# A Report on
# Naina Devi Landslide

**May 2023**


## Uttarakhand Landslide Mitigation and Management Center (ULMMC), Dehradun.

# Report on Field visit of Naina Peak Landslide, Nainital

Consequent upon the DMO Letter No. 721/13 CRA/2022 223 dated 13.03.2023 related with the recent landslide activity occurred on 4th of March, 2023 in Naina Peak, Nainital and USDMA letter no 444/XVIII B 1/2023 15(25)/2021 dated 27 March 2023, an expert team was constituted to carry out survey in the area to suggest solution /mitigation measures with following members:

1. Dr. Shantanu Sarkar, Director, ULMMC,
2. Dr. Ruchika Tandon, Senior Geologist, ULMMC,
3. Er. Sarthak Chaudhary, Assistant Engineer, ULMMC,
4. Er. Koushik Pandit, Scientist, CBRI,
5. Mr. Sunil Yadav, Assistant Geologist, GSI
6. Mr Shailesh Kumar Disaster Management Officer, Nainital.

The expert team along with Dr. D. S. Chand (Senior Geologist), DGM along with other officials of PWD, Forest departments and Mr Neeraj Dhaiya, Research Scholar, CBRI carried out the geological survey in the Naina peak on 11th April 2023. Based on the field observation and available information, further recommendation regarding the detailed investigation and mitigations measures (both short and long term) are suggested in this report.

**Figure 1: Team at Naina peak landslide zone**

## 1.0 Location of the Study Area:

The study area is a part of Nainital township of Kumaon Himalaya located at an altitude of approximately 2050 m above mean sea level. It is bounded between the latitude N29°29'40" and N29°30'20" and longitude E79°30'45" and E79°31'20". The topography of the area is strongly controlled by complex tectonic structure and characterized by multiple steep, dissected and nonparallel ridges from all the sides with Nainital lake at the center. Towards the NW of the Nainital lake, the highest peak known as Naina peak is situated where slope instability and rock fall is reported. The Naina Peak hill is located to the N•NW of Nainital lake on NW-SE trending hill. The highest point of Naina Hill is at ~2600 m, whereas the base is at ~2000 m.

