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Experimental Study of Solutions to Reduce the Effect of Soil Swelling on Concrete Lining of Conveyance Canals

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ABSTRACT: Damage to canal concrete lining is one of the common problems in irrigation and drainage network projects. Results of several studies show that swelling of unsaturated expansive soils usually led to these damages. In a recent paper, this phenomenon is studied by physical modeling. In this paper, two different ways are studied to control and reduce the effect of swelling soil on canal lining. The first way is the optimization of the number and location of joints on canal lining and the second is the investigation of the effect of canal wall slope on soil-lining interaction behavior. For this purpose, the irrigation and drainage network of the Tabriz plain canal that is under construction on expansive soil is selected as a reference for the geometric properties of the canal section. The physical models are constructed on a small scale (1/10) in the laboratory and two techniques are used in tests: the PIV method and instrumentation. By using of PIV method displacement vectors, volumetric contours, and the magnitude of them in bed soil are obtained and drawn. In addition, the results of physical modelings show the effect of joints to control and distribute of expansive soil-canal lining interaction forces. In the other hand the strain gauges recorded data show that the relative displacement of panels and destructive bending moments of lining are decreased by considering joints on location of maximum internal forces in the canal section. Also it is inferred that the variation of canal wall slope is not an effective way to reduce the lining damages.

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1. INTRODUCTION

One of the most common types of problematic soils is expansive soils. They pose problems for civil engineering in general and geotechnical engineering in particular [1]. They undergo severe volume changes corresponding to change in moisture content [1-4]. The damages in the hydraulic canals constructed on expansive soils are observed in the forms of cracking in the concrete lining and their uplift. Over time and with the occurring of thaw and freezing cycles, lining fine micro-cracks are become larger and provide a situation for water penetration and plant growth. These factors eventually lead to a change of hydraulic canal characteristics and finally its destruction [5]. To overcome the swelling of soil and to prevent structural damages during the site selection and/or construction stages, engineers have developed several techniques. Stabilization of clay soils using lime, cement, or fly ash has long been used to improve the workability and mechanical characteristics of the soils in geotechnical engineering. Fundamentally, lime stabilization refers to the stabilization of the soils by the addition of burned limestone products, either calcium oxide or calcium hydroxide. Lime is the most effective and widely used chemical additive for expansive soils [6]. However, in many projects such as irrigation canals, chemical stabilization is not a suitable option to deal with swelling and impose huge costs on the project.

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This paper aims to study and discuss the effect of expansive soil on canal structure by physical modeling. Also, it is attempted to suggest ways to control and reduce the effect of soil swelling on canal lining damages. For this purpose, the geometric properties of the Tabriz plain canal are selected as a reference for physical models considering small-scale relations (1:10).

2. METHODOLOGY

A physical model is a small scale of structure or mass in the desired scale. In this part of the paper, the physical models that are planned to study the interaction behavior between expansive soil and canal lining are explained.

2.1. Test box

As discussed before, in this research Tabriz plain canal dimensions are considered as reference. Therefore the dimensions of the text box are selected based on these canal characteristics by considering small-scale requirements (scale: 1:10). As shown in Fig. 1, the test apparatus consists of a bottom box (i), a top extension (ii), a lid (rigid plate) (iii), and two Perspex sheets. The bottom box, the principal

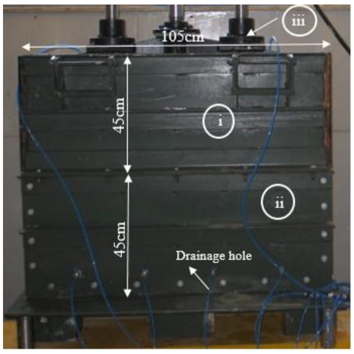

Fig. 1. Configuration of the laboratory test box.

part of the test apparatus where the canal is constructed, has a rectangular shape with open side faces. It has 1050 mm length, 200 mm width, and 450 mm height (this height is doubled when the top-extension is added).

2.2. Soil sample preparation

In this study, Bentonite and Kaolin are selected for preparing the slurry of test samples. Several laboratory tests are done to select the percentage of these soils in the sample mixture. Based on the results of these tests, in the first step, the weighted mixture of 30% Bentonite and 70% Kaolin is selected to prepare the slurry (Test 1). This mixture becomes to 20% Bentonite and 80% Kaolin in Tests 2, 3, and 4 based on obtained results from Test 1.

