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ANALYSIS FILTRATION LINE POSSITION AND SEEPAGE FLOW THROUGH THE „MESIC" DAM USING THE SEEP/W SOFTWARE

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Keywords: *numerical modeling, software package SEEP/W, water flow in porous environment, dam and reservoir „Mesic"*

Research area: *hydraulic engineering*

ABSTRACT

In this work theoretical basics of planar flow of water in porous environment will be given. Principles of numerical modeling by the model of numerical analysis-software package SEEP/W will be described. Vast majority of practical tasks cannot be solved in a satisfying way with available analytic results. Solution is in approximate results of mathematical model by numerical methods. SEEP/W is a numerical model that can mathematically simulate the real physical process of water flowing through a particulate medium. Water flow in porous medium consisting of granular material will be taken into consideration. In this paper, porous medium is homogenous and isotropic. This paper presents estimation position of filtration line and seepage flow thought the "Mesic" dam for extreme flood events (1000 year). The main objective of the analysis position of filtration lines through the dam Mesic is to check filtration stability of the dam and assess the value of the drain flow on the downstream slope. Valid geomechanical and hydrological data for the dam and reservoir were used in order to obtain more realistic results.

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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 is 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 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 [3]. 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 $\Delta\Pi$.

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 [6]. Fig. 1 shows diagram of appearance of sufozion and fluidization depending on coefficient of uniformity of grain and of output gradient.

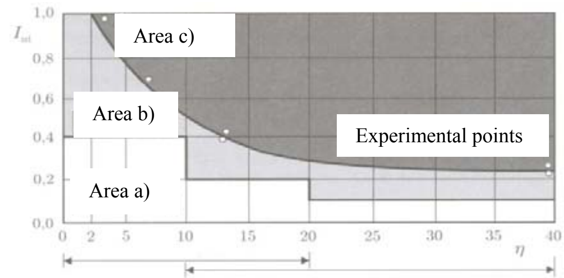

Fig. 1. Diagram of sufozion and fluidization appearance [6]

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 leachete and groundwater 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 mids to time variable problems in saturated-nonsaturated conditions.

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

SEEP/W numerical model is based on the finite elements method [5]. 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 of analysis of finite elements. First one is discredization, 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 discredization of flow field in finite elements method. It is taken into account that significant changes to piezometric elevations are taking place near the sheet piling.

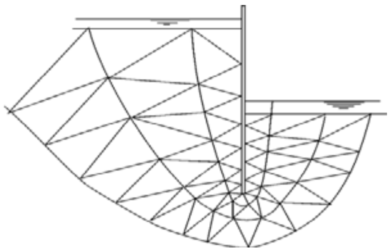

Fig. 2. Discretized flow field under the sheet piling [5]

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

3. Methodology

3.1. Main features of the "Mesic" Dam

"Mesic" accumulation dam is built at the km 7+250 from the confluence of the stream Mesic into Vrsacki channel, immediately upstream from the town of Vrsac. Its role is to collect and retain water formed on the slopes of Vrsac hill in order to protect urban areas of Vrsac from flooding. This object is in a category of large dams regarding the volume of accumulation area for $Q_{0,1\%}$ which includes over 1 500 000 m^3. The dam is located in Republic operative plan for protection of floods for 2013. It is very important to keep it functional [2]. The size of the basin area to the dam profile at km 7+250 is 33,20 km^2.

The purpose of the dam and reservoir Mesic includes accumulation and transformation of flood waves. Designed and built earthy dam on the stream Mesic at km 7+250 has homogeneous composition, with maximum height of H=6,68 m. The width of the dam crown is b = 4,00 m, with inclination of slopes: upstream - m_1=2,50; downstream - m_2=2,00 [2]. In order to provide protection from waves, reinforced concrete wall (seawall) is built with height of 1,00 m at the upstream slope. Prevention of filtration water through the lens was made by clay-concrete diaphragm. There is a drainage length of 5 m at the downstream end of the dam.

