SOIL SLOPE REMEDIATION WORKS USING SOIL NAIL

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DEDICATION

To my family members and lecturers, I couldn’t have done this without you.

Thank you for your relentless support.

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ABSTRACT

In urban development, the road development plays an important role in development process. However, earthworks as the main activity in road construction creates large area of man-made slopes. Slopes are tends to be unstable after being constructed if it is not properly designed. Therefore, slopes which are unstable need to be designed with the proper mechanism to ensure the safety of the users besides minimizing the long term maintenance cost. Soil nail is the common type of mechanism used in Malaysia because only limited excavation and reasonable right-of-way (ROW) and clearing limits are required. Given the wide use of soil nails, a proper design of slope geometry based on engineering sound fundamentals is necessary in order to ensure the soil nail slope performs satisfactory during its service line. In this paper, a study was being conducted to identify the effect of the slope geometry in term of Factor of Safety (FOS) on a soil nail treated slope of a road construction works. The analysis to access the FOS of treated slopes of different geometries are performed by GeoStudio using Morgenstern Price method. The results obtained in this study suggests that the correct combination of slope geometry with the soil nail treatment can increase the FOS of a treated slope.

ABSTRAK

Dalam pembangunan bandar, jalan raya memainkan peranan yang penting dalam proses pembangunan. Akan tetapi, kerja pengorekan tanah merupakan aktiviti utama dalam proses pembinaan jalan telah membentuk banyak cerun buatan manusia. Dalam menangani masalah ini, cerun hendaklah direkabentuk dengan mekanisme yang tepat untuk memastikan keselamatan pengguna dan meminimumkan kos penyelenggaraan jangka panjang. 'Soil Nailing' merupakan sejenis mekanisma yang biasa digunakan di Malaysia. Teknik ini akan menambahkan daya kekuatan dan memperkukuhkan keadaan tanah yang tidak stabil. Teknik ini hanya memerlukan penggorekkan dan perbersihan tanah yang terhad. Memandangkan penggunaan 'soil nailing' yang luas, reka bentuk geometri cerun yang sesuai berdasarkan fundamental kejuruteraan adalah perlu bagi memastikannya berfungsi dengan baik. Dalam kertas kerja ini, satu kajian sedang dijalankan untuk mengenal pasti kesan geometri cerun dari segi Faktor Keselamatan pada cerun yang menggunakan 'soil nailing' dalam pembinaan jalan raya. Analisis untuk mengenalpasti Faktor Keselamatam cerun ini diperlakukan dengan geometri yang berbeza dengan menggunakan GeoStudio dengan kaedah Morgenstern Price. Keputusan yang diperolehi dalam kajian ini menunjukkan bahawa gabungan geometri cerun yang betul dengan rawatan 'Soil Nailing' ini dapat meningkatkan Faktor Keselamatan cerun.

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LIST OF SYMBOLS

FHWA	-	The Federal Highway Administration, U.S Department of Transport
D_{DH}	-	Diameter of soil nail drill hole
FOS	-	Factor of Safety
GWL	-	Grown Water Table
H	-	Vertical height of slope
JKR	-	Jabatan Kerja Raya
ROW	-	Right of Way
LL	-	Liquid Limit of Soil in Atterberg Limit Test
LRFD	-	Load and Resistance Factor Design
$P_{pullout, ult}$	-	Ultimate grout-ground pullout resistance
$P_{pullout, working}$	-	Allowable grout-ground pullout resistance
Q_U	-	Ultimate grout-ground bond stress
SI	-	Site Investigation
SLD	-	Service Load Design Service Load Design
SPT-N value	-	The sum of the number of blows required for the second and third 150mm to a depth of 450mm in Standard Penetration Test
A_t	-	Area of soil nail bar
S_H	-	Horizontal spacing of soil nail
S_V	-	Vertical spacing of soil nail
T_{ult}	-	Allowable ultimate nail tensile strength
c_D	-	Factored soil cohesion
c_u	-	Ultimate soil cohesion of soil behind the wall
c'	-	Cohesion of soil in drained condition
fy	-	Tensile strength of steel reinforcement bar
ϕ_{bar}	-	Diameter of soil nail bar
ϕ_{dia}	-	Diameter of grout-ground bond of soil nail
ϕ_D	-	Factored soil friction angle
ϕ_U	-	Ultimate friction angle of soil behind the wall

ϕ'	-	Friction angle of soil in drained condition
η	-	Degree of inclination of soil nail bar
α	-	Face batter of soil nail wall
β	-	Angle of inclination of slope behind soil nail wall
γ	-	Soil unit weight behind the wall

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In urban development, the better connectivity and accessibility of peoples is always the top priority in the development planning. One of the important way of connectivity in urban civilization is the road transportation. In Malaysia, the road network plays a major role in urban connectivity as most of the transportation modes (motorcycle, cars, lorries, buses, and etc.) move on roads. However, to construct a road network, earthworks with major cutting and filling are the main activities that create large area of man-made slopes. As Malaysia is located close to the equator line with tropical climates which receive high rainfall. It makes Malaysia prone to landslide events as rainfall is one of the main triggering factor that cause landslide to slopes (Muhammad, *et al*., 2014.). Therefore, slopes need to be stabilized by design means to ensure the users' safety besides with the minimum long term maintenance cost. Soil nailing is amongst the best alternative for roadway cuts because only requires limited clearing and excavation within the reasonable right-of-way (ROW). (Lazarte *et al*., 2015).

