SLOPE STABILITY ASSESMENT OF REMEDIAL MEASURES ADJACENT TO TRANSMISSION TOWER

YVONNE PUI

A project report submitted in partial fulfilment of the
requirement for the award of the degree of
Master of Engineering (Geotechnics)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

ACKNOWLEDGEMENTS

It is a great pleasure to address people who had assist and support me in the journey of preparing this project. They have contributed towards my understanding and thoughts. Hereby, I would like to express my deepest and sincere appreciation to my master project supervisor, Professor Dr. Nazri Ali for his encouragement, guidance and advice in doing this project.

I also wish to express my sincere gratitude to Universiti Teknologi Malaysia (UTM) and computer laboratory of School of Civil Engineering in supplying me the resources, particularly literature and licensed computer program (PLAXIS) throughout the project. They deserve a special thanks for the assistance.

I am also grateful and appreciate my ex-superior, Dr. Addy Kho Kai Tze for allow me to use the resources and information as my project data. The information and guidance provided by Dr. Addy are very valuable for me in order to produce a reliable study.

Last but not least, I would also extend my sincere appreciation to everyone who has contributed whether directly or indirectly to this project, including my classmates and family members. This project would have been impossible without your guidance, advice and support.

ABSTRACT

Slope stability analysis has received an increased attention in construction and development to ensure public safety and avoid economic loss. A high and steep soil slope failure had occurred on the slope adjacent to a newly built transmission tower in Murum, Sarawak. An effective slope remedial measure is demanded to protect the transmission tower. This paper presented the slope stability assessment conducted using a well-established Finite Element Method computer software, i.e. “PLAXIS 2D” and “PLAXIS 3D”. Two remedial works alternatives had been proposed, which including retaining wall and secant bored pile. The slope stability of each remedial works was assessed in term of factor of safety (FOS). The impact of the material model on FOS was assessed using both Mohr-Coulomb model (MC) and Hardening Soil model (HS). Topography, laboratory and field data were obtained to simulate the actual slope failure. The slope stability assessment conducted found that the most effective remedial work is secant bored pile (SBP) to prevent soil movement. FOS obtained from PLAXIS 3D was more conservative in complex geometry. Material model did not significanty impact FOS. FOS of HS model was slightly lower than MC model. The remedial measures were assessed with respect to the slope stability only which it did not consider the factor of construction cost.

ABSTRAK

Analisasi kestabilan cerun telah mendapat perhatian yang meningkat dalam sektor pembinaan dan pembangunan demi memastikan keselamatan nyawa dan mengelakkan kerugian ekonomi. Satu kejadian runtuhan cerun telah berlaku pada cerun bersebelahan dengan menara transmisi di Murum, Sarawak. Justeru, kaedah penstabilan cerun yang berkesan perlu dilaksanakan bagi melindungi menara transmisi tersebut. Kajian ini membentangkan penilaian kestabilan cerun yang dijalankan dengan mengunakan perisian komputer Kaedah Unsure Terhingga (FEM) yang mantap, iaitu PLAXIS 2D dan PLAXIS 3D. Dua jenis alternatif kaedah penstabilan cerun telah dicadangkan dalam kajian ini, termasuk dinding penahan dan cerucuk gerek ‘secant’. Kestabilan cerun bagi setiap kaedah telah dinilaikan dengan menggunakan kaedah faktor keselamatan (FOS). Kesan model bahan tanah terhadap FOS pula telah dinilai dengan menggunakan model *Mohr-Coulomb (MC)* dan *Hardening Soil (HS)*. Data topografi, data makmal dan data tapak telah diperolehi bagi mensimulasikan runtuhan cerun tersebut. Penilaian kestabilan cerun ini mendapati bahawa kaedah penstabilan cerun yang paling berkesan di tapak ini ialah cerucuk geren ‘secant’ untuk mengelakkan pergerakan tanah. FOS dari PLAXIS 3D didapati lebih konservatif dalam geometri kompleks. Model bahan tidak menyebabkan pengaruh yang besar terhadap FOS. FOS dari HS model hanya sedikit lebih rendah daripada FOS dari MC model. Walau bagaimanapun, kaedah penstabilan cerun ini hanya dinilai dari segi kestabilan cerun sahaja dan tidak mengambil kira faktor kos pembinaan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
FOS	-	Factor of Safety
FEM	-	Finite Element Method
PWD	-	Public Work Department
LEM	-	Limit Equilibrium Method
2D	-	Two Dimensional
3D	-	Three Dimensional
MC	-	Mohr Coulomb
HS	-	Hardening Soil
SBP	-	Secant Bored Pile

