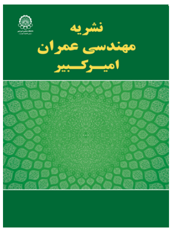

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Study of water flow drainage in sandy soil due to surface recharge conditions using a laboratory model

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ABSTRACT: In the present study, laboratory methods were used to investigate the drainage conditions of the steady-state with the surface recharging. In the study, fine and coarse sandy soil samples were used to study changes in groundwater level. The test specimen was poured into a large-scale flume, with 5.4 m long, which led to uniform vertical precipitation and vertical drains on both sides. The parameters of precipitation rate, soil gradation and water level within the drains were investigated as variables in this study. The results showed that the maximum change in water height in coarse sand due to increasing water height in drains from 0 to 40 cm is equal to 56.9 cm and 72.5 cm, respectively, which caused an increase of 15.6 cm. However, in fine sand, these changes are very small (2 cm) and equal to 87.2 cm in free drainage conditions and 89.2 cm in the conditions of 40 cm of water height inside the drains. The obtained laboratory results were compared with the Dupuit-Forchheimer analytical relationship. It was concluded that this relationship is able to accurately predict the level of water in the fine sand, but in coarse sand, the relationship underestimates the water table height in the soil.

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1. INTRODUCTION

Increasing water content in the sandy soil reduces the shear strength of the soil and its bearing capacity and increases the soil settlement and the possibility of liquefaction. This issue is more important in areas where the groundwater level and rainfall rate are high. Therefore, designing appropriate drainages by considering the critical rainfall conditions to reduce the pore water pressure is one of the basic principles in geotechnical engineering. Accurate groundwater level determination despite lateral drainage and surface rainfall has always been a controversial issue for many researchers from the past to the present.

In order to determine the water table height under constant surface recharge, the Dupuit-Forchheimer equation has been widely used [1]. Engelund proposed an equation to predict the water table height under surface recharge with horizontal drainages by inspiring Dupuit-Forchheimer assumptions [2]. In 1959, Massland found an analytical solution to overcome the problem of water phreatic surface in two-layered soil with transient recharge [3]. Later, in 2003 Rushton modified the Dupuit-Forchheimer relation to present a better equation for predicting water table height between two drainages [4]. Casro-Orgaz and Giraldez showed that the Dupuit-Forchheimer equation could not appropriately predict the water phreatic surface in the case that rainfall does not occur, but they suggested this equation to determine the water table under surface recharge [5]. In 2017, Castro-Orgaz and Hager proposed an equation by modifying the Dupuit-Forchheimer solution [6].

There is not a comprehensive experimental study in order to analyze and determine the validity of the Dupuit-Forchheimer equation under different conditions of soil and recharge rate. Therefore, the main purpose of this study is to analyze the behavior of water table height under recharge and drainage condition using laboratory method and examine the precision of the Dupuit-Forchheimer equation.

2. METHODOLOGY

To study the groundwater table in the soil due to surface recharge and under drainages conditions, a laboratory flume was built in the Geotechnical Laboratory Center of Yasouj University. The flume has 5.4×0.6×1.0 m^3 dimensions (L*W*H). The system of recharge was installed from the top of the box using a plastic tube. The levels of water inside the ditches were controllable. Fig. 1 illustrates the experimental setup.

Two types of soil were used in the study: fine and coarse sand. The permeability of the fine sand and coarse sand was 0.0056 and 0.08 cm/s.

The sample was prepared for the experiments in the desired conditions with different rainfall rates and different water heights in the drains. After a steady-state water seepage through the soil, the water table was measured by the piezometers installed along the flume.

