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Technical Note

Experimental study on heterogeneous slope responses to drawdown

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ABSTRACT

In order to investigate the responses of the heterogeneous slope to drawdown, four slope models with different structures were made using the silty soil, mixed soil and medium sand. Three testing schemes with different drawdown rates were carried out. In the testing, some partial failures were observed along the surface of each slope model. The partial failures displayed the influence of the structure and material of the slope model on its stability. The pore water pressure was measured using the piezometer tubes buried in the models. The testing results indicated that the pore water pressure was much affected by the material of the slope model, but was very little affected by the thin middle layer in the slope model.

1. Introduction

The failures in natural and constructed slopes induced by drawdown were reported by Dai et al. (2004). The methods, which were used to investigate the effects of water on slope stability, may be divided into four types, i.e., (1) the chart method (Morgenstern, 1963), (2) the numerical method (Berilgen, 2007), (3) the experimental method (Yan et al., 2010), and (4) the analytical method (Zheng et al., 2004). The present study focused on the influence of the drawdown on the slope stability and the pore water pressure in slope models. In order to investigate the problem, some laboratory physical model tests were done.

2. Design of physical model

Four slope models (SM) were built (Figure 1) in the testing water channel (see Figure 1 in works of Yan et al., 2010). The height and thickness of each model were 80.0 cm, the top width 20.0 cm, the grading angle 30°, and the base length 158.6 cm. The SM #1 (Figure 1A) was a homogeneous model, which is acceptable simulating the operation of a homogeneous dam. The SM #2 (Figure 1B) and SM #3 (Figure 1C) were double-layer structures, which may be accepted only if coarser material is placed in the lower part of the dam embankment. The SM #4 (Figure 1D) is a three-layer structures, which may simulate a horizontal drain.

The pore water pressures were measured using piezometer tubes buried in the models (Figure 2). The piezometer tubes were made of plastic pipe with 3.0 mm in inner diameter and 3.4 mm in external diameter. In order to avoid three-dimensional effects, all piezometer tubes were buried along the center line of the model. In order to observe end effects, the piezometer tube P1 was buried at the end of the model. The water table in the model slopes during the testing should be observed by the vertical tube (see upper in Figure 2) which was fixed on the wall of the inspection well. The horizontal tube (under in Figure 2) was used to intake groundwater during the testing.

A silty soil, which was excavated from the Three Gorges Reservoir in Chongqing of China before the reservoir level rising again, was used in the model experiments. The silty soil basically consists of six different grain-size fractions: 5.0–2.0 mm (2.8%), 2.0–1.0 mm (0.97%), 1.0–0.5 mm (2.0%), 0.5–0.25 mm (0.94%), 0.25–0.075 mm (89.5%), and <0.075 mm (3.7%). Its saturated hydraulic permeability coefficient soil ranged from 1.08×10^{-4} m/s to 2.90×10^{-4} m/s, with an average value of 1.99×10^{-4} m/s. Otherwise, a mixed soil, which was called "silty (70%) + sand (30%)" in Fig. 1B and C, was also used to make the upper layer of the SM #2 and the lower layer of the SM #3. The mixed soil was made by mixing the silty soil (70% in volume percent) and a medium sand (30% in volume percent). Its average value of the saturated hydraulic permeability coefficient was 5.42×10^{-4} m/s. The medium sand, which was called "sand" in Fig. 1D, was also used to make the thin middle layer of the SM #4.

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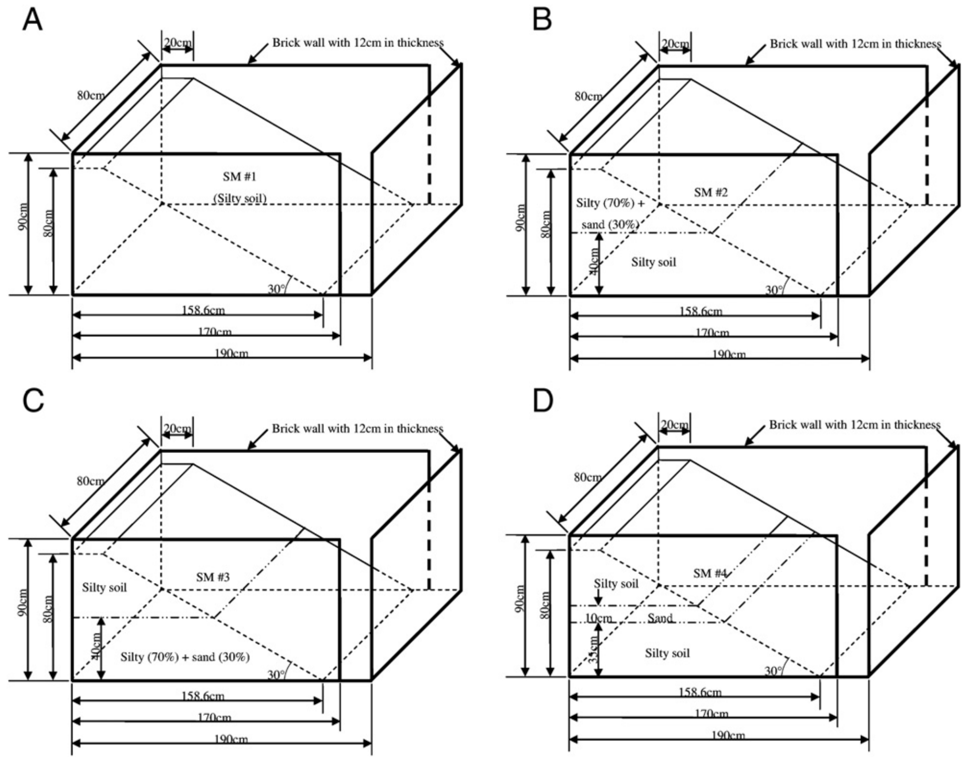

