Applicability of Ground Penetration Radar (GPR) Technique to Optimize Soil Nail Wall Designs

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Abstract

Soil nailing is used to stabilize existing natural slopes or excavations using soil reinforcement technique. Due to lack of information on ground profiles and thickness of soil layers, the required soil nail lengths cannot be determined in advance, for most of the steep slopes. Furthermore, the cost of drilling in fresh rock is much higher than the cost of drilling in soft soil and weathered rock. Without proper information on the depth at which the fresh rock is found, a cost-effective soil nail wall design cannot be finalized. This research was focused on studying the methods that can be used for soil nail wall design optimization by applying Ground Penetration Radar (GPR). The study was carried out on an unstable slope near Nursing Training School located in Kandy in the central part of Sri Lanka.The physical properties of soil were determined by direct shear tests, and stability analysis was done by means of "Slope-W" software. GPR techniques were also used in this study. The investigation results showed that the existing slope is unstable, and necessary to be protected. Further, it was identified that the basement rock cannot be encountered at already designed depths of the soil nails, which was subcequently proven as correctbased on data from ongoing drilling for soil nail installations. With the precise knowledge about the underground geological structure using GPR technique, the drilling cost, nail transporting cost, nail off cutting time to complete the total work can be reduced.

Keywords: Ground Penetration Radar, Soil Nailing, Slope Stability Analysis

1. Introduction

Soil nailing is a technique in which soil slopes, excavations or retaining walls are passively reinforced by insertion of relatively slender elements, normally steel reinforcing bars [1]. Soil nailing is generally considered as a cost-effective technique in the world, the cost effectiveness has not yet been achieved in most of the soil nailing applications in Sri Lanka. It is one of the most expensive methods which are being used for slope stabilization in Sri Lankan construction industry. Due to lack of information on ground profiles and thickness of soil layers, the required soil nail lengths cannot be determined in advance, for most of the steep slopes. Furthermore, the cost of drilling in fresh rock is much higher than the cost of drilling in soft soil and weathered rock. Without proper information on the depth at which the

fresh rock is found, a cost-effective soil nail wall design cannot be finalized.

When the fresh rock is encountered it is possible to terminate the soil nail after advancing 3.5m into the fresh rock. A 3.5m advancement is required to confirm that the rock is not a boulder. Therefore, the information on bed rock profile is advantageous to optimize the design and the BOQ. [2, 3]

1.1 Study Area

This study area is situated near the Nursing Training School (NTS) in Kandy. It is based on an unstable slope that is to be stabilized using soil nailing techniques. The excisting hostel building of the NTS is situated just infront of an unstable slope, and the site map is given in Figure 1.

At this location, a weathered quartzite rock layer and a Charnokite rock layer are present. Here, the slope that is to be protected by soil nailing is very much steep, and hence a drilling machine cannot be mobilized to get the required geological information by a borehole survey.

However, the basically required subsurface information have been gathered by advancing two boreholes such that one at the top of the slope and one infront of the hostel building where the drilling machines could be mobilized easily.

