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Original Research Paper- Engineering

Effects of Breakwater Construction for Anzali Port Development Plan on Adjacent Coast Morphology

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ABSTRACT:
Marine structures, such as groins, coastal walls, and detached breakwaters are built to improve and protect the coast against erosion resulting from changes in patterns of waves and currents on the coasts. Thus, marine mechanisms for hydraulic structures need serious study. Breakwaters are among the most important structures for coastal protection. The most substantial hydraulic performance of breakwaters is to control current along the coast, decrease the destructive effects of the waves, and create a safe condition for the port environment. Now, the coastline reaction to these structures is not well-determined. Nowadays, simulation and computer models are used for sediment transport patterns and coast morphology near the marine structure to alleviate the application of experimental and laboratory assessments. The purpose of this study is to examine the interaction between waves, coast, and breakwater, and to model the sedimentation and current regime model based on the mathematical MIKE 21 models and computations in the southern margin of the Caspian Sea within the breakwater area of Anzali Port's (Bandar-e Anzal) development plan. According to conducted studies, it is found that sediment accumulation will appear after breakwater construction in the coastal area.

Keywords: Anzali, Coast, Breakwater, Morphology, Hydrodynamic

INTRODUCTION:

Around 71% of Earth's surface is covered by the oceans and lakes that have met many human needs. With increasing population growth, it seems necessary to enhance marine exchanges and transportation due to its cost-effectiveness all around the world. In this case, sea coasts have also played a significant role because population density is seen in the coasts and oceans, as well as the human access to seas. Moreover, the tourism industry, some factories, and marine ecosystem preservation centers see their survival in a place near the costs. Therefore, coasts are among valuable areas both economically and ecologically. More than 2500km of coastal borders in northern and southern areas of Iran on the one hand and a dramatic rise in the number of industrial, commercial, and tourism projects, on the other hand, would considerably reveal the importance of these areas. Erosion and sea storms are some factors that make hazards for the preservation and expansion of coasts. A large volume of coastal sediments is annually displaced under the effect of environmental forces, such as water surface fluctuations, waves, wind, and coastal currents depending on the morphological characteristics, natural geography, and hydrodynamics of coastal areas. Coast engineering evaluates and identifies the processes in coastal areas. It is usually important in coast engineering studies to evaluate erosional and sedimentation processes in the coastal areas and identify the hydrodynamic nature of the sea (waves and currents resulting from it) and the behavioral reaction of the coast to the mentioned forces [1].

Fig 1. Planet Earth [1]

Studied Area:

Bandar-e Anzali is located in northwest Iran in Gilan Province. This port is located within 40km distance northwest of Rasht City in the central district of Anzali County in a narrow area between the Caspian Sea and Anzali Marsh between eastern longitude 36° 43′ and northern latitude 41° 49′.

Fig 2. A view of Anzali Port

Numerical model MIKE 21:

The numerical model used in this study is a computer software called MIKE 21, which was projected and gradually developed by the Danish Hydraulic (DHI) and Water Quality Institute. This model provides high computational and graphical potentials for modeling phenomena related to estuaries, gulfs, lakes, and shallow coastal areas. This comprehensive software package is used to model currents, waves, and sediments in rivers, lakes, seas, and ocean areas based on the 2D method.

Sediment modeling includes three types of models: sand sediment transport (ST), mud transport (MT), and particle transport (PA) models [2].

Development project of Anzali Port gas has been used to examine current and sediment in the place, and analysis of non-cohesive sediment and flow has been done through Mike–FLOW MODEL FM, which components of this model include HD, Transport, ECO Lab, Mud Transport, and Sand Transport. A hydrodynamic model and non-cohesive sediment have been used in this research.

Modeling data of Caspian Sea's waves:

The "modeling waves of Iran's seas" project was done during a 7-11-year period by the National Oceanography Centre and DHI and waves' characteristics of this period have been prepared and presented for the areas with 0.125-degree distance for Iran's waters and with 3hr time step. The modeling has been implemented through a third-generation model (MIKE21–SW) on an irregular triangular mesh in which, computational data of ECMWF (European Centre for Medium-Range Weather Forecasts) are used in input wind into the model. Calibration and evaluation of the model have been done based on the available satellite data. The modeling results mentioned above can serve as the main information source that appropriately consists of temporal and spatial data of wave climate used for determining wave characteristics in different areas. The general characteristics of the model are presented in Table 1 and the modeling area of the Caspian Sea is shown in Fig 3.

