EFFECT OF CLIMATE CHANGE ON EROSION PROCESS OF COHESIVE RIVERBANKS

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1. Introduction

The mean annual temperature has increased by 1.0°C in Japan over the last century while it is expected to rise by 2 to 3°C within the next 100 years1). As a result, precipitation and the frequency of intense precipitation events are also projected to increase throughout East Asia2). Summer precipitation in Japan is expected to increase 17 to 19%1). There has been an increase in the maximum amount of rainfall during the period 1961 to 20003).

Heavy rainfall is commonly known to cause failure to slopes and the like riverbanks. Infiltration of rain water results in reduction in soil matric suction and shear strength, which eventually leads to reduction in slope stability. This reduction in slope stability has been identified to be affected by both rainfall intensity and duration.

There are three factors controlling the riverbank failure; 1) Undercutting by the effect of river flow. 2) the bank geometry, and 3) soil characteristics which vary with the saturation degree which in turn depend on rainfall intensities. Therefore, for a given river flow hydrograph, rainfall event, and bank geometry these properties control the evolution of factor of safety.

The objective of current paper is to investigate the influence of current and future rainfall events (intensity and duration) on the stability of a typical synthetic riverbank by using numerical modeling. The factor of safety and the plane of failure are calculated under different rainfall events. Progress of the pore water pressure is also calculated.

2. Problem Geometry and Hydraulic Conditions.

Hypothetical riverbank with shape, soil properties and boundary conditions as shown in **Fig.1** is considered in this study. The slope above the water level and the top of the riverbank are assumed to be rainfall boundaries. As a result of climate change, the number of days with heavy precipitation and the number of days with no precipitation have increased1). Based on this fact, two patterns of rainfall are assumed as shown in **Fig.2**. Rainfall pattern for the current situation (Case 1) has a rainfall intensity (i) = 5 *mm/hr* for 240 hours. While the rainfall pattern for the future situation (Case 2) has a rainfall intensity (i) = 10 *mm/hr* for 120 hours. Both cases have the same volume of rainfall. Rainfall is assumed as uniform and continuous during the simulation time. The initial ground water condition was set up by conducting a steady state seepage analysis under the specified hydraulic boundary head condition.

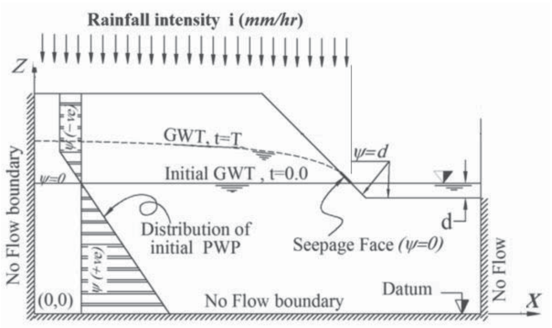

Fig.1 The simulated riverbank and boundary conditions

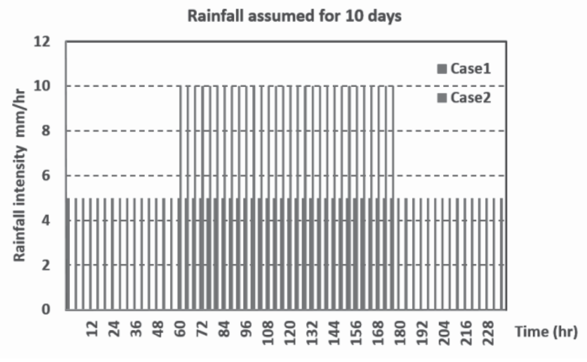

Fig.2 Rainfall record measured for month of August, 2014

3. Simulation Procedure

Undercutting process by the flowing river is considered. The river bed is assumed rigid so the hydraulic erosion occurs at the river bank only, while erosion doesn't occur at the river bed. Uniform flow rate is also assumed as 300 m^3/sec. Unsteady saturated-unsaturated seepage flow model5) based on the Richard equation is coupled with a slope stability model6) which is based on the strength reduction technique. Both models are based on the finite-element method.

4. Results and discussion

The trend of factor of safety (FOS) through time is shown by **Fig.3**. The factor of safety reduces progressively in both cases because the removed material and the eroded toe of the bank reduce the gravity forces resisting failure.

