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Prediction models for estimation of exit hydraulic gradient and uplift pressure under the influence of downstream filter

M. Nouri*, F. Salmasi, J. Parsa

Department of water engineering, Faculty of agriculture, University of Tabriz, Tabriz, Iran.

ABSTRACT: This study investigates the impact of filter which is located in downstream of the hydraulic structures for reduction of uplift pressure and hydraulic gradient. Effective parameters for design of filter are: length of filter (L), distance from downstream of structure (X) and upstream water head (H). The outcomes of this study showed that design of filter with L/H equal to 0.057, results 60% reduction of downstream uplift pressure and 10% reduction of upstream uplift pressure. Thus the effect of filter in uplift pressure in downstream of floor is impressive. By increasing the filter length, exit hydraulic gradient always decreases and with increasing the distance of downstream (X), the effect of filter in reduction exit gradient increases. Design of filter with L/H equal to 0.057 have a good impact on exit hydraulic gradient reduction (65%), witch by increasing the length of filter, hydraulic gradient reduction will be reduced. Finally, regression and artificial intelligence models (RBF, MLP and SVM) were used for prediction of uplift pressure and exit hydraulic gradient in structure with filter. Comparison of these models base on two error measurements (R2, RMSE and MAE) demonstrated that regression model is a suitable model and SVM as a poor model in prediction of uplift pressure and hydraulic gradient.

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1. Introduction

Hydraulic structures are usually used for flow control in rivers and distribution of water in farms for irrigation. Most of these structures are built on alluvial foundations that depending on permeability coefficient of foundation materials, the seepage occurs from foundation of structures. Seepage under structures, will cause to increase in uplift force, high exit hydraulic gradient and piping under structures. These dangerous phenomena are reason for failure of structures and reduction of their stability. One of the methods for control of seepage and preventing of piping phenomenon, is filter design in downstream of structures. This filter with high permeability (16 – 25 times the protected soil materials), facilitates output flow, prevent protected soil particles migration and can increase structure stability [1]. Several studies are carried out about stability of structures under influence of filter [2-6].

Lately the artificial intelligent methods have been used in water engineering and other fields. These methods are simple but strong and can manage nonlinear processes easily, for example in topic of flow in saturated and unsaturated soils, instead of solution of Richards' equation, with having of upstream and downstream head and seepage values can be trained the models and without solving of Richards' equation can be predicted the seepage values [7, 8].

In this study, single filter is modeled with SEEP/W-2012 software and the optimum filter parameters in hydraulic gradient and uplift force control is introduced. Then by using of regression analysis, SVM, RBF and MLP, exit hydraulic gradient and uplift force under influence of filter is estimated.

*Corresponding author's email: meysamnouri71@gmail.com

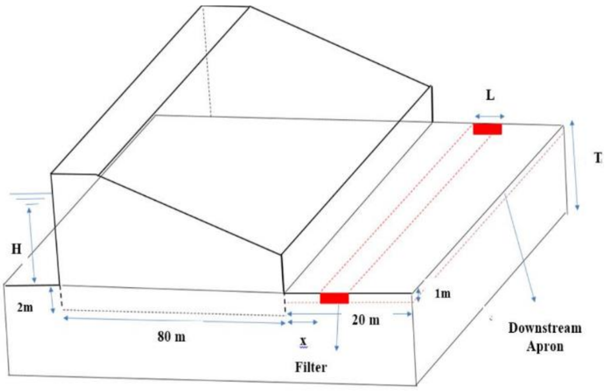

Fig. 1. Geometric and hydraulic parameters for proposed structure

2. Material and methods

2.

The hydraulic structure that have been studied has shown in Figure 1. The variable parameters are: filter length (L), filter distance from downstream (X), upstream water head (H) and foundation thickness (T). Hydraulic conductivity of foundation material is considered to be 3×10^{-5} m/s. Hydraulic conductivity for filter material is 0.0006 m/s that implies 20 times of foundation materials permeability coefficient. This

