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Irrigation Sciences and Engineering (JISE) **Vol. 42, No. 1, Spring 2019, p. 129-143**

EXTENDED ABSTRACT

Estimating Scour Below Inverted Siphon Structures using Stochastic and Soft Computing Approaches

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Received: 16 May 2017 Revised: 6 July 2017 Accepted: 12 July 2017

Keywords: Scour, Inverted Siphon, Neural Network, Genetic Programming. ***DOI:*** 10.22055/jise.2017.22069.1584.

Introduction

Hydraulic structures that change the flow pattern around themselves may cause local scouring, since changing the flow characteristics (velocities or turbulence) can lead to changes in sediment transport capacity. The difference in height between the upstream and downstream bed levels of the river-intersecting structures will form a vertical waterfall in the tail-water that plays an important role in grade-control structures. An example of these structures is the Balaroud inverted siphon structure in Dez irrigation and drainage network in the south of Andimeshk county, Khuzestan province, Iran. Various experimental studies on downstream scour of hydraulic structures are available in the literature. The main objectives of this study were to investigate the scour process, estimating the maximum depth and location of the scour hole, and evaluating the maximum height and location of the sedimentary mound at the downstream of the grade-control structure. In this study, the experimental data obtained by the previous researchers was used, and the equations were reviewed and re-written using the D'Agostino and Ferro (2004) studies in order to improve the accuracy of the existing relationships. In the next step, the hydroinformatic science and the soft computing technique were used to achieve more accuracy for the relationships of the hole's characteristic and the sedimentary mound in alluvial ducts containing non-cohesive sediments.

Methodology

After reviewing the previous study, the laboratory data that carried out by D'Agostino(1996) was selected for our study because it had a favorable situation for the experimental data analysis and processing.

The effect of the independent parameters b/z, h/H, Fr_{D50}, D_{90}/D_{50}, and b/B on the dependent parameters φ/z is introduced in the form of following equation(1):

$$\frac{\varphi}{z} = a \times \left(\frac{b}{B}\right)^b \left(\frac{D_{90}}{D_{50}}\right)^c \left(\frac{h}{H}\right)^d \left(\frac{b}{z}\right)^e \left(Fr_{D_{50}}\right)^f \tag{1}$$

In this equation, the coefficients *a*, *b*, *c*, *d*, *e*, and *f* are constant numbers, and their effects are determined using the statistical analysis of the experimental observations made by the SPSS software using the non-linear regression technique by the forward stepwise regression method.
In the second part of the study, comparing the presented relationships genetic programming and artificial neural network data mining system were used
Genetic programming (GP) is used as one of the evolutionary algorithm techniques in order to flourish the presented relationship accuracy in the second part of this work. GP is an automatic programming technique used for evolving computer programs to solve problems.
The artificial neural network (ANN) is one of the most common network models, which generally presents a system of inter-connected neurons that can compute values from raw inputs. A neuron consists of multiple inputs and a single output. There is an input layer that acts as a distribution structure for the data being presented to the networks. This layer is not used for any type of processing. After this layer, one or more processing layers follow, called the hidden layers. The final processing layer is called the output layer in a network. This process is repeated until the error rate is minimized or reaches an acceptable level or until a specified number of iterations has been accomplished.

Results and discussion

1-Non-linear regression method

The SPSS software was used for determining the effective equations in this research work. The observed values for the independent dimensionless relative parameters b/z, h/H, Fr_{D50}, D_{90}/D_{50}, and b/B were evaluated versus the dependent parameters maximum scour relative depth s/z, maximum relative distance of maximum scour depth XS/z, relative height of sedimentary mound h_d/z, and maximum relative distance accumulation of sediments to weir toe XD/z in order to determine the mapping space between the independent and dependent parameters mentioned in equation (1). The mapping space between the independent and dependent parameters can be shown as equations (2)-(5):

