

## The effects of constructing Groynes to protect the coasts of the Dehnehsar Sefidroud area

Mohammad Javad Azmudeh<sup>1</sup>, Mehdi Nezhadnaderi<sup>2\*</sup>, Vali Ghaseminejad<sup>3</sup>, Babak Pordel Maragheh<sup>4</sup>, Babak Fazli Malidareh<sup>5</sup>, Mohammad Hossein Vafae<sup>6</sup>, Ali Sheykhbahaei<sup>7</sup>, Seyed Mohammad Mousavi<sup>8</sup> and Abolfazl Bagheri<sup>9</sup>

<sup>1)</sup> Department of Civil Engineering, Tonekabon Branch, Islamic Azad University, Tonekabon, Iran. [a.azmudeh@yahoo.com](mailto:a.azmudeh@yahoo.com)

<sup>2)</sup> Department of Civil Engineering, Tonekabon Branch, Islamic Azad University, Tonekabon, Iran. (Corresponding Author). [mehdi2930@yahoo.com](mailto:mehdi2930@yahoo.com).

<sup>3)</sup> Department of Civil Engineering, Nowshahr Branch, Islamic Azad University, Nowshahr, Iran. [Vghaseminejad@iaui.ac.ir](mailto:Vghaseminejad@iaui.ac.ir)

<sup>4)</sup> Department of Civil Engineering, Ardabil Branch, Islamic Azad University, Ardabil, Iran. [civil\\_babak2005@yahoo.com](mailto:civil_babak2005@yahoo.com)

<sup>5)</sup> Department of Civil Engineering, Babol Branch, Islamic Azad University, Babol, Iran. [Fazli.babak@babolia.ac.ir](mailto:Fazli.babak@babolia.ac.ir)

<sup>6)</sup> Assistant Professor, Department of Civil Engineering, Pooyesh Institute of Higher Education, Qom, Iran. [M.h.vafae2024@gmail.com](mailto:M.h.vafae2024@gmail.com).

<sup>7)</sup> PhD Candidate in Physical Oceanography at university of Hormozgan/ Iranian National Institute for Oceanography and Atmospheric science, [Ali.sheykhbahaei@inio.ac.ir](mailto:Ali.sheykhbahaei@inio.ac.ir)

<sup>8)</sup> Department of Civil Engineering, Tonekabon Branch, Islamic Azad University, Tonekabon, Iran. [Mosavi.622@gmail.com](mailto:Mosavi.622@gmail.com)

<sup>9)</sup> Department of Civil Engineering, Tonekabon Branch, Islamic Azad University, Tonekabon, Iran. [Abolfazl.Bagheri@yahoo.com](mailto:Abolfazl.Bagheri@yahoo.com)

### ARTICLE INFO

#### Article History:

Received: 22 Jan. 2024

Accepted: 15 Sep. 2024

#### Keywords:

**Groyne, Flow pattern, Erosion, Computational fluid dynamics, Sefidroud mouth.**

### ABSTRACT

With the increase in construction in the sea, the use of protective structures to prevent their instability in the marine environment is of environmental concern. Coastal protection structures are used in marine structural engineering to reduce flow turbulence around marine structures to prevent scouring. In this research, the flow simulation around breakwaters constructed in the Dehnehsar Sefidroud area located in Guilan province was investigated using computational fluid dynamics and Fluent software. By constructing the breakwater structure, the speed between the breakwaters is reduced and conditions for sediment accumulation are provided. Also, the negative pressure on the west side of the western breakwater is reduced and reaches a positive value, changing from erosion potential to sedimentation potential. There is negative pressure in a part of the western tip of the breakwater, which will cause local scouring and needs protection. The results of the 2D and 3D models of isovelocity vectors with the installation of breakwaters of 90, 94 and 55 meters in length on the shore of the mouth of the Sefidrud River show that the velocity in the space between the 90, 94 and 55 meter breakwaters

<sup>1, 7,9)</sup> MSc

<sup>2)</sup> Associate Professor

<sup>3 to 8)</sup> Assistant Professor

decreases, reducing the risk of scouring and allowing sediments that move west to east on the shore to accumulate. Also, the results of is velocity vectors and contours show that with the installation of breakwaters implemented on the shore of the mouth of the Sefidrud River, the pressure in the space between the 94 and 55 meter breakwaters decreases, reducing the risk of scouring.