LIST OF SYSMBOLS

τ	-	Shear strength of soil
c_u	-	Undrained cohesion
c'	-	Cohesion
σ'	-	Effective normal stress
ϕ'	-	Angle of friction
τ_f	-	Shear strength at failure
τ_m	-	Shear stress
H	-	Height of slope
β	-	Slope angle
η_{fe}	-	Safety factor
E_{50}	-	Triaxial loading stiffness
E_{ur}	-	Trixial unloading stiffness
E_{oed}	-	Oedometer loading stiffness
γ	-	Unit weight
E	-	Young modulus
v	-	Void ration
m	-	Power factor
ϕ	-	Diameter

LIST OF APPENDICES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Introduction

Slope is defined as a soil or rock surface that incline from a horizontal plane at an angle (Ahmad, 2016). The ground surface of the Earth is rarely flat that slopes are naturally formed due to its geomorphology activities. Manmade slopes such as cut and filled slope are created in connection with building construction and infrastructure development. The main engineering issue of soil slope that we shall overcome is its stability. Unstable slope may collapse in sudden and consequently lead to vital destruction, death and economic losses. The most recent tragic slope failure incident had happened at Bukit Kukus paired roads project site in Penang on 19th October 2018 and killed nine workers. Hence, it is in need to acquire deep understanding on the slope engineering to secure public safety and avoid economic loss.

The issue of frequent landslide in Malaysia had led to increasing attentions from the government. Rahman and Mapjabl (2017) had reported that there are 21,000 landslide prone area throughout Malaysia. The landslide from 1973-2007 caused an economic loss of approximately US $ 1 billion, as reported in National Slope Master Plan 2009-2023 (PWD, 2009). These landslide tragedy could be avoided through proper slope stability assessment and provision of stabilisation works prior to failure. In 2010, Public Work Department (PWD) published a design guideline to implement slope design and slope assessment in order to minimise the risk in slope failure disaster. All slopes design shall fulfil geotechnical design criteria as published in the guidelines.

1.2 Background

There are several factors that lead to slope failure. Steep slope, continuous heavy rainfall and poor slope management are common reasons of slope failure in Malaysia. Generally, slope failure occurs when shear stress build up in the soil exceed the corresponding shear resistance of the soil. However, the failure of slope is not contributed by a single factor only because most of the time the slope failure mechanism is complex and complicated. By conducting the slope stability assessment, we can investigate the stability of the slope, determine the potential failure mechanism, design optimum slopes and propose most suitable remedial measures.

Several method of slope stability assessment had been developed since decades ago. Among the technique of slope stability analysis developed are including limit equilibrium method (LEM), boundary element methods, finite element methods (FEM) and neural network methods. Engineers shall understand the mechanism and limitation of these technique upon application. FEM are commonly applied for analysis for many reason nowadays. PLAXIS is one of the well-established FEM computer program to assist engineers in analyse complexity of slope failure. We can simulate slope system in two dimensional (2D) or three dimensional (3D) and at the same time study the impact of material models on the stability of the slope. In common, slope stability are assessed in term of factor of safety (FOS) as mentioned in guideline published by PWD in 2010.

