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Research paper

Experimental Study and ANFIS Modeling for Scour Behind Al-Shamiya Barrage

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Abstract

Generally, the scour behind hydraulic structures considered as an important matter the may be lead to failure. So, in this paper an experimental study and ANFIS modeling for a selected case study which is Al-Shamiya Barrage in Iraq. The M-9 device and GIS technique were used for collecting the data from field. The collection of data started from 1/12/2016 until to 1/3/2017 with monthly observation. A grid of (10 × 10) m for the 40 m length behind the floor of barrage was used to collect the experimental data. Furthermore, samples of sand from bed in that region were collected in order to implement the sieve analysis to specify the d_{50} and then to specify the Manning coefficient. Some equations used to calculate depth of scour behind the barrage. Then the data obtained was divided randomly into two parts: 80 % for training and 20 % for testing the model to implement the model by using ANFIS technique. The ANFIS model gave RMSE equal to 3.3965 $\times 10^{-6}$ m for training and 0.273 m for testing the model, respectively. This study concluded that the scour behind Al-Shamiya Barrage was clear experimentally using M-9 device and can be modeled using ANFIS model.

Keywords: *Al- Shamiya Barrage, ANFIS model, Hydraulic structure, M-9 device, Scour.*

1. Introduction

Hydraulic structures such as Barrages were very important and used to control water. These structures were subjected to failure due to scour behind them. A river deviation barrage through its operational life has to be protected in contradiction of random local scouring due to unreliable flow conditions and gate openings. It might affect its structural constancy. Additionally, in the low deep reservoir, sedimentation behind a barrage might result to adversative conditions that may disturb its normal performance [1]. Several formulae for scour subsequent the hydraulic jump developed by Pillai [2], Rice and Kadavy [3], Baghdadi [4], and Dargahi[5]. Different procedures to decrease the local scour have been used in previous researches by using splitter plates or collars. In addition to that, Rajaratnam [6] carried out an earlier research about hydraulic jump over rough apron. This study was displayed that, the length of jump upon rough apron is less than the length of classical jump. Many researchers dealt with that matter. An optimal design for Barrage according to subsurface flow aspects was introduced by Garg N.K. et al. (2002). A barrage, is defined as a structure crosswise a river to move flow into a man-made channel, is considered to satisfy surface and subsurface flow aspects. There is no method to fix the basic barrage factors. These parameters are the length and thickness of floor, depth of sheet piles/cutoffs and, in a cost-effective manner. An approach to eliminate the charge of a barrage using an optimization method is displayed in this study. The feasibility of the approach has been demonstrated with two cases representing its appropriateness to evolve a cost-effective design. A parametric analysis has been implemented also to increase understanding into the impacts of different factors on the ideal design barrage [7].
The work presented by Hossam M.A. et al. (2014) to study the scour downstream due to hydraulic jump in the local area of the hydraulic structures. In this research, an experimental study was implemented to find the impact of using various spaced corrugated aprons on the downstream local scour. Because of submerged jump, sixty runs were carried out in a horizontal rectangular flume to find the optimal corrugation wavelength which reducing the scour. A flat apron (as a case) was included to estimate the effect of corrugated aprons on scour holes' dimensions. Two categories of non-cohesive soil were used. The study was achieved for a range of Froude numbers ranging from 1.68 to 9.29. The results displayed that using spaced triangular corrugated aprons reduce the scour depth and length of fine sand and for coarse sand in comparing with classical jump [8]. Fahmy S. Fahmy (2013) studied the local scour downstream hydraulic structures. For the experimental study that was carried out to forecast the scour downstream a Fayoum type weir and to eliminate the scour via a row of semicircular baffle blocks. In this study, it is easy to use the considered shape as an extra element to existing water structures so that the scour which is down stream of these structures can be minimized. There was about 153 runs were conducted with various heights and positions of baffle blocks and different flow conditions. It also include the scenario of a case of flat floor without baffles in the test program to examine the impact of the baffle piers that might be used [9].
Bakhiet et al. (2012) presented a study on a new method that was enhanced to find the scour downstream regulators on movable beds. Into two groups, this study was separated; the first is to calculate the total lengths of rigid apron which is located behind the gates plus the length of scour hole that formed downstream. The second is to discover the least length of rigid apron which is located behind the gates in order to prevent the erosion downstream it. For both symmetrical and asymmetrical under gated regulations were covered for both cases (submerged and free) hydraulic jump conditions. The results show that the least length of rigid apron to avoid scour (Ls) is highrt than the total lengths of rigid apron and that of scour hole formed behind it (L+Xs). Moreover, in case of submerged hydraulic jump, the scour hole dimensions is always higher than free

one. Furthermore, the scour hole in symmetrical operation dimensions is lower than asymmetrical one [10].

