کارگاه های آموزشی مرکز اطلاعات علمی چهار دانشگاهی

مباحث پیشرفته یادگیری عمیق؛ شبکه های نویه گرافی
(Graph Attention Networks)

کارگاه آنلاین آموزش استفاده از وب آ ساینس

کارگاه آنلاین مقاله‌های روزمره انگلیسی

Daily English
Numerical Modeling of Concrete Lining Uplift in Tabriz Plain Canal

Fariba Behrouz Sarand*, Masoud Hajialilue Bonab, Ali Pak

a Faculty of Civil Engineering, Sahand University of Technology, Tabriz 331811111, Iran
b Faculty of Civil Engineering, University of Tabriz, Tabriz 5166616471, Iran
c Faculty of Civil Engineering, Sharif University of Technology, Tehran 1136511155, Iran

Received: 25 September 2012; Accepted: 17 April 2013

Keywords: Concrete lining, Canal, Expansive soils, Filter, Numerical modeling

1. Introduction

Unreinforced concrete canals are one type of sensitive and important water conveyance structures. Whereas these structures are inevitably constructed on different types of soils, investigation of geotechnical issues related to the interaction of soil and concrete lining is important for reducing damages to the canals. These damages in the hydraulic canals are observed in the forms of cracking in the concrete lining and their large displacement.

Due to numerous cases observed in Iran, construction of irrigation canals on the problematic soil has led to serious damage to the structure of canals and finally losses a lot of costs. One of the most common types of problematic soils is expansive soils. Every year many of new structure are constructed on the swelling soils, over 60% of these structures suffered minor damages such as cracking and approximately 10% of these structures are heavily damaged that cannot be repaired.

In a comprehensive definition, expansive soils are referred to the soils which have the potential of swelling and shrinkage and show significant volumetric changes and eventually lead to serious damages to different structures, especially light structures. These damages in the hydraulic canals are observed in the forms of cracking in the concrete lining and their tuck. Over time and with the occurring of melting and freezing cycles, lining fine micro cracks are become larger and provide a situation for water penetration and plant growth then these factors eventually lead to changes of hydraulic canal characteristics and finally its destruction. Since the repair and rehabilitation of damaged structures impose huge costs on project, doing research for understanding the mechanism of interaction between the soil and canal lining seems necessary.

Therefore, by considering the presented introduction, construction of canals on problematic soils such as expansive soils is inevitable and appropriate procedures should be followed to reduce the damages.

For this purpose, in this study the section of trapezoidal canal with real dimensions has been modeled by Geo-Studio (2007) software and interaction of the soil-concrete lining and the effect of considering filter layer under canal have been studied in the impounding conditions and finally the result of numerical analyses have been compared to in-situ observations.

Since the soil of canal bed is in the unsaturated condition and has a swelling potential, firstly it is necessary to mention the background of previous studies for numerical modeling of unsaturated soil behavior and efforts have been done by researchers to implementation presented theories

2. Methodology

The behavior of an unsaturated expansive soil can be formulated using the theory of unsaturated soils, using two independent stress variables, the constitutive relationships for the soil structure and water phase, and flow laws for the water phase [1-4]. The two stress state variables are net normal stress, \( \sigma - u_a \), and matric suction \( u_s - u_w \), where \( \sigma \) is total normal stress, \( u_a \) is pore-air pressure, and \( u_w \) is pore-water pressure. Changes in the void ratio and degree of...
saturation of an unsaturated soil can be expressed as functions of the stress state variables to form two three-
dimensional constitutive surface [5].

Approximate volume change (and water content) coefficients should be adequate for most engineering analyses. Procedures for the approximation of the volume change coefficients assist in the implementation of unsaturated soil mechanics into geotechnical engineering practice.

The primary interactive processes involved with a volume change analysis of an unsaturated expansive soil are stress deformation and water flow. The stress-deformation process is governed by static equilibrium, while the water flow is governed by water continuity equation. Solutions for volume change require that both the equilibrium equation and the continuity equation be solved. The solutions can be obtained using either a coupled or an uncoupled approach.

As mentioned, the behavioral models of unsaturated soils are complex. In addition a large number of parameters required for analysis and there are many problems related to measuring or calculating the values of these input parameters. Because of that, these behavioral models are rarely used by geotechnical engineers.

According to the conducted surveys, these behavioral models are not applied to common software of geotechnical engineering. Therefore, some geotechnical engineers have wrongly assumed these kinds of soils as a saturated soil and used the related behavioral models such Cam-Clay or Modify Cam-Clay.

In recent years, many attempts have been made by researchers to apply behavioral models of unsaturated soils and using these models in geotechnical engineering softwares.

For applying these models, simplifying assumptions are made but these should not undermine the accuracy of the results.

Based on the review of the available technical resources, the behavioral models of unsaturated soils are applied only to the two pieces of geotechnical engineering software so far which are Plaxis2D 2010 and GeoStudio 2007.

In this research, GeoStudio 2007 software package is used for modeling. The basis of this software for modeling of unsaturated expansive soils is the behavioral model and presented equations by Vu and Fredlund [4].

For verifying the accuracy of the results, presented example by these researchers was modeled by the software and the proposed behavioral model for unsaturated soils was assigned to it. By comparing the results, accuracy and precision of the software can be realized and the software gives a close agreement between the results by application of both coupled and uncoupled analysis methods, which has been previously described.