## 1. Introduction

The village of Dehnesar Sefidrud is located on the Caspian Sea, north of Astaneh Ashrafieh County and east of Bandar Kiashahr. The distance from the village to Lahijan County and Astaneh Ashrafieh is about 38 kilometers. This village is bordered by the sea to the north, Hasan Ali Deh Village to the south, Jirbagh Village to the east, and Dastak and Lokh Village to the west. Dehnesar Sefidrud is part of Bandar Kiashahr. Identifying the condition of the southern coast of the Caspian Sea in terms of erosion and sedimentation characteristics to determine sensitive and unstable areas versus active and stable sedimentary areas is the main issue of this research. For this purpose, the erosion and sedimentation conditions in this area are investigated using numerical modeling.



Figure 1 - Geographical location of the Dehnesar Sefidrud region in Gilan, adjacent to the Caspian Sea

Breakwaters are usually constructed to protect shores or to provide sufficient depth for navigation purposes. Known by names such as epis, groynes, and cross arms, these structures can be grouped by their shape, such as T-shaped or L-shaped.

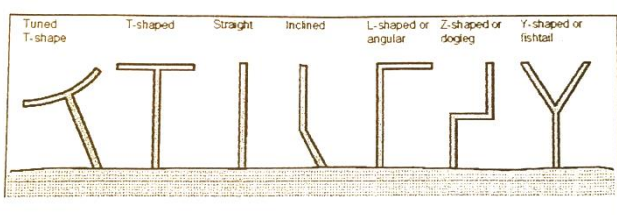


Figure 2 - Types of breakwaters that so far have been built

The most important parameters that should be considered in the design of breakwaters are: breakwater design plan, breakwater length, distance between breakwaters, orientation with the flow path, crest height, slope of the bank, materials used in the breakwater section.

In 2015, Vaghefi et al. investigated the effect of supporting structures on the flow pattern around T-shaped spur dikes in a 90-degree bend. Numerical methods can be useful for evaluating hydraulic parameters for spur dikes because of the reduced simulation time, while experimental experiments are time-consuming and require a large number of tools to simulate each model. In this paper, the flow patterns around a T-shaped spur dike and a supporting structure, which is located above the T-shaped spur dike, in a 90-degree bend channel are analyzed with the Flow-3D model. Numerical and experimental data are compared in the longitudinal section to validate the numerical model. The results show that there is a good agreement between the numerical and experimental data. After the numerical model was validated, the supporting structure was installed above the T-shaped spur dike with 3, 5, 7 and 9 times the distance of the T-shaped spur dike length. Support structure changes flow patterns and hydraulic parameters such as secondary flow strength and separation zone in all sections. By increasing the support structure from 3L to 9L, the secondary flow around the main circle decreases by approximately 40-120% and the length of the separation zone becomes 0.8 to 2.5 times larger than the length of the T-shaped dike[1].

Vaghefi et al. (2015) conducted a laboratory study of turbulent flow in a 180-degree bend. The high flow velocity near the free surface of rivers is due to the presence of shear stress near the bed and its absence at the free surface. This phenomenon leads to instability of the vertical velocity profile. In addition, secondary flows in river bends cause velocity changes, thus leading to changes in shear stress near the bed. In this study, the effect of velocity changes, maximum velocity distribution and secondary flow strength on the distribution of bed shear stress in a 180-degree bend constructed in the hydraulic laboratory of

