ISBN No. : 987-602-17221-2-1

HIMPUNAN AHLI TEKNIK TANAH INDONESIA
INDONESIAN SOCIETY FOR GEOTECHNICAL ENGINEERING (ISGE)
MEMBER SOCIEY OF INTERNATIONAL SOCIETY FOR SOIL MECHANICS
AND GEOTECHNICAL ENGINEERING (ISSMGE)

Proceedings

18th Annual National Conference on Geotechnical Engineering

"Geotechnical Engineering for Future Infrastructure Development in Indonesia"

Bidakara Hotel - Jakarta, 11-12 November 2014

Support by :

Departemen Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia

Lembaga Pengembangan Jasa Konstruksi Nasional

Proceeding *18th Annual National Conference on Geotechnical Engineering*
Jakarta - INDONESIA, 11-12 November 2014

"Geotechnical Engineering for Future Infrastructure Development in Indonesia"

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TABLE OF CONTENTS

Session IV

Other Session

Effect of Rainfall Intensity and Initial Matric Suction on the Stability of Residuals Soils Slope

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ABSTRACT: Seepage and slope stability issues concerning infiltration in unsaturated slopes are investigated and presented. A two dimensional transient finite element analyses are used to study the effects of the rainfall intensity and initial matric suction on the stability of slope in tropical region in Northern Territory, Australia. The Jabiru landslide occurred in March 2007 after severe rainstorm with rainfall amount of 0.8 m in 3 days. This landslide occurred at a soil slope with height of 23 m and angle of 19˚. Field and laboratory investigations were carried out to determine soil parameters required in slope stability analysis. Parametric study was performed to find out which cases with respect to rainfall intensity and initial matric suction triggering the landslide occurrence. The results indicates that if the rainfall intensity is greater or equal to the saturated hydraulic conductivity of the soil ($I \geq k_{sat}$), the slope stability is controlled by the saturated hydraulic conductivity of the soil. In general, the results conclude that the slope stability is highly dependent on the initial matric suction.

Keywords: rainfall, infiltration, matric suction, slope stability, residual soil

1 INTRODUCTION

Shallow slopes failure have been identified while extreme rainfall throughout the entire Magela Creek catchment occurred at late February to early March 2007 (Moliere et al., 2007) at Northern Territory, Australia. The location and typical of landslide is shown in Figure 1 and 2 respectively. During a week period between 23 February and 16:30 h 2 March, 945 mm of rain was recorded from closest rainfall station at Jabiru Airport. Within a three-day period between 27 February and 2 March, 784 mm of rain fell at Jabiru Airport. As a result of this intense rainfall, landslides were initiated where the sandstone has been removed to expose Oenpelli Dolerite. This landslide occurred at a soil slope with a height of 23 m and angle of 19˚ (Erskine et al., 2012; Saynor et al., 2012). The intense rainfall may have a significant impact on the stability of a rehabilitated mine. Figure 2 illustrates the typical of slope failure. Study need to be performed to find out which cases with respect hydraulic parameter to triggering the landslide occurrence. Effect of rainfall pattern and distribution has been investigated by Suradi and Fourie (2013), Muntohar et al. (2014), Suradi et al. (2014). The main objective of this research was to investigate the effect of rainfall intensities and initial matric suction on stability of the slope.

2 NUMERICAL MODELING

2.1 *Seepage analysis*

In this study, analyses for transient seepage conditions were conducted on a 23 m high slope inclined at 19°. The slope was composed of a homogenous, isotropic soil. The thickness of soil was relatively shallow about 2 m (assigned as R2). An impermeable soil and rock layers (assigned as R1) was found below the soil layer. The finite element seepage analysis software Seep/W 2004 for saturated–unsaturated soil systems was used in this study. The finite element mesh, along with the boundary conditions, is shown in Figure 3a. At the left and right edges were modeled as infinite element. Along the left and right boundaries beneath the soil layer (R2), a

