APPLICATION OF SEEP/W TO TESTING ON FILTRATION STABILITY OF WATER LOCK BEZDAN

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Summary: *In this work the principle of numerical modelling by the model of numerical analysis of the software package SEEP/W will be described. SEEP/W is a numerical model which mathematically simulates the actual physical process of water flow through special environment. Water stream in porous medium consisting of granular matter will be considered. Whilst taking into consideration the porous medium, it will be assumed to be homogenous and isotropic that is, to have uniform features in whole volume considered. Purpose of the work is analysis and verification of filtration stability of the water lock "Bezdan" for two extreme cases-the first, when the water level in Danube is maximal, and the level in channel is minimal, and the second, when the water level in the channel is maximal, and the level in Danube is minimal.*

Keywords: *numerical modelling, software package SEEP/W, water stream in porous medium, water lock "Bezdan"*

1. INTRODUCTION

Groundwater flow is an important aspect of soil mechanics. It is obtained in various geotechnical situations and hydraulic situations which include soil. Basics for water flow examination in porous environment are presented by Darcy's experimental work. Based on this work, Darcy's law of filtration, which defines free water flow through porous environment, is taken. Water flow through porous environment considers movement of water through enbankments and earthen dams, below the object, etc. Filtration line

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represents the line of free water surface in the soil. Position of filtration line enables determining weight and cohesion of all parts of the enbankment, determining the location for drainage and filter, that is, estimating the filtration flow.

During the flow through porous environment on downstream end, which is often under the water, processes which could significantly change the flow regime are taking place. Sufozion is the process of rinsing and „removing" the small grains from the porous environment during the real velocity of flow, which is a long process. Fluidization is the process of lifting the ground due to difference in piezometric elevations ΔΠ.

Both sufozion and fluidization depend on coefficient of uniformity of grain, η, and on output gradient I_{izl}. Experimental research by B.C. Istomina show that the condition defined by theoretical critical output gradient (<1) is not sufficient to provide stability to porous environment [1]. Fig. 1 shows diagram of appearance of sufozion and fluidization depending on coefficient of uniformity of grain and of output gradient.

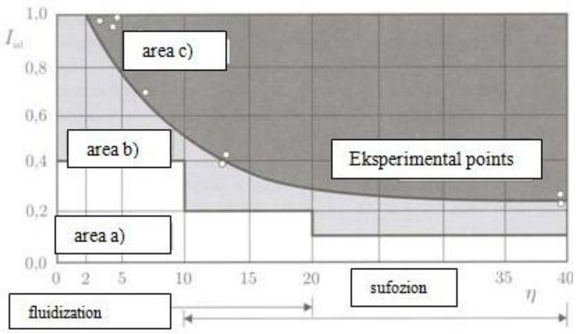

Figure 1. Diagram of sufozion and fluidization appearance [3]

2. FLOW MODEL THROUGH POROUS ENVIRONMENT-SEEP/W

Software package SEEP/W has been developed by GEO-SLOPE International Ltd., Canada. This software uses the method of finite elements in order to analyze leachate and groundwater flow with the change in pore pressure inside the material. Problems which could be solved by this software range from simple ones of steady flow in saturated conditions to time variable problems in saturated-nonsaturated conditions.

SEEP/W is the numerical model which mathematically simulates the actual physical process of water flow through special environment.

SEEP/W numerical model is based on the finite elements method [4]. Method of finite elements is in significant advantage when compared with other methods while dealing with irregular areas of flow and sudden change of basic size near certain locations. There are three main parts in analysis of finite elements. First one is discretization, division of the domain into smaller areas called elements – SEEP/W model creates a web of finite elements by itself. Second part is assessment and determination of material features. Third part is determination and application of boundary conditions. When determined, the second and third part are very easily set in the programme. Fig.2 shows the flow beneath the sheet piling and discretization of flow field in finite elements method (triangular elements are used). It is taken into account that significant changes to piezometric elevations are taking place near the sheet piling.

