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THE EFFECTS OF GROUND WATER LEVEL FLUCTUATION ON SLOPE STABILITY BY USING SLOPEW

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ABSTRACT

This study is a continuation of previous research work conducted by the author on the stability of man-made slope constructed in UPNM campus. This paper presents the effects of ground water level (GWL) fluctuation on slope stability by using numerical simulation program, SlopeW. Ground water rises were simulated from 5 m below the ground until 10 m above the ground. Soil samples were taken from the site and tested in laboratory and then were incorporated into the program. It was found that the stability of the slope decreased with an increase of GWL. The critical slip surface formed by each case study is categorised as deep seated with circular and non-circular shapes.

1.0 INTRODUCTION

Road developments on hilly areas often involve excavations, earthwork and slope construction. Slopes are cut and designed accordingly to comply with specific requirements to satisfy safety, stability and cost factors. In a tropical country like Malaysia, slope failures are common particularly during rainy season. It was reported that 28 major slope failures occurred between 1993-2011 and the death toll was more than 100 [1]. Although geotechnical engineers might have designed a safe slope, it remains a challenge to ensure its stability. The complexity of materials forming the slope [2-4], geological conditions [5] and hydrological system [6-7] are among the contributing factors influencing slope stability. Despite these, ground water level (GWL) greatly affects slope stability [8-9]. Considerable studies pertaining to GWL fluctuation in inducing slope failure have been conducted by researchers in recent years [10-11]. Many empirical and analytical equations were developed to analyze the relationship between slope failure and GWL quantitatively. However, most of the empirical and analytical research were focused on specific slope regions and only considered limited parameters. With the advent of computer technology nowadays, numerical simulation programs have become a powerful tool and are widely used by researchers due to their capability to solve complicated computation problems [12]. Nonetheless numerical simulation can provide more accurate results in comparison to analytical methods.

This research is a continuation of previous work conducted by the author pertaining to stability of man-made slope constructed in UPNM campus [13]. There were five different slopes constructed along the road and only one was selected for investigation as shown in Figure 1. This slope was located at the highest point among others as well as the steepest. Field survey was carried out to determine the existing ground water table and seepage location. Previous research had determined the safety factor of the slope without taking into consideration the GWL fluctuation. In this paper, further analysis was conducted to study the effects of GWL rising and to determine the shape of slip surface formation. The laboratory data presented in this paper were obtained from the local soil and then were incorporated into numerical simulation program, SlopeW.

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Figure 1. Slope construction in UPNM campus [13]

2.0 METHODOLOGY

The methodology of this research was divided into two parts. The first part was laboratory work. Disturbed and undisturbed soil samples were taken at the top and bottom of the slope to determine the types of soil and shear strength properties. For sieve analysis, test and samples preparation were carried out as stated in BS1377: Part 2:1990. British Soil Classification System (BSCS) was used to classify the types of soil. Meanwhile, for soil shear strength determination, Automated Direct Shear Test machine was used as shown in Figure 2.

The second part of this research was to conduct numerical simulation analysis by using SlopeW program. Two analyses were carried out including the determination of the safety factor of the slope due to GWL fluctuation and identify slip surface formation. The geometry of slope model set up is shown in Figure 3, which consists of nine berms. The estimated slope height and slope inclination angle were approximately 22 m and 70 ° respectively. All the units and scales used in the program were in meter and kilo newton. Two different types of soil layer, namely the upper and lower soil were constructed to replicate the actual site condition. The soil parameters for both layers were obtained from the laboratory test and assigned in the SlopeW program. The laboratory test data are tabulated in Table 1. The assumed GWL was initially setup at 5 m below the ground (recorded as 1 m) as shown in Figure 3. The GWL was then increased to 1 m interval. Therefore, the variation of GWL used in this study was assumed at level 1 m until 15 m. The Factor of Safety (FOS) of slope for each GWL increment was computed by using the Morgenstern-Price method.