Figure 1 Location of the studied area

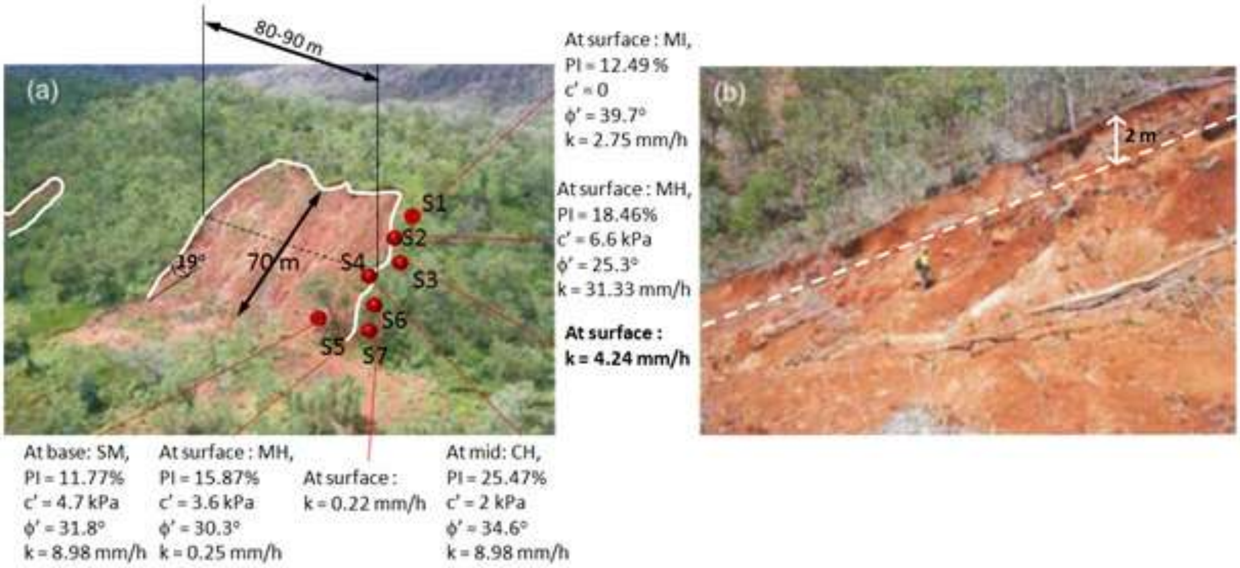

Figure 2 Typical of the landslides (a) landslide area and soil properties, (b) longitudinal section of failure plane

constant head was applied. A zero flux boundary was applied along the left and right boundaries of R2 layer. The rainfall intensity was modeled by applying unit flux boundary (q) to the surface of the slope for 120 hours. Three rainfall intensity, I = 0.006 m/h, I = 0.008 m/h, I = 0.012 m/h, were applied to investigate their effect on the slope stability. The pore-water pressure distributions above the water table were plotted for all time steps at selected sections; top, mid, and toe section, as shown in Figure 3a.

A hydrostatic initial condition was established at the beginning of the transient seepage analysis. Initial pore water pressure was generated from initial suction by applying nodes pressure in R2 layers (Figure 3b). A limiting negative pore-water pressure was imposed as an initial condition would ensure that the pore-water pressure distributions were more realistic and represented a steady state condition. Three matric suction conditions were applied on slope surfaces, 10 kPa, 33 kPa, and 75 kPa, to evaluate the effect of initial matric suction on the slope stability.

2.2 *Slope stability analysis*

For the slope stability analysis, the Bishop method of slices was used to compute the factor of safety within the soil. The field observation confirmed that a shallow slope failure occurred with planar planes. The fully specified failure planes as illustrated in Figure 4 were used in the analyses. The depth of slip plane was determined at 2 m below the slope

