslide location with slope protection and drainage improvement at Tindharia on NH-110 (previously NH-55) (Km 50.155 to Km 50.182, Km 52.650 to Km 52.929 and Km 53.452 to Km 53.475) in Darjeeling district of West Bengal

STRUCTURE TYPE
TerraLink® - A composite/ hybrid structure using TerraNail® and FreyssiAnchors® with GeoTrel® facing panels and High Adherence GeoStrap® 5 soil reinforcements

OWNER
The Ministry of Road Transport & Highways, Government of India and Public Works (Roads) Directorate, NH Circle - III, P. W. (Roads) Department, Government of West Bengal

DESIGNER
Terre Armée India (Reinforced Earth India Pvt. Ltd.)

CONTRACTOR
SSPL-Pioneer (JV)

AUTHORITY ENGINEER
TASPL - Xplorer JV

CONSTRUCTION
March 2017 to January 2021

Department, Government of West Bengal took the initiative to restore the landslide location and the historic road.

Initially the project was tendered and awarded in 2013 using conventional reinforced soil structure with gabion facing. After commencing the construction, the contractor could realize that the requirement of backfill and boulder for such structure was very high and eventually the project had to be cancelled due to cost over-run.

After two years, the project was again initiated with a fresh Detailed Project Report (DPR) prepared by the consultant (LEA Associates South Asia Pvt. Ltd.). LEA discussed the problem with various technology providers in the field of soil reinforcement and accepted the TerraLink® concept proposed by Terre Armée India.

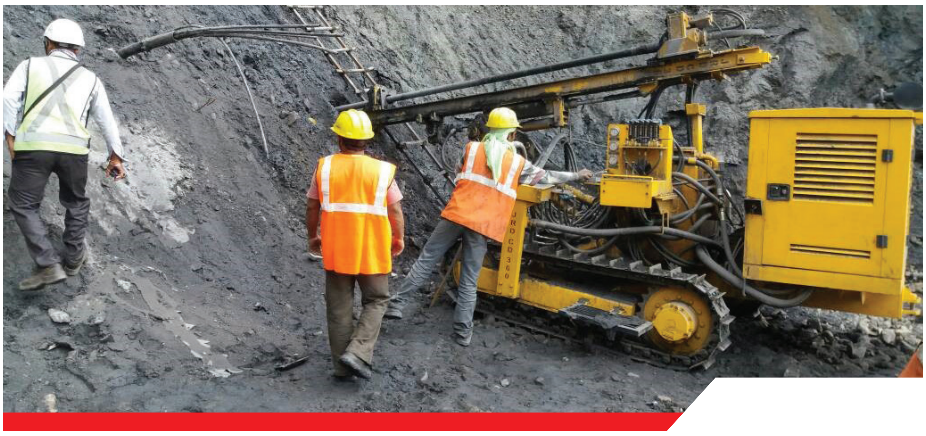
Later, the project tender was awarded to the contractor and Terre Armée India was appointed as the specialized technology provider for the detailed design and engineering of the structure.

Solution

After going through the details of this project, Terre Armée India promptly made a site visit and prepared a detailed feasibility report keeping in mind the technical and practical challenges of this location and client's requirement. Out of various possibilities, Terre Armée India chose to propose TerraLink® as the solution in this project.

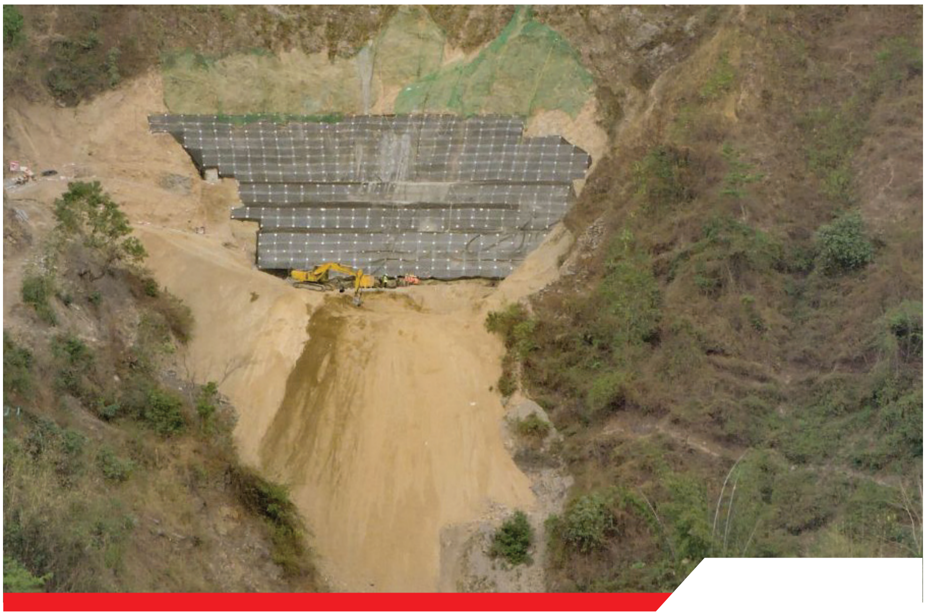
TerraLink® is a shored Reinforced Earth® structure. In this project, the soil reinforcing High Adherence (HA) GeoStrap®5 of the Reinforced Earth® structure is mechanically connected with the GeoTrel facing on front and with TerraNail® and FreyssiAnchors® on the rear end. Galvanized steel GeoTrel® facing has been used in this project having mechanical connection with HA GeoStrap®5 soil reinforcements. The choice of TerraLink® was made in a scientific manner considering the following facts in the project ;