1.3 Research Problem

Slopes along Murum-Murum Junction (275V transmission line) supporting Sarawak Energy Berhad's transmission tower had been investigated and assessed in 2015. A slope failure, namely MJM 117 had occurred on the slope supporting the transmission tower and threaten the transmission tower. Slope stability assessment and suitable remedial measures need to be undertaken to protect the transmission tower.

The Murum-Murum Junction Transmission Line stretches along mountainous and rugged terrains that overlie the rock of Belaga Formation. A total of 58 transmission towers had been constructed and completed in late 2012 along 47.5km of transmission line stretch from Murum Substation to Murum Power, as shown in the Figure 1.1. Most of the transmission tower were constructed on top of the hill slope, as illustrated in Figure 1.2. The tower sites are ranges from 195m to 709m above mean sea level. Sign of failure were observed at the slopes after the completion of tower construction.

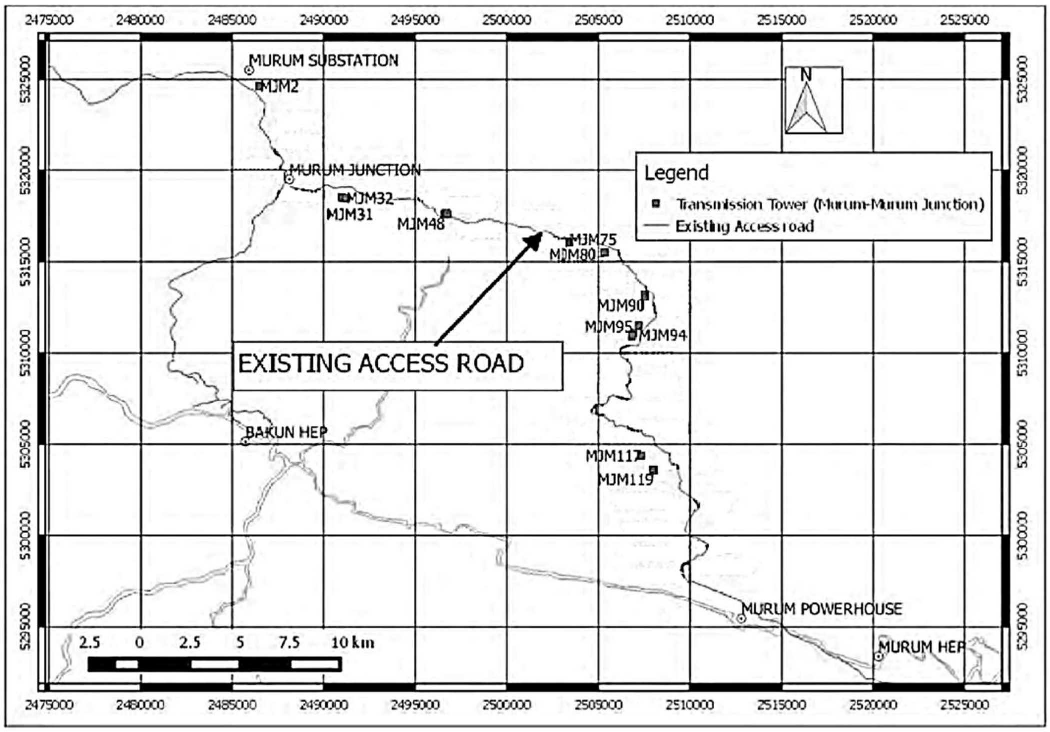

Figure 1.1 Locality map of project site

Figure 1.2 Transmission tower constructed on top of slope

Slope failure was observed at tower site MJM 117 after the construction of the transmission tower. It was suspected that the slope failure occurred on the natural slope due to the change in land use and construction dumped materials. MJM 117 is the highest tower site which located 709m above mean sea level and approximately 3km from the main road. Figure 1.3 shows the view of tower site MJM 117 from bottom. The tower leg was located very close to the failed slope which was approximately 4.0m as noticed in Figure 1.4. Any further movement of the failed slope may threathen the stability of the transmission tower and cause huge economic loss. Hence, slope stability assessment was in urgent need to evaluate the stability of the slope and propose the most suitable remedial measures to protect the transmission tower.

