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ABSTRACT

The Railway route through south – west part of India (Konkan Railway) is passing through a hilly terrain. The route is developed by cutting the mountains in slopes and construction of tunnels. Many slopes along this route are very deep and steep. The region is characterized by lateritic soil. A heavy monsoon initiates some of the deep slope failures resulting in large magnitude of loss – both in money and life.

The initial failure of one of the slope at Chainage 344/900 Km was stabilized by Gabion walls. West side of the Soil cutting was about 100 m long and a lateritic hilly slope steeply rises to 20 m above the track level at the collapse location. Initially the cutting line was 15m away from external track edge. However, after the heavy monsoon in June 2000, the soil slope collapses causing the lateral movement of the gabion wall and lateral shifting of the nearby railway track.

The investigation was carried out to study the failure. The scheme of combination of conventional Soil Nails and Micropiles in addition to Gabion wall was proposed. The scheme was executed in Jan 2001 to May 2001. Load Tests were performed on Micropiles and Nails to verify the design. The slope is successfully stable for last 10 years.

INTRODUCTION

The Railway route through south – west part of India (Konkan Railway) is passing through a hilly terrain. This route is of 700 Km long. It is developed by cutting the mountains in slopes, constructing high embankment, high bridges, excavating Tunnels. Many slopes along this route are very deep and steep. The route is opened for traffic in 1998 and immediately after opening of traffic, during monsoon season many accidents happened.

A heavy monsoon initiates some of the deep slope failures resulting in large magnitude of loss – both in money and life.

SITE CONDITIONS:

The case study discussed in further paragraphs is for the stabilization of Deep cutting located at Ch 344 of Konkan Railway Route. This cutting is a deep uphill cutting on both side, to east and west side, of the Konkan Railway Track. In general, monsoon in this region happened to be in month of June to September of every year. Average annual rainfall in this region is 4000 mm.

West side of the Soil cutting was about 100 m long. It is a lateritic hilly slope steeply rises to 20 m above the track level, at the collapse location. Initially the cutting line was 15m away from external track edge. A Gabion wall of 5 m base was provided to retain the soil face. In June 2000 after initial heavy monsoon rains the soil face collapse. The collapsed soil descended and caused lateral movement of the toe of Gabion wall near chainage 344/900 Km. It caused heaving of the Railway tracks and flow of the soil from hill face on to the Railway Tracks. It was decided to take permanent measure for stabilising this slope using some innovative techniques. A complete field work for stabilization of slopes carried out during Jan 2001 to May 2001.

Subsoil Condition

As a part of the project, 5 Nos boreholes were taken to ascertain the design parameters. Two Boreholes were sunk at the track level. One at the top of the slope and other at intermediate benches. These boreholes reveled following subsurface profile.

Stratum 1: Backfill (RL. 25.72 m to 23.22 m): The back fill of 2.50 m thickness was existed at the ground. It consists of loose state sandy – silty soil having bulk density 16 kN/m^3.

Stratum 2: Light Yellow and mottled white colour silty sandy soil with clay (RL. 23.22 m to 16.22 m) Upper backfill material is followed by light yellow and mottled white colour silty clayey sandy lateritic (lithomarge) soil. This soil existed to 9.50 m (RL. 16.22 m) below the top level of Gabion wall (RL. 25.75). The Standard Penetration Test Values (N) in this stratum was varying from 7 to 17. Laboratory test results showed the soil is non-plastic in nature. It contains very fine sand and predominantly silts. The properties of the layer are as follows.

- Bulk Density 17 kN/m^3
- Natural Moisture Content (%) 32
- Cohesion 22.50 kPa
- Undrained Angle of Internal friction 10 degrees

Stratum 3: Brown Colour Silty Sandy Soil With Cobbles And Gravels (RL. 16.22 M To 11.22 M) This layer encountered below the soft stratum 2. This stratum is comparatively dense having N value 36. This is medium to hard residual layer of lateritic origin. Thickness of the sol is about 5.00 m. The lateritic boulders are intercalated in stiff to hard clay.