- **Stability of the Slope:** The construction was required to be done on valley side of a collapsed hill slope. Heavier load imposed on the slope by conventional structures such as RCC retaining wall, gabions etc. would reduce the stability. On the other hand, TerraLink® is constructed after stabilizing the failed slope using TerraNail® and FreyssiAnchor®. Therefore, TerraLink increases the stability of the collapsed slope and at the same time widens the road bench without increasing the dead load on the slope significantly.
- **Construction within Limited Space:** Innovative TerraLink® technology makes it possible to build very tall retaining structures (>35m) with limited available space at base (<2m), using direct and mechanical connection systems.
- **Reduction of Backfill Quantity:** Almost 650,000 cum backfill was required with conventional reinforced soil structure. TerraLink® can reduce the backfill quantity to 1/10th i.e. 60,000 cum. This would reduce the number of transportation loads on the narrow hill road, cut down on the use of machinery, reduce carbon foot print and eventually reduce the cost.



In the detailed design stage, lidar survey along with geological and geotechnical investigation were done at the project site. Based on the inputs of these investigation, Terre Armée India conducted internal, external and global stability analysis to define the design of the structure. Terre Armée India validated the design using finite element model. The maximum length of TerraNail® and FreyssiAnchor® drilled and installed in this project were 25m and 32m respectively. FreyssiAnchors® are completely re-stressable cable ground anchors used in this project to stitch the new construction with the existing hill profile.

Tindharia is located in a high rainfall zone. Drainage is very crucial for this kind of structure and improper drainage is often considered to be one of the major root causes of landslides in the hills. Special care was taken to improve and facilitate the surface and sub-surface drainage systems in this project. Semi-perforated drainpipes wrapped with non-woven geotextile were drilled and installed within the collapsed slope to drain out the entrapped water and release the pore water pressure. The location at S2 had a depth of 102.8m, hence Terre Armée India designed the benches in slope for channelizing the surface drainage. Drops and guide drains were also designed and constructed on both sides of the structures.



Challenge

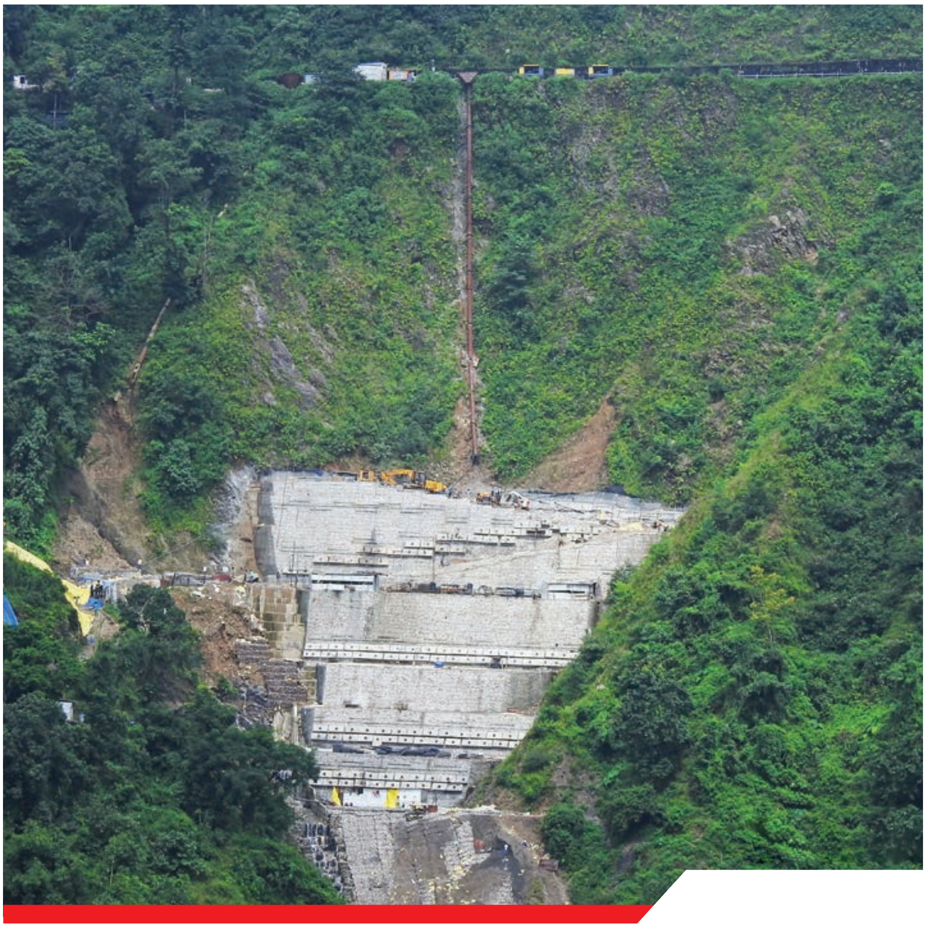
- **Inclement Weather:** Tindharia receives approximately 185 cm of average rainfall annually. Monsoon is active from end of May to beginning of October. Work got either suspended or very limited activities could be carried out during this period. With the heavy rainfall and surface water, the risk of damage to the structure was also very high during construction. Suitable measures had to be taken to cater this challenge.
- **Unfavourable Geology:** The geological strata of this area are susceptible to weathering and fracture. The available bond strength within the soil strata was also not very high. The drilled holes were found to be connected with each other in many occasions. This resulted in collapse of the drilled hole also. Consolidation grouting was adopted to solve this problem.
- **Presence of Ground Water:** The strata was almost saturated due to continuous percolation of water during monsoon or