Table 1. Soil parameters for upper and lower soil layers assigned in SlopeW

Depth (m)	Soil Layer	Cohesion, c (kN/m^2)	Angle of friction, θ°	Unit weight, γ (kN/m^3)	Colour Legend
0 - 13	Upper	16	21	16	Yellow
13 - 22	Lower	13	23.3	17	Green

Figure 2. Automated Direct Shear Test apparatus

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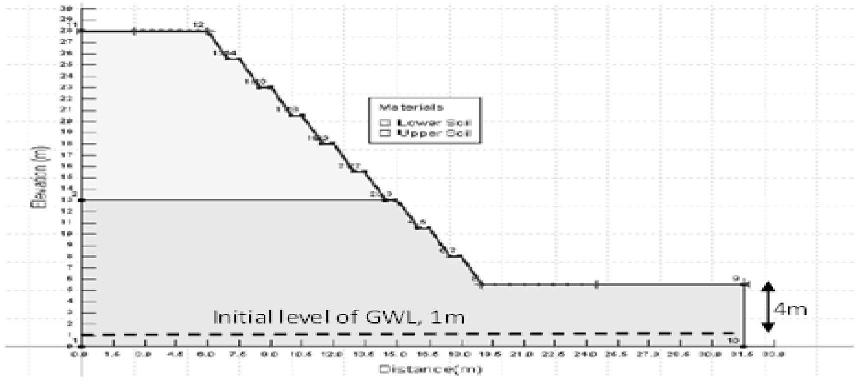
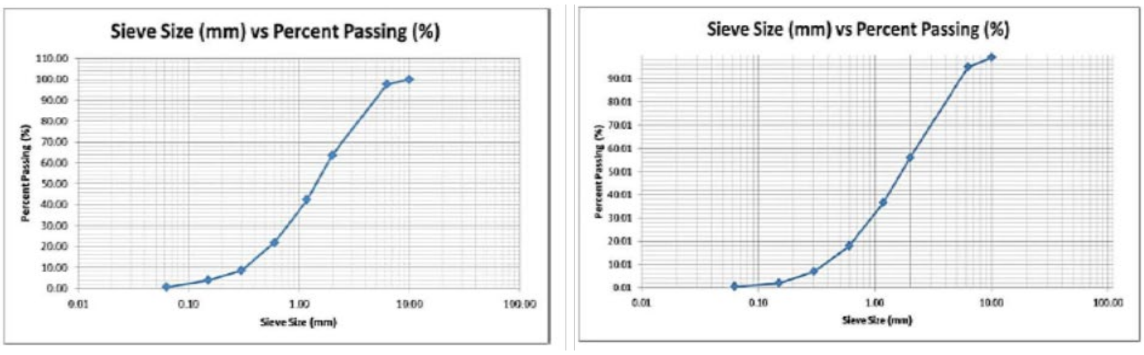


Figure 3. Geometry of slope model set up in SlopeW

3.0 RESULTS AND DISCUSSIONS

The particle size distribution for both soil layers is shown in Figure 4. According to British Soil Classification System, the soil is classified as sandy slit and silty sand for upper and lower soil layer respectively.



(a) (b)

Figure 4. Sieve analysis results (a) upper soil layer is classified as sandy silt (b) lower soil layer is classified as silty sand

There are nine undisturbed soil samples were tested to determine the shear strength properties for both soil layers. The average results are shown in Figure 5 and Table 1.