Soil nail is commonly used in Malaysia as the stabilization measure for distressed slopes and for very steep cut slopes. The popularity of use is because of its technical suitability as an effective slope stabilization method, easy construction and is almost maintenance free. As such, the soil nail slopes of up to 25m high are increasingly being used as remedial mechanism for Malaysia slopes. (Chow and Tan, 2006). However, due to the height of such slopes, a proper and systematic design procedures based on strong fundamentals and extensive research is needed to ensure the performance of the slopes during its service life. The proper and systematic design procedures include the determination of nail's parameters such as position of nail, length of nail, angle of nail inclination, and nail spacing.

The FOS is the accessing factor that determines the safety of the slope defined by the ratio of the resistance forces to motion against the driving force initiating motion required for equilibrium. If the resistance force to sliding is greater than the driving force, it results in FOS greater than one (1) and the slope considered stable. However, if the FOS value is equal to one (1), the slope is about to fail and if it is less than one (1), then the slope at site would have already failed. (Rouaiguia and Dahim, 2013). Thus, the slope stability need to be improved by some mechanism where the soil nailing is one of them.

According to Nadhre H.A, (2012), the optimum length of nail depends on height and angle of slope while the optimum angle of nails is found to be ranged between (10-25) degrees down from the horizontal, but also related with the angle of slope. Despite the angle of slope which is directly related to the slope geometry plays an important role in influencing the performance of the soil nail slopes and the amount of earthworks activity. Thus, the steeper slopes require less excavation to form compare to a gentle angler slope.

Currently, there are many commercial geotechnical software in the market for analysing the slope stability. For this research proposal, a study will be carried out using computer programme, GeoStudio which is developed by GEOSLOPE International, Canada. In GeoStudio a software component named SLOPE/W which adopted the Limit of Equilibrium will be used to evaluate the global stability modelling of the slope to obtain the FOS of the slope before and after the inclusion of the soil nailing system. The output from the SLOPE/W with the soil nails position that achieve the required FOS will be used to design the soil nailing for the cutting slope.

1.2 Problem Statement

Due to the rapid development growth, numerous road constructions have been carried out in Malaysia. Limited right-of-way (ROW) in road construction has constrained the space for slope construction. Landslides can occur on slopes when slopes are unstable after the soil slopes being formed. However, this phenomena can be controlled with the means of slope stabilization mechanism and soil nails is one of the mechanism that is popularly used in Malaysia.

However, proper and systematic design procedures include the determination of nail's parameters such as position of nail, length of nail, angle of nail inclination, and nail spacing is needed to ensure the performance of the slopes during its service life.

1.3 Objectives of Study

The aims of this study are to identify the effect of the slope geometry in term of Factor of Safety (FOS) on a soil nail treated soil slope of a road construction works and further to identify the suitable slope geometry in order to reduce the cut volume of earthworks while complying to the required FOS.
To achieve the aim, the following are the objectives to meet:-

i. To establish the soil stratification of the case study site for modelling the slope for slope stability analysis.
ii. To identify the stability performance of the original soil nail slope geometry design in terms of FOS by comparing to the JKR guidelines for slope design.
iii. To identify the effect of the slope geometry on the FOS of a soil nail treated slope.
iv. To identify the suitable slope geometry in order to reduce the cut volume of earthworks while complying with the required FOS.

1.4 Scope of Study

The study is based on a proposed cut slope with soil nails application located in a proposed two directional double carriageway highway project in Negeri Sembilan, Malaysia. The soil nail is designed stabilize the proposed five tiers cut soil slope. . This study will focus on accessing the stability of the slope in terms of FOS of in global stability analysis. The FOS of these slopes for both untreated and treated with soil nails of same soil nail parameters are being accessed by performing the slope analysis using the Morgenstern Price Method in SLOPE/W programme of GeoStudio version 2012.

However, the study of this paper is only limited to the global stability analysis. Other safety analysis such as sliding, overturning and bearing capacity of foundation soil are not covered in this study.

1.5 Significant of Study

This study is to identify the effect of the slope geometry in term of Factor of Safety (FOS) on a soil nail treated slope of a road construction works and further to identify the suitable slope geometry in order to reduce the cut volume of earthworks while complying to the required FOS.

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