2. Al-Shamiya Barrage as a Case study

Al-Shamiya Barrage considered as one of the largest hydraulic structures in Al-Qadisiyah Governorate. This Barrage lies 39 Km from Al-Shamiya river. Moreover, this barrage contains six gates with discharge 200 m^3/s for each one and 1200 m^3/s in total. The upstream and downstream water level were 22.5 m and 19.5 m, respectively. The total area that irrigated using this Barrage was about 230000 donem. The region in downstream of Barrage suffered from scour. So, the scour downstream must be studied experimentally and theoretically using certain model. The following Figure shows the GIS photo for that Barrage.

Fig. 1: GIS photo for Al-Shamiya Barrage.

2.1. Field work

The region of case study behind the Barrage was divided into four regions with five sections which are: A, B, C, and D. each region far 10 m from the other. Figure (2) shows the five regions behind the Barrage. A grid of (10 × 10) m for the 40 m length behind the floor of barrage was used to collect the experimental data.

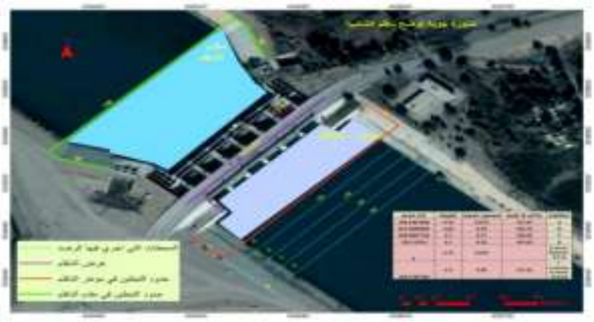

Fig. 2: The four regions in the case study.

The following data was collecting using M-9 device which shown in Figure (3): Discharge, cross section, velocity, and the depth of water for four months starting from 1/12/2016 to 1/3/2017. Due to the changes in depth from month to other, since the bed is sandy soil and in fact when the interval increased, then more accurate data will be obtained but that require more time and efforts, however, the selected intervals was considered to be adequate.

Fig. 3: The M-9 Device.

The following Figure represents the cross section for the five sections which were obtained using M-9 Device for the December month.

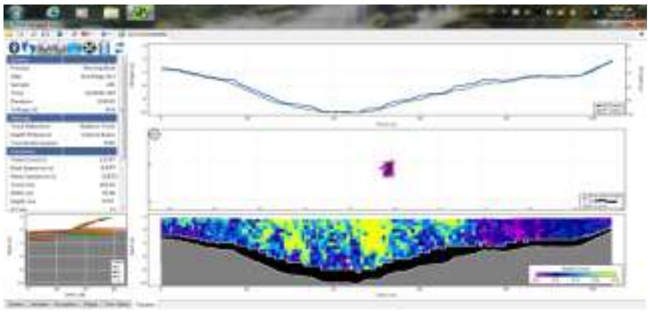

Fig. 4: M-9 data for section A.

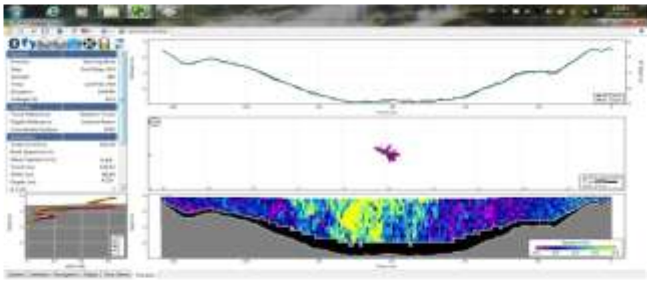

Fig. 5: M-9 data for section B.

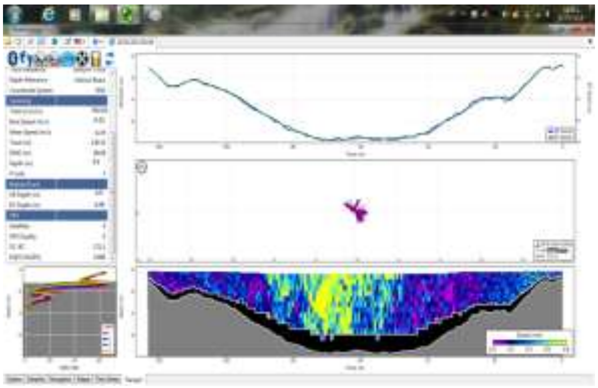

Fig. 6: M-9 data for section C.