Persian Gulf University has been investigated and analyzed. The results show that the maximum secondary flow strength is in the second half of the bend. Evaluation of the bed shear stress distribution using TKE, modified TCE and Reynolds methods in the turbulent boundary layer showed that the maximum shear stress occurs from the bend entry into the bend shear zone near the inner wall. In addition, a comparison of the Reynolds shear stress method at a distance of 5 and 15% of the flow depth from the bed showed that the maximum shear stress moves from the 40° section in the lower layer to the 60° section in the upper layer[2]. Van-den Heuer (2013) conducted a laboratory study to investigate erosion, sedimentation and flow hydraulics in a laboratory model constructed to resemble a meandering river. The length, spacing and angle of the weirs were the variables studied. From the results of his research, it can be noted that a low-velocity zone is created between the weirs, where sedimentation takes place. As the distance between the sluice gates increases, the velocity between the sluice gates increases, which causes a change in the sedimentation pattern between the sluice gates[3].

In 2012, Mehrnohad and Fedesian conducted an experimental study of the effect of the parameters of the sluice gate length and the diameter of the materials on the scour around a T-shaped sluice gate located at a 90-degree bend.

In this paper, laboratory studies were conducted to investigate the combined effect of the sluice gate length and the diameter of the bed materials on the scour around a T-shaped sluice gate located at a 95-degree bend. The experimental results indicate that the dimensions of the scour hole (including the maximum scour depth, the length of the scour hole upstream of the sluice gate, and the maximum width of the scour hole) are directly proportional to the length of the sluice gate, while the maximum scour depth and the length of the scour hole upstream of the sluice gate are inversely proportional to the average diameter of the materials[4].

Shaker and Shafai Bajestan conducted a laboratory study in 2013 of the effect of the length and angle of rectangular breakwaters on the distribution of velocity and shear stress in a 90-degree bend.

The results of the study showed that the presence of a series of breakwaters causes the upstream velocity to be uniform and the high-velocity zone to be transferred from the vicinity of the outer wall to the middle of the channel to the inner wall. The bed shear stress increases due to the presence of breakwaters, and increasing the length of the breakwaters increases it by about six times the shear stress upstream of the bend, but it does not have much effect on the location of the shear stress occurrence, so that in all cases, the maximum shear stress occurs at an angle of 70 to 80 degrees of the bend [5].

In 2009, Vaghefi et al. studied the temporal changes in scour around a T-shaped breakwater in a 90-degree bend. This paper investigates the temporal changes in scour hole dimensions and bed topography around T-shaped culverts fixed in a 90-degree bend. For this purpose, experiments were designed and conducted in a laboratory channel with a 90-degree bend and a gentle bed of sediment with an average grain size of 1.28 mm and clear water conditions. In these experiments, the effects of the parameters of culvert length, culvert crest length, culvert position in the bend, and the Froude number of the flow on temporal changes in scour hole dimensions around the T-shaped culvert and changes in bed topography were investigated. The results indicate that increasing the length of the spillway, decreasing the length of the spillway top, increasing the number of landings, and changing the position of the spillway downstream of the bend increase the dimensions of the scour hole. The experiments were conducted in a channel with a 90-degree bend at the Hydraulic Laboratory of Tarbiat Modares University, Tehran [6].

## 2. Methods

In this paper, Gambit software version 16.3.2 is used to generate the geometry and mesh. The mesh pattern is Quad element and map type is used for the surfaces. The existing boundary conditions are velocity input from the left and north and the pressure output boundary condition is at the outlet from the right. Fluent software uses continuity and Navier-Stokes equations in flow analysis. If the flow is turbulent, then the governing equations are transformed into Reynolds equations and one-equation, two-equation, five- or six-equation models are used to determine the eddy viscosity, with the user specifying the type of model. The flow field is solved based on the separation of equations by the finite volume method and different methods of separation of the transfer terms of the equations such as upstream, second-order upstream, power and Quick can be selected by the user. In order to couple the velocity field and the pressure field, the Simple, Simple C and Piezo methods are available in the program. In this article, Fluent software version 6.3.26 has been used to simulate the flow field.