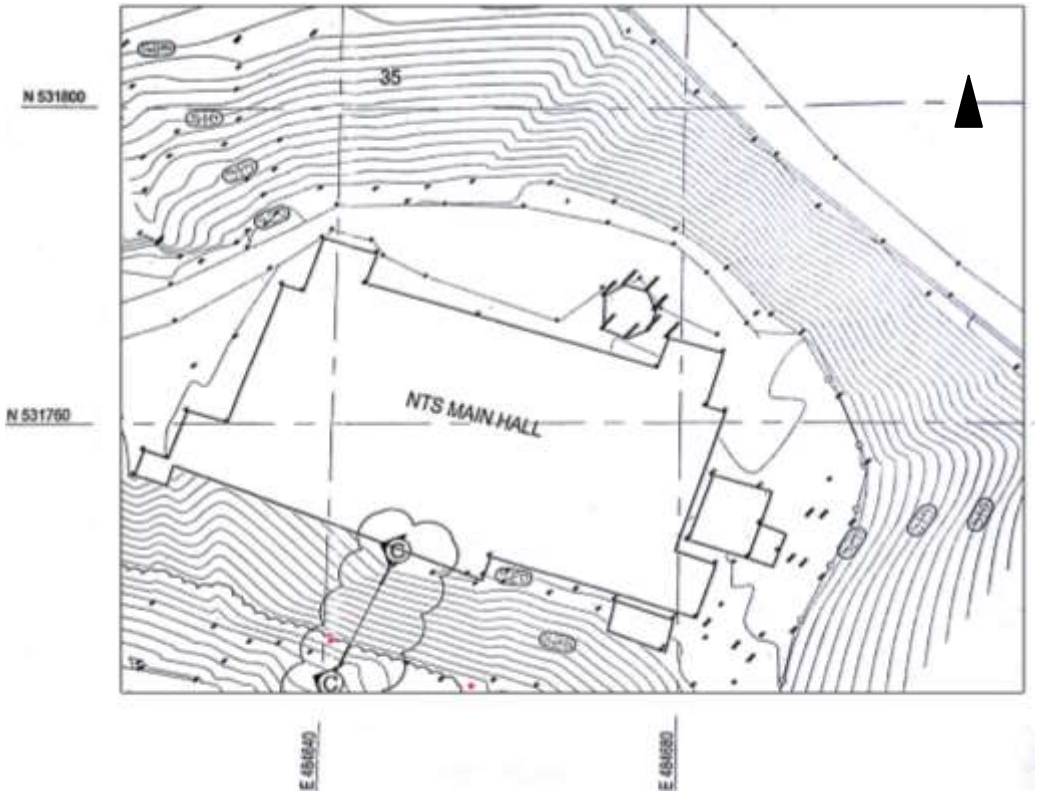

Figure 1 - Soil nail wall construction site near to the Nursing Training school (NTS) at Kandy. (Not to scale)

2. Methodology

2.1 Preliminary Investigations

Familiarising with the site conditions was the first step of the project. The background information and the technical aspects of soil nailing were gathered through a literature survey. Further details were gathered using available topographical and geological maps, interpretations from contour survey and borehole investigations that had already been conducted by ELS Pvt. Ltd.

2.2 Determination of Physical Properties of Soil

Physical properties of soil at the site was determined by performing direct shear tests, on the undisturbed soil samples which were collected from the site.

2.3 Stability Analysis

One of the steepest slopes was selected and cross sections of the slopes were drawn by AutoCAD software. Slope stability analysis was carried out under the saturated conditions for the selected cross sections, and possible slip surfaces for each cross section were identified by means of 'Slope/W' software.

2.4 GPR surveys

GPR surveys were conducted on the crest of the slope to find the bedrock levels.

2.5 Geological Interpretation of the Profile

GPR data and Drill hole data (taken from the actual site when drilling) were used for this process by taking required measurements at the site. With the combined effect of all the data the cross-sectional geology was identified by means of 'AutoCAD' software.

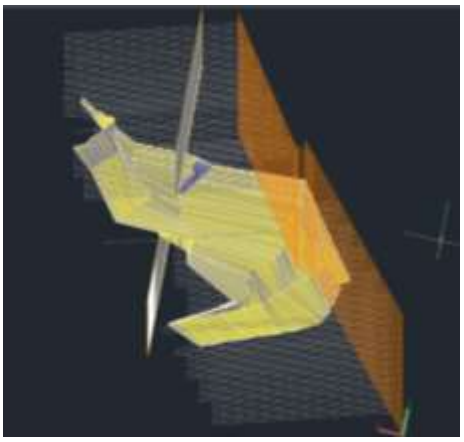

Figure 2 - Comparing GPR & soil nail drill hole data by means of AutoCAD software

3. Results

3.1 Stability Analysis

According to the data which were available at NTS Kandy soil nail site we were able to develop a model using the "Slope/W" modeling software to determine whether this soil surface is able to resist against failure conditions. Stability analysis were done and factor of safety was determined for

- Slope without soil nailing
- Slope after inserting the 12m long nails in to the soil slope
- After fresh rock was found shortning the nail length up to 3m into the fresh rock

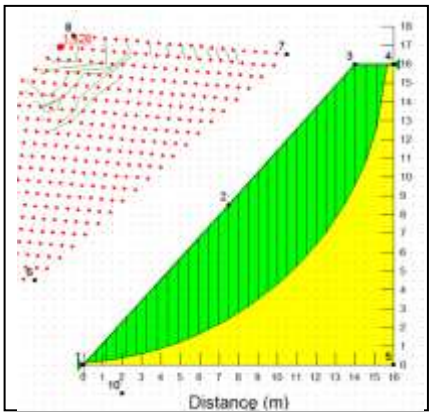

Figure 3 - Identified slip surface (Not to scale)

3.2 GPR field survey

The depth of penetration of the GPR instrument was 10m to 15m and it was sufficient to identify rock formation at the location of the GPR survey. However, the boundaries between top soil layer, weathered rock layer and fresh rock layer were identified by using GPR survey results as shown in Figure 4.

