Experimental and Numerical Evaluation of an Optimum Slope Covering Layer Thickness of Low Permeable soil (Masado) for Small Earth fill Dam Embankment

Kyushu University, Student, ○ MABOJANO Jalalya
Kyushu University, Professor, YASUFUKU Noriyuki
Kyushu University, Assistant Professor, ISHIKURA Ryohei
Kyushu University, Student, ALOWAISY Adel

1. Introduction

Failure of small earthen embankments are the most common type of dams in the world and reports show that the frequency of failure of such dams is about four times greater than that observed for concrete and masonry dams. [2)] The problem is severe in tropical regions where the intense rainfalls originate large and quick variations of the water surface of earth fill dam embankments. Covering the face of the riverside slope or earth fill embankment dams slope with impervious materials (impervious soil, concrete, impervious sheet or other artificial materials) prevents the river water from penetrating into the embankment.[1)]

In this paper, 2D numerical simulations was conducted at laboratory scale to evaluate the optimum slope covering layer thickness of low permeable soil as an improvement mechanism of small homogeneous earth fill dam embankment and the results are compared with the experimental results.

2. Material used

Two different types of soil were used, (Toyoura sand as embankment material and Masado as a covering layer). Standard laboratory experiments were conducted to obtain the basic parameters of both soils as indicated in Table 1. & Fig. 1. The soil-water characteristic curves (SWCC) for embankment material (Toyoura sand) was conducted using Tempe cell to obtain the hydraulic parameters as represented by Fig. 2. The SWCC was best-fitted using Van Genuchten equation (180) which is the general form of Mualem (1976)

$$S_r(h_p) = S_{res} + (S_{sat} - S_{res})\left[1 + \left(g_a\left|h_p\right|\right)^{g_n}\right]^{\frac{1-g_n}{g_n}}$$

Where S_r, S_{res}, S_{sat}, are degree of saturation, residual degree of saturation and saturated degree of saturation respectively. The parameters were obtained from laboratory, while g_a, g_c, and g_n are the empirical parameters related to air entry value of the soil, rate of water extraction from the soil, and function of residual water content respectively. The parameters were obtained by best fitting the laboratory data by Van Genuchten equation,. h_p is suction pore pressure head.

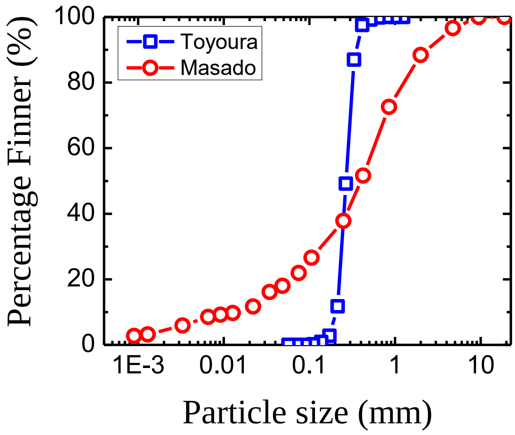

Fig.1. Grain size Distribution

Table 1. Material Properties

Material Properties	Test Results	
	Toyoura	Masado
Maximum dry density, g/cm3	1.56	1.768
Optimum water Content, %	14.7	16.5
Natura Water Content,%	0.06	1.17
Specific Gravity	2.646	2.717
Permeability, m/sec	1.55×10^{-4}	1.23×10^{-5}
Maximum Void ratio,e_{max}	0.939	1.851
Minimum Void ratio,e_{min}	0.6105	1.117
Relative Density,%	80	80

3. Numerical Analysis

Seepage flow analyses by FEM software PLAXIS 2D was conducted at laboratory model scale. It was initially assumed that flow conditions within the embankment correspond to a steady-state ($\Delta t = 0$) which was firstly performed, followed by transient analysis by water infilling upstream side of the dam until it reaches the maximum level and then maintain constant for a specific time interval. In this analysis a linear variation of hydraulic head versus time was specified as a boundary condition. Numerical simulation was done under 3 Cases; Case 1 embankment without covering layer, Case 2 embankment covered by 6 mm layer thickness and Case 3 embankment covered by 9 mm layer thickness. It was difficult to model 3 mm layer thickness because the layer was too small such that the software could not recognize. Previous publications by the author show Experimental results for 3 mm cover. [4)]

