Identification of Soil/Rock Interface using GPR Technique for Soil Nail Wall Design

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Abstract

Soil nailing is one of the common slope stabilization techniques which has been used in Sri Lanka during the past decade. Due to the advantages of this method, its applications are growing rapidly around the landslide hazard areas in Sri Lanka. Applications of subsurface investigation methods which are used to identify soil/rock interface are limited due to steepness of the slope areas. Since lesser information available about the bed rock geometry, this leads to generate a low cost effective design for soil nailing. The aim of this research is to demonstrate applicability of GPR for optimizing soil nail length. The study area is located near the Nursing Training School Kandy, that has been proposed to be stabilized by using soil nailing technique. GPR readings were taken on the pre-determined traverse lines. Soil/Rock interface identification was done by using survey results together with their interpretation, and geological cross section was produced. GPR imaging indicated that the bed rock level variation at this location is from 15 m to 18 m. It was identified that design length of the soil nail is shorter than depth to the bed rock on the slope with the aid of the diagram. Therefore, it was identified that soil nail length cannot be optimized for the location. The scope of the GPR survey was to find the depth to the bed rock. By using that, length of the soil nail can be optimized and soil nailing process can be performed more efficiently. However, the depth to bed rock level on the slope has to be less than the design length of the soil nail to optimize the soil nail length by means of this technique. This research illustrates the benefits of using GPR to provide understanding about the soil/rock interface in a slope area for the optimization of soil nail length.

Keywords: Ground Penetration Radar, Slope stabilization, Soil nailing, Subsurface investigation

1. Introduction

Soil nailing is a practical and cost effective technique to stabilize slopes and excavations through the introduction of reinforcement into the soil mass [1]. Soil nailing technique is used in many geotechnical applications to improve stability of excavated vertical cuts and existing slopes [2]. Even though, this method is very cost effective, the same level of cost effectiveness had not yet been achieved in Sri Lanka. In order to achieve the cost effectiveness, analysing and profiling subsurface geology is very much important. People normally install soil-nails

without studying variations in subsurface bed rock geometry. However, by examining the bed rock geometry of a slope, soil nailing can be carried on more cost effectively.

In the designing stage of any soil nail project, a broad range of information is needed to ensure an economical design. To gain the necessary information on the subsurface geology, several borehole samples are required. Due to the steepness of the slope and lack of it's accessibility, the applicability of borehole investigation method is limited. When bed rock is encountered, soil nail could be terminated after advancing at least 3.5 m into the bed rock, after confirming that it is not a boulder. Therefore, according to the depth of the bed rock on the slope, nails are required in different lengths to stabilize the slope. However, in most of the projects, soil nails are fabricated at a fixed length. Therefore, this leads to produce a large number of off-cuts of soil nails, which is a waste.

Identification of exact length of required nails is very much advantageous for planning of any soil nail project.

1.1 Study Area

This research was carried out on an unstable slope. The slope was proposed to be stabilized by using soil the nailing technique.

This study area is located near the Nursing Training School Kandy. The steepness of the slope to stabilized (nearly 40^0 to 45^0 to the horizontal). Makes the mobilization of the drilling on to the slope. The staff accommodations of the Kandy Hospital are located in the upper and lower section of the slope. The whole slope area is fully covered with soil and no exposed rocks are observed on the slope. Part of the slope is proposed to be stabilized by soil nailing technique. Further, another unstable section of the slope located down side of the study has now been stabilized by means the same technique.

Figure 1- Satellite image of the study area (Source: Google Earth)

2. Methodology

2.1 GPR Survey

GPR survey methodology is based on the transmission of an electromagnetic wave into the medium and a later reception [3]. "Akula 9000C" GPR instrument and "GAS XP" software were used for this survey. Survey traverse explained in Figure 2 was followed to gather more results about underneath rock/ soil layers.

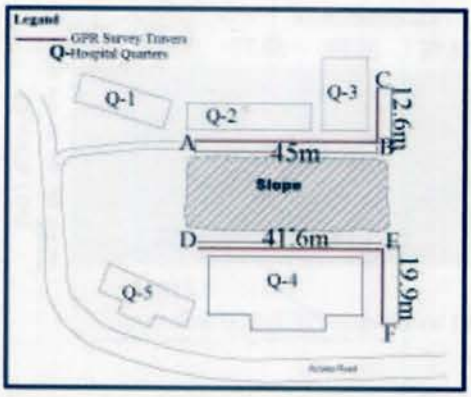

Figure 2 - GPR survey traverse

2.2 Data Processing

Data processing is essential to identify respective subsurface rock/soil layers and their thickness.