To solve the flow using computational fluid dynamics, the following steps must be performed (Shojaifard and Noorpour Hashtroudi, 1995):

- Selecting the Gambit model to create the geometry
- Selecting the computational model
- Selecting the calculation solution method in the model
- Selecting the basic equations to solve
- Determining the physical characteristics of the materials

- Determining the boundary conditions
- Specifying the problem solving parameters
- Making an initial guess in the entire solution field
- Performing the solution and outputting the calculations.



Figure 3- Coastal deformation in the presence of a non-submersible breakwater in the Dehne Sar Sefidroud area (Summer 2019)



Figure 5- Location of the breakwater near the coastal road in the village of Dehne Sar Sefidroud in Gilan Province



Figure 4- Location of the breakwater near the coastal road in the village of Dehne Sar Sefidroud (Dastak Astaneh Ashrafieh)

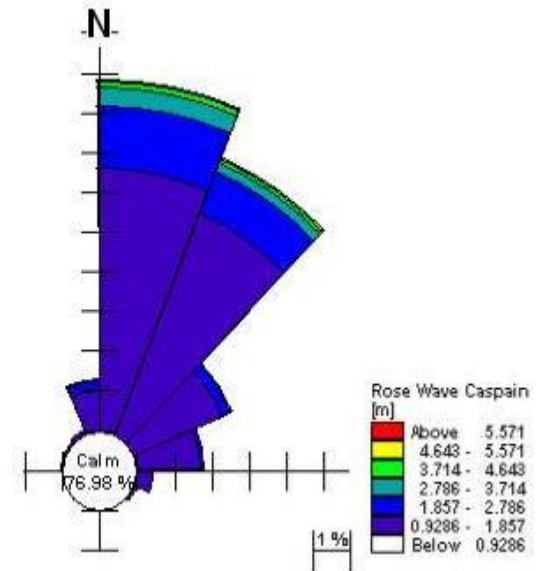


Figure 6- Wave mud based on ISWM results (Iranian Ports and Shipping Organization, 2003)

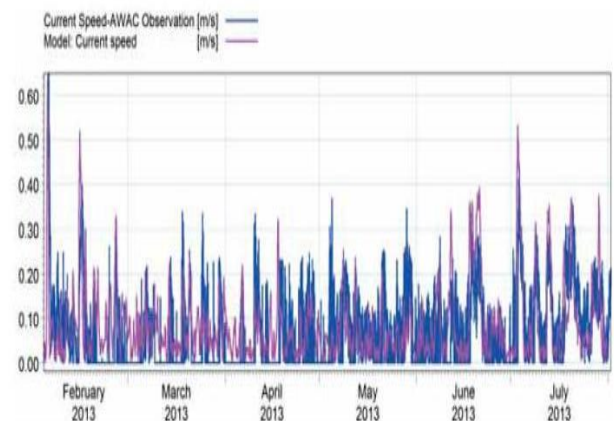


Figure 7- Results of field velocity observations in the village of Dehne Sar Sefidroud in Gilan Province

### 3. Results and Discussions

In this study, Gambit software version 3.3.2 was used to generate the geometry and mesh it. The mesh pattern was Quad element and map type was used for the surfaces. The existing boundary conditions are velocity input from the left side from the top of the arc and pressure output boundary condition at the bottom of the arc outlet. The simulation results from Fluent software are seen in Figures 8 to 11.

The first and second stages of the solution process require a geometry and mesh generator. The GAMBIT preprocessor or one of the CAD/CAE software can be used to generate the geometry and mesh. The Tgrid preprocessor can also be used to generate a mesh with volume elements from an existing surface mesh. In the third stage, the two-dimensional FLUENT software must be run. The velocity input boundary conditions from the north and west of the area are based on previous studies and the pressure output boundary condition is applied from the right side of the area. The entire southern part is considered as the wall boundary for the beach.