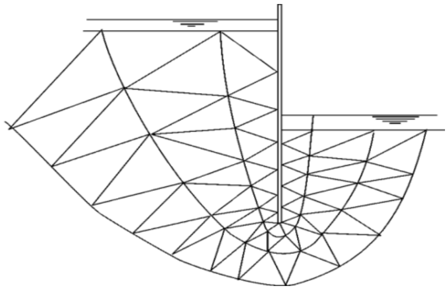

Figure 2. Discretized flow field under the sheet piling [4]

In finite elements method, greater accuracy is achieved by the usage of smaller elements in more significant changes of piezometric elevations zone.

3. RESULTS AND DISCUSSION

3.1. Analysis of filtration stability from the main project of locks reparation

Old ship lock in Bezdan has not been in use for a number of years due to condition of its construction and its hydromechanical equipment. It has been repaired number of times, its purpose has been changed and its construction has been topped two times. It represents an important object in DTD hydrosystem and therefore it is necessary to be in function [2]. This part of the work is directed to analysis of filtration stability of soil beneath stock-beam shutters and the possibility of sufozion and fluidization appearance in the soil, by application of SEEP/W software package, and to comparison of obtained results with the results of the main repair project of ship lock "Bezdan" [2].
Based on the main project "Reparation of the Bezdan lock" total length of the lock is 120 m. Wheel base with Danube in front of the lock is 79,0 mnm, and the wheel base of channel is 82,3 mnm. Wheel locks bottom is 79,0 mnm that is, 78,9 mnm. Wheel locks foundation is 76,5 mnm. Defining geological structure terrains and geomechanical characteristics of the isolated environment in the "Bezdan“ lock zone was done by geomechanical research on 14 exploration wells along the channel of the lock, on both sides of the channel. Geomechanical characteristics of the soil, that is coefficient of permeability, is determined.
Whether the soil will be destructed under the influence of filtration, and what type of local soil fracture will appear (sufozion or fluidization) depends on granulometric composition and soil compaction and on the size of the output gradient filtration [5]. Diagram from the Fig. 1 has been used as the criterium for the assessment of filtration stability of soil.

Analysis of filtration stability has been done by approximate method, where the following form for approximate determination of filtration gradient has been used [2]:

$$I_{izl} = \frac{\Delta H}{L} \tag{1}$$

Approximate values for filtration gradient in the main project "Reparation of the Bezdan lock" are:

Case of filtration of the Danube to the channel:

- Maximal level of Danube 88,71 mnm
- Minimal level of water in the channel 84,00 mnm
- The length of water filtration L≈120 m

$I_{izl.}=0{,}039<I_{crit.}=0{,}1$

Case of filtration of the channel to the Danube:

- Maximal level of water in the channel 85,30 mnm
- Minimal level of Danube 79,15 mnm
- The length of water filtration L≈120 m

$I_{izl.}=0{,}051<I_{crit.}=0{,}1$

where $I_{crit.}$ represents the critical value of output gradient, which causes filtration stability loss.

3.2. Analysis of filtration stability of the water lock by SEEP/W numerical model

Situation of the lock in actual conditions that is, conditions of the soil on the terrain, has been analysed first. For the existing condition, two variants have been done, for the maximal level of Danube and the minimal level in canal, and for the minimal level of Danube and the maximal level in the canal. Due to limitation on three types of material, that is, soil materials with three different filtration coefficients, reference coefficients of watertightness have been adopted. These values were adopted from the geomechanical part which was used in the main project. Values of the filtration coefficient on right and left river bank are [2]:

Right bank:

1. $4\cdot10^{-7}$ m/s
2. $1{,}5\cdot10^{-6}$ m/s
3. $6{,}5\cdot10^{-5}$ m/s

Left bank:

1. $2\cdot10^{-7}$ m/s
2. $2\cdot10^{-6}$ m/s
3. $3\cdot10^{-5}$ m/s

3.2.1. Filtration of Danube to the channel DTD

On the following figures equipotential lines and streamlines in porous media are shown. Flow rate beneath the lock entering the section of flow when creating models is easily determined.

