Structural Mitigation for Stabilizing Rock Slope Failure at Peradeniya on Colombo-Kandy Main Road; Geotechnical and Constructional Aspects

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Abstract: Rock slope failure at Kandy -Colombo highway near Peradeniya town has been identified as a major threat to the highway as well as the people and properties of the vicinity. This study proposes a permanent mitigation plan for the rock slope failures at this site. Study was initiated with the analysis of similar case studies and field studies on the site area and mitigation options. Two level surveys were carried out to collect topographical data for preparation of a 3D model of the slope. Material identification was done by using particle size analysis and plasticity tests; direct shear tests were carried out to determine the friction angle, cohesion and density of the material. Mitigation plan was designed according to the site conditions. The design was analysed for nine sections on the slope for its stability with the test results by using Geo-studio 2004 software. Reinforcements were proposed to improve the stability whenever needed. An appropriate drainage system was also designed having analysed the past rain fall data of the area. The proposed mitigation plan in this study is a highly stable, safe, trouble-free and economically feasible one, and that can be implemented on this site.

Key words : cohesion, factor of safety, friction angle, reinforcements

1. Introduction

Landslide is one of the main natural hazards in Sri Lanka, especially in the central hilly part of the country. A large amount of lives and properties were destroyed by these landslides in the past. (Arambepola et.al, 1997) The abandonment of such sites without going for a mitigation program was practiced as the main solution for many decades. But there are sites such as urbanized area related, road related, reservoir related & etc which are essential to be mitigated to recover due to the importance of the location. E.g.: Watawala, Viharagala, Pussellawa & etc. (www.nbro.gov.lk).

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The first landslide in the hill area adjacent to the Peradeniya town was reported in 1979 and several failures have been reported from the site since then. Though several temporary measures had been taken time to time, no proper mitigation design has been proposed for this site until 2006 failure (Wijewickrama, 2006).

After 2006 failure this site was proposed for mitigation, having understood the importance of the location. (Colombo-Kandy high way runs adjacent to this site, Peradeniya town lies beside that site & it's a highly populated area). Therefore National Building Research Organization (NBRO) was given the responsibility of mitigating this site. Since then NBRO has done a considerable work on the site by managing the threat with temporary measures. Presently NBRO is in the process of revising the slope stability designs according to latest data of the mitigation design.

The main objective of this study is to propose a suitable mitigation design to stabilize this slope failure which fulfils the requirements of the site and evaluate the performance of the complete mitigation project

2. Material and Methods

2.1 Literature review & Site visits.

Data collected on past and present condition, geological features, land use, potential causes etc.

2.2 Level surveys & 3D model

Two level surveys were carried out on the exposed rock to get accurate data on the bed rock position of the slope. The data regarding the top soil overburden was collected from NBRO. 3D model of the slope was prepared with Surfer 8.0 software

2.3 Geotechnical testing

Well representative samples were collected from four sections (H, J, L & N) (Fig. 1) of the slope and their particle size distribution & the plasticity were analysed.

Direct shear tests were carried out on undisturbed samples to determine the friction angle (Ø), Cohesion (c) and density (r) which were used for the assessing of the factor of safety of each section of the slope with Geo-Studio 2004 software.

2.4 Designing the model

The most vulnerable sections of the slope (section G to N in Fig. 1) were selected and their stability levels were checked with Geo-slope 2004 by means of the factor of safety (FOS). A

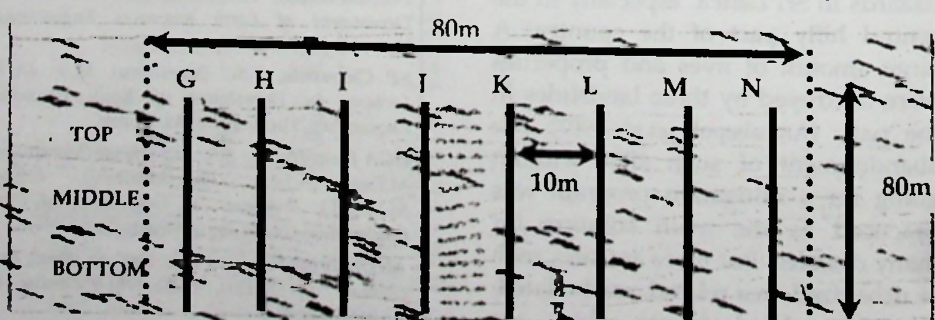

Figure 1 Section plan of the site

suitable, economical and practicable slope design which improves the stability of the slope in all sections was

Table 1- Sieve analysis test results

Section	Classification	Gravel M (%)	Gravel F (%)	Sand C (%)	Sand M (%)	Sand F (%)	Silt C(%)	Silt M(%)	Silt F(%)	Clay (%)
H	SM	2	5	26	44	74	84	92	98	100
J	SM	4	10	21	37	78	87	96	99	100
L	SM	7	14	28	53	77	88	95	99	100
N	SM	7	16	28	48	77	87	96	98	100

designed and their improved stability was calculated. The sections in which the FOS below 1.5 were proposed to improve their stability by using soil anchoring.