3.2. Vulnerability of the town of Vrsac from large water of the stream Mesic

Mesic stream flows below the top Kulmea Mare, runs through the town of Vrsac and pours into the channel of Vrsac outside of the town. Stream Mesic has a torrential character. Due to its large slope during rain or snow melting, raising the water level of the stream can be achieved suddenly, during several hours. The problem of accepting and redirecting of external water through town of Vrsac is very complex problem especially due to unfavorable position of the town according to hydrological aspect. Vrsac is placed on slopes of Vrsacki breg and it is permanently faced with surface water which move along slopes of Vrsacki breg and streets due to least rain and move to natural recipients in form of flooding the immediate town zone and agricultural surfaces near town zone. The problem is more obvious since town of Vrsac does not have solved rainwater sewerage while existing streams are not all regulated and connected into integrated protection system in order to redirect internal and external waters into main recipient – Vrsacki channel [2].

In order to at least partially solve problem of excess water, design of Technical documentation for protection of town of Vrsac from great water from stream Mesic has been conducted (company „Hidrobiro", Novi Sad, Serbia). According to developed technical documentation, the earthy dam with accumulation in stream Mesic with following objects was designed in 1980.

Within regular annually inspection of protecting objects for defense from floods, it is concluded that concrete plates on the dam crown started to crack and the body of dam started to slump. Serious damages on crown and slope of the dam were detected, including numerous horizontal cracks over profiles of earthy body of the dam. It indicated on appearance of sliding planes. Regarding these information, the main objective of this work is determining of position of filtration line and the amount of leach water which occurs through dam Mesic.

3.3 The objective of analysis of filtration line through "Mesic" Dam and threshold conditions

This work is focused on review of position of filtration line in conditions of thousand-year great rain in accumulation Mesic in the stream Mesic. The main objective of the analysis was defined due to possible occurrence on the defended slope of the dam and possible demolition of the dam. As a result, the values of flow into drain on the downstream slope will be indicated.

Defining of position of filtration line was conducted using program software SEEP/W developed by GEO-SLOPE International Ltd., Canada.

As the upstream threshold condition for calculation of filtration line and the amount of leach water, the current thousand-year rain was used. Its level has the value Z(1‰)=110,02 m.n.J.m [1].

The drain was used for downstream threshold condition. In the SEEP/W software, characteristics for drain are used as for the potential line of water appearance through slope or dam. The dam "Mesic" was modelled as homogenous earthy dam and analyses for two values of filtration coefficient were conducted: $K = 10^{-8}$ m/s and $K=10^{-9}$ m/s [4]. Values of filtration coefficients were determined according geomechanical and laboratory samples of the soil taken from drills from 3 dam profiles, before its construction [1].

4. Results of analysis and discussion

The results of conducted analyses for conditions of thousand-year great water/rain at the dam Mesic are presented as following.

4.1. Results of analysis for filtration coefficient K=10-8 m/s

The program software SEEP/W created model of the dam with threshold conditions, geometric properties of the dam and properties of the soil of which the dam was built. In other words, the filtration coefficient was used. As it can be seen in the model, drainage at the downstream side of the dam "Mesic" is 5 m long.

The figure 3 presented the result of analysis of mentioned problem. Position of filtration line, stream through dam, flow into drain, and equipotential lines were presented.

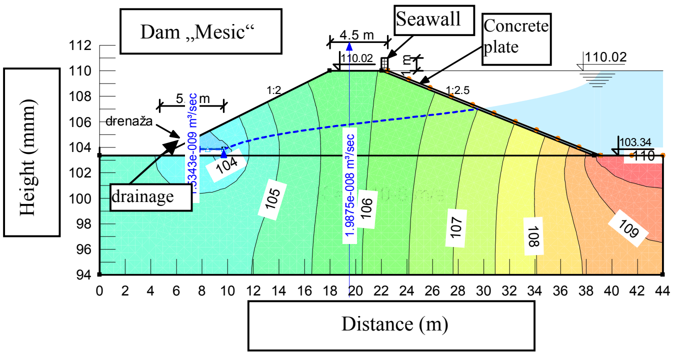

Fig. 3. Result of the analysis with equipotential lines for К = 10^{-8} m/s

Figures 4 and 5 presented piezometric levels and diagram of the fall of piezometric level and diagram of change of hydraulic gradient in case of stream through dam “Mesic”.