It should be noted that the input parameters of the software and the solution of the equations are simplified as much as possible toward the method of Vu and Fredlund to be applicable for geotechnical engineers. Thus, SIGMA/W software can be used to estimate the amount of swelling with appropriate accuracy in unsaturated expansive soils that are affected by changes in wetting conditions and consequently caused negative pore pressures.

SIGMA/W, which is in the GeoStudio software package, is based on the finite element method for stress-deformation analysis of earth structures. Its comprehensive formulation makes it possible to solve any kind of simple and complex problem. For instance, by using this software, both simple linear-elastic deformation analysis and complicated effective-stress analysis based on non-linear elastoplastic behavior can be conducted. When this software is used together with other products of GeoStudio package, changes in pore pressure and its distribution in soil mass due to the external loading can be computed by using coupled and uncoupled formulation. In addition, SIGMA/W can be used for modeling of soil interaction with beam or bar elements.

In this study Tabriz Plain Canal is selected as a case study. The irrigation and drainage network of Tabriz plain is under construction in six regions and 40000 hectares in the northwestern part of Iran. The length of the main canal is 29 km, the width of floor is between 2.5 to 5.0 m, and its height is between 2 to 2.75 m. The slope of canal walls is 1 (vertical) to 1.5 (horizontal). The canal lining is made of unreinforced concrete. In the construction phase of first 10 km, due to a heavy rain and flooding, a part of canal was filled with water. After the water was emptied out, cracks and heave were observed in some parts of the canals. In order to investigate this phenomenon, an undisturbed soil specimen was obtained from heaved zone and a free swelling test was performed.

3. Results and discussion

The results of laboratory tests show that the surface soils of Tabriz plain are composed of silt and clay. In this research, standard methods are used to predict swelling potential of these soils.

Generally there are two indirect methods for anticipating the swelling potential in references, Seed et al. method (1962) [6] and Van der Merve method (1964) [7]. The result show that the swelling potential of soil samples vary from low to high and the result of free swelling test show that the free swell height and the swelling pressure of undisturbed sample are about %5.4 and 40 kPa respectively. These values show that the soil heave should be considered in lightweight structure designing such as Tabriz plain canal.

As observed in in-situ investigation, the swelling phenomenon has led to cracking and relative displacement of canal panels in joint locations from few to 30 mm. To prevent the occurrence of this phenomenon, using a filter layer with 30 cm thickness was proposed in this project.
Application of filter layer doesn’t have direct effect on soil heave but the properties of filter material lead to reduce the swelling potential. The filter is composed of granular material so it can uniformly transfer the local pressure of canal bed soils to lining and lead to reduce the relative displacement of adjacent panels. Another parameter is the weight of filter layer. This layer applies about 5 kPa additional pressure to expansive canal bed soil although this pressure isn’t more than the swelling pressure but it can compensate that amount of swelling pressure.

This proposed method was tentatively performed in 50 m length of real canal. For evaluation the efficiency of this method, surveying points were observed on canal section and displacement of these points were measured.

As mentioned before, in this research the actual dimensions of the under construction water canal of the irrigation and drainage network of Tabriz plain, which is located on the expansive soils, is used for numerical modeling. Three series of joint are considered in canal section, two joints in canal walls in the level of 0.5 meter from floor and one joint in canal floor. As a real condition for modeling of joint, two centimeter space is vertically considered in lining surface.

For the simulation of the initial conditions (local conditions), it has been assumed that the canal bed soil is somewhat dried and a constant suction is established in the soil. For modeling the infiltration into the soil, water level inside the canal is applied as a water head to the lining elements. The lining has been modeled by beam elements. Generally, it is assumed that in the initial conditions, a suction equal to 200 kPa was available in the environment.

In the first step of analysis, the initial in-situ stress conditions are applied to the model and primary balance is obtained. In this step linear elastic behavior is considered for the soil and concrete lining and the environmental suction of -200 kPa is considered in the computation.

For analysis of heave coupled case, the soil behavior is considered elastoplastic and the proposed model by Vu and Fredlund [4] is used to predict the behavior of unsaturated expansive soils. This should be considered that all equations used in the computations and the mechanism of soil behavior are functions of time.

Since the aim of the presented research is to study the soil-lining interaction behavior in various moisture conditions and also the effect of implementation of filter layer to control the swelling of canal bed soil by using site investigation and numerical methods and comparing the results of two methods, two types of analyses are done in this research. In the first case, the filter layer has not been considered under the lining and calculations have been performed and in other case, the filter layer has been considered and all calculations have been repeated. In any of cases, the water level in the canal is assumed as constant and 2 meter above the floor.

4. Conclusions

The results of numerical analyses and in-situ observations have acceptable consistent in prediction of the deformation shape of panels, the values of displacement and the effect of filter layer on these phenomenon. The use of a filter layer under the concrete lining leads to the relative reduction of general heave in unsaturated expansive bed soil and also prevents the lining cracking.

The intersection point of the canal wall with floor, the upper corner of the canal wall and middle point of lining length are considered as the locations of concentration of internal forces in the canal section. The joints along the wall act as a hinge, the values of moment in these points are zero and they have a functional role to control the cracking in the canal wall. The optimization of the location of joints and the modification of the geometric properties of canal section are others ways to reduce the lining damages in canals which are constructed on expansive soils.

5. References