After completing the GPR survey, data processing was carried out at the university and with processing completed using "GPRSoft PRO" software [4], [5].

2.3 Generating a Geological Cross Section

The prime object of the research was to produce a geological cross section of the slope. With the completion of the geological interpretation, a cross section was developed along the CBEF plane by using AutoCAD software. Identified details of the upper surface and lower surface were separately mapped. Then, the details of the upper surface and the lower surface were connected and full cross section was produced.

3. Results and Discussion

3.1 GPR Survey Results

Acquired GPR data were processed and bed rock profiles were identified in the radargram. GPR profiles of four main traverses are given in the Figure 3 to Figure 7. Separation line between top soil and weathered rock is given by No 01, whereas separation line between weathered rock and fresh rock is given by No 02.

GPR profiles along the lines AB, CB, DE and FE are illustrated in Figure 3 to Figure 7 respectively

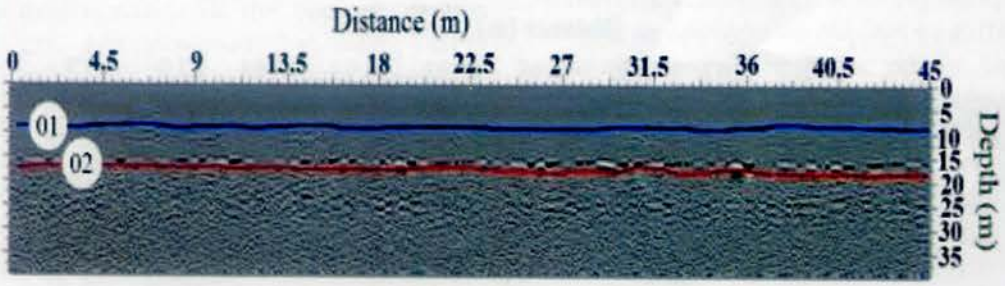

Figure 3 - GPR survey profile from A to B

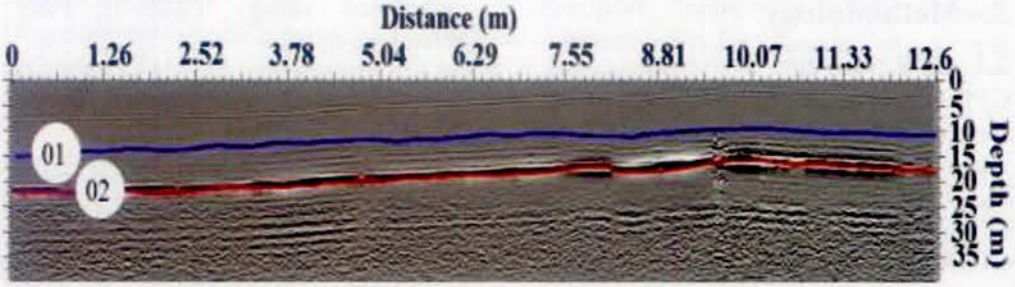

Figure 4 - GPR survey profile from C to B

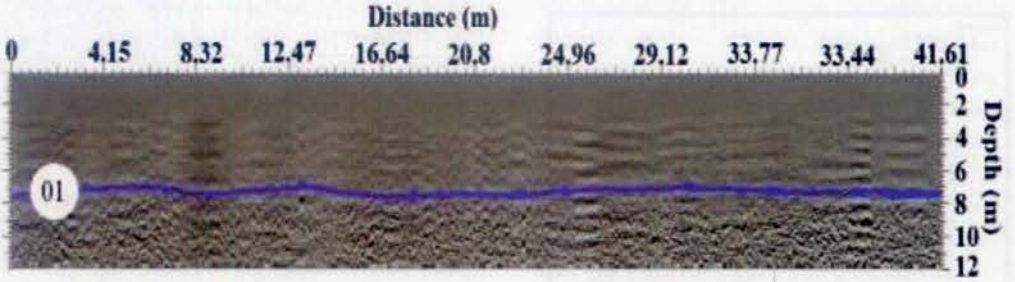

Figure 5 - GPR survey profile from D to E with GCB 100 antenna

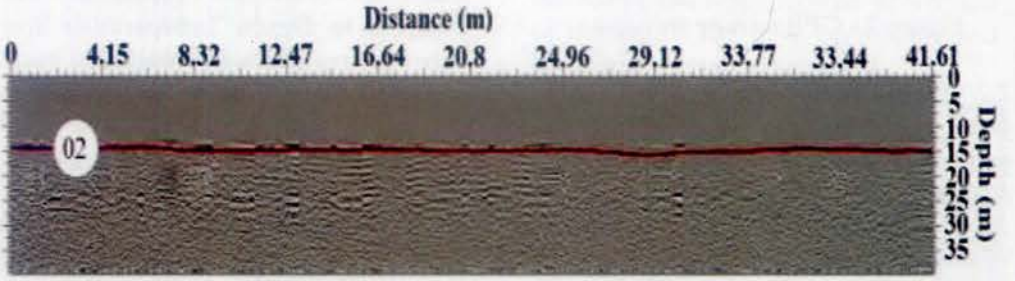

Figure 6 - GPR survey profile from D to E with Gekko 60 antenna

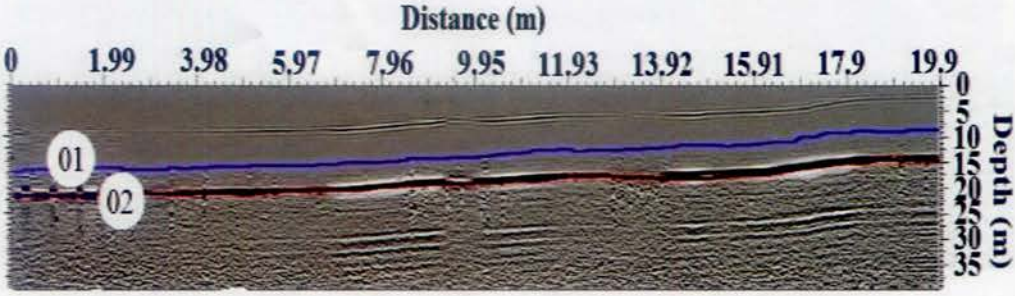

Figure 7 - GPR survey profile from F to E

3.2 Geological Cross Section of the Slope Area

According to site conditions, the maximum length of a soil nail is 12 m with 15^0 to the horizontal [6]. By analysing the cross section, It was identified that the soil nails are not intercepting the bed rock profile, on bed rocks were identified to be lying deeper.

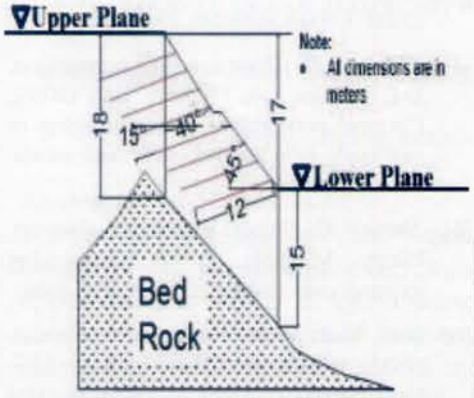

Figure 8 - Bedrock profile of the slope (not to scale)

4. Conclusions