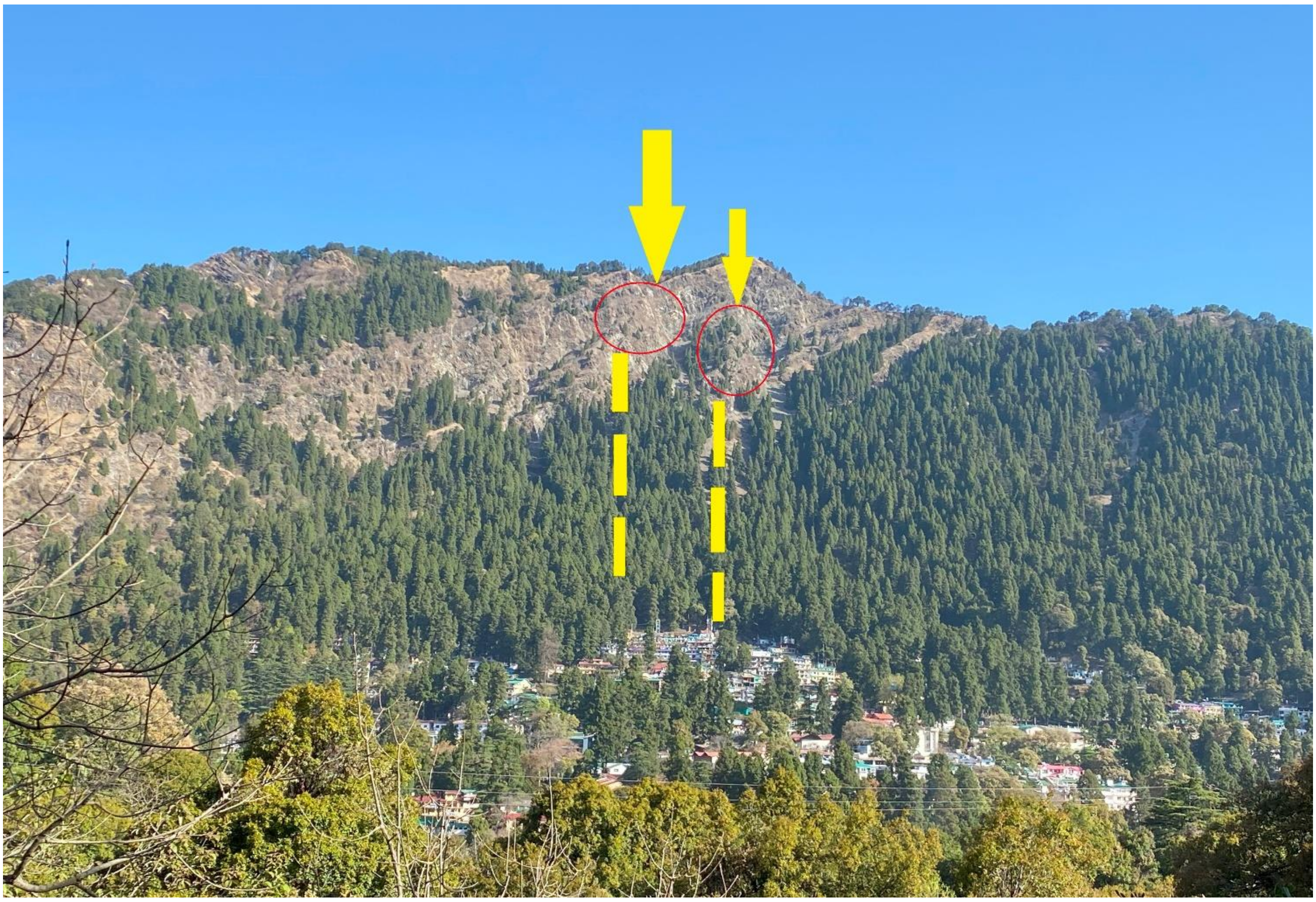


**Figure 2: Panoramic view of Naina Peak landslide and the settlement just below the rock fall zone**

## 2.0 Geology and Geomorphology of the area

Naina Peak area dominantly exposes the rocks of the Lower Krol Formation along with the patches of the Middle Krol Formation and the Upper Krol Formation. The geological map of the area is shown in Figure 3. Geologically, the rock type exposed in and around Naini Hills are thinly bedded Shale with intercalations of Limestone. The rocks are highly weathered, shattered and jointed near the top of the hill (Fig 4) whereas rocks exposed in the middle and lower part of the slope is relatively competent. The rocks dip 25° towards N300° (bedding joint). Apart from bedding joint, there are four to five joints sets present in the area.