Table 1. General characteristics of the project

Model	MIKE 21-SW
Wind field	ECMWF (3hr-2D-computational data-7/11-year period)
Output storage	3hr time step

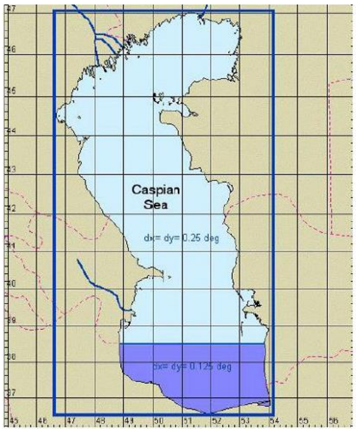
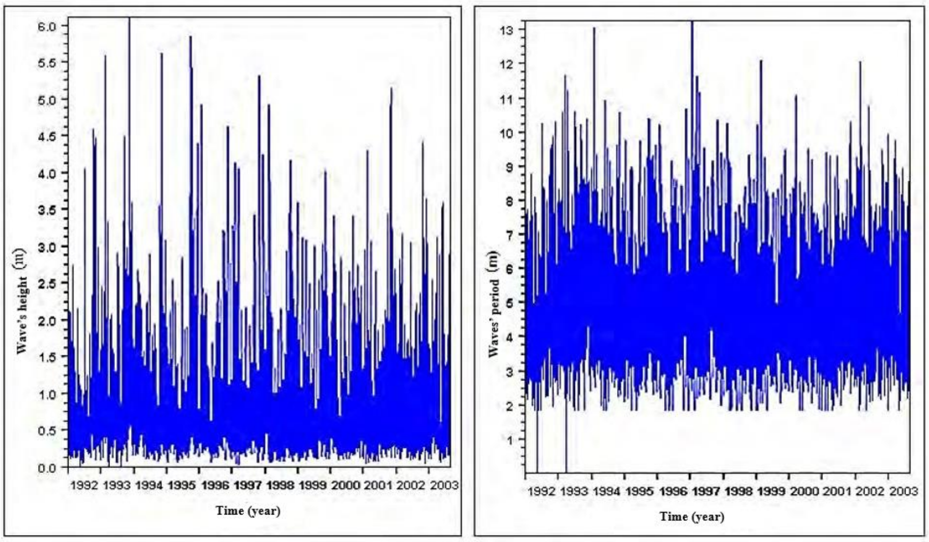


Fig 3. Modeling area of the Caspian Sea in the ISWM Project [3]

Data of used waves:

This study used the results of (ISWM) studies conducted by the National Oceanology Center that were ordered by the Organization of Ports and Shipping to determine waves' characteristics. In this case, results' time series were received for the 7-11-year period of study with 3-hour intervals, including height, direction, and period of waves from the Organization of Ports and Shipping, and then these data were statistically processed [3].

Information and characteristics about deep water waves in the studied area, including height, period, and direction of wave have been shown in figures 4-5 based on the results of the ISWM project.



Figs 4-5. Information of waves' height and period based on the ISWM results

Relationships Ruling Mathematical model:

Many signs of progress have occurred in the prediction and estimation of waves in different activities of coastal areas over recent five decades by using mathematical models based on the energy conservation equation. These models have also been changed dramatically, so that the most advanced ones include spectral models of third generation, such as MIKE 21-SW. The model base for wave forecast is to solve the energy transfer equation along with spring and well terms. To consider the stochastic nature of sea waves, the energy transfer equation of the wave in this model has been considered in its spectral form. This software has many potentials for simulating wave-related phenomena, the most important ones are as follows:

- Wave growth and development in deep water
- Wave refraction
- Wave stacking and breaking in shallow water
- Consideration of both deep-water waves and wind waves in a consecutive way
- White-capping dissipation
- Nonlinear wave-wave interaction

Calculation and determination of waves' characteristics in mathematical models for wave forecast, including SW are based on solving spectral energy conservation equations discontinuously in spatial, angular, and frequency dimensions.

Equation (1)

$$\frac{\partial E}{\partial t}+\frac{\cos\theta}{C}\frac{\partial(ECC_g)}{\partial X}+\frac{\sin\theta}{C}\frac{\partial(ECC_g)}{\partial y}+\frac{C}{C_g}(\sin\theta\frac{\partial C}{\partial X}-\sin\theta\frac{\partial C}{\partial X})\frac{\partial C}{\partial\theta}=S$$

In Equation (1), left-side terms indicate wave transmission, and in this part of the equation, refraction, low-deep, and stacking effects of waves are considered. However, the right side of the equation includes spring and energy well terms that include input energy obtained from wind, nonlinear interaction between components of the wave, and energy loss caused by wave breaking.