- Density of the soil 18 kN/m^3
- Cohesion (Cu) 25 kPa
- Undrained Angle of Internal Friction 25 degrees

Stratum 4: Grey Colour Fractured Schistose; A distinct fractured zone of schistose rock was existed below the stratum 3. Core recovery of the stratum varies from nil to 60 % and crushing strength of 200 kg/cm^2 indicating medium strength rock.

Based on the soil profile and site condition the design parameter are tabulated below

Table 1

Properties	Density	Undrained Cohesion	Angle of Friction
	(kN/m^3)	(kPa)	(Degrees)
Layer 1	16	0	10
Layer 2	17	22.50	25
Layer 3	18	30	25
Layer 4	22		35

PROTECTION MEASURES

From the geometry of the collapsed slope and soil lines, it was reasonably assumed that the causes of the collapse could be-
Increase in density of soil due to in grace of rainwater. This increases weight of soil behind the wall in turn increases in stresses significantly.
Reduction in soil strength due to increase water content.
The seepage of water would have increase the seepage pressure drastically
Therefore, remedial measures suggested were based on
Removal of loose soil from the hill face.
Strengthening of the Gabion wall.
Provision waterproofing and cover on the exposed hill face.
Drainage of the rainwater falling on and around the hill slope.

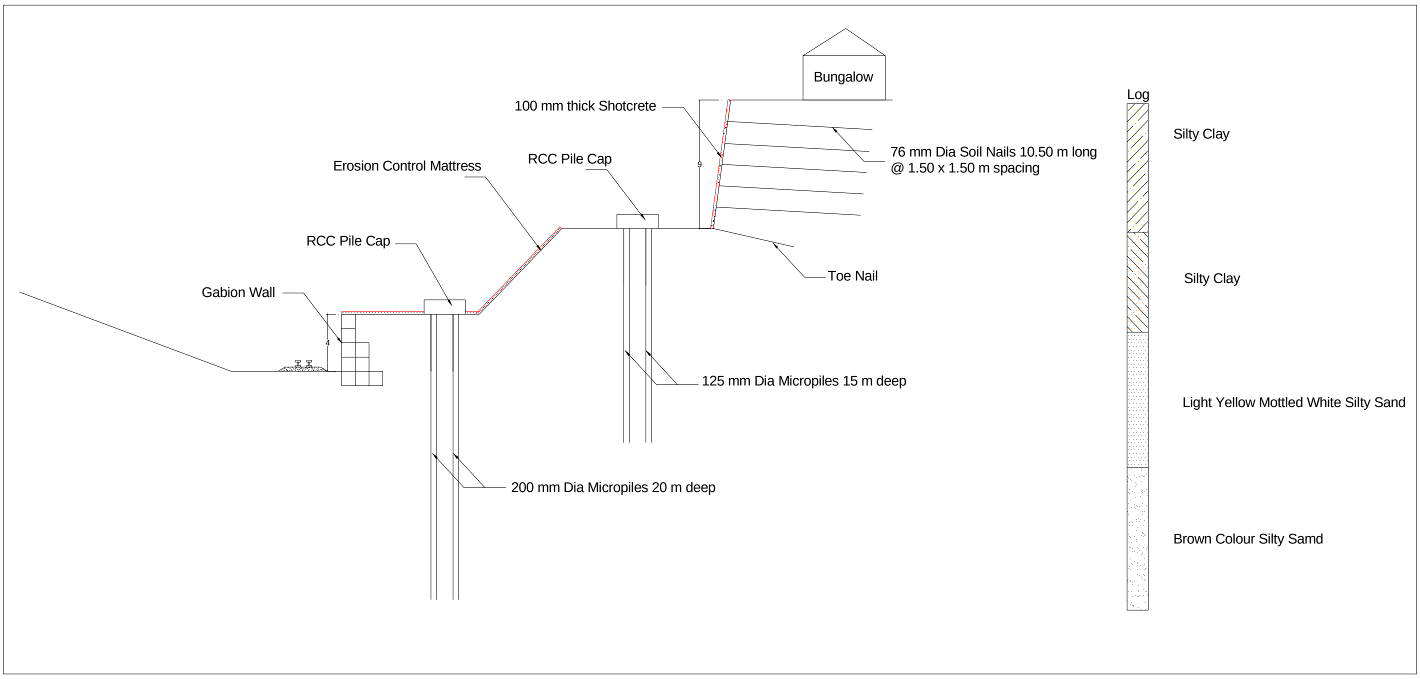

Fig.1. Schematic representation of Micropiles and Soil nail proposal

Scheme of Stabilisation of slope using Micropiles and Soil Nail (Fig. 1)

- Protecting the vertical 9 m high face of the top zone (Lateritic soil - Sandy) by Shotcrete. Provision of soil nails to strengthen the soil active wedge behind the face of Shotcrete wall. Soil Nails were spaced at 2 x 2 m grid.
- Strengthening of the Gabion wall by constructing 200 mm diameter reinforced Micropiles and supports it on stiffer layer. Depth of the Micropiles was 20 m. Such piles will be in two rows behind the toe-wall. Along the each row, the piles will be approx. 1.00 m centers.
- Strengthening the first bench by providing 125 mm diameter reinforced Micropiles in two rows having 1.00 m spacing in both the direction. Depth of these piles were 15 m
- Laying of the erosion control mattresses on the exposed slopes.

Basic Assumption for design

Micropiles are considered intermediate and fixed at ends.
Soil behind the Micropiles wall is cohesionless soil as the water level is high.