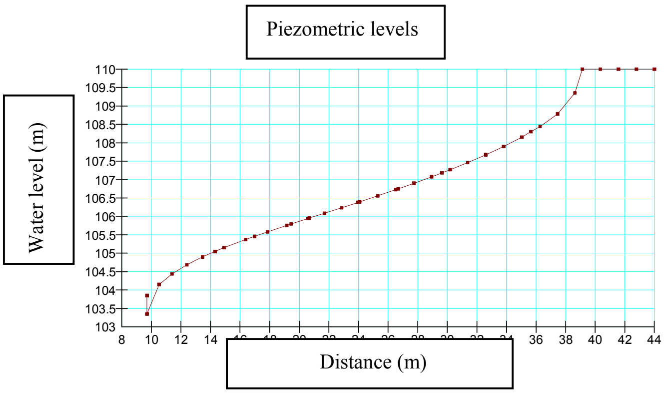

Fig. 4. Diagram of a slope of piezometric level - К = 10^{-8} m/s

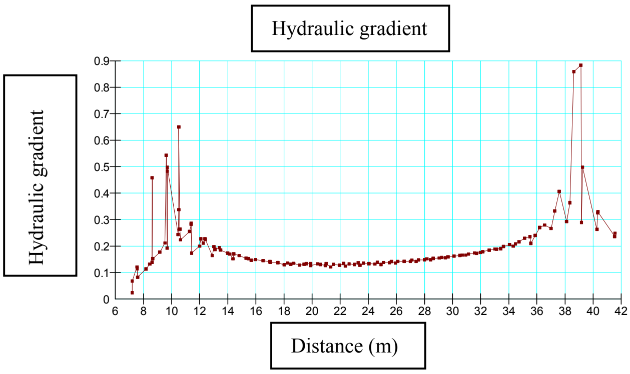

Fig. 5. Diagram of a change of hydraulic gradient - К = 10^{-8} m/s

4.2. Results of analysis for the value of filtration coefficient $K=10^{-}$ m/s

Hydraulic model of dam “Mesic” was formed in identical way like in previous case, while the only difference lies in properties of the soil from which the dam is built, i.e. filtration coefficient. The figure 6 presented the result of analysis of mentioned problem, position of filtration line, stream through dam, flow into drain, including equipotential lines.

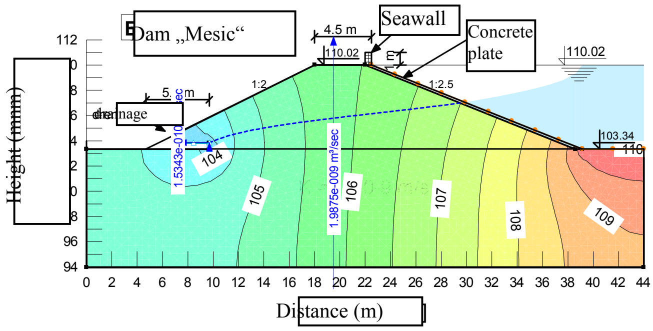

Fig.6. Result of analysis with equipotential lines for $K = 10^{-9}$ m/s

Figures 7 and 8 presented piezometric levels, diagram of the fall of piezometric level and diagram of the change of hydraulic gradient in case of flow through dam “Mesic”.