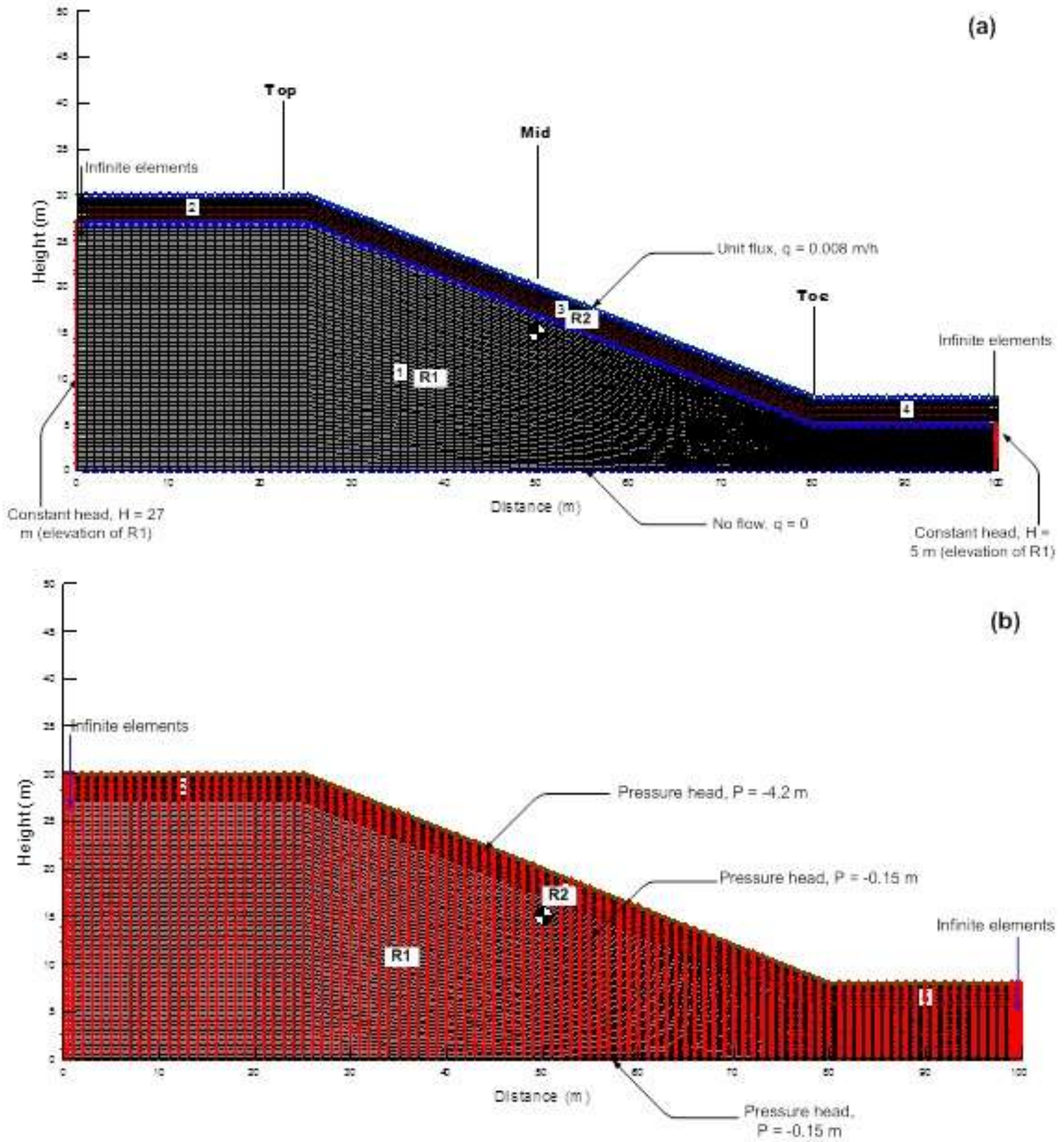

Figure 3 (a) Slope geometry and boundary conditions of the slope for transient analysis (b) Boundary conditions for generating initial pore-water pressure

surface. The pore–water pressures that were determined in the seepage analysis by Seep/W 2004 were used as input data for the slope stability analysis. Slope/W 2004 determines the elements that lie closest to the centre of each slice base and computes the pore–water pressure at each location from the nodal pore–water pressure conditions of the element nodes.

Soil properties

Laboratory tests were conducted to estimate the hydraulic shear strength and properties of the slopes. The location of soil samples and its properties was shown in Figure 2a. Figure 5 shows the soil water characteristic curve (SWCC) and unsaturated permeability which was obtained from pressure plate test (Suradi and Fourie, 2013). The saturated hydraulic conductivity (k_{sat}) of R1 and R2 layers were 1 x 10^{-10} m/h and 0.008 m/h for region R1 and region R2 respectively. The shear strength parameter for region R1 were c' = 0 kPa, ϕ' = 40°, ϕ^b = 20°, and γ = 23 kN/m^3, while for region R2 were c' = 3 kPa, ϕ' = 16°, ϕ^b = 20°, and γ = 18 kN/m^3.