Figure 1.3 View of MJM 117 from bottom

Figure 1.4 Slope failure adjacent to transmission tower

1.4 Research Objectives

This project was conducted to analyse slope stability of remedial measures for the slope failure occurred at tower site MJM117 in Murum, Sarawak. The specific objectives of this project are:

a) To conduct slope stability analysis using FEM PLAXIS 2D and PLAXIS 3D.
b) To study impact of material model using Mohr Coulomb Model and Hardening Soil Model
c) To propose suitable remedial works for the slope failure.

1.5 Scope and Limitation

This project covered the slope stability assessment of remedial measures proposed for the slope failure at tower site MJM 117. The purposed remedial works was meant to stabilise the slope in order to protect the transmission tower. Figure 1.5 shows three slope failures had occurred surrounding the transmission tower at MJM 117. This project was limited to the analysis of the most critical slope, i.e. Section C-C (East Slope). East slope is the steepest slope and only 4.0m distant away from the tower leg. Figure 1.6 indicated the three dimensional view of MJM 117.

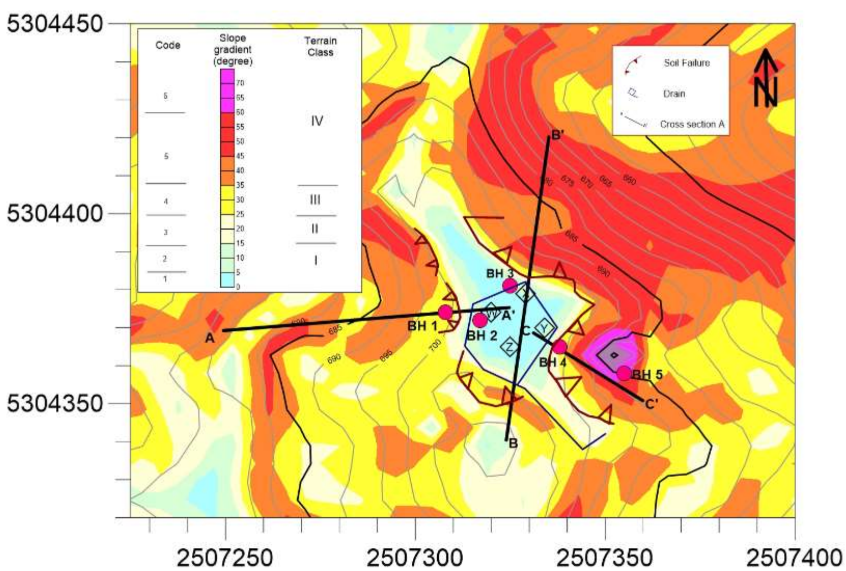

Figure 1.5 Slope gradient map at MJM 117

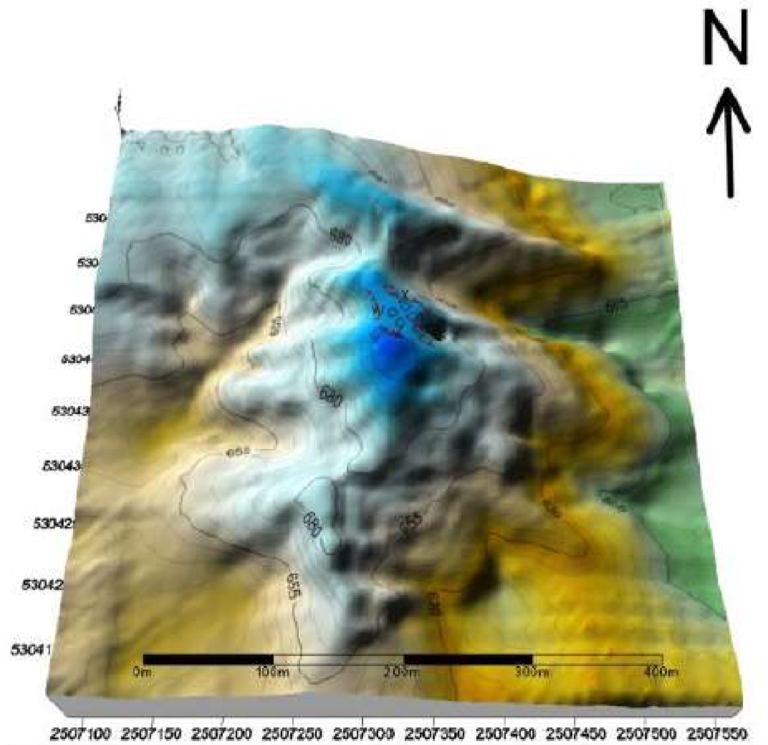

Figure 1.6 Three dimensional view of MJM 117

Slope stability assessment of remedial works was conducted using FEM method with the applications PLAXIS 2D programme and PLAXIS 3D programme. The slope was assessed for its slope stability in term of factor of safety (FOS). A total of two remedial measures were proposed, i.e. retaining wall and secant bored pile. The model was assessed in both 2D and 3D condition to obtain the critical FOS and analysed using both Mohr Coulomb and Hardening Soil Model to investigate the impact of material models on the stability analysis. The input of the model such as topography, geometry, soil properties and groundwater level were based on proper survey and site investigation report. The proposed remedial measures shall fulfil the criteria published by PWD.

