III-407 NUMERICAL SIMULATIONS ON THE INFILTRATION BEHAVIOURS OF HAIDO SLOPES

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1. INTRODUCTION

Natural slopes in areas aboundant in weathered soils of unwelded tuff (locally called "*Haido*") are prone to catastrophic failure in periods of heavy rainfall. A number of slope failure disasters have been recorded in the surburbs of Kumamoto city during the 1980, 1982, and 1985's rain seasons. The main cause of these slope failures is considered to be the reduction of shear strength due to the increase of pore pressure induced by the seepage flow in the slopes during or after the rainfall.

This paper presents the results of both field monitoring and numerical simulation on the variation of pore water pressure with the amount of rainfall in a natural slope.

2. FIELD INSTRUMENTATION

A natural slope was choosen and observations carried for more than one year. Tensiometers and pressuremeters have been used to monitor the variation of pore water pressures during the wetting and drying cycles. About 10 auger borings were drilled outside the catchment to envestigate the rough layering system of the slope and the boundary conditions to be used in the analysis. The results from the borings have shown that the slope was layed by a thin Haido soil layer followed by a semi-permeable soft and weathered rock layer (Fig. 1).

3. NUMERICAL ANALYSIS

Unsteady two - dimensional saturated - unsaturated flow in a slope can be analysed numerically using using the finite element method based on the following partial differential equation [1];

$$div\ K(\psi)\vec{\nabla}(\psi + x_3) = (C(\psi) + \alpha S_s)\frac{\partial \psi}{\partial t} \qquad (1)$$

where $K(\psi)$ is a permeability tensor of second order, ψ is the capillary potential, x_3 is the gravitational potential and t is time. Parameter α is a coefficient; $\alpha = 1$ for a saturated zone and $\alpha = 0$ for unsaturated zone. $C(\psi)$ is the specific moisture capacity determined from the $\psi - \theta$ curve for unsaturated soil.

Inorder to solve $Eq.(1)$, one needs to provide the appropriate initial and boundary conditions [1]

The variation of the pore pressure was predicted using the above analytical model introducing the recorded rainfall, the established geometry and boundary conditions, and soil properties. Distribution of natural water contents from boring data and actual observed suction at a particular initial time gave valuable informations on the probable initial conditions. The adopted FEM model showing locations of tensiometers, pressuremeters and seepage collectors is as in Figure 1. Material properties used in the present analysis are summarised in Table 1.

4. DISCUSSION

Results of observations from 30th June 1991 to 4th July 1991 are used as an example. The results from the observed pore pressure in Figure 3 reveals the typical behaviour of *Haido* soils, for an immediate decrease in suction immediate after the start of the rainfall. There was an immediate sharp increase and decrease in the measured pressure at pressuremeter $P1$ in the weathered rock soon after start and end

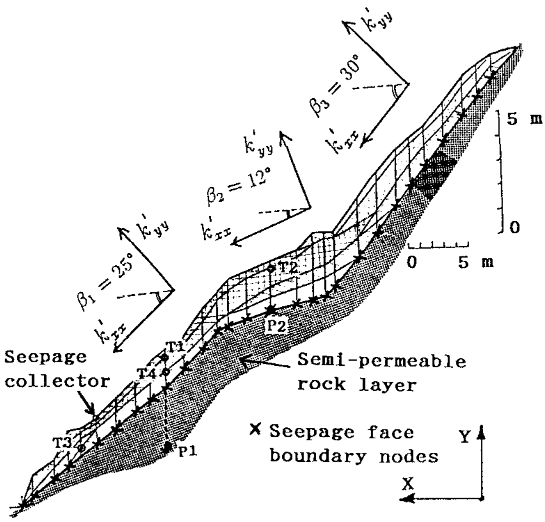

Fig. 1 FEM model with location of Tensiometers and pressuremeter

TABLE 1 Input data for seepage analysis

	LAYER NO.			
	1	2	3	4
Wn (%)	40 - 45			
Gs	2.563	2.640	2.667	2.689
n	0.567	0.608	0.537	0.523
S_{r0}(%)	70 - 80			
$k_{xx}=2k_{yy}$ ($\times 10^{-4}$cm/s)	3.79	4.14	2.96	1.785

of the rainfall [2]. This gave an indication that the rock was semi-permeable, rather than impermeable. This information was then utilised in numerical analysis by declaring the base nodes as seepage faces (i.e prescribed pressure head $\psi = 0$ when saturated) as shown along the base of the soil layer in Figure 1. A gradual decrease in the predicted pore pressures by tensionmeter *T1*, *T2* and *T3* after the stop of the rainfall (Figure 2), proves the validity of the above assumption for this particular slope; otherwise an assumption of an impermeable base could lead into predicting a gradual building up of the pore water pressure, especially at the toe of the slope.

