Slope Stabilization & Rockfall Protection at Chenani Nashri Tunnel Portal

– A Case Study

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ABSTRACT: This article presents detailed slope stabilization and rock fall mitigation works done at north portal for Chenani-Nashri section of NH 1A from Km. 89.00 to Km. 130.00 including 9 km long tunnel with parallel escape tunnel in the state of J&K. The Chenani-Nashri tunnel cuts through the mountain to develop the road connecting the two places reducing the present distance of 30 km to 10 km, besides cutting down travel time by an hour. It was of the major importance that the tunnel stays safe of the imminent rock fall and landslide hazards. As a protective measure, the flexible slope stabilization system using high-tensile steel wire meshes was selected in combination with nailing along with Rock fall Barriers. The protective measure, the flexible slope stabilization system using high-tensile steel wire meshes (TECCO\textsuperscript{®}) having tensile strength of (1770 N/mm\textsuperscript{2}) in offset grid pattern was designed in combination with nailing depth ranging from 6m to 20m along with 500 KJ GBE Rock fall Barriers. Coir mesh in combination with hydro-seeding was used for vegetation growth. This widely used way to stabilize soil and rock slopes is economical and a good alternative to shotcrete solutions or massive supporting structures. Safety, cost-effectiveness, and sustainability: these are the main qualities of high tensile steel wire mesh (1770 N/mm\textsuperscript{2}) which is also easy to install and maintain.

Keywords: RUVOLUM, TECCO, dimensioning, flexible slope stabilization system, Tunnel Portal

1. Introduction

The use of flexible slope stabilization systems has proven their suitability around the world, including Europe, Asia, North America and in colder climates, where the stabilizing facings need to be able to flex under the freeze/thaw cycle. Historically, the mesh used for these purposes is produced using mild steel wire with a tensile strength of 400–500 N/mm\textsuperscript{2}. The development of mesh made from high-tensile steel wire with a tensile strength of at least 1770 N/mm\textsuperscript{2}, offers new possibilities for the efficient and economical stabilization of slopes (Fig.1 and 2). Sophisticated dimensioning concepts serve to dimension these kinds of slope stabilization systems against superficial instabilities by taking the statics of soil and rock into account [3].

2. Project

The site was initially proposed to be treated with shotcrete but persistent seepage of water which caused slope failures and cracks on the portals led the concessionaire to go for an alternate solution which doesn’t only stabilize the slopes but also offers a green solution and lets the hydrostatic pressure to disperse. NHAI decided to actively stabilize the tunnel portals. A protective measure had to be selected to stabilize the exposed cutting against superficial instabilities, tilting as well as sliding of individual blocks and rock fall. Total area of the slopes to be treated and protected amounts to a total of 32,000 m\textsuperscript{2} which includes 4 berms and the top path up to a maximum height of 55 meters approximately.

3. Protection Measures

The slope stabilization solution consisted of both active and passive protection measures.
3.1 Slope Stabilization using High Tensile Steel Wire Mesh

The flexible slope stabilization system consists of TECCO G65/3 high-tensile steel wire mesh and coir mesh, system spike plates and soil nails has been selected. The TECCO G65/3 wire mesh is made from 3 mm high tensile wire and uses a zinc-aluminum coating for protection against corrosion. Each diamond of the single twist of TECCO G65/3 mesh measures 83 mm x 143 mm. The high tensile steel wire of the mesh has a tensile strength of 1770 N/mm², compared to mild steel which has a tensile strength of 400–500 N/mm². As a result, TECCO G65/3 mesh has a tensile strength of 150 kN/m, which means substantially higher forces can be absorbed by this mesh in comparison to conventional mild steel wire mesh [1]. Aside from the higher bearing capacity, another advantage of TECCO mesh over conventional mild steel wire mesh is that it has an even load transmission and no weak zones within the mesh.

Total area of the slopes to be treated and protected amounts to a total of 32,000 m² which includes 4 berms and the top path up to a maximum height of 55 meters approximately. Each berm is stabilized using rock-bolts of a maximum depth of 20 meters in conjunction with high tensile steel wire mesh. Perforated drain pipes, wrapped in geotextile, at an interval of 6m x 6m are also installed to allow excess water to pass. In addition to this, vertical and horizontal drainage channels are provided to channelize rain and excess water to pass and not accumulate and seep under the slopes. Variable grid patterns of 2m x 2m and 2.5m x 2.5m are adopted on this project. 32 mm Ø, fully threaded rock-bolts are used in this project and total drill depth achieved is approximately 1,10,000 meters.

Special diamond-shaped system spike plates which match the load capacity of the mesh serve to fix the mesh to soil or rock nails. By tensioning these nails, and recessing the spike plates into the ground, the mesh is adequately tensioned to ensure it follows the surface contours.

With this slope stabilization system, the rows of nails are offset to each other by half a horizontal nail distance. This limits the maximum possible break out between the individual nails to a width “a” and a length of “2 x b” (see Fig. 4). The staggered layout is shown in Fig. 5 for this project after installation.