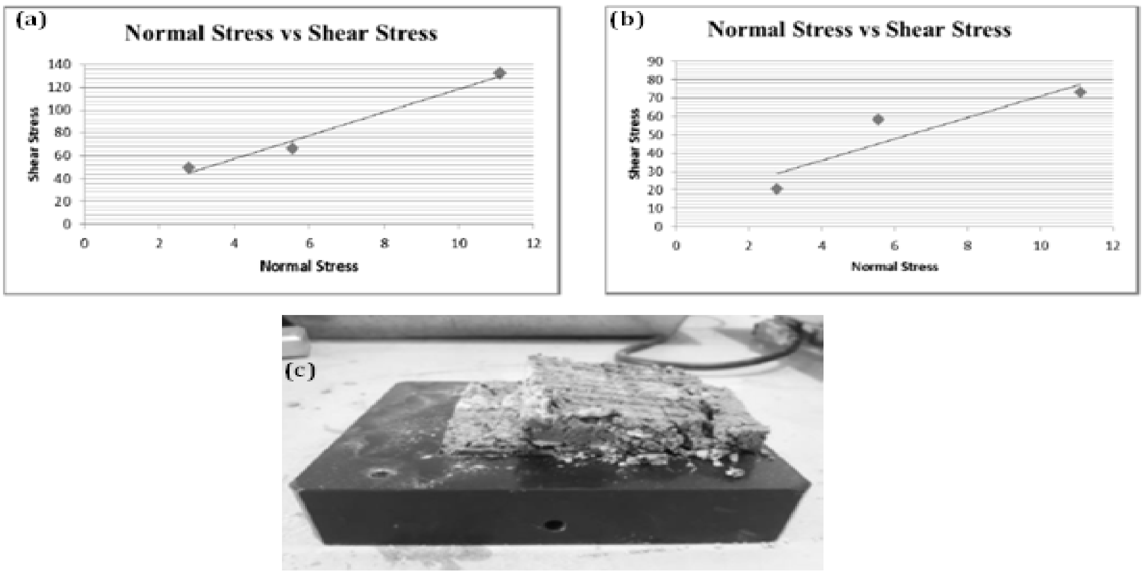


Figure 5. Shear strength results (a) upper soil layer (b) lower soil layer (c) failure of soil sample

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The influence of GWL rise upon FOS is presented in Figure 6. The GWL was simulated for each 1 m height increment, and it was started from 5m below the ground. The 1 m to 5 m heights of GWL depicted in the Figure 6 indicate water level below the ground. Meanwhile, 6 m to 15 m heights are water level above the ground. The highest FOS value obtained from SlopeW was 0.733 for water level height of 5 m below the ground (the farthest GWL). A further increase of GWL resulted in the decrement of FOS. The decrement was noticeable for the GWL between 1 m to 5 m below the ground. However, no significant changes were observed when the GWL increased every 1 m height above the ground. The overall FOS values were lesser than 1 regardless of any water level heights carried out in this study. This indicates instability condition for the slope and eventually, with the presence of GWL at any level could potentially cause slope failure or landslide. This finding is similar with previous studies that showed that the FOS decreased when GWL rose, and the decrement declined dramatically when water height reached critical depth [14].

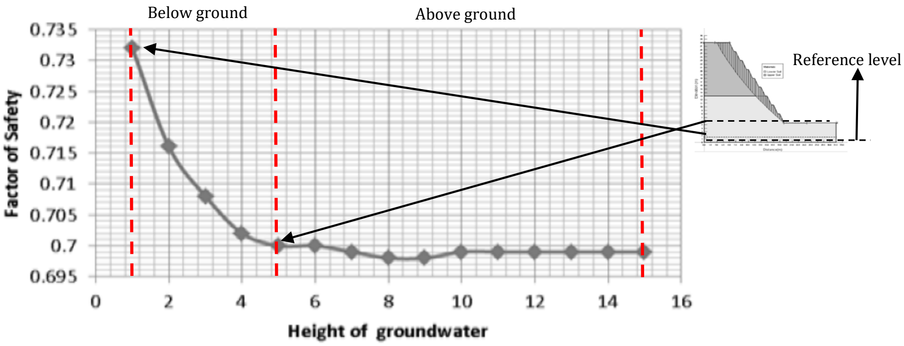

Figure 6. GWL influence on FOS of slope

Figure 7 shows the formation of critical slip surface for different GWL heights located below the ground. For all case studies, as the GWL increases to ground level, the shape of slip surface tends to become semi-circular and have relatively thicker soil mass. The slip surface line was observed passing through the crest of slope and extended to the toe. This type of failure is categories as deep-seated failure with circular shape. Deep-seated failure may induce large scale soil failure that can cause remarkable damage. For GWL in case (a), the slip surface is much thinner as compared to other cases. This is expected to be due to GWL being located at the farthest and FOS the highest.