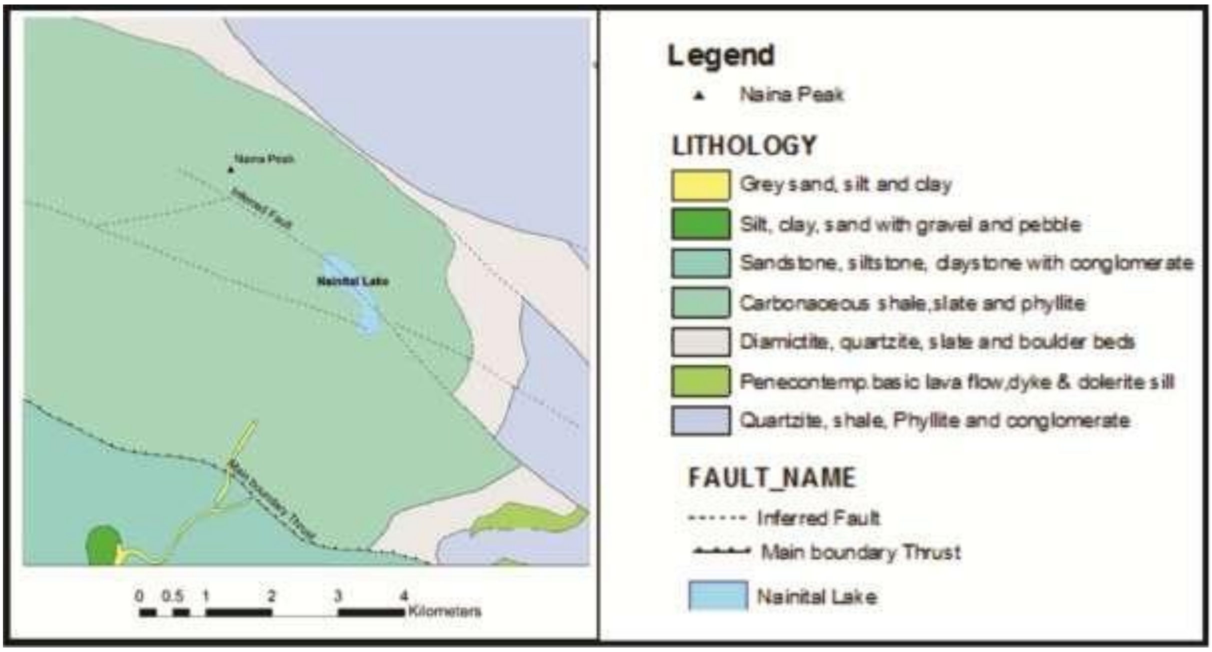



**Figure 3: Geological Map of the area**

Geomorphologically, the slope in the upper and the middle part of the hill is near vertical and ~70° respectively whereas at the base it is ~30°. The middle part of the slope is covered with thick forest whereas at the base settlements are situated. The Naina Peak landslide is situated near the crest of the slope. To the west of this landslide, numerous tension cracks having < 2m long and >50 cm wide were observed at several locations (Fig 4b).

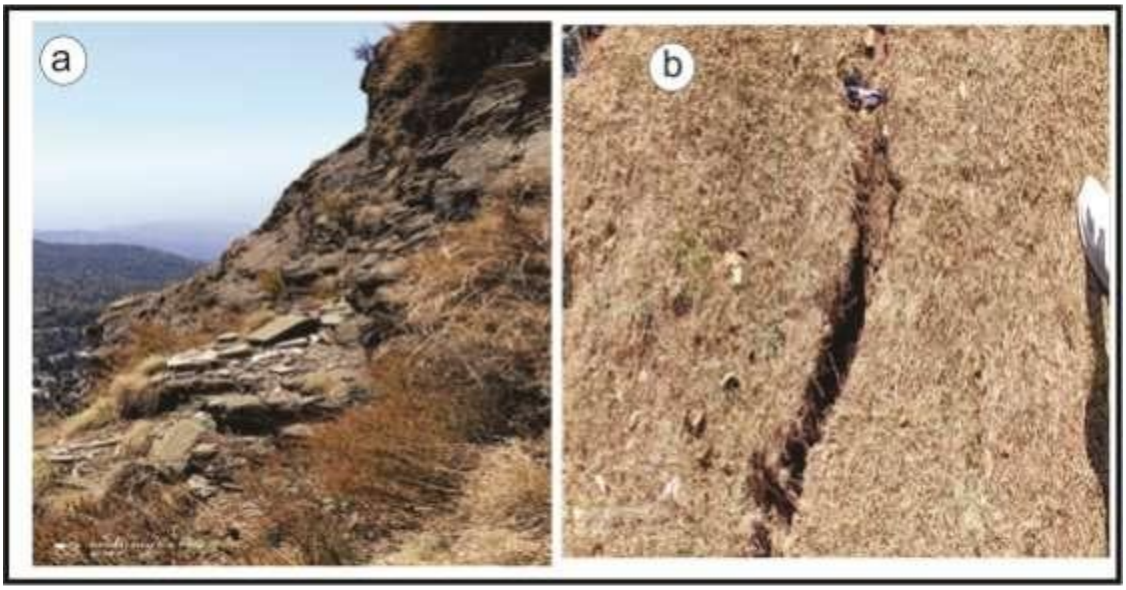



**Figure 4: (a) highly shattered and jointed condition of rock mass exposed at crest of Naini Hill (b) tension cracks on the crown of Naini peak**

The area between the toe of the slide till kilbury road is covered with the moderately dense forest The slided material/slope wash material stopped to enter into settlement area through the retaining structure (Figure 6) constructed in the middle of the slope .at various elevations that has successively reduced the velocity of the falling rock debris. The average dimension of rock pieces is 50-100 cm (Figure …).


**Figure 6: Retaining Wall structure above the Kilbury Road**

Figure … The slided rock pieces obstructed by the retaining wall

**Previous Study**

Previously an expert team was constituted by the Uttarakhand State Disaster Management Authority (USDMA) vide letter No 228/USDMA -781 (2020) dated 3rd March 2020. The team visited the Naina Peak landslide zone on 19th June, 2020 to carry out a reconnaissance survey of the area.

The expert team carried out the surface geological and geomorphological observations including nature and condition of the rock mass and the trends of the various discontinuities present in the area. In order to understand the sub-surface condition of the material, Electrical Resistivity Tomography (ERT) survey was also carried out at the Naina Peak.

The Electrical Resistivity Tomography (ERT) survey was carried out on a single profile line along the contour (i.e., along the observed cracks) at the ridge top area of the Naina Peak landslide area. This method measures the changes in information about sub-surface conditions, which commonly correlate with the interfaces linking different material layers with varying properties.