3 RESULTS AND DISCUSSION

Figure 6 presents the results of numerical simulation on the effect of rainfall intensity and initial matric suction on the slope stability. For the rainfall intensity, I = 0.008 m/h and 0.012 m/h, the change of FS is relatively the

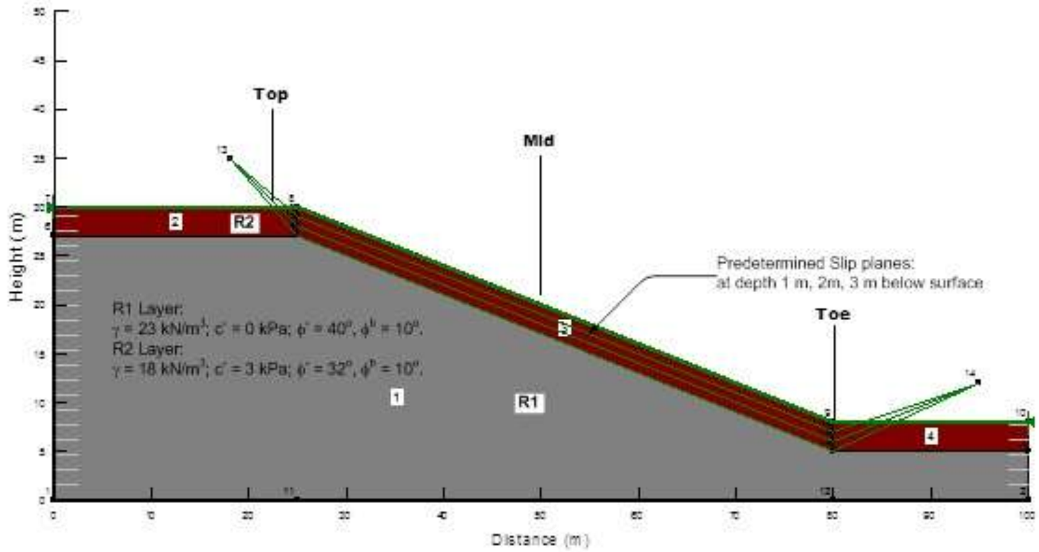

Figure 4 Range of possible critical slip surfaces used for the slope stability analysis

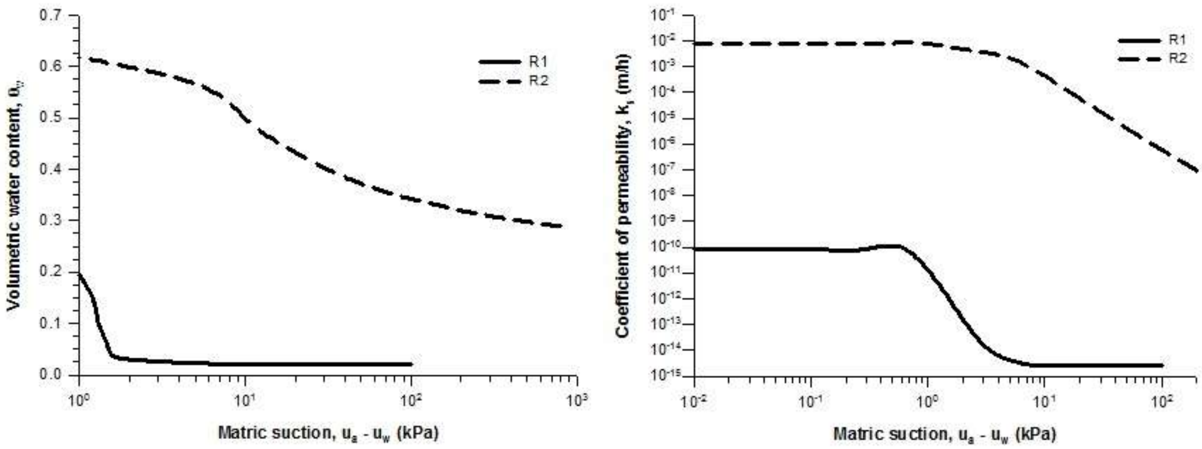

Figure 5 Soil-water characteristic curves and permeability functions with varying values for the soils used in the study

same for all initial matric suction condition. The result indicates that if the rainfall intensity is greater or equal to the saturated hydraulic conductivity of the soil ($I \geq k_{sat}$), the slope stability is controlled by the saturated hydraulic conductivity of the soil. In contrast for a low-intensity rainfall, I = 0.006 m/h ($I < k_{sat}$), the soil in the unsaturated zone remains unsaturated as the wetting front moves through it and results in delay slope failure or the slope remains stable. Mahmood et al. (2011) show the similar characteristics with for anisotropic hydraulic conductivity. Tsaparas et al. (2002) explained that if the ratio I/k_{sat} is low, then more water will infiltrate the ground and less amount of the rainfall will disappear as runoff. If the ratio is too small then negative pore–water pressures may not even be affected by the infiltration.