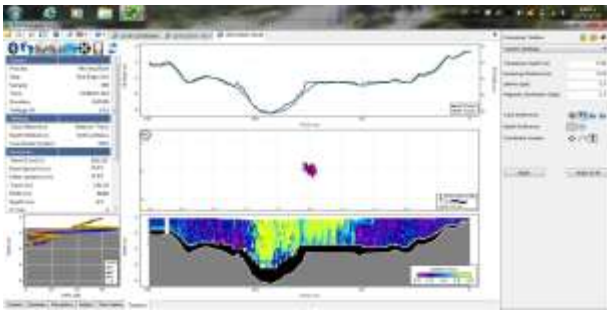

Fig. 7: M-9 data for section D.

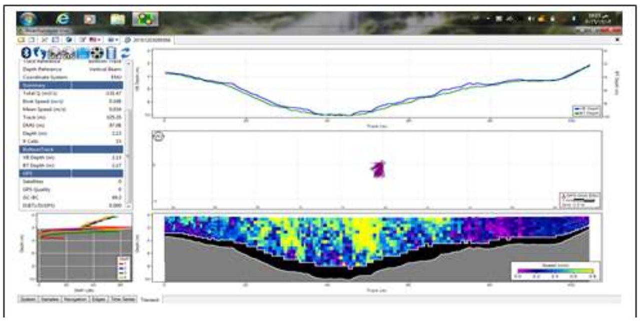

Fig. 8: M-9 data for section E.

The following figures (Figure 9 and 10) show the 2-D contour line for the elevation and 3-D surface for the bed behind the Barrage using Surfer V15, respectively. These figures represent the establishing and forms of scour behind the Barrage specially near the gates. Furthermore, these figures represent the distance between the ground surface and water surface. The largest distance was near the most gates opened.

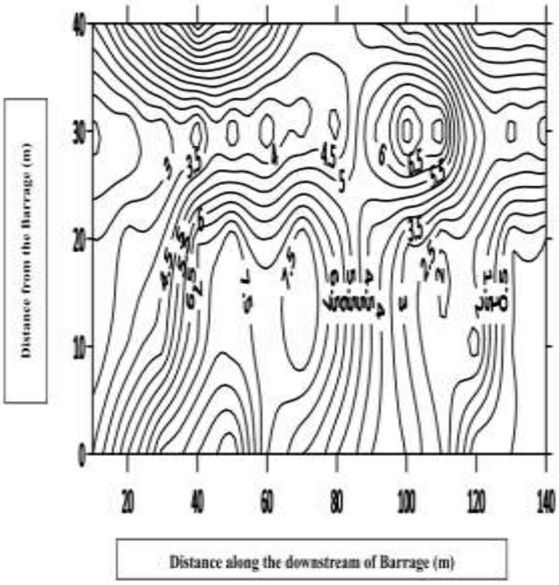

Fig. 9: 2-D contour line for the region behind the Barrage.

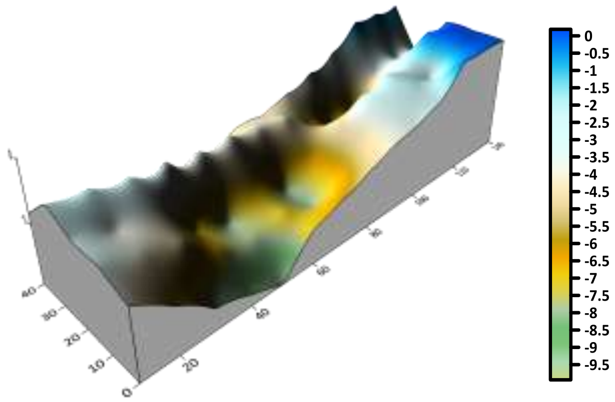

Fig. 10: 3-D contour line for the region behind the Barrage and the distances in m.

Many samples of soil were taken from bed in order to make a sieve analysis for estimating d50 which equal to 0.22 mm and then to estimate Manning coefficient n. Moreover, the weight density γs was 25676 N/m3, and specific gravity was 2.62

3. Theoretical Work

Theoretically, the depth of scour depends on velocity of flow V, critical velocity sediment entrainment Vc, friction factor f, and the distance from the Barrage D. The following equations were used in estimating the depth of scour [Melville; 2014].

$$V_c = 0.19 \times d_{50}^{0.1} \times \ln\left(\frac{2h_2}{d_{50}}\right) \quad (1)$$

$$\frac{1}{\sqrt{f}} = 2 \times \log\left(\frac{12.6\ h_2}{d_{50}}\right) \quad (2)$$

Where h2 is the depth of water downstream of Barrage. All the experimental data and above equations were used to build the ANFIS Model for scour depth as shown below.