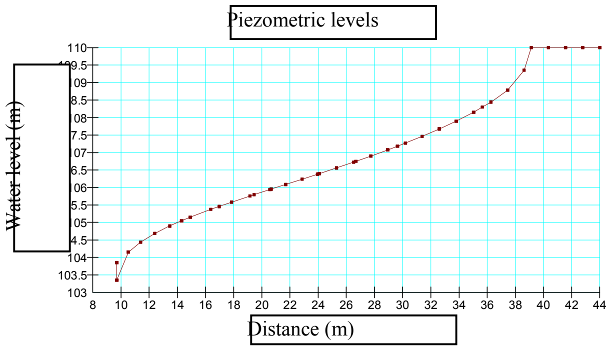

Fig. 7. Diagram of the slope of piezometric level - $K = 10^{-9}$ m/s

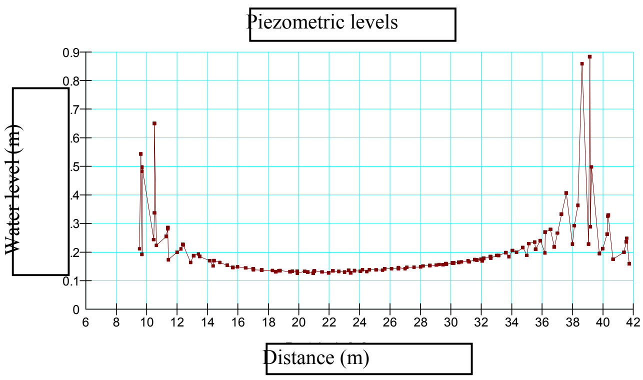

Fig. 8. Diagram of the change of hydraulic gradient - $K = 10^{-9}$ m/s

4. Conclusion

The use of software tool such as SEEP/W indicated that traditional current networks are no longer necessary. SEEP/W provides all information which could be provided from energy/current network which helps in development of analysis of several different problems. Also, performing of SEEP/W analysis is easier than development of energy network. This work presented the hydraulic modelling of flow through dam "Mesic" and analysis of filtration line. The problem of water flow through dam "Mesic" is solved by student version of SEEP/W software. The limited version of software can obtain position of filtration line, amounts of filtrate water, hydraulic gradient, power grid etc. in very simple and fast way.

In case of model of dam "Mesic", for which the value of filtration coefficient is 10^{-8} m/s, it concluded that great influence on decreasing of level of filtration line can be provided by concrete lens at the upstream slope. The value of flow into drain is $Q = 1{,}53 \cdot 10^{-9}$ m^3/s. For this model, where the value of filtration coefficient is 10^{-9} m/s, it is concluded that great influence in decreasing of filtration line had a concrete lens at the upstream slope. The value of flow into drain in this case is $Q = 1{,}53 \cdot 10^{-10}$ m^3/s. As a conclusion, there is a fact that for both analysed case (for two values of filtration coefficient) there is no danger of suphosion and fluidization occurrence in the body of the dam. Slightly larger value of hydraulic coefficient at the entrance into drainage on downstream slope is not dangerous.

Possibilities of limited student version are wide and therefore numerical tool SEEP/W is very good for solving of different problems of water streaming through porous environment.

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АНАЛИЗ НА ПОЛОЖЕНИЕТО НА ДЕПРЕСИОННАТА КРИВА И ФИЛТРАЦИЯТА ПРЕЗ ЯЗОВИРНА СТЕНА „МЕШИЧ“ С ПОМОЩТА НА СОФТУЕРЕН ПРОДУКТ SEEP/W

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Ключови думи: *числено моделиране, SEEP/W, течения през порьозна среда, язовирна стена и езеро“Mesic”*

Научна област: *хидротехническо строителство*

РЕЗЮМЕ

Настоящата статия представя определяне на положението на депресионната линия и филтрацията през язовирна стена „Mesic” за екстремна висока вълна (с вероятност за превишение веднъж на 1000 години). Целта на анализа на депресионната крива в тялото на язовирната стена „Mesic” е проверка устойчивостта на насипа и оценка на филтрационното водно количество, което преминава по въздушния откос. Актуални геотехнически и хидроложки данни са използвани при моделиране на стената и езерото с цел получаване на достоверни резултати. В доклада ще бъдат представени теоретичните основи на филтрация в равнинни услови. Основните принципи на математическото моделиране ще бъдат представени на база софтуерния пакет за филтрационен анализ SEEP/W. SEEP/W е числен модел, който симулира реалните физични процеси на филтрация на вода в нехомогенна среда. Голяма част от практическите задачи не могат да бъдат решени задоволително посредством наличните аналитични методи. Добро приближение дават математическите модели, базирани на числени методи. Филтрационният поток ще бъде разгледан за случай на порьозна среда, съставена от несвързан материал. В настоящата публикация е приета хомогенна изотропна порьозна среда.

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