2.5 Rain fall data analysis & drainage system

Complete rain fall records of last six years and maximum rain fall data of past 43 years of the site area were analysed and a suitable drainage system including a gutter system and a surface protection method were proposed for the site.

3. Results

3.1 Sieve Analysis & plasticity test.

Results show that the slope material is non plastic sandy soil. (Table 1)

3.2 Direct shear test

Direct shear tests results can be finalized as follows.

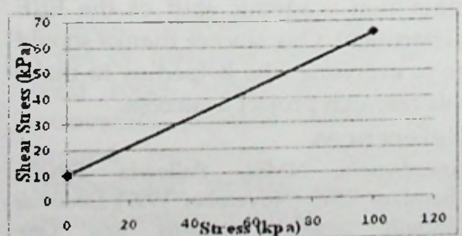

Figure 2 – Direct shear test results

Table 2 - Direct shear test results

Cohesion (c)	10kPa
Friction angle (Ø)	29°
Material Density (r)	15.1kN/m³

3.3 Proposed slope design for the site.

Slope design that is proposed by this study for this site (Fig. 3).

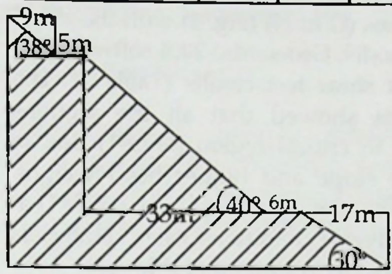

Figure 3 – Proposed slope design

3.4 Factor of safety calculations

FOS of all eight sections for existing, adverse and new design conditions

Table 3 - Factor of safety calculations

Section	Existing SF	Adverse SF	New Design SF
G	1.153	0.825	1.52
H	1.117	0.793	1.706
I	1.419	0.978	1.551
J	1.171	0.843	1.507
K	1.145	0.786	1.552
L	1.221	0.932	1.725
M	1.117	0.927	1.573
N	1.201	0.882	1.556

3.5 Material to be removed.

Table 4 – Gutter dimensions

Vol. of existing slope	147062.57 m³
Vol. of the proposed cut	131753.48 m³
Material to be removed	15309.09m³

3.6 Calculated gutter dimensions.

Proposed gutter dimensions for the site.

Table 5 – Gutter dimensions

Gutter	Depth	Width
Toe gutter	40.0cm	30.0cm
Side gutter	12.5cm	14.0cm
Head gutter	12.5cm	14.0cm
Bench 1 gutter	10.0cm	10.0cm
Bench 2 gutter	12.5cm	20.0cm

4. Discussion

The pore water pressure develops within the jointed rock space during heavy rain period was identified as the main cause for this slope failure.

Results of particle size analysis tests (Table 1) confirmed that the soil material was a sand dominant one and plasticity test confirmed that there is no plasticity in it.

Stability of the slope was analysed as sections (G to N) (Fig. 1) with the aid of 3D model, Geo-studio 2004 software and direct shear test results (Table 2). The results showed that all the sections were in critical region (FOS≈1) due to steep slope and higher head weight. The situation becomes worse (FOS<1) at the adverse conditions where materials are heavily saturated (Table 3).

The mitigation of this type of unstable slopes can be done by; reducing the head weight, maintaining proper slope gradients, controlling the water table (http://landslides.usgs.gov) because the tendency to material movement as flows is quiet low. New mitigation plan was designed by considering slope angles, head weight, bench heights & width, applicability, water table, Economical factors & etc. The most suitable design (Fig. 3) was obtained by using the trial and error method with respect to the FOS and the sections of which FOS were not up to the desired level (FOS<1.5) were proposed to reinforced with soil anchoring. Material to be removed according to new cut is 15309.09m^3 (Table 4).

Drainage system and gutter dimensions were designed (Table 5) on the base of past rain fall data (six years) of the site area. Hydro seeding on the slope face was proposed to reduce the erosion as well as the percolation of surface water to the underneath.

5. Conclusions

FOSs of sections G to N (existing slope conditions) are in near critical range (1.1-1.2). FOSs for the adverse conditions are even worse and they were in the range of (0.8-0.9), well below the recommended value of FOS (1.5) as well as the critical value (1.0).

The proposed slope design (Fig. 3) is a highly stable design which has a FOS over the recommended 1.5 value (under adverse conditions) in all eight sections. Stability will be further enhanced after the implementation of this drainage system and grass covering.

Mitigation design proposed by this study is a highly stable, trouble-free and economically feasible, that can be implemented on the Peradeniya rock slope failure site as the permanent mitigation option.

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