$$\frac{s}{z}=0.5292\times\left(\frac{b}{B}\right)^{0.3104}\times\left(\frac{D_{90}}{D_{50}}\right)^{-0.0651}\times\left(\frac{h}{H}\right)^{0.0849}\times\left(\frac{b}{z}\right)^{0.5052}\times\left(Fr_{D_{50}}\right)^{0.5302} \quad (2)$$

$$\frac{XS}{z}=1.8113\times\left(\frac{b}{B}\right)^{0.0333}\times\left(\frac{D_{90}}{D_{50}}\right)^{-0.0839}\times\left(\frac{h}{H}\right)^{0.1161}\times\left(\frac{b}{z}\right)^{0.3583}\times\left(Fr_{D_{50}}\right)^{0.3601} \quad (3)$$

$$\frac{h_d}{z}=1.369\times\left(\frac{b}{B}\right)^{1.1387}\times\left(\frac{D_{90}}{D_{50}}\right)^{-1.5679}\times\left(\frac{h}{H}\right)^{-0.0573}\times\left(\frac{b}{z}\right)^{0.3413}\times\left(Fr_{D_{50}}\right)^{0.7772} \quad (4)$$

$$\frac{XD}{z}=4.5856\times\left(\frac{b}{B}\right)^{0.4987}\times\left(\frac{D_{90}}{D_{50}}\right)^{-0.6068}\times\left(\frac{h}{H}\right)^{0.05}\times\left(\frac{b}{z}\right)^{0.3136}\times\left(Fr_{D_{50}}\right)^{0.5035} \quad (5)$$

The angular coefficient of the fitted line extracted from the results of equations indicates that the non-linear regression estimates of the dimensionless parameter values s/z, XS/z, h_d/z, and XD/z are, respectively, 0.7%, 0.37%, 0.5%, and 0.13% lower than the observed values. The skewness results obtained from the statistical prediction dimensionless parameters s/z, XS/z, h_d/z, and XD/z had desirable distributions.

2- Genetic programming

The angular coefficient of the fitted line extracted from the results of the model indicated that GP estimated the values for the dimensionless parameters s/z, XS/z, h_d/z, and XD/z to be, respectively, 0.78%, 0.9%,1.2%, and 0.65% lower than the observed values. The skewness results obtained from

 DOI: 10.22055/jise.2017.22069.1584

the predicted dimensionless parameters *s/z*, *XS/z*, h_d/z, and *XD/z* using the GP data mining system was satisfactory.

3- Artificial Neural Network

The angular coefficient of the fitted line extracted from the results of the model indicated that ANN estimated the values for the dimensionless parameters, i.e. *s/z*, *XS/z*, h_d/z, and *XD/z*, to be 0.3%, 0.4%, 0.3%, and 0.08%, respectively, lower than the observed values in the training phase, the dimensionless parameter *s/z*, 0.2% more, and the dimensionless parameters *XS/z*, h_d/z, *XD/z*, 2.6%, 3%, and 0.04%, respectively, lower than the values observed in the testing phase. The skewness results obtained from the statistical prediction of the dimensionless parameters *s/z*, *XS/z*, h_d/z, and *XD/z* had desirable distributions.

Conclusion

By comparing the results tabulated in Tables 2, 4, and 5, it can be seen that the angular coefficient of the fitted line extracted from the results of the predicted parameters *s/z*, *XS/z*, h_d/z, and *XD/z* resulting from ANN is 45 degrees closer to the slope of the line of the non-linear regression and GP comparing to the predicted values. This indicates that the ANN model was more successful in estimating these parameters. The root mean square error had fewer values in predicting the parameters *s/z*, *XS/z*, h_d/z, and *XD/z* by the ANN than non-linear regression and GP, and this indicates the advantage of this approach in estimation of these parameters. GP may serve as a robust approach, and it may open a new area for an accurate and effective explicit formulation of many water engineering problems. Generally, with regard to this point that since using the presented non-linear regression for estimating scour parameters does not require a computer, it can, therefore, be claimed that using the non-linear regression compared to GP and ANN in estimating the scour hole dimensions in the downstream grade-control structure is better and more effective.

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