The inverse image of the ERT profile line is given in Figure 5. The ERT image is interpreted in terms of depth and type of sub-surface material layers and probable slip surface. Two different material layers could be interpreted at this site (i) the disturbed slope mass material (debris) layer with lower resistivity (<800 Ωm) values and (ii) the highly fractured incompetent rockmass layer (i.e., shale alternating with limestone) with middle range of resistivity values (800-1100 Ωm). It has been interpreted that the top layer is mostly dominated by disturbed slope mass debris material comprising of silt, clay and rock chips with stray patches of highly fractured incompetent rockmass at two places as observed at the site. Beyond 20-22 m depth, highly fractured incompetent rockmass layer with similar range of resistivity values as observed on the surface (i.e., 800-1100 Ωm)was found. Therefore, it can be inferred that the probable slip surface of this portion of the Naina peak landslide zone may exist at the interface between disturbed slope mass debris material and highly fractured incompetent rockmass layers at a depth of about 20-22 m.

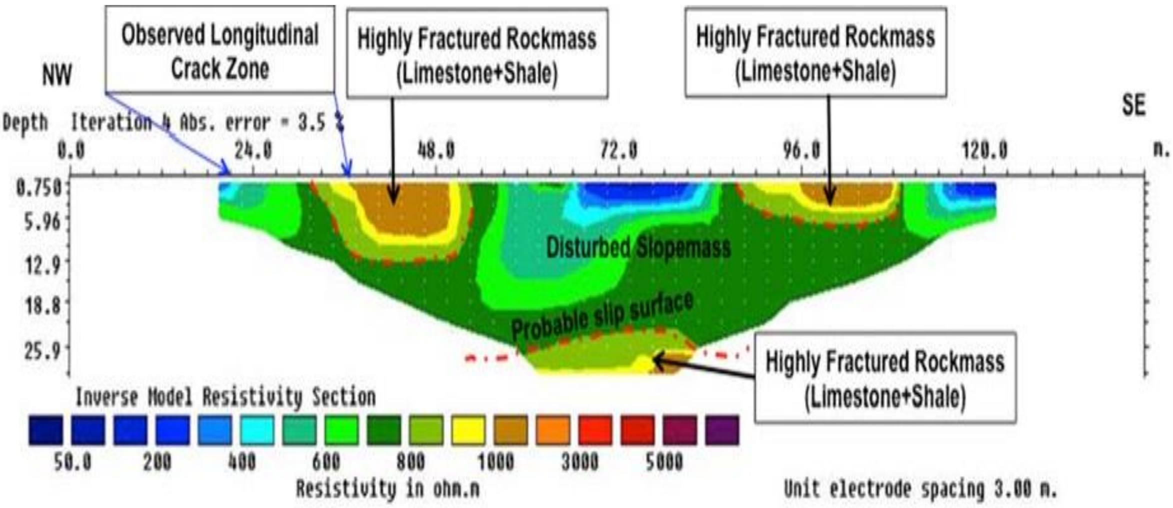



**Figure 5: Inverse image of ERT profile at Naina Peak landslide**

Based on the reconnaissance survey of the area and the ERT profiling, the previous committee recommended the following short and long term mitigation measures.

**Short Term**

It is strongly recommended that the ingress of rain water into the slope must be avoided in order to arrest any further movement/distress the crown portion of the slope. Therefore, the followings are suggested:

- At the first instance, it is recommended to fill up the existing cracks at site with the local material by scrapping the side-walls of the cracked portion and then to compact the filled up portion with simple timber-compaction method.
- Subsequently, the entire crest portion of the slope under distress, particularly the area where the ground cracks had been developed, must be covered with suitable impermeable lining/geo-textile material to prevent the ingress of rain water.

**Long Term**

The long-term mitigation measures should be implemented after studying the slope in details as mentioned below:

- Since many stretches of the area is inaccessible, the area must be surveyed using Drone.
- The entire hill must be scanned using terrestrial laser scanner (TLS), and periodic scanning must be done in order to observe any changes in the topography and to understand the movement mechanism, if any.
- ERT survey along and across different elevation contours is recommended to ascertain the geometry of sub-surface lithologies and probable failure surface and to draw realistic geological profile sections along the distressed slope.
- Detailed surface geological and geomorphological mapping on 1:1,000 scale must be carried out.
- Numerical slope stability analysis to understand the failure mechanism
- Planning and design of suitable remedial measures
- Numerical slope stability analysis with scheme of remedial measures
- Recommendation for implementation of scheme of remedial measures

## 6.0Causative Factors

The causative factors for the slope instability at Naina Peak based on the present field observation are as follows:

- The entire slope is composed of shale which is a soft rock and very prone to weathering. The rocks are highly fractured and jointed and forming rock pieces which are falling and rolling down the steep slope (Figure….).

