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VARIATION OF SAFETY FACTOR WITH SUCTIONS OF INFINITE CLAY SLOPE UNDER PARTIALLY SATURATED CONDITION

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ABSTRACT

In this paper, the simulation results of variation of safety factor with suctions of infinite clay slope under partially saturated condition are presented. The variations of safety factor with matric suction ranging from 1 to 100, 000 kPa are presented. The undrained shear strength, which is a function of matric suction, is back-calculated from the laboratory bearing tests reported by Uchaipichat and Man-koksung (2011). The simulations results show that the safety factor increases with increasing matric suction for all values of slope thickness. The results also show a decrease in safety factor with increasing values of slope thickness.

Keywords: infinite slope, partially saturation, safety factor, clay, slope stability.

INTRODUCTION

Earth structures are often encountered in geotechnical engineering works. Typical examples of these types of structures are dams, roads, canals, bridge abutments and other types of embankment. The stability of earth structures is crucial since the failure of structure can cause massive disasters and losses of lives. Thus the safety of the earth structure must be checked and approved by geotechnical engineers with lots of experiences.

Typically, the slope stability analysis of earth structure is based on the assumption, in which fully saturated and completely dry conditions are assumed for soils below and above ground water level, respectively. Although, the analysis using this assumption is simple, the construction costs unnecessarily increase due to misunderstanding behaviors of partially saturated soils. Moreover, a decrease in safety factor of slope can occur upon wetting during rainy season.

The important parameter in slope stability analysis is shear strength of soil which can varies with water content or suction under partially saturated condition (e.g. Vanapalli *et al*., 1996; Khalili and Khabbaz, 1998; Cunningham *et al*., 2003; Thu *et al*., 2006; Zhou and Sheng, 2009; Uchaipichat, 2010). Moreover, Uchaipichat and Man-koksung (2011) found that the ultimate bearing capacity of foundation on clays increased with increasing matric suction.

This paper focuses on the stability analysis of infinite clay slope since it can indicate the potential for a slope to generate a mudflow. Figure-1 shows the diagram for infinite slope stability analysis. Uchaipichat (2012) derived the general equation for safety factor of infinite slope for unsaturated soils, which can be expressed as,

$$FS = \frac{c}{\gamma z \sin\beta \cos\beta} + \left(1 - \frac{\chi s - u_a}{\gamma z \cos^2\beta}\right)\frac{\tan\phi}{\tan\beta} \tag{1}$$

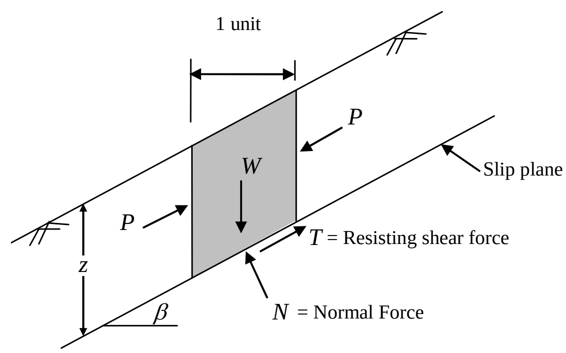

Figure-1. Infinite slope stability analysis.

in which, FS is the factor of safety, c and ϕ are the cohesion and the internal angle of friction of soils, γ is the unit weight of soils, β is the soil slope angle, u_a is the pore-air pressure and χ is the effective stress parameter attaining a value of unity for a saturated soil and zero for a dry soil.

In case of undrained condition, c is equal the undrained shear strength (S_u) and ϕ is zero. Thus the safety factor can be expressed as,

$$S_u = \frac{q_{ult} - q}{N_c} \tag{2}$$

where, S_u is the undrained shear strength, q_{ult} is the ultimate bearing capacity, q is the surcharge at foundation base, which is equal to zero in this investigation, and N_c is bearing capacity factors which is equal to 5.14.

Figure-2 shows a plot in the semi-log scale between the undrained shear strength and matric suction. The plot shows an increased in undrained shear strength with increasing matric suction. The relationship between the undrained shear strength and matric suction can be expressed as,

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$$S_u = 43.026\ s^{0.3488} \tag{3}$$

where, s is the matric suction.

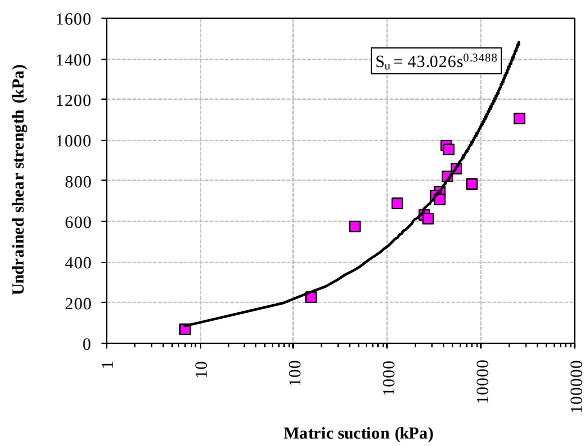

Figure-2. Variation of undrained shear strength of kaolin with matric suction.