There are few limitations found in this project. The information input such as topographic, subsurface investigation result and laboratory adopted in this project was obtained by contractors in 2015 which was few year back. Dense vegetation covering the tower site made it difficult to differentiate the fill materials. Suitable assumption were included to overcome the shortage of information. Besides, the suitability of the

REFERENCE

Abbas, J.M. (2014) 'Slope Stability Analysis Using Numerical Method', *Journal of Applied Science*, 14, 846-85.

Albataineh, N. (2006). *Slope Stability Analysis using 2D and 3D Methods*. M. Tech. Thesis, University of Akron, 1-36.

Anagnosti, P. (1969) Three Dimensional Stability of Fill Dams. Proc. 7*th Int. Conf. on Soil Mech. and Found. Engg*, Mexico.

Bishop, A. W. (1955) 'The Use of The Slip Circle in the Stability Analysis of Earth Slope', *Geotechnique*, 5(1), 7-17.

Celik, S. (2017) Comparison of Mohr-Coulomb and Hardening Soil Models' Numerical Estimation of Ground Surface Settlement Caused by Tunneling. *Iğdır Üni. Fen Bilimleri Enst. Der. / Iğdır Univ. J. Inst. Sci. & Tech*. 7(4), 95-102.

Fredlund, D. G. and Krahn J. (1977) 'Comparison of Slope Stability Methods of Analysis', *Canadian Geotechnical Journal*, 16, 121-139.

Gaur, A. and Sahay, A. (2017) 'Comparison of Different Soil Models for Excavation using Retaining Wall', *SSRG International Journal of Civil Engineering*, 4(3).

Gofar, N. and Kassim, K.A. (2007). *Introduction to Geotechnical Engineering*. Singapore: Prentice Hall.

Griffiths, D. V. and Lane, P. A. (1999) 'Slope Stability Analysis by Finite Elements', *Geotechnique*, 49(3), 387 – 403.

Griffiths, D.V. (2013). Effect of Slope Height and Gradient on Failure Probability. *Geo-Congress 2013*.

Hamed, N., Khairul, A., Kassim, A.G., Ramli, N. and Sayyed, Y.Z.F. (2012) 'Investigation of Slope Failures in Soil Mechanics', *Electronic Journal of Geotechnical Engineering*, 17 (Bundle R), 2703-2720.

Hammouri, N., Malkawi, A. H. and Mohammad, M. A. Yamin (2008) 'Stability Analysis of Slopes using The Finite Element Method and Limiting Equilibrium Approach', *Bulletin of Engineering Geology and the Environment,* 67 (4), 471-478.