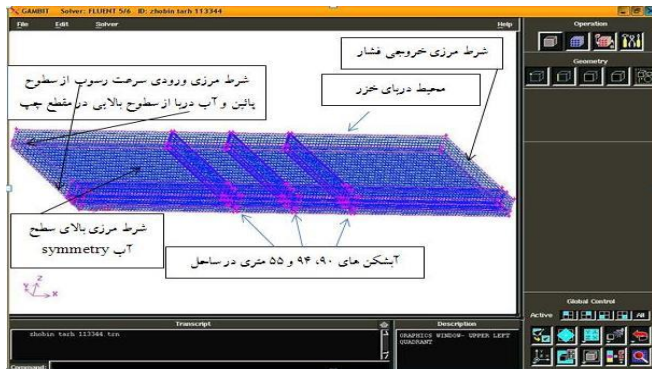


Figure 8 - Meshing in Gambit software of the 3D seawater space in the Dehnehsar Sefidroud area with the implemented breakwaters with lengths of 90, 94 and 55 meters respectively from right to left. The boundary condition of water and sediment velocities input from the left cross-section surfaces and the boundary condition of pressure output from the right cross-section and the boundary condition of symmetry for the water surface and the boundary condition of the wall for the surfaces of the breakwaters.

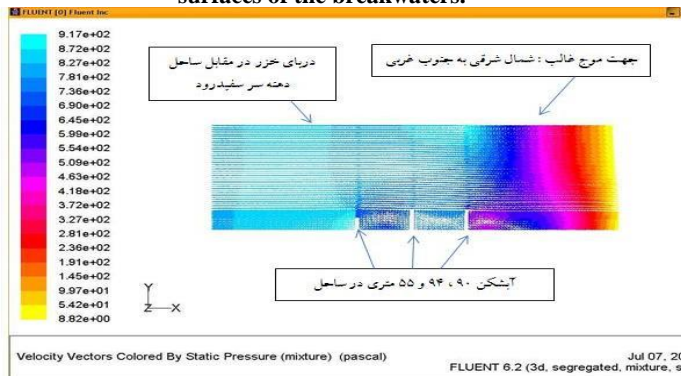


Figure 9- Equal pressure vectors are created by installing breakwaters on the shore of the mouth of the Sefidroud River, which reduces the pressure in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring.

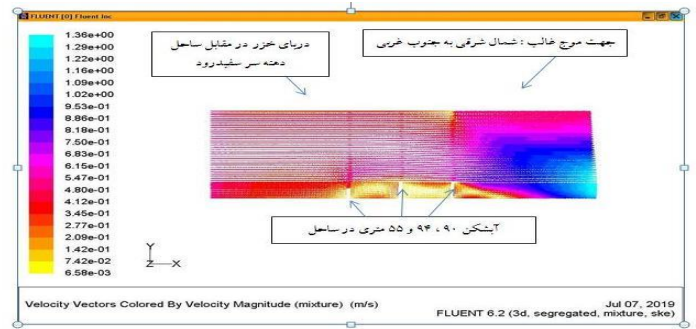


Figure 10 - The same velocity vectors are created by installing breakwaters on the shore of the mouth of the Sefidroud River, which reduce the velocity in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring and allowing sediments that move west to east to accumulate on the shore.