3.2 Rockfall protection using barriers

Based on the survey results authorities decided to apply an additional rockfall protection system from the GBE-Series. With its nets made of high-tensile steel wire the barrier design has been tested and approved to absorb impact energies of up to 500 KJ.

4. Dimensioning

4.1 Superficial slope analysis using Ruvolum

The RUVOLUM dimensioning method for flexible slope stabilization system includes not only wedge-shaped one body sliding mechanisms but also two-body sliding mechanisms are investigated when considering local instabilities. The geometry should be selected with simplifications so that a more or less shell-shaped failure body is simulated as far as the sliding mass is concerned. It is normally assumed for simplification’s sake that, as a reaction, a tensile force parallel to the slope is active on the nail immediately above the local failure mechanism to be investigated and a tensile force in nail direction is active on the nail underneath this mechanism.

The flexible slope stabilization system was dimensioned against superficial instabilities based on the RUVOLUM concept [2], (Fig. 6). The maximum nail spacing and the required nail length can be determined, and by utilizing the high bearing capacity of the mesh, significant cost savings can be realized by reducing the number of nails required. Conventional slope design methods are still required for deeper seated failure mechanisms.

Figure 6 illustrates the corresponding superficial instabilities parallel to the slope.

Fig. 6 The dimensioning concept is based on the investigation of superficial slope-parallel instabilities and
investigation of the local instabilities between single nails.

<table>
<thead>
<tr>
<th>Client</th>
<th>IL&amp;FS/Chenani – Nashri Tunnelway Limited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of installation</td>
<td>June ’15 to Jan ’17</td>
</tr>
<tr>
<td>Height of slope</td>
<td>60-70 m</td>
</tr>
<tr>
<td>Inclination of slope</td>
<td>65-70°</td>
</tr>
<tr>
<td>Stabilized area</td>
<td>32,000 m²</td>
</tr>
<tr>
<td>Nail type</td>
<td>Fully threaded rock bolts ø32 mm</td>
</tr>
<tr>
<td>Nail pattern</td>
<td>2.2m x 2.2m – 2.5m x 2.5m</td>
</tr>
<tr>
<td>Nail length</td>
<td>6-20 m</td>
</tr>
<tr>
<td>Mesh type</td>
<td>High-tensile steel wire mesh</td>
</tr>
<tr>
<td></td>
<td>TECCO G65 / 3 and Erosion Control Mat.</td>
</tr>
<tr>
<td>Spike plates</td>
<td>System spike plate</td>
</tr>
<tr>
<td>Rock-fall barriers</td>
<td>Rockfall barrier with energy</td>
</tr>
<tr>
<td></td>
<td>absorption capacity of 500 kJ</td>
</tr>
</tbody>
</table>

4.2 Rockfall simulation using Rockfall software

ROCKFALL is a computer program for the simulation of rockfall. It was developed by Dr. Rer. nat. R.M.Spang, Dr.-Ing. L. Weber, Dipl. Geol. N. Graf and Dr.-Ing. B. Romunde. The program is based on the laws of motion and the collision theory (Fig. 7). At each point within a profile (especially at the positions of planned interception structures or rockfall barriers) the kinetic energies and bounce heights can be calculated. The input data are varied by a random number generator within user defined boundaries. The results are presented in class and summation histogram (Fig. 8).

Fig. 7 Kinds of motion and resulting paths, (a) sliding, (b) rolling, (c) toppling, (d) inclined throw, (e) impact on surface.

5. Installation

Firstly, the slope was cleaned of eroded soil and smaller loose rocks. Due to the fact that the slope was quite steep and high, the installation company had to use various machineries such as crawler drills, cranes, boomers and platform mounted rigs were used (see Fig 10). It was very important that the nails should be installed in deep seated spots so that the mesh could been tensioned and kept in contact with the surface.

6. Re-vegetation / Erosion protection

Erosion control mats was installed underneath the mesh to aid in re-vegetation. The application of a vegetation layer can be limited by the soil or rock properties, groundwater and climate. The steeper the slope cutting, the more difficult it becomes for vegetation to grow. If re-vegetation is to be carried out, a species of plant or grass should be selected that is fast growing and suitable for the local conditions (Fig 11).
7. Conclusions
The Slope stabilization system and Rockfall barriers can be adapted to the site specifics and static conditions in a very flexible manner. The systems can be designed and dimensioned against superficial instabilities, which is the first time flexible surface support measures can be properly designed. This approach offers the possibility to arrange the nails in a more economical way due to the capability of high tensile steel wire mesh in absorbing and transferring high loads. When slopes stabilized with flexible high tensile steel wire mesh are combined with erosion control mats, they can regain a natural or vegetated appearance, which aesthetically is normally preferred.

References
Brändlein P. (2004). LGA Nuremberg, Germany, Monitoring and supervision of laboratory testing of the TECCO slope stabilization system, Test report BPI 0400046/1.
