学 位 論 文 要 旨

SLOPE STABILIZATION BY USING FILTER GABION WITH DRAINAGE PIPE

排水管付き蛇篭による斜面安定化に関する研究

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Slope failures due to heavy rainfall events are phenomena that can cause serious damage to social infrastructures and the loss of lives. The number of victim rates and damages of sediment disasters due to heavy rainfalls becomes serious every year. Based on the previous studies, natural slope failures are generally shallow and starts from the slope toe where infiltrated rainwater accumulates. Hence, it is extremely important to prevent initial minor failures from inducing entire slope failures. To reduce and delay the initial failures, more systematic disaster protection plans are needed. In this study, a series of experiments using slope models with filter gabions and drainage pipe was conducted to investigate the effect of those measures against rainfall-induced failures. The models had similar conditions as the typical natural slopes, thus they had a permeable residual layer on a relatively firm rock foundations. The slope model composed of a surface sand (Kasumigaura sand) layers and a silt (DL clay) foundation. The sand layer was considered as the residual layer in this study. Then, a filter gabion with a drainage pipe installed was placed at the slope toe to reinforce the slope and to drain accumulated rainwater from the slope toe. Three cases of the model tests with different pipe diameters (inner diameter = 56 mm and 107 mm) and two different pipe insertion ratio R_p = 35% and 70%, where R_p is the ratio between the pipe insertion depth and the sand layer depth, were conducted. The rainfall intensity of I = 60 mm/h and the relative density D_r = 25% for the sand layer were selected for the test conditions. Temporal changes in pore water pressures (PWPs), displacements, and the amount of drained water through the pipe were measured during the tests.

The results indicated that the infiltrated rainwater came to the slope toe slowly in the cases with R_p = 70%. The amount of the positive PWPs at the slope toes significantly decreased in the cases with R_p = 70%. The displacements also significantly decreased as the pipe diameter R_p increased. Water did not discharge through the pipe until the PWPs around the pipe reached positive values. The drainage in the case with R_p = 35% started earlier than the cases with R_p = 70%. This could be because the infiltrated rainwater came to slope toe quickly and the

phreatic surface formed around the pipe faster in the case with R_p = 35%. The failures always started when a phreatic surface appeared on the slope surface. Thus, it is very important to prevent a phreatic surface from forming within the surface layer. In the case with the d_i = 107 mm and R_p = 70%, the phreatic surface did not appear on the slope surface and kept the slope stable compared to other cases. Thus, adequate arrangement of a filter gabion with a drainage pipe may increase the slope stability.

The model tests were then simulated by using the saturated-unsaturated consolidation analysis method coupled with an elastoplastic model for unsaturated soil considering two suction effects. The analytical model conditions were the same as those in the experimental tests. The simulated and observed results were then compared. It was observed in both in the experiment and simulation of slope model failures tests that the rainwater accumulated over time and the pore water pressures (PWPs) increased to be positive or be larger than the air entry value of the surface soil. As the positive PWPs increased with the elapsed time, the phreatic surface appeared on the slope surface. Once the phreatic surface reached the soil slope surface, the initial failure or large displacement started in, respectively, experiments and simulations. Nevertheless, once the initial large displacement started in the simulations, large deformations followed quicker than the experiments.

Therefore, discharging the accumulated rainwaters from the slope toe is crucial. The simulated displacement starting point was the same as the model test. The initial failure time extended and the phreatic surface much reduced when the pipe diameter and R_p increased both in the experiments and simulations. The displacements also decreased as the pipe diameter and R_p increased. The dominant displacement area in the simulations was almost consistent with those in the experiments. The large shear strains area in the simulations and the failure area in the experiments were almost the same. In both experiments and simulations, in the cases with R_p = 70%, the infiltrated rainwater reached to slope toe slower than the case with R_p = 35%. Therefore, it can be concluded that the analysis method was an effective tool to simulate the behaviour of the slope during rainfall. However, proper pipe modelling is still needed to get more accurate comparison results. It was investigated that the pipe diameter and R_p were strongly interrelated with the slope failure behaviours in both experiments and simulation.