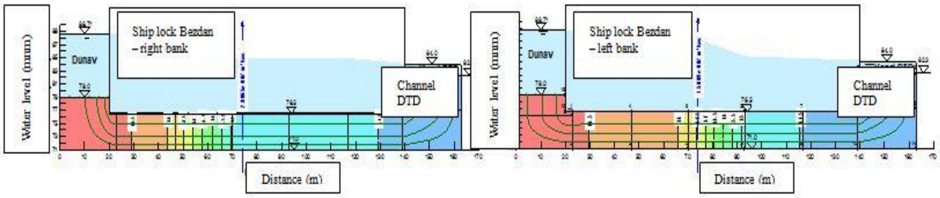

Figure 3. Solution of flow beneath the lock for the case of flow from Danube to canal – right and left bank

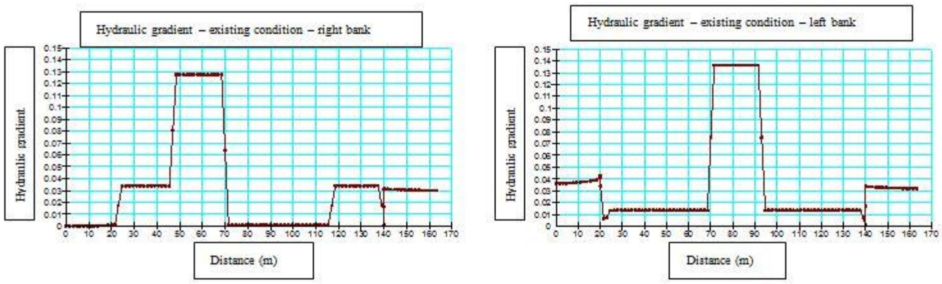

Figure 4.Diagrams of change of hydraulic gradient for the case of flow from Danube to canal –right and left bank

On fig. 3 equipotential and streamlines and the section for measurement of water flow are shown. Here can be seen the values of water flow of $2{,}8\cdot10^{-7}$ m^3/s and $1{,}5\cdot10^{-7}$ m^3/s, which are pretty similar values. Different values of water flow on fig.3 occur because the difference of the values of coefficient of permeability. Diagrams on fig. 4 show hydraulic gradient beneath the lock, where the value of output gradient is easily read. For the right bank I_{izl}=0,0316, and for the left bank output gradient is I_{izl}=0,0339.

3.2.2. Filtration of the channel DTD to the Danube

Situation for the maximal level of water in canal and the minimal level of Danube is analysed. On following figures equipotential lines and streamlines in porous media are shown. Flow rate beneath the lock is also shown.

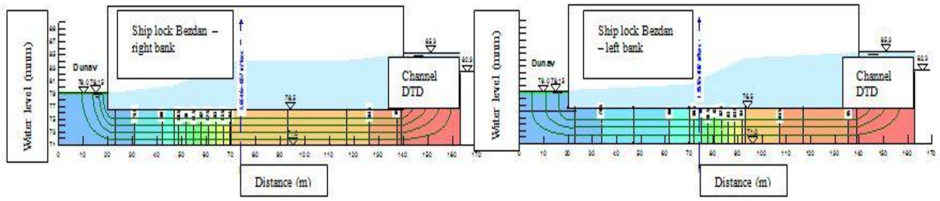

Figure 5. Solution of flow beneath the lock for the case of flow from canal to Danube – right and left bank