SIMULATION OF SAFETY FACTOR OF INFINITE CLAY SLOPE WITH MATRIC SUCTIONS

The simulations of safety factor with suction of infinite clay slope under partially saturated condition are carried out. The material used in simulations is kaolin clay. Its properties were reported by Uchaipichat and Man-koksung (2011) as shown in Table-1. Figure-3 shows the soil-water characteristic curve (SWCC) of the samples. The values suction separating saturated from unsaturated state (s_e) and the residual suction (s_r) are 700 and 7, 000 kPa, respectively.

Table-1. Index properties of sample.

Property	Value
Liquid limit	52%
Plastic limit	31%
Specific gravity	2.72
Maximum dry unit weight (γ_{max})	14.1 kN/m^3
Optimum moisture content (OMC)	27.5%

The simulation results of variation safety factor with matric suction for of infinite clay slope with thickness of 1, 2, 4, 6, 8 and 10 m are shown in Figures 4 and 5. The safety factor can be calculated using Equation (2). The undrained shear strength, which varies with matric suction, can be obtained from the expression in Equation (3). The simulations results show that the safety factor increases with increasing matric suction for all values of slope thickness as shown in Figure-4. Figure-5 shows a decrease in safety factor with increasing values of slope thickness.

It can also found that the safety factor of slope with thickness of 8 and 10 m can reduce from the value greater than 10 at very high value of matric suction to the value less than 1 at the low value of suction. Thus, the slope can become instable when the soil state enters to saturated condition.

CONCLUSIONS

The simulations of safety factor of infinite clay slope under partially saturated condition at various matric suction values are performed. The variations of safety factor with matric suction ranging from 1 to 100, 000 kPa are presented. The undrained shear strength, which is a function of matric suction, is back-calculated from the laboratory bearing tests reported by Uchaipichat and Man-koksung (2011). The simulations results show that the safety factor increases with increasing matric suction for all values of slope thickness. The results also show a decrease in safety factor with increasing values of slope thickness.

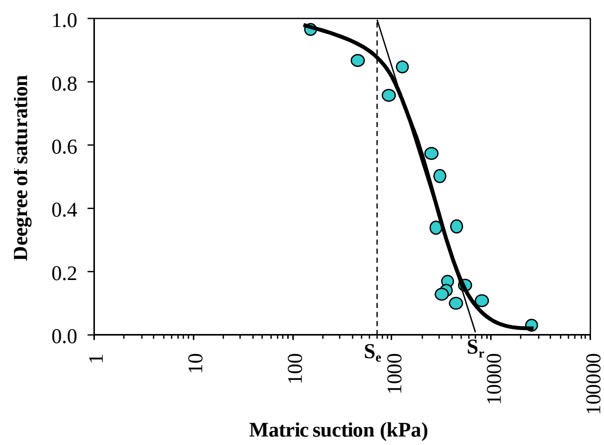

Figure-3. Soil water characteristic curve of compacted kaolin (Uchaipichat and Man-koksung, 2011).

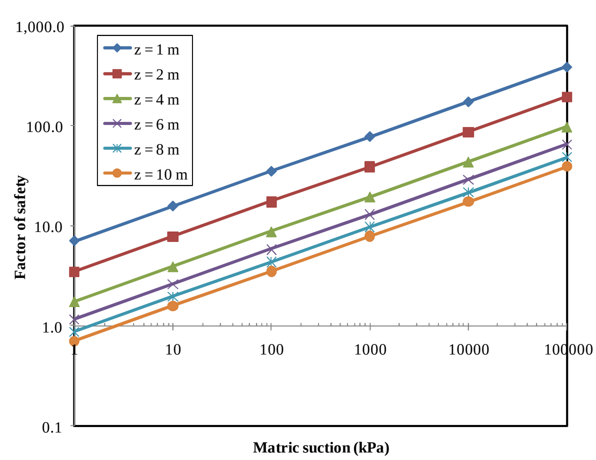

Figure-4. Variation of safety factor of infinite clay slope with matric suction at various values of thickness.

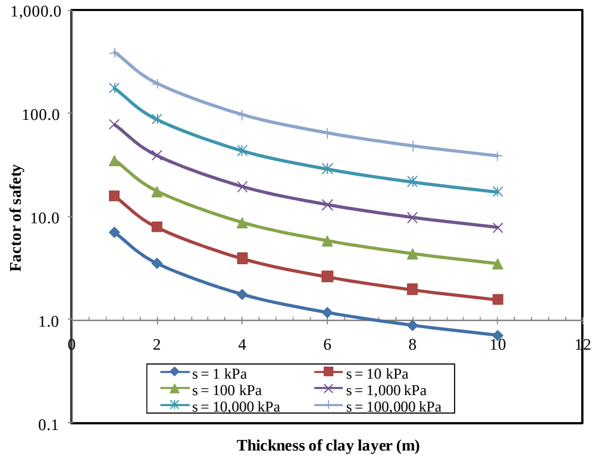

Figure-5. Variation of safety factor of infinite clay slope with thickness at various values of matric suction.

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