III-422 STUDY ON THE MECHANISMS OF SLOPE FAILURE DUE TO HEAVY RAINFALL BY USING LABORATORY AND NUMERICAL MODELS

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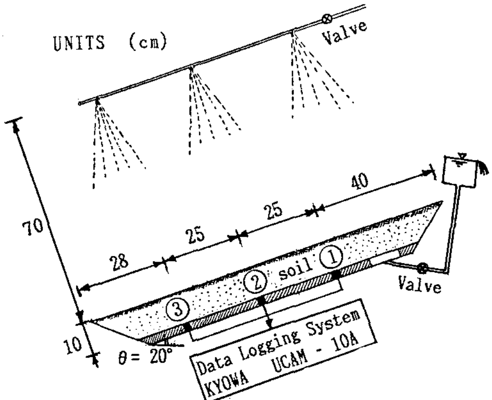
1. INTRODUCTION

Climate acts in several ways to promote the occurance of slope failure, but rainfall has the most significant influence.

In this paper the mechanism of rapid failure of Haido slopes due to heavy rainfall is studied at laboratory scale. Both Model test and Numerical predictions are used to facilitate the simulation procedure, and the results are compared. The failure pattern is derived from the failure criterion based on stresses.

2. MODEL TEST METHOD

The slope was first infiltrated by sprinkling at a rate of 25 mm/h until the pore water pressures at the base of the soil layer reached a steady state. The saturated slope was then brought to failure by piping at the base of the soil layer as shown in Fig. 1. Details on the soil sample and preparation of the slope are given Ref.1 below.



①②③ : Pore pressure gauges No.1, No.2, No.3

Fig.1 Schematic diagram of Lab. model

3. NUMERICAL SIMULATION METHOD

Numerical prediction was conducted by using a *deterministic model- FEM* analysis combining saturated-unsaturated flow analysis and stability analysis. Infiltration behaviors were obtained from the solutions of a two-dimensional quasilinear partial differential equation for saturated-unsaturated flow through porous media; while the failure pattern was derived from the Mohr-Coloumb failure criteria (Iseda[2], 1985). The prediction considers both the reduction of the soil strength due to increase of degree of saturation and the increase of the self-weight of slope due to seepage.

The material properties used in the present analysis are summariesed in Table 1.

TABLE 1: MATERIAL PROPERTIES

	SOIL	SOIL-CEMENT MIX
Wn (%)	41.5	54.8
Gs	2.497	2.778
ρ_t (g/cm³)	1.390	1.640
ρ_{sat} (g/cm³)	1.557	1.650
ρ_d (g/cm³)	0.982	1.059
e	1.543	1.623
S_{r0} (%)	67.2	93.8
k_{sat} (cm/s)	2.62×10^{-4}	1.00×10^{-10}
c' (kgf/cm²)	0.15 (0.025)	6.0 (6.0)
ϕ' (°)	35.0 (35.0)	45.0 (45.0)
υ	0.35	0.20
E_i (kgf/cm²)	30.0	3600

NOTE: ( ) —Bracketed figures represent values at saturated state

4. RESULTS AND DISCUSSION

4.1 MODEL TEST

The slope was piped after 130 minutes of sprinkling. The first crack appeared in 181 min at a location 15 cm from the crest. This was followed by heaving and formation of radial cracks at time 190 min. From time 206 min, there was gradual flow of the heaved area and extension of cracks, to a total failure at time 210 min. The sketch of the final state is given in Fig. 2.

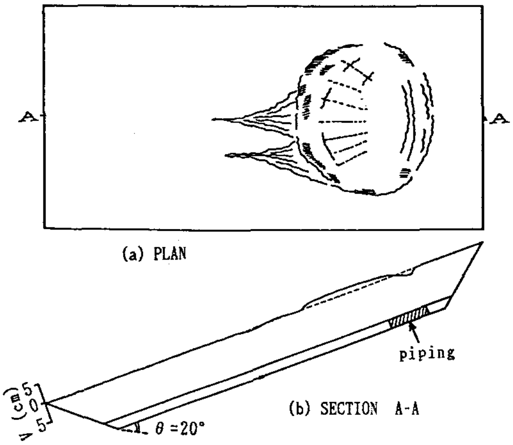


Fig. 2 Sketch of the final state

4.2 NUMERICAL PREDICTION

The contours of the predicted local safety factors are given in Fig. 3. The failure zone is located around the piping area and at the region close to the toe of the slope, which agrees with experimental results. These results were obtained by reducing the saturated cohesion at elements with negative mean stress.

There were no failure zone at normal saturated cohesion as given in Table 1 above.

5. CONCLUSIONS

From this research, we have learned that the failure pattern due to piping can be predicted by reducing the cohesion at saturation with the decrease of the mean stress.

Besides the effect on cohesion, further researches are to be carried to check the effect of piping on the modulus of elasticity.

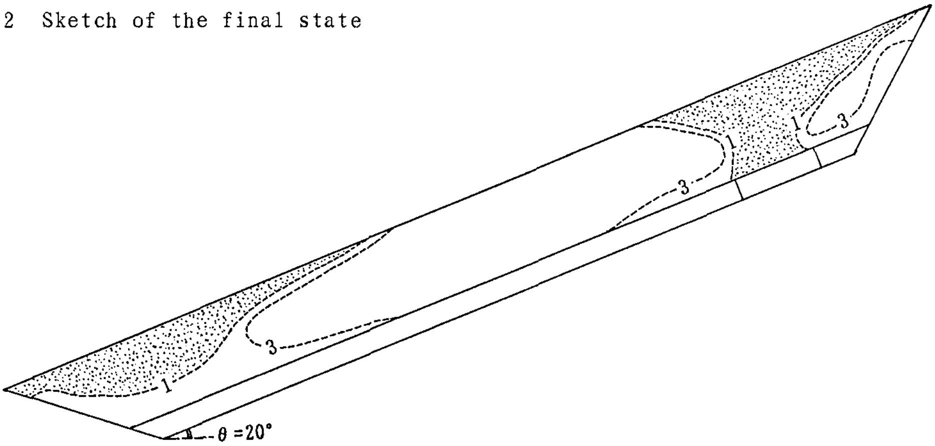


Fig. 3 Contours of the predicted local safety factors (Time = 131 min)

REFERENCES

1) Mshana, Suzuki, Kitazono(1990): Study on Infiltration behaviors of unsaturated slopes by using Laboratory and Numerical model. (JSCE-Seibu, pp. 394-395).

2) Iseda et al(1985): A study on the Gentle Slope Failure at the Nagasaki Heavy Rainfall(in Japanese) JSSMFE, Vol. 25, No. 2, pp. 173-185.