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Multi-Objective Optimization of Spur Dikes Dimension Plan using Harmony Search Algorithm

Case Study: Zanjanrood

Babak Shahinejad [**], HojjatAllah Yonesi [2], Maryam Mirbeik Sabzevari [3]

1- Assistant Professor, Water Engineering Department, Lorestan University, Khorramabad, Iran
2-Associate Professor, Water Engineering Department, Lorestan University, Khorramabad, Iran
3- PhD student of Water Structures Engineering, Lorestan University, Khorramabad, Iran

1-Introduction

Under the influence of various factors such as the topography of the river valley, the hydrological characteristics of the basin, the hydraulic conditions of the flow, and the way humans use it, the river has a natural tendency to reach a dynamic balance. The changeable nature of some of the above factors causes the river to be subject to changes even in the short term and in its different intervals. River changes occur as erosion and intermittent sedimentation in the bed, destruction, and widening of walls and banks, displacement of the spiral pattern and direction of the flow, change of the river form (arterial-spiral-straight), shortcut or deviation of the path. Erosion of the river banks causes damage to agricultural lands, damage to nearby structures such as bridges and roads, widening of waterways, and environmental issues; this problem causes a lot of money to be spent to protect the river banks against erosion every year. The construction of river spur dikes, which are important structures for the organization of the river, changes the flow pattern in the river and prevents the banks from being exposed to erosion. The construction of spur dikes has caused erosion or sedimentation in different areas of the river, so it is necessary to check the balance in the river in addition to its cost-effectiveness. Zare and Honar (2016) studied the effect of a simple spur dike on the reduction of bank erosion in the river arch in laboratory conditions. Abbasi et al. (2019) investigated bed morphology changes in channels with a series of parallel spur dikes with unequal lengths and different orientations. They used FLOW-3D software for their numerical simulation. In this research, it was tried to study the optimal plan of spur dike dimensions according to the standard criteria with the goals of minimizing the plan cost and maximizing the bed load while maintaining the stability of the section. For this purpose, the non-linear multi-objective optimization model was used using the harmony search algorithm. The two objective functions considered in this model are the structure

* Corresponding Author; **E-mail:** shahinejad.b@lu.ac.ir

construction cost function and the stable section function, which should minimize the cost and maximize the bed load transfer capacity. Then the presented model was compared with the previous studies conducted on the spur dike built in the Zanjanrood.

2-Methodology

Zanjanrood is one of the main tributaries of the Ghazal Ozon River in the northwest of Iran, which was considered in the present study. A multi-objective optimization model is required in the plan of the spur dike, which considers a combination of two plan and morphological models to minimize the plan costs and maximize the load transfer capacity. In this study, the Van Rijn (1987) equation is used to calculate the sediment discharge (Equation 1) and Gill (1972) equation is used to calculate the depth of spuring (Equation 2-5). The cost of building a spur dike is based on Equation 6. To evaluate the cross-section stability were used hypothetical theories and for optimization, the non-linear model used the harmony search algorithm. Inputs required optimization model Provide in Table 1.

$$\phi=0.053\frac{\left(\frac{\tau_0-\tau_c}{\tau_c}\right)^{2.1}}{D_{50}^{0.3}\left[\frac{(G_s-1)g}{\upsilon^2}\right]^{0.1}} \quad (1)$$

$$d_{s\_total}=(d_{s\_local}+d_{s\_general}) \quad (2)$$

$$d_{s\_local}=d_{s\_1}\times\left(\left(0.07\times\frac{L}{b}\right)+0.14)\right) \quad (3)$$

$$d_{s\_general}=Y_1\times\left(\frac{B_1}{B_2}\right)^{-\frac{6}{7}}\times\left(\left(\frac{B_1}{B_2}\right)^{-P}\times\left(1-\frac{\tau_c}{\tau_1}\right)+\frac{\tau_c}{\tau_1}\right) \quad (4)$$

$$d_{s\_1}=8.4\times Y_1\times\left(\frac{D_{50}}{Y_1}\right)^{0.25}\times\left(\frac{B_1}{B_2}\right)^{6/7}-Y_1 \quad (5)$$

$$COST=2\times N_{groyne}\times(b+root)\times(H+d_{s\_total})\times T\times UPRC_{groyne} \quad (6)$$

Table (1): Required inputs of the optimization model (Sazeh Pardazi Iran Consulting Engineers, 1993)

$L_t(m)$	$\boldsymbol{T}_{\text{groyne}}(\boldsymbol{m})$	$\text{UPRC}_{\text{groyne}}$	$Q_s\left(m^3/s\right)$	$\boldsymbol{D}_{50}(\boldsymbol{m})$	$B_1\left(m\right)$	s	$\rho_s\left(kg/m^3\right)$	n
17000	2	1	0.2012	0.011	100	0.005	2650	0.038