**Figure 7: Shale rocks falling from landslide zone.**

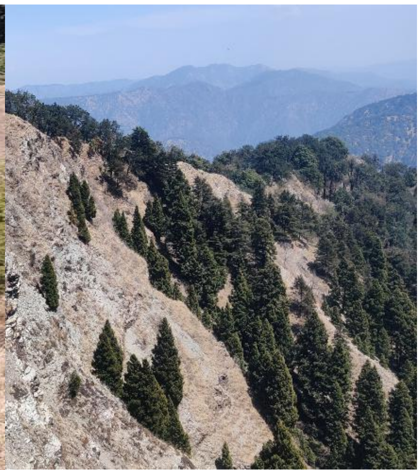


**Figure 8: The team taking geological data at Naina Peak**

- The presence of major tectonic feature namely, the Nainital Lake Fault near the area worsen the quality of the rock mass resulting in very poor quality of slope forming material.
- The top portion of the slope is barren with an average slope of about 50°-55° due N150°.
- The disposition of the joint sets present in the rock mass facilitates wedge and planar failures.
- The rainwater percolation along the joint planes during rainy season and frosting & thawing affect along the joint plane during the winter season widens the openings of joint planes which ultimately facilitates the rock failure.

## 4.0 Kinematics Analysis

The team collected geological joint data for carrying out the kinematic analysis to determine the probable failure mechanism. The kinematic analysis is used to evaluate whether blocks or masses of rock may move along geologic weak planes and slide out of the face of a slope**.** Based on field data of joint sets, kinematics analysis has been done and the results are represented in Figure 9. The basic data for kinematics analysis is the slope direction and orientation of various joint sets. The joint sets used for the analysis are

$J_1$ = 25° towards N 310° (bedding joint)

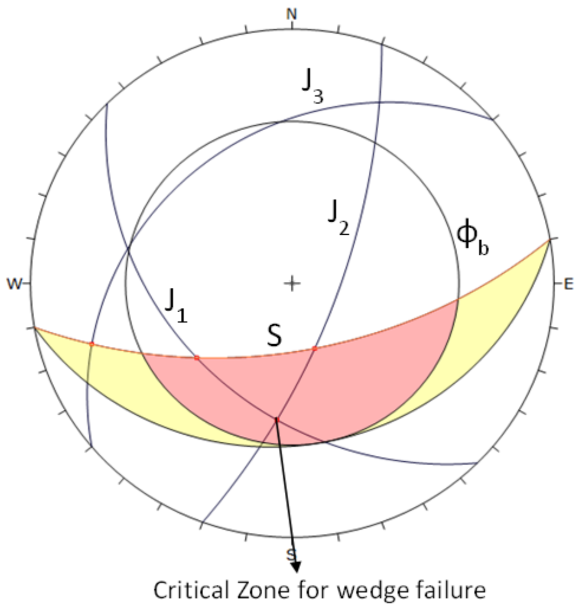
$J_2$ = 35° due N 210°

$J_3$ = 60° due N 70°

$J_4$ = 40° due N 110°

$J_5$ = 60° due N160°

Kinematic analysis indicates the wedge failure formed by the intersection of joint $J_1$ and $J_2$. Here, the plunge angle is less than the slope angle but greater than the basic friction angle that is the condition of wedge failure.



**Geological Strength Index (GSI)**

Structure Rating = -17.5 ln (26.3) + 79.8 = 22.7
Surface Condition Rating = 1+5+2= 8
Quantified GSI= 33

**Rock Mass Rating (RMR)**

RMR b = 12 + 8 + 8 + 9 + 15 = 52 (Fair Rock Mass Quality)
Slope Mass Rating (SMR)
SMR = 52 + (0.85 * 0.85 * (-60) ) + 15 = 23.6 (Unstable)

The UCS of a collected sample is 103 MPa that has been calculated using point load strength index. The calculated quantified GSI of this slope is 33 that is fall under blocky disturbed category of GSI chart. The determined RMR basic value of this slope is 52 which indicates Fair Rock Mass Quality of this slopes. The calculated SMR value of this slope is 23.6 that fall under unstable category of SMR chart.