The wave conservation equation in Cartesian coordinates is as follows:

Equation (2)

Equation (3)

$$\frac{\partial N}{\partial t}+\nabla\,.\,(\vec{V}\ \ N)=\frac{S}{\sigma}$$

$$N=\frac{\sigma}{E}$$

where

$N(\vec{x},\sigma,\theta,t)=$ Wave action density

$E(\sigma,\theta)=$ Wave energy density

$\vec{v}=(C_x,C_y,C_\theta,C_\sigma)=$ Wave propagation speed

The source term for the balance is S, angular frequency is σ, wave energy is E, wave velocity is V, velocity gradient is ∇, and θ depicts the angle of wave propagation. The equation above indicates that each component moves as a frequency-directional energy spectrum with wave group speed, and its route is affected by energy increase or decrease caused by seabed topography, velocity, wind direction, and spectrum shape. The last term on the left side of the equation considers the effect of wave refraction and creep. The term of spring on the right side of the wave transfer equation is defined as follows:

Equation (4)

$$S=S_{in}+S_{nI}+S_{dis}+S_{Surf}$$

where S_{in} represents energy transfer from the wind to the water surface, S_{nI} indicates energy transfer through nonlinear interaction between waves, S_{dis} depicts the wave energy resulting from bed friction, and S_{surf} represents the wave energy depreciation caused by fracture in shallow area. Waves' energy equations are solved based on the cell-centered finite volume method on an irregular triangular meshing. One can achieve a better estimate of wave characteristics by downsizing the mesh's dimensions in the considered area. It is worth noting that the wave spectrum of JONSWAP has been used in this modeling [2], [3], [4], [5].

Modeling through MIKE 21 Software:

This modeling has used the data related to depth measurement of Mapping organization in the Anzali Port and ISWM wave data that contains 11-year statistics of the Caspian Sea in the Anzali Marine Area. Modeling steps are as follows: this modeling has been done by using the Mesh Generator Subprogram in the MIKE 21 Software Packages of depth measurement plan that is applicable in other programs. The considered marine area has been divided based on the triangular irregular meshing and the area of meshes selected as 15000m^2. Fig 6 depicts the meshing of coastal and marine areas of Anzali Port for the modeling.

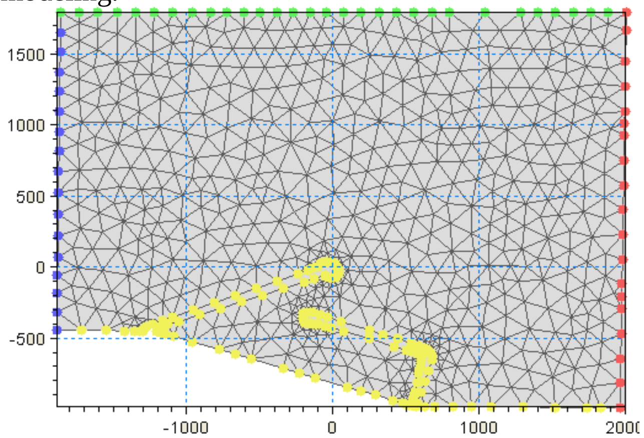


Fig 6. Meshing the marine area of Anzali Port

Radiation stress in the Sxx, Sxym, and Syy directions in marine areas studied by the SW model was measured through MIKE 21 software packages based on the JONSWAP method. Moreover, this operation has been done with wave radiations over six months by consideration of wave characteristics, including period, height, and direction of the wave. Therefore, radiation stress was measured for six months within 3-hour time steps. SW (Special Wave) Model can simulate the wind blow effect and its subsequent currents by applying suitable coefficients.

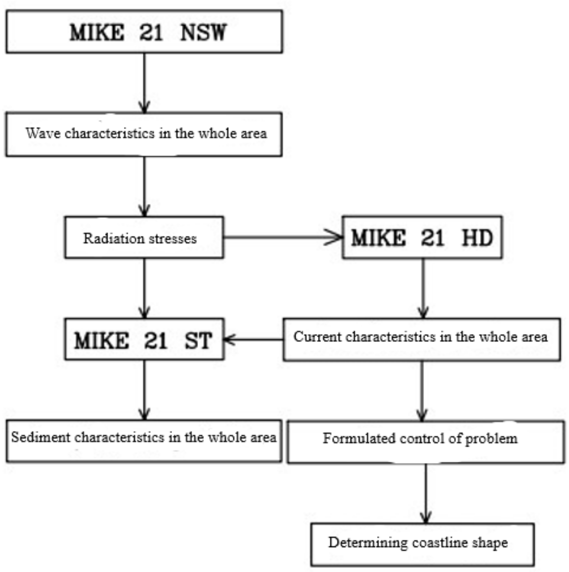


Fig 7. Sediment measurement algorithm

The velocity of marine waves in the determined coordinates (linearly):

For a more accurate assessment, the sea currents are coordinated in the previous mode and after structure construction. Fig 8 has been considered for measuring current speed, and because there is the probability of splitting current occurrence in time step 5 based on the previous studies, a more precise assessment has been done in this time step. Sediment displacement will occur when return flow and any other type of flow is created. The shape of the coast and its morphological change will be found through a more accurate assessment.