Hongjun, L. and Longtan, S. (2011) 'Three Dimensional Finite Element Limit Equilibrium Method for Slope Stability Analysis Based on the Unique Slideing Direction', *Geotechnical Special Publication*, 48-55.

Jamaludin, S. and Hussein, A.N (2006). Landslide Hazard and Risk Assessment: Malaysian Experience. *IAEG2006*, 455.

Ahmad, K. (2016). *Geotechnical Designs*. Universiti Teknologi Malaysia: Pearson.

Kalatehjari, R and Ali, N. (2013) 'A Review of Three-Dimensional Slope Stability Analyses based on Limit Equilibrium Method', *The Electronic Journal of Geotechnical Engineering*, 18, 119-134.

Kazmin, D., Qasim, S., Harahap, I.S.H, Baharom, S., Imran, M. and Moin, S. (2016) 'A Study on the Contributing Factors of Major Landslide in Malaysia', *Civil Engineering Journal*, 2, 12.

Kokten, O. (2014). *Design of 20m Deep Excavation with Permanent Anchored Secant Bored Pile Wall (SBPW) and Contigouus Bored Pile Wall (CBPW) as Retaining Structure of Cut and Cover Tunnel*. Temelsu International Engineering Services Inc. Ankara Turkey.

Kubba, F.A. and Lamy, A.R. (2013) 'Assessmet of Earth Dams Slope Stability by Computer Software', A*ustralian Journal of Basic and Applied Science*, 7(6), 229-236.

Leong, EC. and Rahardjo, H. (2012) 'Two and Three-Dimensional Slope Stability Reanalyses of Bukit Batok Slope', *Comput, Geotech*, 42, 81-88.

Malin, S. (2016). *Numerical Modelling ans Sensitivity Analysis of Tunnel Deformation in London Clay*. KTH Royal Institute of Technology in Stockholm. Sweden.

Manna, B., Rawat, S., Zodinpuii, R.and Sharma, K.G. (2014). Effect of Surcharge Load on Stability of Slopes-Testing and Analysis. *EJGE*, 19, 3398-3409.

*M*ukhlisin, M., Matlan, S.J., Ahlan, M.J. and Mohd, R.T. (2012) 'Analysis of Rainfall Effect to Slope Stability in Ulu Klang, Malaysia', *Jurnal Teknologi*, 72, 3.

Obrzud, R. (2010) 'On the Use of the Hardening Soil Small Strain model in Geotechnical Practice', N*umerics in Geotechnics and Structures*, 16.

PLAXIS. *PLAXIS Scientific Manual (2014).* The Netherlands:Plaxis B.V.

Putu, Tantri K.S and Lastiasih, Y. (2015). *Slope Stability Evaluation Using Limit Equilibrium Method (Lem) And Finite Element Method (Fem) For Indonesia Soft Soil.* BISSTECH.

PWD (2009). *National Slope Master Plan 2009-2023*. Kuala Lumpur: Public Works Department.

PWD (2010). *Guideline for Slope Design*. Kuala Lumpur: Public Works Department Malaysia.

Rahman, H. A.and Mapjabl, B. (2017) 'Landslide Disaster in Malaysia: An Overview', *Heatlth & the Environment Journal*, 8, 58-71.

Terzaghi, K. (1942). *Theoretical Soil Mechanics*. New York: Wiley.

The Sundaily. Chronolofy of landslide in Penang since 2017. Retrieved Oct 20, 2018, from http://www.thesundaily.my.

Varga, G. and Czap, Z. (2004) 'Soil Models: Safety Factors and Settlements. *Periodica Polutechnica Ser.Civ.Eng*', 48 (1-2), 53-63.

Varnes, D. J. (1978). Slope Movement Types and Processes. In: National Academy of Science. *Special Report 176: Landslides: Analysis and Control.* Washington.