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4. ANFIS Model

By Jang in 1993, the ANFIS was first announced, is skilled of approximating any actual continuous function on a compact set to different degree of accuracy [11]. The neuro-adaptive learning process mechanism is the same as of neural networks. A neuro fuzzy system is a combination of fuzzy systems and neural network in such a way that neural network algorithms or neural network are employed to find the parameters of the fuzzy system. It is mean that the focal purpose of neuro fuzzy approach is to generate or enhance a fuzzy system robotically by means of neural network systems. ANFIS are a type of adaptive networks that are functionally like to fuzzy interpretation systems. Because of that the functionality of the knowledge line function ANFIS and the Neuro-Fuzzy Designer are the same, they are employed slightly interchangeably, excluding when precisely describing the Neuro-Fuzzy Designer application.

Fig. 11: ANFIS model designer.

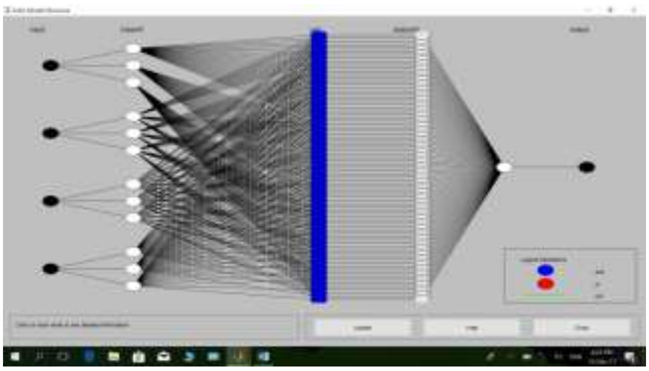

Fig. 12: ANFIS model structure.

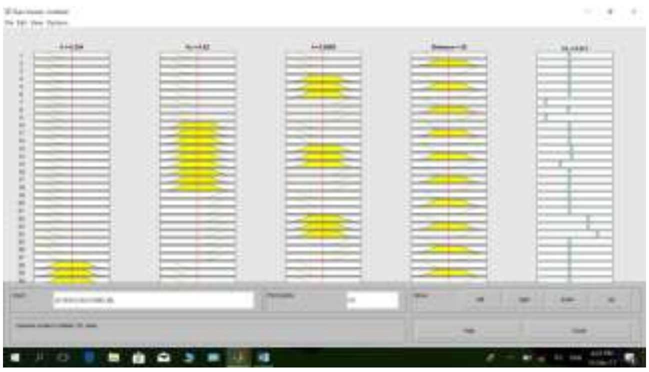

Fig. 13: ANFIS rules viewer.

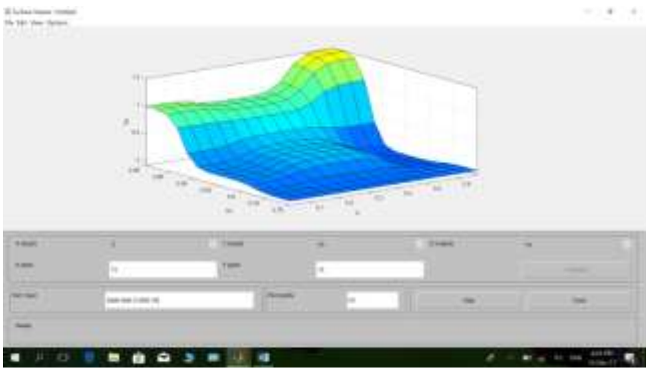

Fig. 14: ANFIS surface viewer for the Vc, V, and Ys.

5. Conclusions

In this paper, the scour behind Al-Shamiya Barrage was studied experimentally for four months since 1/12/2016 until 1/3/2017. The data were collected using M-9 device and many samples of bed soil were collected and the sieve analysis in soil laboratory was done. All the data obtained were modeled using the soft computing technique which is ANFIS Model. The modeling gives good estimation with RMSE about $3*10^{(-6)}$ m for the training data and about 0.273 m for testing data. The RMSE was calculated automatically through the modeling by MATLAB. This study concluded that the scour behind Al-Shamiya Barrage was can be measured experimentally by using M-9 device and then can be modeled using ANFIS model

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