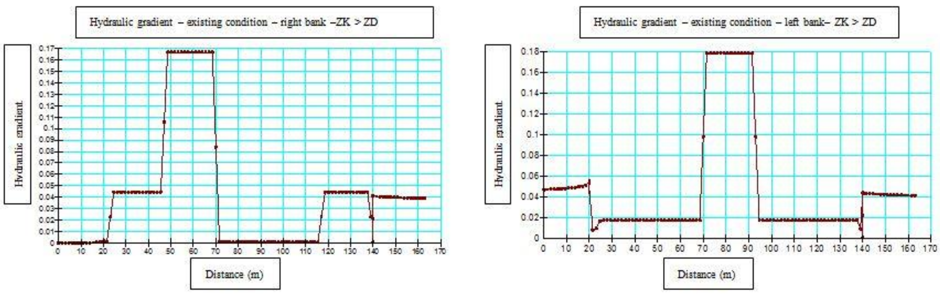

Figure 6. Diagrams of change of hydraulic gradient for the case of flow from canal to Danube - right and left bank

On fig. 5 equipotential lines and streamlines are shown, together with the section for waterflow measurement. Here the values of water flow are $3{,}66\cdot10^{-7}$ m^3/s and $1{,}96\cdot10^{-7}$ m^3/s, which is pretty similar value and the difference goes to the difference of water permeability coefficient value. Diagrams on fig. 6 show hydraulic gradient beneath the lock, where the value of output gradient is easily read. In the case of the right bank I_{izl}=0,0445 and in the case of the left bank the output gradient is I_{izl}=0,0559.

4. CONCLUSIONS

After completion of the analysis of filtration stability from the main project of the "Bezdan" lock reparation, it could be concluded that on the left and on the right bank of the Bezdan lock, theoretically speaking, there is no danger of filtration stability loss. Furthermore, local deformation and subsidence in the area of warehouse beam-shutter are not the concequence of filtration instability of soil [5].
Comparing the values of the output gradient, obtained by the application of software package SEEP/W, for the case of filtration from Danube to canal with the value of the output gradient I_{izl}=0,0339, obtained in the main project, it is noticeable that the values are insignificantly lower. Comparing the values of the output gradient obtained by the application of software package SEEP/W, for the case of filtration from canal to Danube with the value of the output gradient I_{izl}=0.051, obtained in the main project,

insignificant difference is noticeable. Reason is the diversity of material and its structure. Values are approximately equal. As it has already been said, water flow from canal to Danube is not significant because the level in the canal cannot influence the level of water in Danube. It can be concluded that the approximate procedure gives approximately accurate solution, however the adventage of work in SEEP/W package is that hydraulic gradient along the whole flow is very accurately determined. Basic parameters, such as boundary conditions or types and characteristics of material, and geometry of problem can be changed very fast. Diagram of porous pressure, which can be significant for general account of lock stability, is easily determined. Through the application of SEEP/W package it has also been concluded that there is no danger from sufozion and fluidization, nor in the main project of the lock raparation, in the case of flow from Danube to canal, in the most extreme case that is, when level in Danube is maximal and the level in the canal is minimal.

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ПРИМЕНА SEEP/W НА ПРОВЕРУ ФИЛТРАЦИОНЕ СТАБИЛНОСТИ БРОДСКЕ ПРЕВОДНИЦЕ БЕЗДАН

Резиме: У раду ће се описати принцип нумеричког моделирања преко модела нумеричке анализе-софтверског пакета SEEP/W. SEEP/W је нумерички модел који математички симулира стварни физички процес течења воде кроз једну посебну средину. Разматраће се струјање воде у порозним срединама које се састоје од зрнастих материјала. При разматрању порозне средине претпоставиће се да је хомогена и изотропна тј.да има униформне особине по целој разматраној запремини. Циљ рада је анализа и провера филтрационе стабилности бродске преводнице "Бездан" за два екстремна случаја-први, када је максималан ниво воде у Дунаву, а минималан ниво у каналу, а други када је максималан ниво воде у каналу, а минималан ниво у Дунаву.

Кључне речи: *нумеричко моделирање, софтверски пакет SEEP/W, струјање воде у порозној средини, бродска преводница "Бездан"*