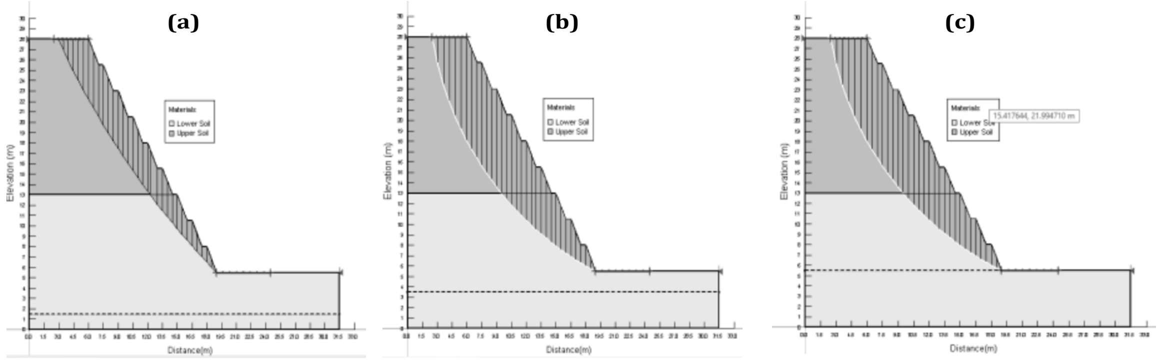

Figure 7. Critical slip surface formation for GWL heights below the ground (a) 5 m (b) 3 m (c) 0 m

Figure 8 shows the critical slipe surface for GWL rising above the ground. As the GWL increases, the slip surface tends to lie close to the slope surface and the line is not circular. This can be explained due to FOS having small changes through the cases (b) to (e). This is supported by the graph shown in Figure 6.

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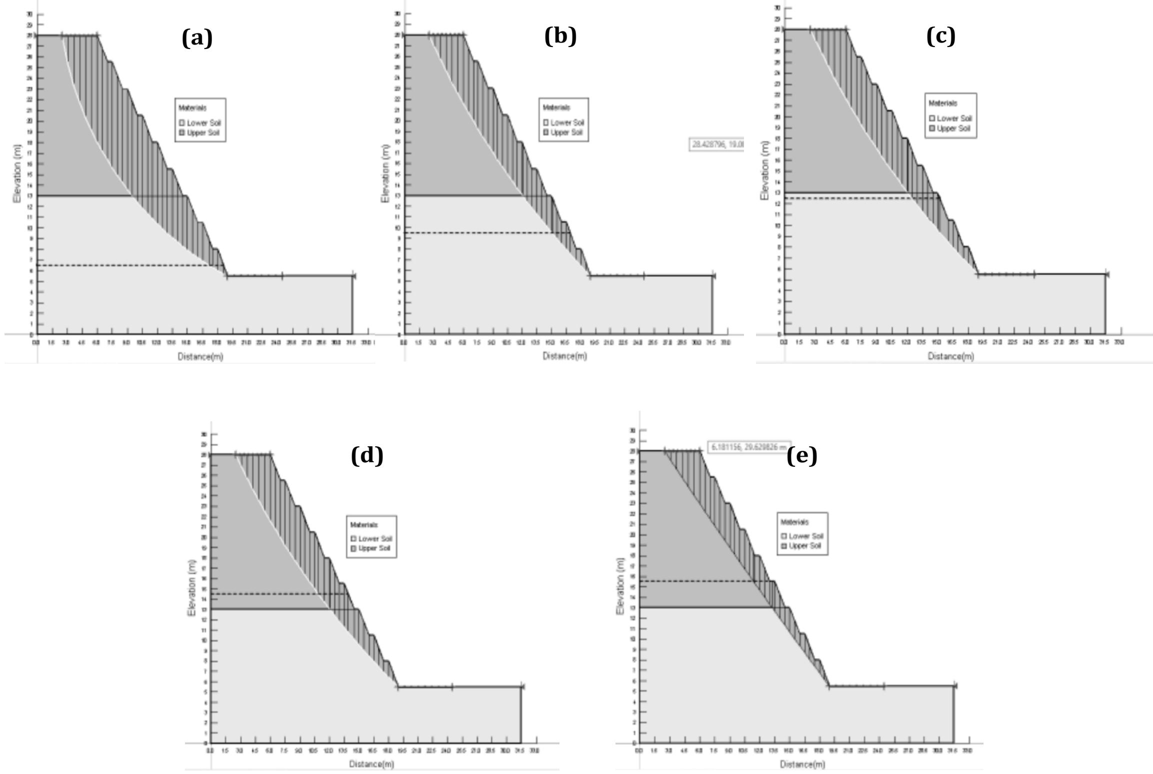