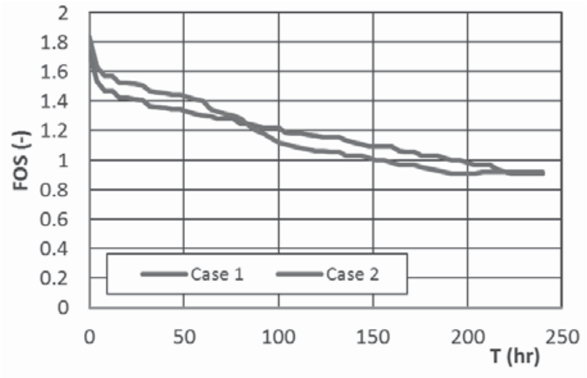

Fig.3 Variation of factor of safety through time

For Case (2), the increase in rainfall amount produces an increase in the height of the ground water table to levels higher than those produced from Case (1). The riverbank in Case (2) becomes more saturated. Saturation reduces the negative pressure (apparent cohesion(C)) in the unsaturated zone. On the other hand, the positive pore water pressure is developed and reduces the effective stress. In addition, saturation reduces friction (φ) between soil particles and increases the unit weight of soil (become heavy). In Case (2), failure occurs earlier (after 150 hours) than that of Case (1) (after 188 hours). It should be noticed that the FOS decreases rapidly at the start of the calculation because the GWT inside the bank is initially assumed below the WSL in the river, and with the passing time the GWT rises while the WSL remains almost constant. The high rainfall intensity is thought to be the cause of the early failure in that case.

Seepage flow field at the end of simulation time for both cases is shown in **Fig. 4**. Level of GWT in Case (2) is higher than that of Case (1).

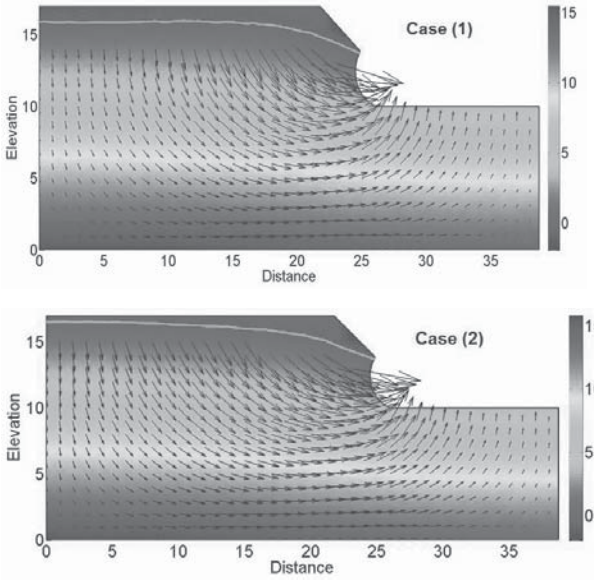

Fig.4 Seepage flow field at the end of simulation time

5. Conclusions

The four factors of 1) Rainfall intensity and duration, 2) hydraulic conditions of the river, 3) the riverbank geometry, and 4) soil characteristics are thought to control the riverbank failure.

Riverbank failure may occur due to reduction in negative pressure (suction) which in turn decreased the soil shear strength even without any change in positive pore water pressure in the soil.

The change of rainfall pattern as a result of climate change has a significant effect on the stability of riverbanks.

References

1) MOE (Japanese Ministry of the Environment), 2006. Chapter 5: Vulnerability Assessment, Climate Change Impacts and Adaptation Measures. pp. 191-202

2) Ichikawa, 2004: Global Warming – The Research Challenges: A Report of Japan's Global Warming Initiative. Springer, 161 pp.

3) Kanai, S., T. Oki and A. Kashida, 2004: Changes in hourly precipitation at Tokyo from 1890 to 1999. Japan Meteorological Society Japan, 82, pp. 241-247.

4) http://163.49.30.82/cgi-bin/SiteInfo.exe?ID=106041286618080 Water Information System, Japanese Ministry of Land, Infrastructure Transport and Tourism

5) Gottardi, G. et al. Computers & geosciences, 2001.

6) Griffiths, D. V. et al. Geotechnique, 1999.