Field measurement about water content in embankment covered by slope protection work

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ABSTRACT

Slope protection works are often used on the surface of slopes of road and railway embankments, in order to prevent from seepage of rainfall and erosion. However, the effect for the reduction about water content has not been clarified by experimental and numerical studies. In this paper, the measurement of the water content in the test embankment with the leaking isolation sheet was conducted. From the comparison of the measurements with the presence and absence of slope protection works, it was revealed that the slope protection works played a role for prevention from seepage of rainfall.

Keywords: embankment, field measurement, water content, slope protection work

1 INTRODUCTION

In Japan, slope protection works are often used on the surface of slopes of railway and road embankments, in order to prevent from seepage of rainfall and erosion caused by surface flow. There are several kinds of slope protection works and the features of each work are listed in documents of design standards about earth structures for railway and road, qualitatively (Railway Technical Research Institute, 2007).

In order to clarify the seepage flow in existing embankments and natural slopes, filed measurements of water contents and pore water pressure were conducted in several studies (e.g., Takeshita, 2007 and Mori et al, 2011). These measurements could clarify the seepage in embankments and natural slopes caused by rainfall. In the point of view of the prevention from seepage of rainfall, it seems that the works which cover the slope of the embankment perfectly can reduce the amount of seepage of rainfall. However, the effect for the reduction about water content has not been clarified by using field measurements.

In this paper, the authors constructed test embankment with the slope protection work and measured water content for long terms. In the embankment, the soil moisture meters and the tensiometers were installed for measuring the degree of saturation and pore water pressure. From the comparison of the measurements with the presence and absence of slope protection works, the effect of slope protection works for prevention from seepage of rainfall was examined. Furthermore, during the period of the field measurement, snow fall occurred at the site of the embankment before the preparation of slope protection work. In this period, the seepage of thaw was measured successfully.

2 TEST EMBANKMENT AND SLOPE PROTECTION WORK

2.1 Outline of test embankment

Fig 1. shows the top view and the cross section of the test embankment. The test embankment was constructed with a height of 3.0 m, the slope gradient of 1:1.5. The crest width was 5.5 m in the longitudinal direction and 4.0 m in the short direction. The properties of the embankment material were shown in Table 1 and the particle size characteristics and compaction characteristics were shown in Fig 2. The embankment material was classified the fine gravelly sand (SFG). The fine fraction is as relatively high as 27 %, and the permeability is as relatively low as 1.03×10⁻⁶ m/s. The embankment material was spread out so that the finish thickness would be 50 cm, and it was compacted to 1.274 g/cm³ of the dry density with 90 % of the degree of compaction. The initial water content was 33 %, which was higher than the optimum water content. The compaction was carried out by the backhoe and the combined roller.
Fig. 1. Cut section of embankment.

2.2 Measurement method of soil moisture in test embankment

In the soil moisture measurement, two types of sensors were used, EC-5 sensors which are produced by Decagon device co. ltd. and WD-3 which are produced by A.R.P. co. ltd. Both sensors measure the permittivity which is changed according to soil moisture. A lot of sensors were installed at the time of the construction of each layer in the test embankment in order to measure the value of the soil moisture which is not affected by disturbance due to excavation and backfilling.

Assuming that the soil moistures are measured in existing embankments, several sensors were installed after the construction of the embankment using the borehole. In the case of using the borehole, it was concerned that the density and the infiltration characteristics of the embankment material in the measurement point may be changed by the disturbance due to excavation and backfilling to install the sensors. Thus the installation method using cylindrical specimens and the borehole was performed to reduce the influence of the disturbance. The cylindrical specimen which was 1.274 g/cm³ of the density measured by the density logging in the test embankment was prepared by the compaction of the embankment material. The soil moisture sensor was set in the cylindrical specimen. The density in the backfill part was controlled based on the weight and the height of the soil input to be same as the density of the surroundings.

The tensiometers were installed at the same position with the moisture sensors. The sensors were installed after the hole was prepared by use of auger. For the maintenance, water was supplied to the tensiometers in order to avoid the entry of air every one month.

2.3 Slope protection work

For the slope protection work, the leaking isolation sheet was used. The length of the sheet was 6.0 m and the width was 0.8 m. Each sheet was connected by seals so that the rainfall seepage from the slope of the embankment will be perfectly stopped. The top of the embankment was not covered, so the seepage of the rainfall was allowed at the top. Fig. 3 shows the photograph of the slope of the embankment covered by the leaking isolation sheet.

Fig. 2. Particle size distribution and compaction curve of the embankment material.

Fig. 3. Photo of embankment covered by leaking isolation sheet.