4. Discussion

4.1 Nail length analysis using "Slope/W" software

The process of Nail Length analysis using Slope/W software was carried out to determine up to what level we can reduce the nail length of a soil nail with having the required FOS when there is a fresh rock like natural feature inside that soil slope.

The Ground Penetrating Radar (GPR) can be identified as an accurate method to identify the bed rock levels in order to identify the sub surface geology which can be used for precise determination of bed rock profile at a steep slope [4].

GPR can be used to determine the depths to bedrock and reduce the number of required cores [5, 6]. Where soils are suitable, GPR is more reliable and effective than traditional soil survey tools for determining the depth to bedrock and the composition of soil map units that are based on soil-depth criteria.

Software oriented soil nail wall designing is much more flexible and efficient than manual calculation based methods [7].

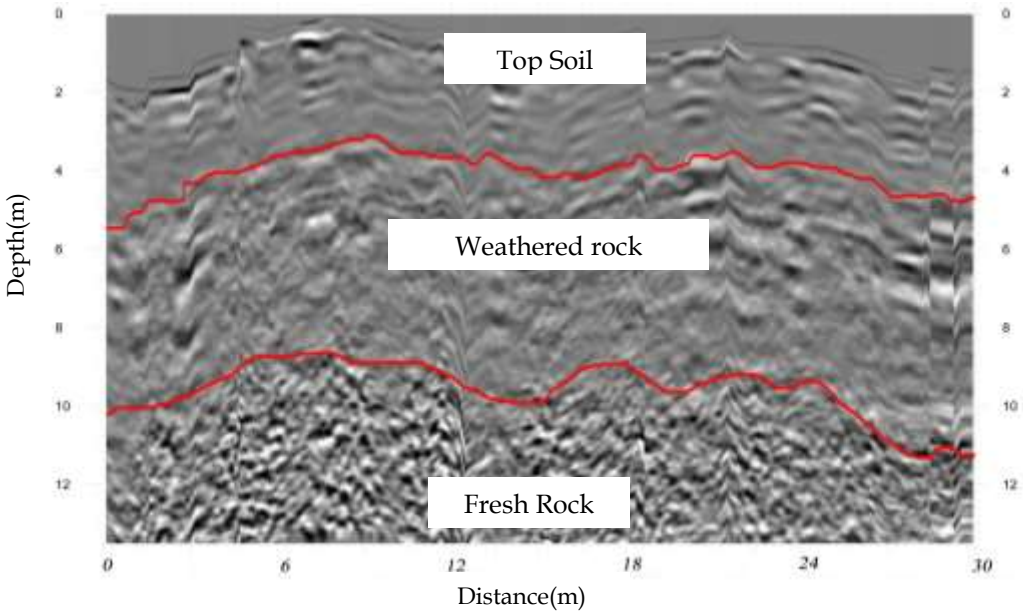

Figure 4 - GPR survey result along the slope (Not to scale)

Man-made materials prove to be a more heterogeneous medium for radar probing, and silty or heavy clay soils prove difficult to penetrate. Where the material is composed of mixtures containing, for example, rubble, the radar pulses are multiply reflected, thus creating a randomly orientated image [8, 9].

Table 1 - Soil nail length vs FOS

Nail Length (m)	Nail length inside the rock (m)	FOS
7.00	3.00	1.678
7.50	3.50	1.686
8.50	4.50	1.702
9.00	5.00	1.710
9.50	5.50	1.718
10.00	6.00	1.727
10.50	6.50	1.734
11.00	7.00	1.742
11.50	7.50	1.750
12.00	8.00	1.758

5. Conclusions

Based on the research outcomes of this study, following conclusions can be made:

- To develop and identify the actual situation of the underground geological structure, a complete and accurate grid survey should be carried out by using the GPR instrument.
- To perform a complete soil nail wall design, a set of information (Field, laboratory testing data of soil and rock parameters, etc.) has to be obtained.
- A soil nail wall design should be done considering the cost and environmental impacts. Furthermore the stability, serviceability and durability during construction and throughout its design life have to be considered.
- Maintaining an adequate safety margin against all the perceived potential modes of failure is a crucial factor while designing a soil-nailed system.
- The soil nail design optimization could be achieved by integrating data from GPR survey and advancing a minimum number of boreholes to confirm the GPR data.
- With the knowledge about the underground geological structure, drilling cost and nail transporting cost, The time taking to complete the total work can be optimized up to a considerable level.

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