3- Results and Discussion

Sensitivity analysis of the model was performed for the parameters of discharge, slope, and initial width of the river, and Calibration and validation of the model were performed by Zanjanrood data. Figure 1 shows the Pareto front of the model run. The horizontal axis displays the cost and the vertical axis is the sediment discharge. The Pareto diagram with its breadth provides very appropriate information for management systems. Finally, one of the Pareto diagrams should be selected for construction and implementation. Choosing the appropriate number depends on the planer opinion and management conditions. The method of choosing different scenarios on the diagram is to have a regular and uniform distribution in the target space and to provide adequate coverage of the Pareto front. Then, among the available options, the scenario that has the smallest Euclidean distance with the ideal point was selected as the optimal plan. The ideal point is the point that has the highest sediment discharge and the lowest cost which is marked with a solid circle in Figure 1. Euclidean distance is calculated from Equation 7 (Carrol et al, 1997).

$$d = \sqrt{\left(x_1 - x_2\right)^2 + \left(y_1 - y_2\right)^2} \quad (7)$$

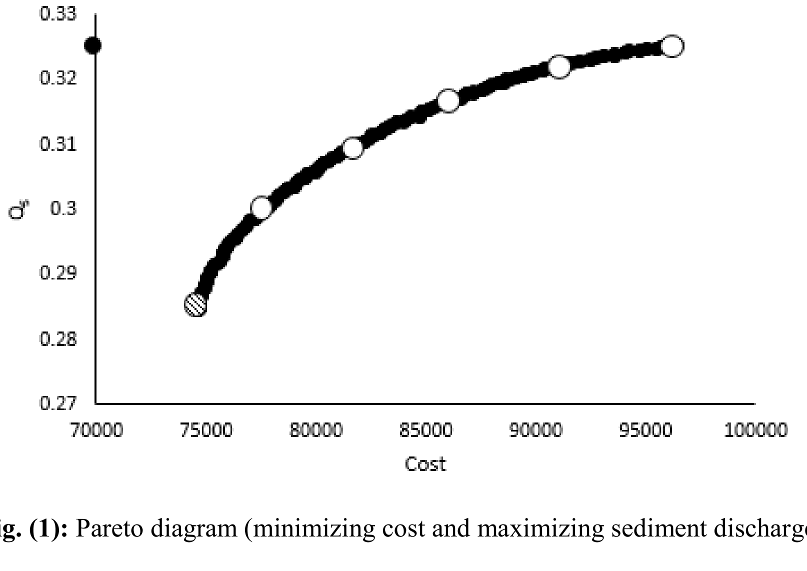

Fig. (1): Pareto diagram (minimizing cost and maximizing sediment discharge)

The results obtained from this research were compared with the plan done by Hosseini et al. (2003) and Ostadi et al. (2014) model. By comparing different scenarios obtained from the Pareto front, better answers were provided than the plan implemented in Zanjanrood and the studies of other researchers.

Finally, one point of the Pareto front must be selected for construction and execution. Choosing the right number depends on the planer's opinion and the existing priorities. In one of the scenarios chosen as the optimal plan, it has the lowest Euclidean distance compared to other scenarios with the ideal point Based on the minimum Euclidean distance compared to the ideal points, respectively 63.90% less cost and 25.48% more sediment discharge than the plan done by Hosseini et al. (2003) and respectively 3.3% less cost and 16.62% more sediment discharge than Ostadi et al. (2014) model that shows the optimal efficiency and better accuracy of the proposed model.

4- Conclusions

One of the common methods of controlling side erosion and river training is the use of spur dikes. It is important to consider several and conflicting objectives in river engineering studies simultaneously. For this purpose, the optimum plan of the dimensions of constructed spur dikes in Zanjanrood was considered to minimize the cost and maximizing the sediment discharge. In the model, a combination of morphological model, plan, and optimization model of multi-objective harmony search algorithm was used and to evaluate the cross-section stability were used hypothetical theories. Calibration and validation of the model were performed by Zanjanrood data with the Van Rijn sediment equation and Gill scouring equation. A sensitivity analysis of the model was performed for the parameters of discharge, slope, and initial width of the river.

The results obtained from this research were compared with the plan done by Hosseini et al. (2003) and Ostadi et al. (2014) model. By comparing different scenarios obtained from the Pareto front, better answers were provided than the plan implemented in Zanjanrood and the studies of other researchers. Based on the minimum Euclidean distance compared to the ideal points, presents respectively 63.90% less cost and 25.48% more sediment discharge than the plan done by Hosseini et al. (2003) and respectively 3.3% less cost and 16.62% more sediment discharge than Ostadi et al. (2014) model that shows the optimal efficiency and better accuracy of the proposed model.

Keywords: River Training, Multi-objective optimization, Pareto front, Euclidean distance, Zanjanrood basin.

5-References

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