According to the developed geological cross section, it can be identified that the soil nails are not penetrating into the bedrock. Therefore soil nailing has to be continued as designed for this location.

Accuracy and precision of determination of the bedrock profile can be increased by using GPR technique at a steep slope compared with conventional subsurface investigation methods. When considering the speed of data collection and ease of use, GPR is identified as a capable instrument. The grid surveys carried out by mean of GPR instrument have been useful to identify the necessary and sufficient information of this steep slope. Usability of the GPR technique depends on the accessibility to carryout the survey at site. Site should be at least accessible in both upper and lower planes (Figure 8) and enough space should be available to establish survey lines.

The understanding about subsurface geology and depth to the bed rock of a proposed site is important in the initial planning stage of the soil nailing project, especially in calculating the Bill Of Quantities (BOQ) for the project. It also helps to minimize the drilling cost, soil nail cost and time consumption, which eventually helps to optimize the soil nail wall design.

5. Recommendations

Applicability of GPR to map geological structures beneath the surface is recommended as an economically viable technique to optimize soil nail wall designs at the initial planning stage of similar projects.

Among several methods, GPR method is easier to implement and is also a cost effective methods that can be used for bedrock mapping. As it presents a clear indication of the bed rock profile, it reduces the number of borehole data needed.

Traverse used in a GPR survey should be in an appropriate manner to gather data precisely beneath the surface. Use of a survey grid is recommended rather than using single survey lines to acquire data on the site. It improves the accuracy of the final geological cross section. Accurate geological cross section is essential for optimizing a soil nail wall design.

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