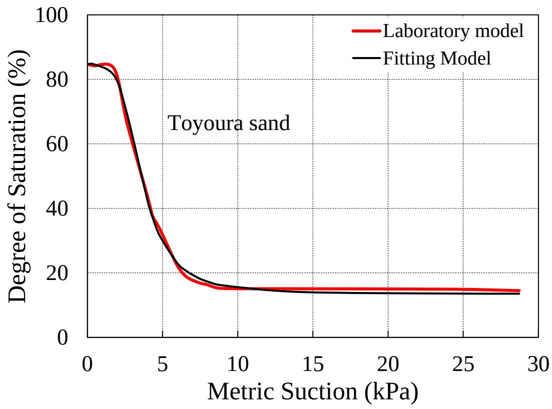

Fig. 2. Toyoura sand SWCC

4. Results and Discussion

Comparisons of suction against time obtained from numerical simulation are presented in Fig. 3. The figure shows comparison of both experimental and numerical analysis.

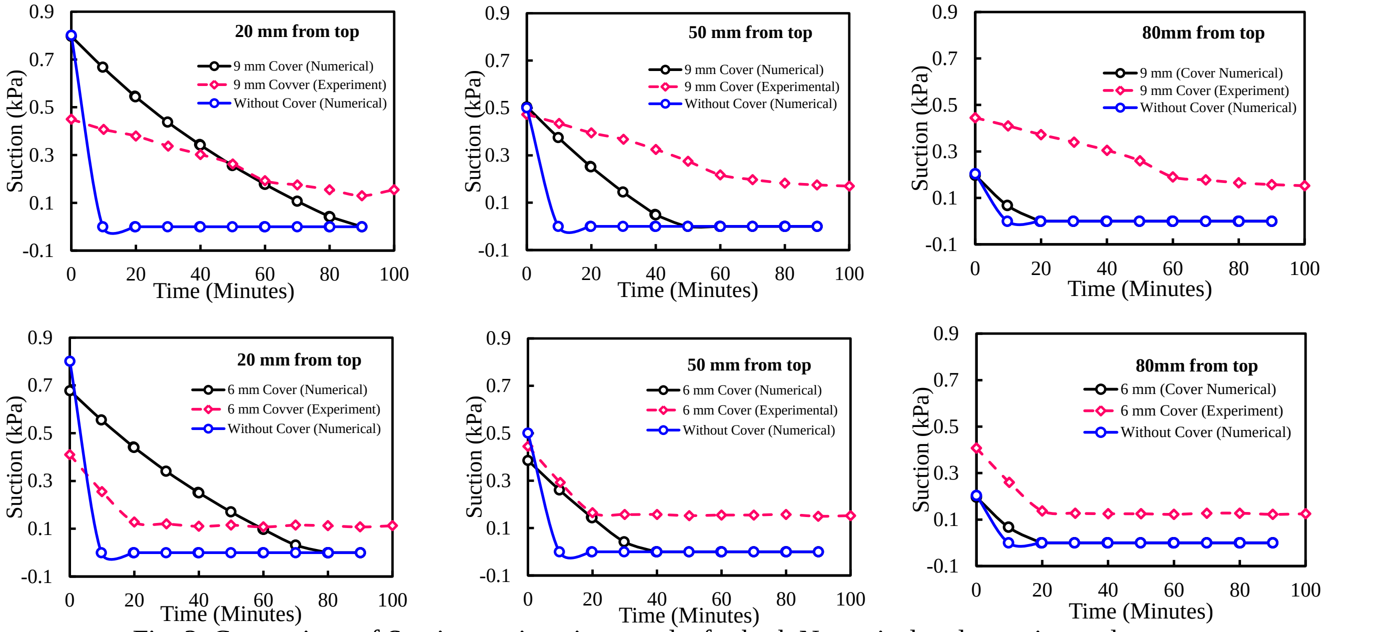

Fig. 3. Comparison of Suction against time results for both Numerical and experimental cases