2.3. Lining and instruments

An aluminum sheet with 2 mm thickness is used to modeling of concrete lining. This thickness is selected based on characteristics of Tabriz plain canal lining and considering the model scale. For monitoring the behavior of canal lining and calculation of bending moment, eight strain gauges are considered on the Aluminum sheet.

2.4. Physical tests program

In this paper, four tests are performed to study the effect of joints and canal wall slope on the interaction behavior of expansive soil and canal lining. The main specifications of these tests are explained in Table 1.

Table 1. Specifications of tests.

Test Number	Mixture of soil sample	Slope of the canal walls	Number of joints on wall
Test1	30%B+70%K	1.5H:1V	1
Test2	20%B+80%K	1.5H:1V	1
Test3	20%B+80%K	1.5H:1V	2
Test4	20%B+80%K	1.75H:1V	2

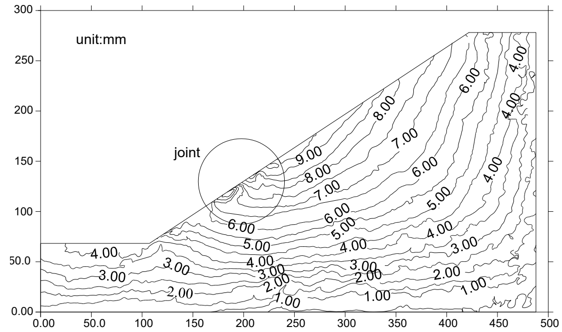

Fig. 2. Vertical displacement contours of soil in Test 1.

3. RESULTS AND DISCUSSION

The distribution of vertical displacement of soil in test 1 that has been obtained from the PIV method is shown in Fig. 2 as contours. By referring to Fig. 2, it can be seen that the amount of soil swelling in the canal surface and just under the lining is greater than other points. The magnitude of displacement vectors in the base of the model is very low. The maximum value of soil swelling is approximately seen in the middle height of the canal section and equal to 9.5 mm in this model. It shows that the middle point of canal section height is a critical point and the maximum value of interaction force between expansive soil and lining has occurred in this position. In addition, the concentration of displacement contours around joint location is clearly seen in this Figure. This phenomenon can be expressed by the relative displacement of panels in two sides of joints in canal walls. Another issue that can be discussed is the different values of heave between bottom and wall.

In Test 2 the characteristics of the soil sample are changed but the properties of lining and the number and arrangement of instruments are the same as Test 1. The maximum value of swelling in Test 2 is recorded at about 4.5 mm. It can be seen that the amount of swelling is approximately halved compared with the first test. This result emphasizes the effect of active clay mineral presence such as Bentonite on soil mass heave.

In Test 3, two series of joints are embedded in the canal wall. Because in Test 3, the specifications of bed soil are the same as Test 2, the magnitude of displacement is approximately equal in these tests. By considering additional joints in the model of Test3, the relative displacement between two panels is significantly reduced. This reduction is led to decreasing the interaction pressure between two panels and ultimately fragmentation in this zone is minimized. This phenomenon emphasizes the effect of joints to control the deformed shape of the lining and relative displacement of panels. The effect of wall slope on canal lining and expansive bed soil interaction behavior studied in Test 4. As already mentioned, the slope of the canal wall is changed to 1.75H: 1V. By comparing the results of Tests 3 and 4, it is derived that the decreasing of canal wall slope has not only been effective in reducing the uplift of panels but also the relative displacement of panels is partly increased insides of upper joint. So based on these results, it is cleared that the optimization of the number and arrangement of joints on the canal section has a more prominent role than the wall slope variation to control expansive soil and lining interaction behavior.

4. CONCLUSIONS

Based on the obtained results from physical tests, by embedding additional joint in the mid-height of the canal section, the destructive forces can be controlled. This suggestion way has been examined in this paper. So, optimization of the number and location of joints in the canal section is a significant way to reduce the lining damages in canals that are constructed on expansive soils. In general and for the current case, considering two series of joints are recommended in both walls of the canal section, first series near the canal bottom, the intersection point of wall and bottom, and second series about the middle height of canal section, the concentration point of interaction forces. Change of canal wall slope is another option that is studied to control soil-lining interaction behavior. The results show that the decreasing canal wall slope has not also affect on reduction of relative displacement of panels but also lead to an increase of destructive bending moments of the lining.

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