Figure 8. Critical slip surface formation for GWT heights above the ground (a) 1 m (b) 4 m (c) 7 m (d) 9 m (e) 7 m

4.0 CONCLUSION

Stability analysis of man-made slope due to GWL fluctuation is studied in which the effects of GWL fluctuation was carried out by using SlopeW program. It was found that the stability of slope decreased with increase of GWL. The critical slip surface formation has an influence on GWL increment. For all case studies, the slip surface formation is categorised as deep seated regardless of any increment of GWL height. The circular slip line with thick soil mass occurred when GWL rose from below the ground. However, the non-circular slip line was formed for the case where ground water rose above the ground.

5.0 ACKNOWLEDGEMENT

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List of Reference

[1] Rahman, H. A., & Mapjabil, J. (2017). Landslide Disaster in Malaysia: An Overview. *Health and the Environment Journal*, *8*(1), 58–71.

[2] Noroozi, A. G., & Hajiannia, A. (2015). The Effects of Various Factors on Slope Stability. *International Journal of Science and Engineering Investigations*, *4*(46), 44–48.

[3] Taleb, A. H., & Berga, A. (2016). Slope Stability Analyzes with Fissured Material. *Journal of Civil Engineering*, *1*(June), 35–44.

[4] Zheng, Y., & Liu, J. (2016). The Influence of Material Factor on Slope Stability. *Electronic Journal of Geotechnical Engineering*, *21*(6), 2379–2388.

[5] Ersöz, T., & Topal, T. (2018). Assessment of Rock Slope Stability with the Effects of Weathering and Excavation by Comparing Deterministic Methods and Slope Stability Probability Classification (SSPC). *Environmental Earth Sciences*, *77*(547).

[6] Hakim Sagitaningrum, F., & Bahsan, E. (2017). Parametric study on the effect of rainfall pattern to slope stability. *MATEC Web of Conferences*, *101*.

[7] Zhang, L., Wu, F., Zhang, H., Zhang, L., & Zhang, J. (2017). Influences of Internal Erosion on

*Corresponding Author | Jelani, J. | jestin@upnm.edu.my

Infiltration and Slope Stability. *Bulletin of Engineering Geology and the Environment*, *78*(3), 1815–1827.

[8] Alsubal, S., Sapari, N., & S.H. Harahap, I. (2018). The Rise of Groundwater Due to Rainfall and the Control of Landslide by Zero-Energy Groundwater Withdrawal System. *International Journal of Engineering & Technology*, *7*(2.29), 921.

[9] Taib, S. N. L., Selaman, O. S., Chen, C. L., Lim, R., & Awang Ismail, D. S. (2017). Landslide Susceptibility in Relation to Correlation of Groundwater Development and Ground Condition. *Advances in Civil Engineering*, *2017*.

[10] Latief, R. H., & Zainal, A. K. E. (2019). Effects of Water Table Level on Slope Stability and Construction Cost of Highway Embankment. *Engineering Journal*, *23*(5), 1–12.

[11] Pirone, M., Papa, R., Nicotera, M. V., & Urciuoli, G. (2015). In situ Monitoring of the Groundwater Field In an Unsaturated Pyroclastic Slope for Slope Stability Evaluation. *Journal of the International Consortium on Landslides*, *12*(2), 259–276.

[12] Kainthola, A., Verma, D., Thareja, R., & Singh, T. N. (2013). A Review on Numerical Slope Stability Analysis. *International Journal of Science, Engineering and Technology Research*, *2*(6), 1315–1320.

[13] Jelani, J., Saiful, M., Hah, A., & Husen, H. (2018). Stability Analysis of Man-made Slope : A Case Study at UPNM Campus , Sg Besi , Kuala Lumpur. *International Journal of Engineering & Technology*, *7*(4.33), 392–394.

[14] Ashland, F. X., Giraud, R. E., & Mcdonald, G. N. (2006). Slope-stability implications of ground-water-level fluctuations in wasatch front landslides and adjacent slopes, Northern Utah. *40th Symposium on Engineering Geology and Geotechnical Engineering 2006*, (March), 33–44.

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