Fig. 1. General arrangement of slope models. (A). SM #1; (B). SM #2; (C). SM #3; (D). SM #4.

3. Testing results and discussion

Three testing schemes with different drawdown rates but same drawdown ratio were selected. The drawdown rates were 20.0 cm/h, 25.0 cm/h and 30.0 cm/h, respectively. The start water level was 76.0 cm, and the end water level 0.0 cm. The responses of the same model to drawdown in different tests were near similar, thus only the testing results in the testing with the drawdown rate 20.0 cm/h were described in this section. The testing results indicated that the end effects induced by the model size and geometry were very small.

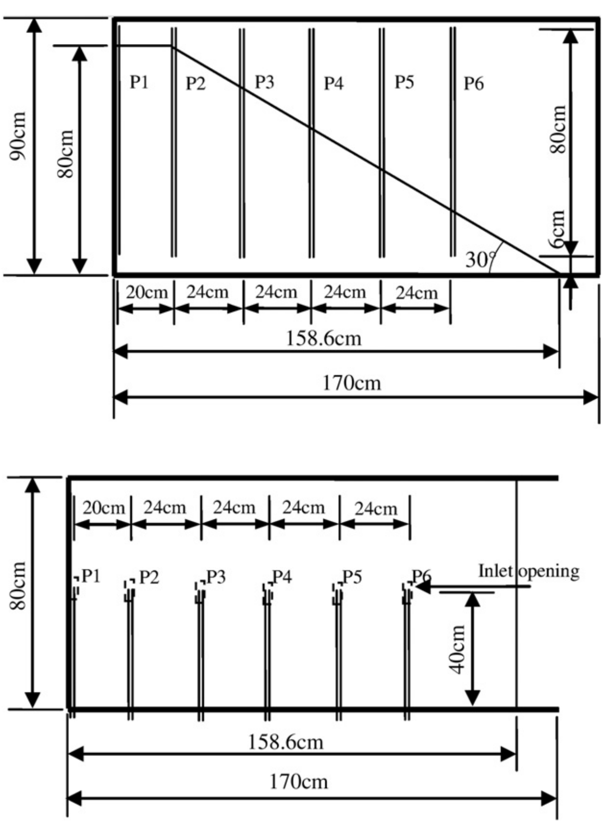

Fig. 2. Layout of piezometer tubes in slope models.

3.1. Partial failure

Some partial failures were observed along the surface of each model during drawdown (Figure 3). It was clear from Fig. 3A that the surface failure was induced in the homogeneous model slope SM #1. The soil along the slope surface was damaged and washed away by the water during drawdown. Fig. 3B showed that the lower part of the slope surface of the SM #2 was damaged and washed away. And Fig. 3C showed that the upper and lower parts of the slope surface of the SM #3 were damaged and washed away, but the damage degree at the upper part was more. The partial failures of the SMs #1, #2 and #3 were mostly along the slope surface made of the "silty soil" rather than that made of the "silty (70%) + sand (30%)". The slope's material might therefore affect its stability under drawdown conditions.

Fig. 3D showed that the upper and lower parts of the slope surface of the SM #4 were also damaged and washed away, but the middle belt of the slope surface wasn't almost damaged. This might mean that the thin middle layer with different saturated hydraulic permeability coefficients from its upper and lower layers might also affect the slope's stability under drawdown conditions.

3.2. Pore water pressure

For the homogeneous slope model as the SM #1, the variation of pore water pressure in the slope under drawdown conditions was investigated by Yan et al. (2010). The authors' works indicated that the formula of Zheng et al. (2004) might estimate reasonably the phreatic line.

The variation of the water pressure with elapsed time for four slope models was shown in Fig. 4. The water pressure was observed from the