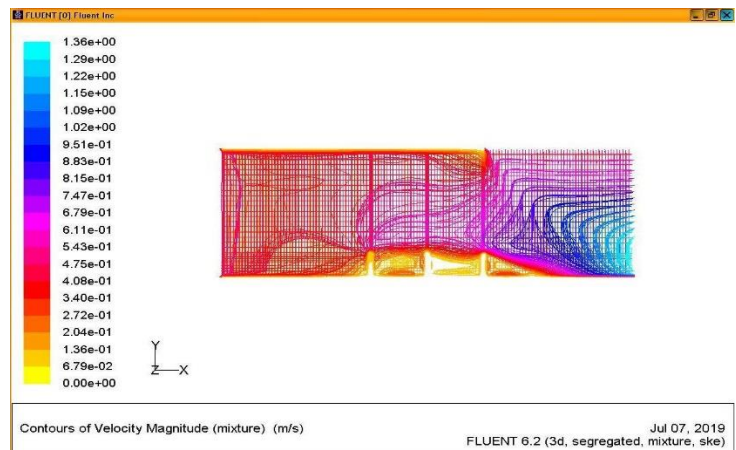


Figure 11 - The same-velocity contours are constructed by installing breakwaters on the shore of the mouth of the Sefidroud River, which reduce the velocity in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring and allowing sediments that move west to east along the shore to accumulate.

The results of the 2D and 3D models of isovelocity vectors with the installation of breakwaters of 90, 94 and 55 meters in length on the shore of the mouth of the Sefidroud River show that the velocity in the space between the 90, 94 and 55 meter breakwaters decreases, reducing the risk of scouring and allowing sediments that move west to east on the shore to accumulate. Also, the results of isovelocity vectors and contours show that with the installation of breakwaters implemented on the shore of the mouth of the Sefidroud River, the pressure in the space between the 94 and 55 meter breakwaters decreases, reducing the risk of scouring.

#### 4. Conclusion

The solutions to reduce the flow turbulence cause the flow lines formed around the coast of the mouth of the Sefidroud River to lengthen, as a result of which the pressure gradient across the base of the breakwater decreases. The reduction of the pressure gradient is one of the main and most fundamental factors in the formation and

development of scour around the base of the coastal protection wall and the formation of the ragab phenomenon around it.

In this research, the flow around the breakwaters of the mouth of the Sefidroud River area was investigated using the computational fluid dynamics method and the Fluent software.

As we approach the breakwaters on the eastern shore of the breakwater, the flow velocity between the breakwaters decreases and the potential for beach sedimentation between the breakwaters on the shore increases, and the probability of erosion decreases.

## 5. References

1. M. Vaghefi, A. Ahmadi and B. Faraji, The effect of support structure on flow patterns around T-shape spur dike in 90° bend channel, *Arab. J. Sci. and Eng.* 40(5): 1299-1307, 2015.
2. M. Vaghefi, M. Akbari and A. R. Fiouz, An experimental study of mean and turbulent flow in a 180 degree sharp open channel bend: secondary flow and bed shear stress, *KSCE J. Civil Eng.* 20 (4):1582-1593, 2015.
3. A. Van den Heever, An Investigation of the use of groynes as a means of riverbank erosion protection, M.Sc. Thesis, Department of Civil Engineering, Stellenbosch University, South Africa, 2013.
4. Mehrnohad, A. and Ghodsian, M. Experimental investigation of the effect of the parameters of gully length and material diameter on scour around T-shaped gully located in a 90-degree bend, *Scientific and Research Journal of Iranian Water Resources Research*, Year 8, Issue 8, 2012.
5. Shaker, M. and Shafai-e-Bajestan, M. Experimental investigation of the effect of the length and angle of rectangular gully placement on the velocity and shear stress distribution in a 90-degree bend. *Journal of Irrigation Engineering Sciences (Agricultural Scientific Journal)*, Volume 38, Issue 3, 2013.
6. Vaghefi, M., Ghodsian, M. and Salehi-Neyshaburi, A. Investigation of temporal changes in scour around T-shaped gully in a 90-degree bend. *Journal of Water and Soil Conservation Research*, Volume 16, Issue 1, 2009.
7. Shojaei-fard, M. J., and Noorpour Hashtroodi, A. (Translators). Versteeg, H.K. and Malalaskara, V. (1995). "Introduction to Computational Fluid Dynamics", Iran University of Science and Technology Press, Tehran, 1379.