presence of natural aquifer. Therefore, while drilling the holes for nail, significant water flow was encountered. Long semi-perforated pipes were installed within the slope to cater to this challenge.

- **Safety:** Working in such a height was also a key challenge from safety point of view for men and machineries.
- **Timely Completion:** A major challenge was to complete the project within time considering the impact of high rainfall during monsoon and a long strike imposed by the local legislation.
- **Impact of Covid-19:** In 2020, the project schedule was badly affected by Covid-19. There was serious scarcity of workforce, the lockdown forced to stop the work for more than months. Utmost safety and precautionary actions were taken collectively by all stake holders in this project to overcome this challenge.

Special Features and Advantages

- **Stabilization of Failed Slope:** The design of the structure was done in such a way that it stabilizes the collapsed slope (landslide area) using TerraNail® and FreyssiAnchor® and also fulfills the requirement of road widening.
- **Design of Tall Structure in High Seismic Zone:** The project is located in Darjeeling Himalayan region and falls under seismic zone IV. The maximum height of the proposed structure was also very significant (102.8m). Thus, the design had to be robust to take care of high seismic load, local and global deformation due to such height during as well as after construction and moreover the stability of the slope and the proposed structure. TerraLink® is the most suitable solution that integrates soil reinforcement, nails and anchors together through mechanical connection as recommended by BS-8006 for high seismic zones.
- **Use of Compressible Panel:** Considering the height, specially designed Compressible Panels were used to provide additional flexibility to the structures. This kind of arrangement makes the structure capable to withstand significant differential settlements and high seismic loads.
- **Improvement of Sub-Surface Drainage:** Multiple layers of semi perforated PVC pipes wrapped with non-woven geotextile were inserted into the slope to drain out the sub- surface water and reduce the hydrostatic pressure.
- **Improvement of Surface Drainage:** Catchment drains, and drops & guide drains were designed and constructed to guide the water in a systematic manner so that the structure dœs not remain unprotected against severe water flow during monsoon. The benches of the tallest structure were also designed in slope to improve natural drainage along the TerraLink® structure.
- **Minimum Environmental Impact:** Reduction of backfill and boulder quantity, usage of steel mesh fascia instead of reinforced cement concrete panel, limited use of heavy machineries reduced the carbon foot print significantly in this project.



Project Specifications

Structure
TerraLink® Composite / Hybrid Reinforced Earth®

Soil Reinforcement
High Adherence GeoStrap®5 made from high tenacity polyester encased in LLDPE sheathing

Anchor System
TerraNail® (Yield Strength ≥ 670 Mpa and Ultimate Tensile Strength ≥ 800 Mpa), prestressed FreyssiAnchor® of 42 MT capacity and completely re-stressable, if needed during the service life

Facia Type
GeoTrel® - Welded Steel Grid (1.3m x 3m, nominal) made of minimum 8mm dia. bars and galvanized to 500 grams per sqm

Specially designed compressible panels with the capacity to withstand higher deformations meeting internal settlements, if any

Connection System
Mechanical, active and positive for transfer of loads in high seismic zones
- Between facia and soil reinforcement: galvanized steel hook and horse-shoe plate
- Between soil reinforcement and TerraNail: TerraPlug®, galvanized steel hook and horse-shoe plate

Area
7724 m^2

Maximum Height
102.8 m

Live Load
24 kPa

Seismic Co-efficient
0.24g (Zone-IV as per IS: 1893 (Part 1):2002)

Design Life
100 years

STAGE-WISE COMPLETION OF S- 2 STRUCTURE