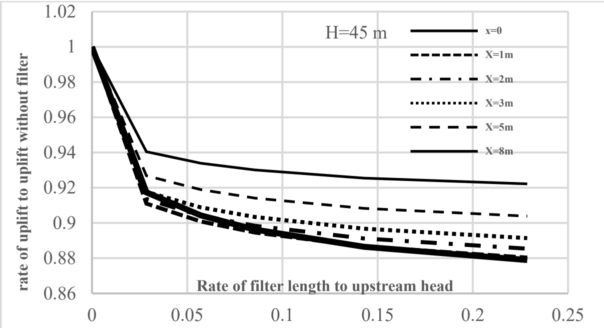

Fig. 2. Effect of filter on uplift pressure reduction

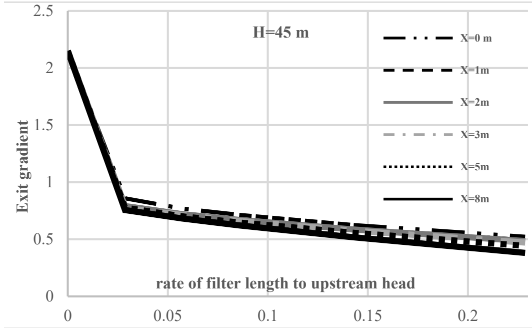

Fig. 3. Effect of filter length on hydraulic exit gradient

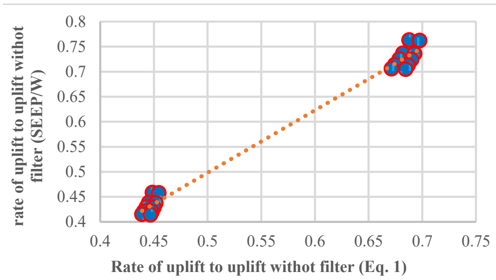

Fig. 4. Comparison of Equation 1 results and seep/w software

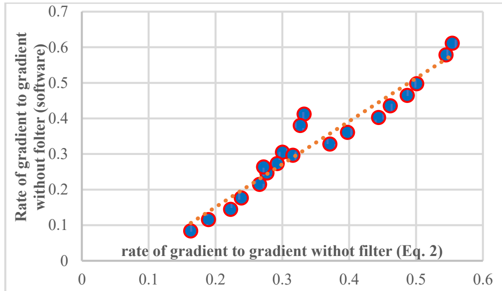

Fig. 5. Comparison of Equation 2 results and seep/w software

study uses SEEP/W (version 2012) software for numerical simulation. SEEP/W is based on finite element method (FEM).

With combination of variable parameters (L, X, H and T), about 100 numerical models were simulated and exit hydraulic gradient and uplift pressure were calculated. Then using of regression, SVM, RBF and MLP, the data set of this finite element simulation were employed for prediction of hydraulic gradient and uplift force.

3. Results and discussion

Effect of filter length and filter distance on uplift pressure has been shown in Figure 2. By increasing of filter length, uplift will be reduced that filter by length of 2 m (L/H= 0.057 m) is the optimum length for control of uplift pressure. In the other words, by increasing of filter length, ability of filter in evacuation of water in beneath of structure will be increased.

The important note that should pay attention, is the effect of filter in uplift at different location of structure floor/apron. The effect of filter on uplift reduction just at downstream of floor is significant and in center and beginning of floor, filter does not have significant effect on uplift reduction. This factor shows that design of single filter cannot provide stability of the structure and this study recommends use of filter with upstream cutoff for control of uplift.

In Figure 3, the effect of filter on exit hydraulic gradient has been shown. As shown in Figure 3, by increasing of filter length, the hydraulic gradient values will be reduced. The optimum length of filter is 2 m (L/H= 0.057). Also by increase of filter distance, exit hydraulic gradient will be reduced that values of this reduction isn't significant.

Four models for prediction of uplift and exit hydraulic gradient were used: regression analysis, RBF, SVM and MLP. Comparison of these models were carried out with error criteria such as: R^2, RMSE and MAE. Comparison of these methods with mentioned factors showed regression equations has acceptable results respect to the other methods in estimation of uplift and exit gradient. Non-linear regression equations are presented at below:

$$\frac{Uplift}{Uplift(withoutfilter)} = (X/H)^{-0.002} + (0.15)(L/H)^{-0.538} + (-0.139)(T/H)^{1.226} \quad (1)$$

$$ExitGradient = (L/H)^{-0.117} + (X/H)^{-0.064} + (-0.007)(T/H)^{2.316} - 1.92 \quad (2)$$

The results of regression equations and seep/w has been shown in Figures 4 and 5.

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