Ground water table is at 2.50 m below the top of the gabion wall (RL. 25.72 m) and likely to remain there permanently.
Critical failure plane is encountered at 6.50 m (RL. 19.22 m) below the top of the gabion wall. As shown in fig. 1. Prior to designing a slope protection scheme, Global stability analysis has been done. The Global stability factor of safety was found to be 0.80.

Salient Features Micropiles

Based on the soil investigations, laboratory test data and field observations during investigation, slope stability analysis was done using GEOSLOPE 5. From the slope stability analysis, it was decided to construct Micropiles at two levels –

- First group at RL 25.75
- Second group at First bench of R L 33.15

At RL. 25.72 m., 200 mm diameter staggered Micropiles were installed in 2-rows at spacing 1.0 meter center to center. Theses Micropiles were encased with Mild Steel Casing till the rock level. Further 4 meter was drilled in the rock to achieve proper socketing.
As the diameter of the pile is 200 mm and the soil properties are very bad, to avoid shrinkage of the grout it was recommended to use sand-cement grout in the ratio of 0.5:1 with water cement ratio, 0.55 to 0.60.
After the completion of Micropiles, three Micropiles of 200 mm diameter and one of 125 mm diameter was tested for design load by applying lateral load and deflection was noted. From the load test following data was observed:
In addition, to reduce the lateral load on the 200 mm diameter piles additional 2-rows of 125 mm diameter Micropiles at 1.00 m center-to-center spacing at upper bench were installed.

Table 2

Pile Diameter	Test Load	Total Deflection	Net Deflection
(mm)	(Tons)	(mm)	(mm)
200	48	5 to 7	0.23 to 0.43
125	30	3 to 4	0.04

For the piles to act in a group pile cap was constructed. The pile cap was designed as continuous beam with 1500 mm as width and 500 mm as depth.

Fig. 2 Construction of Gabion wall along the track

Salient Features of Soil Nail

Passive Soil Nailing Technique has been designed for slope strengthening of upper 9 m high vertical cut.
Soil nails of 76 mm diameter and 10.50 m long with horizontal and vertical spacing of 1.5 m each were installed. From the study of the Borelogs, a layer of lateritic soil of thickness around 3.5 m was observed. Hence, to transfer the load to firm strata an additional row of soil nail of diameter 112 mm and inclined at 45 degrees was designed and installed at the bottom of the vertical cut.