In general, change in matric suction due to climate decreases with the depth. Slope failure is dependent on the initial matric suction condition of soil at the surface and subsurface. Figure 6 show clearly that the slope remains stable at a higher initial matric suction of 75 kPa although a high rainfall intensity of 0.012 m/h is applied on the slope. At a low initial matric suction of 10 kPa and 33 kPa, the slope is likely to fail which is indicated by the FS < 1 for all applied rainfall intensities. From the trial of initial matric suction, the uncertainty of slope failure due to initial matric suction is high. Then, field monitoring should be carried out to observe the appropriate value of matric suction and to have a better slope stability analysis. Using the field observation, Lim et al. (1996) mentioned that the change of matric suction is a function of the initial matric suction in the slope.

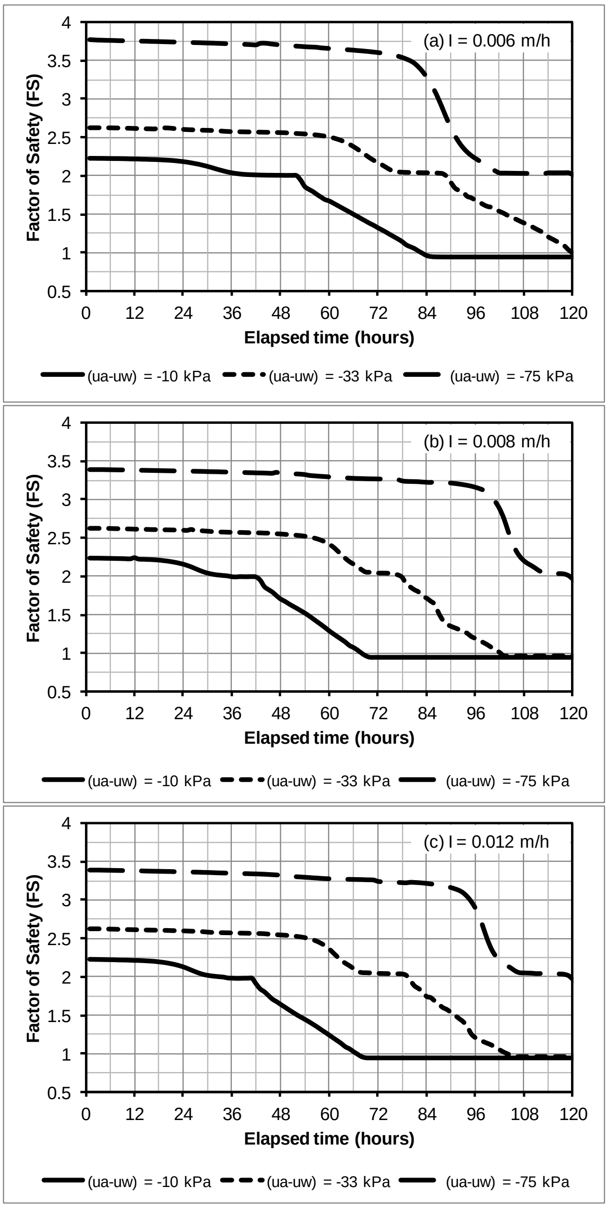

Figure 6 Variation of slope stability with various initial suction condition for (a) I= 0.006 m/h, (b) I = 0.008 m/h, and (c) I = 0.012 m/h.

4 CONCLUSIONS

The numerical study and a case study were used successfully to study rainfall intensity and initial matric suction and its effect on slope stability. The ratio between rainfall intensity and saturated hydraulic conductivity of the soil (I/k_{sat}) controlled the change of slope stability. The results of the numerical study show that in general, the slope stability is more affected by the change of initial matric suction than the rainfall intensity. The strong interaction between the initial matric suction and slope stability, the parameters need for proper and realistic choices when performing transient analysis.

ACKNOWLEDGEMENTS

The first author thanks for the financial support from Ministry of Education and Culture, the Republic of Indonesia under fundamental research grant scheme in 2010-2012 entitled “Numerical and Experimental Studies of Rainfall Infiltration Induced Slope Stability”. Support from Mr. M. Suradi and Prof. Andi Fourie, School of Civil and Resources Engineering, University of Western Australia is acknowledged.

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