The efficiency of the present simulation model is further supported by distribution of the degree of saturation in Figure 3. Figure 3(a) is the the predicted distribution of the degree of saturation on 30th June 1991 (23:00 hrs) soon after the peak hourly intensity. The second figure (Figure 3(b)), shows the distribution during the dewatering process on 2nd July 1991 (1:00 hrs). Gradual decrease of the water content from the soil surface, agrees with the practical behaviour in the field.

5. CONCLUSIONS

Results from a joint simulation scheme have been presented. A bove results reveals that the mechanisms of slope failures due to rainfall are complex interactions between hydrology, geology and geomorphology of the area concerned. The following can be concluded for slopes founded on weathered soil of unwelded tuff (*Haido* soil) that a slight intensity of rainfall can cause an increase in the degree of saturation and subsequently decrease in the suction. On the otherhand, continuous heavy rainfall, causes seepage flow and a sharp pore pressure increase within the slope, especially for slopes layed on an impermeable base rock. As a result, the effective normal stress decreases and hence decrease in the shear strength of the soil at the base of the soil layer. The seepage results obtained above can be used in stability analysis.

REFERENCES

[1] Neuman, S. P. (1973), Saturated - Unsaturated Seepage by Finite Elements, *ASCE, HY12*, pp. 2233-2250.

[2] Mshana, N. S., et al (1992), Field observations on the infiltration behaviours of Haido slopes, *JSSMFE 27th Annual meeting* (to be presented in June, 1992).

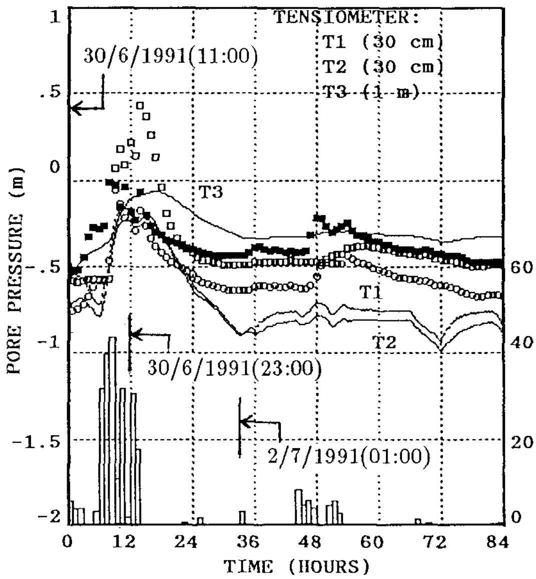

Fig. 2 Predicted and observed pore water pressure.

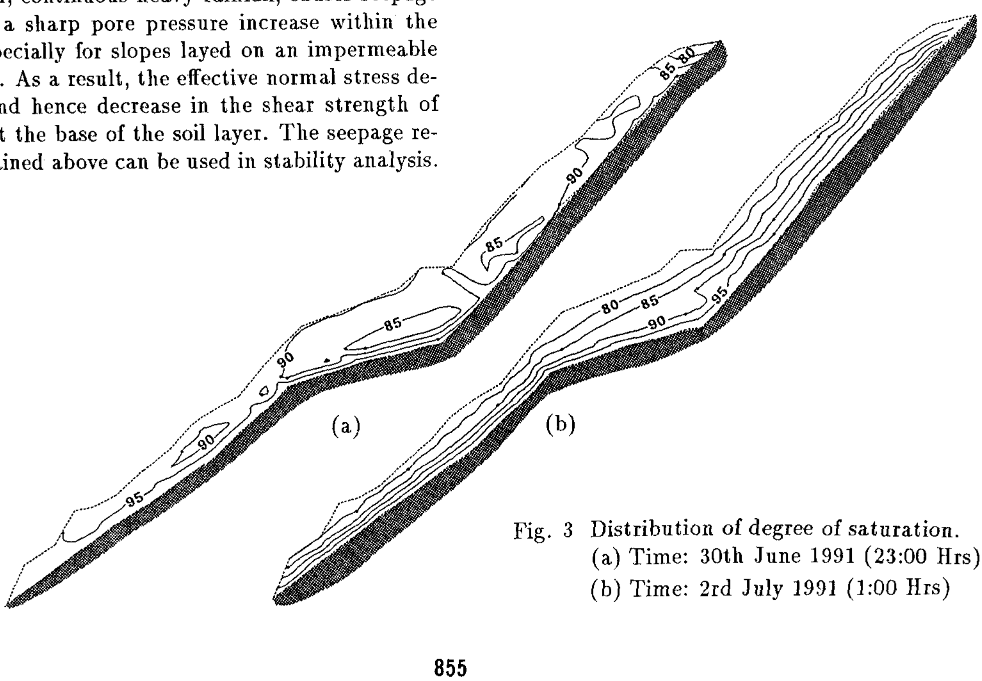

Fig. 3 Distribution of degree of saturation.
(a) Time: 30th June 1991 (23:00 Hrs)
(b) Time: 2rd July 1991 (1:00 Hrs)