Construction of Micropiles and Soil Nail

Machinery:
Drilling Equipment: The construction equipment used for installing Micropiles and Soil nails were as follows
Hydraulic rotary air flushed equipment with Compressor of 450 cfm was used
Grouting Equipment: In order to produce uniform grout mix a high-speed shear colloidal mixer was used. High-pressure pumps like Colomono Pumps used for grouting.
High-speed colloidal mixer of Colcrete was used for grout mix production.

Fig.4. Construction of Micropiles for upper bench and Soil Nails

Material

Permanent Liner*:* This was a flush liner made up of flush-coupled seamless pipe having 219 mm diameter and 4 mm wall thickness.

Steel Reinforcement*:* High Yield Strength Deformed bars as per IS 1139-1966 of grade Fe 415were used in piles. The reinforcement consisted of four Nos. 25 mm bar tied together with spacers at 1 m c/c.

Cement: M53 grade Narmada cement was used for grouting.

Sand: Well-graded local sand was used for sand cement grouting.

Water: Water suitable for concrete was used for grout preparation.

Fig. 3. Construction of Micropiles for the First Bench at RL 25.72.

Construction of Micropiles:

Initially drilling of 219 mm diameter was carried out in overburden with percussion drilling method.

After the hole is drilled upto overburden, the permanent liner was lowered with boring tools through overburden. Thereafter the drilling of 200 mm diameter was continued to the required depth of rock socketing.

Once the full depth of the hole was reached, it was cleaned with air flush to remove unwanted sediments at the base of the borehole. After the drilling and flushing, the reinforcement assembly of four Nos. of 25 mmφ, bound together of suitable lengths was lowered in upto the bottom of the pile. Reinforcement laps were welded in position.

Water was flushed through the central grout pipe until the clear water from hole emerged. Grouting was started only after the clear water emerges out of the drill hole. A stable sand cement grout (Sand: Cement = 0.5: 1.0) with water cement ratio of 0.4 was prepared in a colcrete mixer and sent down through the grout pipe with the help of Colomono pump. This pipe was lowered to a depth about 50 mm above the bottom of the hole. As the grouting proceeded, the pipe was raised gradually such that at least 2 to 3 m of grout will remain above the tip of the grout pipe. Grout cubes were casted during the grouting and tested. Results showed that grout had compressive strength of 200 to 300 kg/cm^2.

Construction of Soil Nail

Initially drilling of 76 mm diameter was carried out horizontally with percussion drilling method to the required depth of nail. Once the full depth of the hole was reached it was cleaned with air flush to remove unwanted sediments at the base of the drill hole.

Construction of Soil Nail

Initially drilling of 76 mm diameter was carried out horizontally with percussion drilling method to the required depth of nail. Once the full depth of the hole was reached, it was cleaned with air flush to remove unwanted sediments at the base of the drill hole.

After the drilling and flushing, the reinforcement - 1 No 25 mm φ - was lowered upto the full depth of the soil nail.

Water was flushed through the central grout pipe until the clear water from hole emerged. A stable cement grout with water cement ratio of 0.40 was prepared in a mechanical mixer and sent through the grout pipe. As the grouting proceeded, the pipe was removed gradually. Grout cubes were cast during the grouting and tested. Results showed that grout had compressive strength of 270 to 465 kg/cm2.

SUMMARY AND CONCLUSIONS

The project involved the stabilization of deep soil slope cutting. For this, Micropiles were constructed at two different levels. At lower bench total 157 piles of 200 mm diameter were constructed whereas at upper bench total 90 piles of 125 mm diameter were constructed. At lower bench, the depth of

Micropiles was 18 m, whereas at upper bench the depth of Micropiles was 10.50 m. Soil nailing was done for the protection of vertical face. Total 65 Nos. nails of 76 mm diameter and 10.50 m depth were constructed. The pile load tests were conducted to check the capacity of pile. Two Micropiles at each level was tested for design load. The work was carried out prior the monsoon. The work was executed in Four months, between January – 2002 to April 2001. During Jan – March 2001.

Fig. 4. Construction of Soil nail

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