## Mitigation Measures

The following mitigation strategy may be considered after a detailed geotechnical investigation of the site.

**Short Term:**

- Seepage of rain water into the slope must be avoided in order to arrest any further movement in the crown portion of the slope.
- Scrapping of the loose filled overburden material from the slope causing instability.
- Open cracks must be filled with the impermeable material at the site with help of local materials present in nearby areas and compact the material to achieve required dry density.
- Further few critical spots were identified during the field where several open tension cracks (~50 cm in length) are present. These should be covered with light weight material as to prevent the seepage of rain water and must be divert the flow of water to other side of the hill slope.
- Since the rock fall activity is continuously occurring for a long time and debris/rock chunks are collected at the previously build retaining walls at different levels, it is suggested that these should be removed in order to create space for further debris collection.

**Long Term**:
The long-term engineering mitigation measures should be designed and implemented after studying the slope in details as mentioned below:

- Drone based mapping of Naini hills to prepare large scale contour map, since many stretches of area are inaccessible. It will help to design and to find the prominent location of the retaining wall structures.
- Wire mesh as stone catching blanket should be used on slopes to prevent the movement of small sized stones.

## Wire meshing

Wire meshing is corrosion resistant material that is installed at the crest and foot of the slope. This insures that any falling debris is trapped behind the mesh. Wire mesh can be used to prevent smaller rocks, less than 0.75 meters. Bolting the mesh to the rock face can prevent from becoming dislodged and provides overall stability of the slope or rock face. Wire mesh also is useful on steep soil cuts, especially beneath talus slopes.

**Figure 10: Wire Meshing Protection Nets**

- 2-tier protection of rock fall barrier and RCC retaining wall of 6m-8m height are required to stop any further movement of big sized boulders entering into habitation area/road.

## Retaining walls

Retaining walls are relatively rigid walls used for supporting soil laterally so that it can be retained at different levels on the two sides. Retaining walls are structures designed to restrain soil to a typically steep, near-vertical unstable slope. They are used to bound soils between two different elevations often in areas of terrain having slope instability problems and in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses.

**Figure 11: Retaining wall**

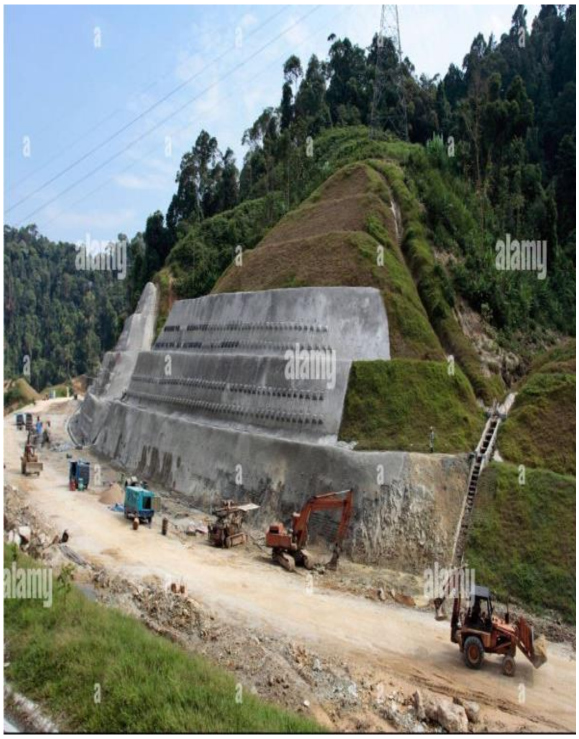


**Figure 12: Retaining wall in North east state site area.**

## Rockfall barrier Protection Nets

A rockfall barrier is a structure built to intercept rockfall, most often made from metallic components and consisting of an interception structure hanged on post-supported cables. Barriers are passive rockfall mitigation structures adapted for rock block kinetic energies up to 8 mega-joules. Alternatively, these structures are also referred to as fences, catch fences, rock mesh, net fences.

**Figure 13: Rockfall Barrier.**

**Concluding Remarks**

The above mentioned mitigation measures are only suggestive measures based on the field observation. There is a need to study the Naina Peak slide zone in greater detail involving engineering geological, geotechnical and geophysical investigation. The investigations along with slope stability analysis should be carried out for analyzing the correct type & position of mitigation measures for the landslide affected zone. The appropriate measures then should be implemented to control the slide and protect measures the habitation from rock falls.

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