Effect of Rainfall Pattern on Slope Stability

[1]Abu Talib MOHD KHAIDIR, [2]Kasa ANUAR, [1]Noriyuki YASUFUKU, [1]Hazarika HEMANTA, [1]Ryohei ISHIKURA
[1]Department of Civil Engineering, Kyushu University
[2]Department of Civil Engineering, Universiti Kebangsaan Malaysia

1. INTODUCTION

Many studies have indicated that the infiltration of rainwater into a slope decreases the stability of the slope. However, the difficulty of quantifying the effect of rain infiltration on slope stability still exists. It would be advantageous to know what amount of rainfall enters a slope as infiltration and how much this infiltration decreases the stability of a slope.

2. BACKGROUND

Generally, Malaysia have a natural terrain with hilly and slopes while receiving high rainfall throughout the year (approximately 3000mm/year). Influence the surface runoff and groundwater flow make this land are more vulnerable to the phenomenon of landslides and slope failures. This failure is always associated with the infiltration of rainfall against slopes but these are still not fully understood. Hydrological characteristics of slope such as soil permeability and rainfall data that occurred prior to failure (antecedent) may indicate that they influence the response of slope stability [1]. Stability of slope wills affected by extreme rainfall in which causing an increase in water pressure and reduces the shear strength of the aggregate [2]. It is very important to know the response of slope against the various state of rainfall, changes in the pore water pressure and water content (moisture) on the stability of slopes. Infiltration of rainwater into slope would increase weight of the slope, change pore water pressure in the slope, and reduce shear strength of the soil. In an unsaturated soil slope, the matric suction, which could be regarded as negative pore water pressure, is one of the major factors that influenced the stability of a slope.

3. METHODOLOGY

For this study purpose, one study case had been selected, that is Bukit Antarabangsa, Ulu Klang, Selangor. The landslide tragedy was occurred here on 6th December 2008 where it has caused four killed and destroyed 14 bungalows. Methodology was summarized in Figure 1 below.

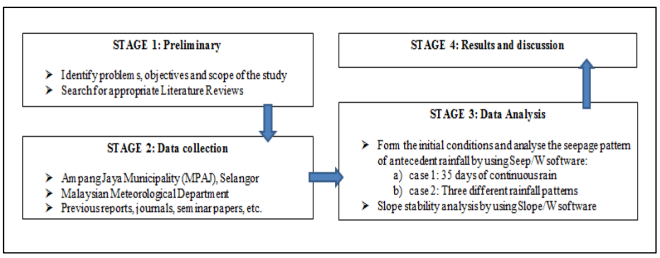

Figure 1 Research methodology

The rainfall data used in this study were provided by Ampang Jaya Municipality (MPAJ), Selangor. The influences of a rainfall on negative pore water pressures and the stability of a slope were analyzed in this paper by simulating negative pore water pressure distribution of the slope under 35 days of continuous rainfall before failure (Case 1) and three pattern of rainfall condition (Case 2). Antecedent rainfall is actually giving a great influence in the movement in the soil and causing a landslide. Antecedent rain means the series of rainfall in few days before the landslide occurred [3]. Numerical models were used to study how infiltration into a slope varied with respect to rainfall intensity and how this infiltration affected the stability of the slope. Transient seepage and slope stability analyses were carried out using commercial software SEEP/W and SLOPE/W. The main objective of this study was to analyst the pattern of rainfall seepage and its effects on pore water pressure and slope stability.

4. RESULT AND DISCUSSION

Figure 2 and 3 shows the relationship between rainfall intensity and changes in porewater pressure for Case 1. It is also observed that degradation of matrix suction gave an impact in degradation of safety factor (Figure 4).

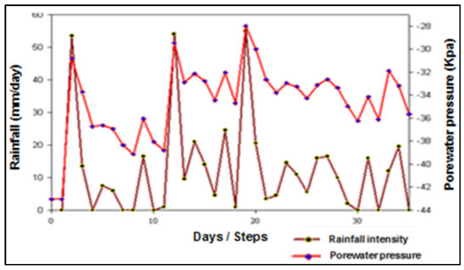

Figure 2 The relationship between rainfall intensity and change in porewater pressure at slope crest (Case1).

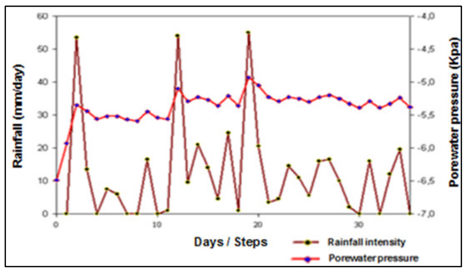

Figure 3 The relationship between rainfall intensity and change in porewater pressure at slope toe (Case1).