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Fig. 1. The experimental setup

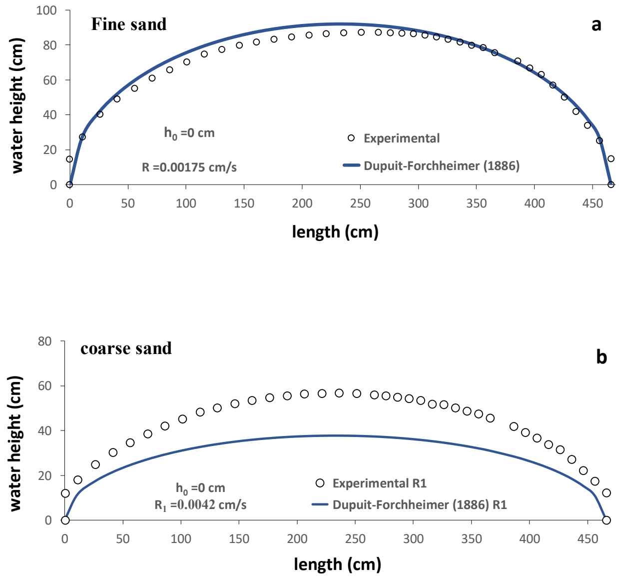

Fig. 2. The experimental results and predicted water table by Dupuit-Forchheimer equation in: a) fine sand b) coarse sand

3. RESULTS AND DISCUSSION

The results showed that the water table height in fined sand is higher than coarse sand, considering that the precipitation rate in coarse sand is 4.2 times higher than the recharge rate in fine sand. The maximum height of the water table is obtained in the mid-way of two drainages. The amount of maximum water table changes due to water level changes inside the drainages from 0 to 40 cm are not considerable in fine sand, however, this change is equal to 15.6 in coarse sand.

From the results obtained for the fine sandy soils under different water levels in the drains, the water height has increased with the increasing water level in the lateral drains. This increase is high in the areas close to the drains and decreases as it moves away from it, so that the least increase in water level in fine sand due to the increase in water level in the drains occurred in the center of the laboratory flume. It is concluded that in fine-grained sandy soils, the change in water height within the lateral drains has very little effect on the maximum water height within the soil profile.

In coarse sand, increasing the water level in the two drains and increasing the precipitation rate has increased the water level. However, this increase is the same throughout the coarse-grained soil sample and does not depend on midpoints close to the drains. The reason for these observations is that in coarse sand, due to the low energy loss, the increase in water level in the drains is effective throughout the sample. However, in fine sand, due to high energy loss, changes in water height inside the drains cannot change the water height of all sample points equally and has little effect on the middle points (farthest points of the drains). Due to the possibility of drainage in coarse sand, increasing the rainfall rate has increased the water level in the middle of the sample. On the other hand, changing the height of water in drains in coarse-grained soil causes a change in water height along the entire length of the soil profile.

Figures 2a and b indicate the comparison of the experimental results in fine and coarse sand with the Dupuit-Forchheimer equation in water level equal to zero in ditches, respectively. It can be seen that the Dupuit-Forchheimer relationship is not able to accurately predict the groundwater level in coarse sand and there is a large difference between the laboratory results and the values obtained from the Dupuit-Forchheimer relationship. **Also,** as depicted, it can be concluded that the Dupuit-Forchheimer relationship is able to accurately predict the water level in fine sand.

Based on results, the Dupuit-Forchheimer solution is recommended to use in fine sand, but it is vise to not to use this solution in coarse sand.

4. CONCLUSION

A series of experimental tests were conducted to determine the water table height under rainfall and drainage conditions. Fine and coarse sand were used in the experiments. The results showed that the water table height in fine sand is higher than coarse sand. The maximum height of the water table is obtained in the mid-way of two drainages. In coarse sand, increasing the water level in the two drains and increasing the precipitation rate has increased the water level. However, this increase is the same throughout the coarse-grained soil sample and does not depend on midpoints close to the drains. From the results obtained for the fine sandy soils under different water levels in the drains, the water height has increased with the increasing water level in the lateral drains. Experimental results were compared with the Dupuit-Forchheimer equation. The comparison results indicate that this analytical solution can give a precise answer in fine sand, but it is not appropriate for predicting water table in coarse sand.

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