3 RESULT OF MEASUREMENT

3.1 Effect of slope protection work

Fig. 3 shows the time histories of data about the degree of saturation and the suction in order to examine the effect of the slope protection work on the prevention from seepage of rainfall. These graphs contain the time histories of the suction, degrees of saturations, the rainfall intensity $r_a$ and the accumulated rainfall $S$. The accumulated rainfall $S$ was reset to zero when the amount of rainfall record was zero over 24 hours.

In the data (a), which was recorded before the slope protection work was prepared, the degree of saturation and the pore water pressure increased rapidly at the top of the embankment and the surface of the slope, when the seepage of rainfall occurred. Sometimes, the pore water pressure changed from negative value to positive due to the seepage of severe rainfall. This means that the peached ground water appeared at the surface of the embankment. This would be caused by the low permeability of the embankment material. When the rainfall was not recorded for several days, the suction continued to decrease. This means that the suction was
affected not only by rainfall but also by evaporation. However, both the pore water pressure and the degree of saturation at the center of the embankment were kept smaller even though large amount of rainfall was recorded at the site of the embankment. From the measurements of the embankment without slope protection works, the degree of saturation and the pore water pressure changed at the surface of the embankments according to the amount of the rainfall.

As shown in (b), in the period after the leakage isolation sheet was set at the surface of the slope, the pore water pressure and the degree of saturation continued to show same value at the surface of slope (M05 and M17), thought those at the top of the embankment still showed increase and decrease caused by the seepage of rainfall (M16). The pore water pressure was still negative even though severe rainfall was observed. This means that the slope protection work was effective for the prevention from the seepage of rainfall. Furthermore, the slope protection work also played a role for the prevention from evaporation from the surface.

Fig. 4. Time histories of pore water pressure, degree of saturation and rainfall.

Fig. 5 shows the distributions of the degree of the saturation in the embankment of the right hand. (a) and (b) was the distribution on 18th Oct. and 23rd Oct. in 2017, before the slope protection work was prepared. In these periods, the embankment was affected by severe rainfall, whose accumulation was about 350 mm caused by the typhoon as shown in Fig. 4 (a). Before the embankment was affected by the rainfall, the value of the degree of saturation was from about 70 to 90 % as shown in (a). On the other hand, the degree of saturation at the top of the embankment and the surface of the slope increased after the embankment was affected by the rainfall. However, the degree of the saturation in the center of the embankment was maintained even though after the embankment was affected by the rainfall, as shown in (b).

The distribution (c) was obtained after the slope protection work was prepared at the surface of the embankment. Even though the accumulated rainfall was about 75 mm on this day, the degree of saturation at the surface of the embankment was about 70 to 85 %, which was almost the same value as that of (a). This means that the slope protection work played a role of prevention from seepage of rainfall.

Fig. 5. Distributions of degree of saturation.
3.2 Effect of seepage of thaw

On 23rd Jan. in 2018, before the slope protection work was prepared, snow fall at the site of the embankment and the maximum value of the accumulated snow became 23 cm at the top of the embankment. After this day, thaw occurred gradually due to the rise of the temperature, so the seepage of thaw would occur. In order to clarify the mechanism of the seepage of thaw, the measured data obtained around this period was examined.

Fig. 6 shows the time histories of pore water pressure, degree of saturation and rainfall including this period. Both the degree of saturation and the pore water pressure at all points were maintained for several days after the day of snow. At the end of Jan., gradual increase of degree of saturation and the pore water pressure at the top of the embankment and the surface of the slope. At this time, rainfall was not observed and the measurement of temperature showed rapid increase. So, the snow melt would occur and the thaw was seeped in the embankment.

Fig. 6. Time histories of pore water pressure, degree of saturation and rainfall.

Fig. 7 shows the distributions of the degree of the saturation on 3rd Feb. in 2018. At the bottom of the embankment, the degree of saturation increased largely. At this period, rainfall was not recorded except the snow on 23rd Jan. So, the seepage of thaw caused this increase.

Fig. 7. Distributions of degree of saturation.

4 CONCLUSIONS

In this study, field measurement in the embankment was performed to clarify the infiltration behavior in embankments during rainfall and evaluate the effect of slope protection work as the countermeasure method for rainfall seepage. Before the preparation of the slope protection work, the degree of the saturation and the pore water pressure showed increase and decrease at the top of the embankment and the surface of the slope, due to the seepage of rainfall and evaporation. On the other hand, after the slope protection work was prepared, the seepage of the rainfall was stopped and the value of degree of saturation and the pore water pressure became smaller even though severe rainfall occurred.

Furthermore, the seepage of the thaw was also observed. From the measurement, it was revealed that the seepage occurred several days later after the snow day. The occurrence seepage would depend on the thaw caused by the increase of the temperature.

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