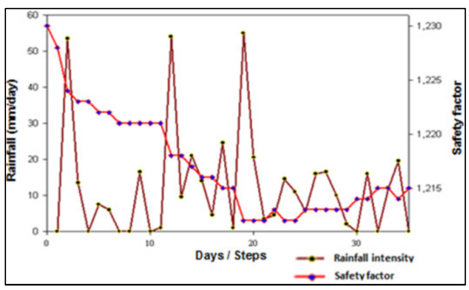

Figure 4 The relationship between rainfall intensity and change in safety factor (Case1)

When there is no or little of rainfall, soil experienced moisture loss process or drying process (evaporation). When the water disappears from the void spaces in the saturated

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Address: 〒819-0395, 744 本岡西区福岡. TEL: 092-802-3378

soil, negative pore water pressure (matric suction) is formed between the soil particles. As more water disappeared, the higher the increase in matric suctions which this matric suction giving additional soil shear strength. In contrast, when infiltration occurs, the matric suction is reduced while reducing the soil shear strength. Occurrence of pore water pressure increase is because slope receive relatively high rainfall when it is still wet (not dry completely). In wet conditions, the permeability of the soil will be greater at the unsaturated zone and thus increase the rate of infiltration. In conclusion, in the event of increased pore water pressure due to heavy rain, moisture content (wet conditions) will increase. Studies have shown that matric suction decrease dramatically at the peak. This event was caused by infiltration of rainfall seep into the soil surface in a vertical direction in this section. Besides that, it also proves that more infiltration occurs in the peak area for this case study. Ground water level was found to increase after the rainfall events on the toe of slope (at a distance of 175m from the left section of the slope). However, the ground water level at peak of the slope does not seen had many changes may be caused by the gradient of the ground water level is high along the slope.

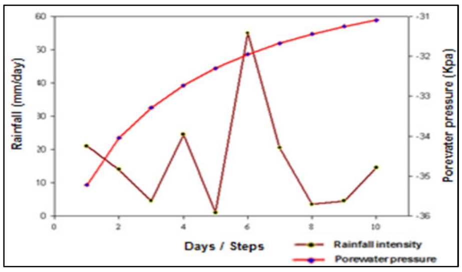

Figure 5 The relationship between rainfall intensity and change in porewater pressure at slope crest (Case2 – Pattern 2).

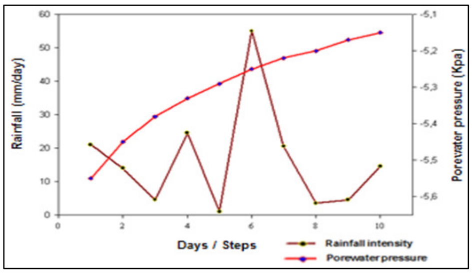

Figure 6 The relationship between rainfall intensity and change in porewater pressure at slope toe (Case2 – Pattern 2).

Figure 5 and 6 shows the relationship between rainfall intensity and changes in porewater pressure for Case 2-pattern 2. In this case, this pattern was seen gave significant effects on the pore water pressure change and their impact on slope stability. In this situation, the continuous rainfall was occurred for 10 days and there was heavy rain in the middle.

5. CONCLUSION

Overall, it can be concluded that the events of rainfall gave an impact on the safety factor degradation for this case study. It was found that the pattern and frequency of rainfall also have a significant impact on increasing the pore water pressure which simulation analysis showed that although the pore water pressure increase highly related to rainfall intensity, but it does not depend entirely on rainfall amount alone. Soil in the dry state has a high value of the matric suction. In this case, the infiltration of rainwater into the slope is quite difficult but after the ground began to wet with rainfall infiltration, then the next rainfall will facilitate an infiltration and thus increasing the pore water pressure. The pore water pressure profile shows the changes in the pore water pressure depends on the intensity and frequency of rainfall itself. It is observed that the negative pore water pressure (matric suction) decreased when soil moisture increased based on the infiltration rate (a result of changing k) of received rain. Soil moisture can be seen closely related to the Soil-Water Characteristic Curve (SWCC). From figure 7, it can be said that the suction distribution is based on the ratio between the intensity of rainfall and saturated soil permeability (I/K_{sat}). The ratio between the coefficient of saturated permeability and rainfall intensity affects the pattern of seepage in unsaturated soil [4].

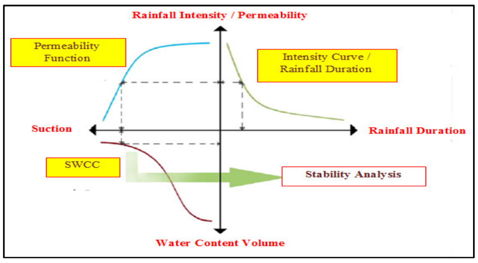

Figure 7 Relationship between rainfall intensity, permeability and water-soil characteristic curves.

As the number of rainfall for this study (in flux) is smaller than the permeability of the saturated soil, the infiltration seen happen a lot. The increasing of pore water pressure will reduce the soil shear strength effectively and therefore will lead to slope failure. Arguably, the effect of this rainfall is the catalyst for other slope failure factors. However, it is not a major factor in the slope failure for this case study because the impact of slope stability declining appeared not too significant.

REFERENCES

[1] Tohari, A,. Nishigaki, M, . Komatsu, M. (2007). Laboratory Rainfall-Induced Slope Failure with Moisture Content Measurement. *Journal of Geotecnical and Geoenvironmental Engineering. 576:93-94.*

[2] D'Odorico, P., Fagherazzi, S., and Rigon, R. (2005). Potential for landsliding: Dependence on hyetograph characteristics. *23 J. Geophys. 1:26-29.*

[3] H. Rahardjo, X. W. LI, D. G. Toll and E. C. Leong (2001). The Effect Of Antecent Rainfall On Slope Stability. *Journal of Geotechnical and Geological Engineering, Vol . 19: 2001, pp 371-399, Netherlands.*

[4] I. Tsaparas, H. Rahardjo, D. G. Toll, E. C. Leong , (2002). Controlling Parameters For Rainfall-Induced Landslides. *NTU PWD Geotechnical Research Centre, School of Civil and Structural Engineering, Nanyang Technology University, Blk N1, 1A- 37, Nanyang Avenue, 639798 Singapore.*