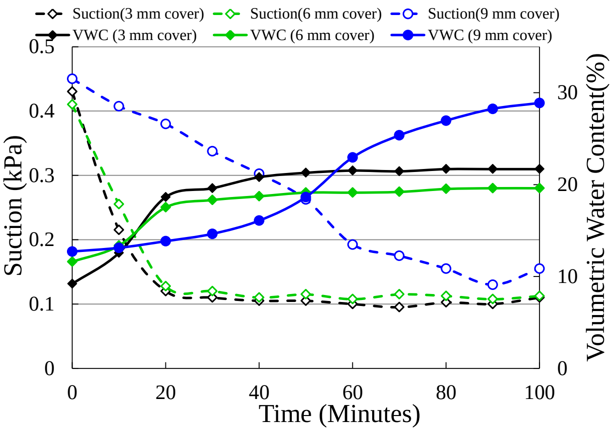

Fig. 4. Effect of varying layer thickness (Experimental data)

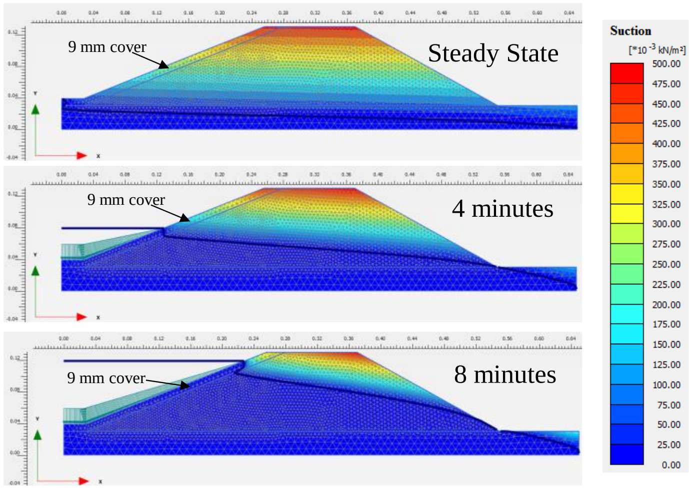

Fig. 5. Suction distribution during change in water level

Observation shows rapid decrease in suction values when the embankment is not covered but when the embankment was covered by low permeable soil the suction values decrease gradually to 0 for numerical data and 0.1 for experimental data and remain constant. Further observation shows small discrepancies for initial suction values especially for the upper layer and deep depth, this may be contributed by uncertainties during preparation of experiment in laboratory.

Thin covering layers (3 mm & 6 mm) shows almost identical results, Fig. 4. [4] The results show good agreement between experimental and numerical simulation results as the covering layer thickness was increased from 6 mm to 9 mm. No significant change observed after the first 100 minutes when the embankment is fully saturated. Fig.5 shows suction distribution due to change in water level when the embankment is covered by 9 mm layer of Masado soil.

5. Conclusion

From the obtained experimental and Numerical simulation results, it is concluded that thin covering layer 3 mm does not show significant decrease in seepage, but when covering layer increases from 6 mm to 9 mm significantly decrease seepage into an embankment.

In order to generalize the obtained results, numerical simulation will be done at prototype scale configuration varying the saturated hydraulic conductivity **(k_{sat})** and slope inclination and will be included during presentation

6. Acknowledgement

The authors acknowledge JICA for their financial support. Special thanks to Professor Hemanta Hazarika and Michio Nakashima of Kyushu University geotechnical engineering laboratory, for their great technical advice.

7. Reference

1) Taizo Kobayashi, et al, (2015) Prevention effect of slope-covering method against seepage failure of river embankment. The Second Japan-India workshop in Geotechnical Engineering
2) Mumba Koalala et al, (2015). The causes of Dam Failures. (IJERT): 2278-0881
3) Plaxis 2D Tutorial & Reference Manual (2016)
4) Mabojano, J. Yasufuku, N. (2016) Unsaturated soil study group Research Paper Collection.