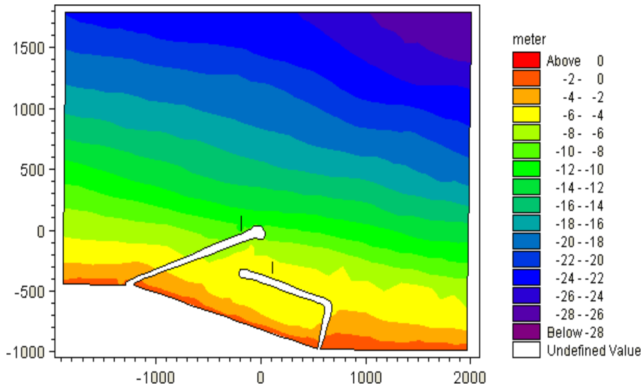


Fig 8. Linear coordinates of current speed (20m) measurement on the east and west coasts before and after construction of the structure

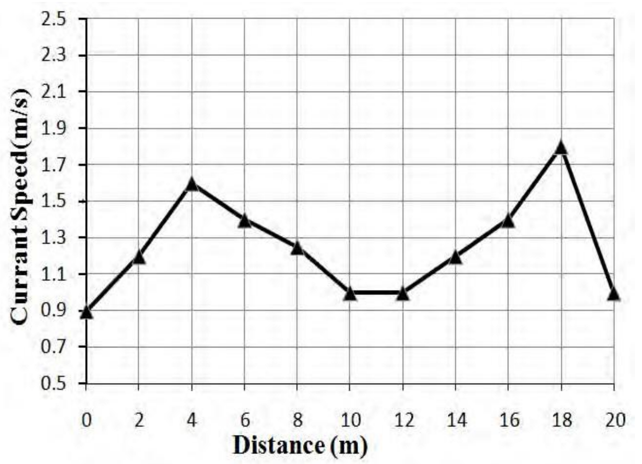


Fig 9. The current speed on the East coasts before the construction of the structure

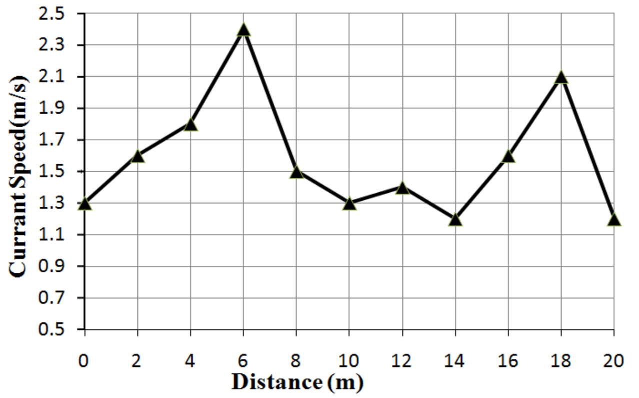


Fig 10. The current speed on the west coasts before the construction of the structure

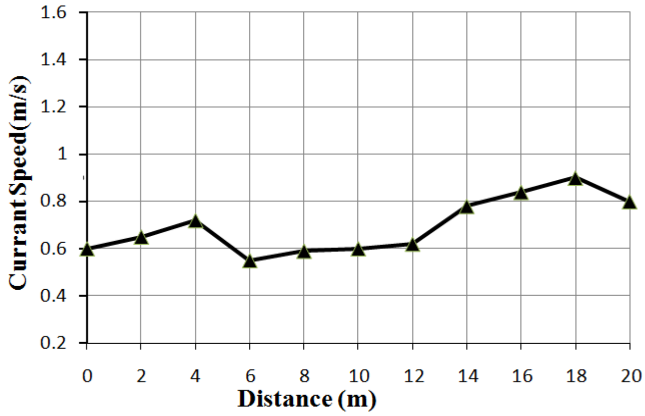


Fig 11. The current speed on the East coasts after the construction of the structure

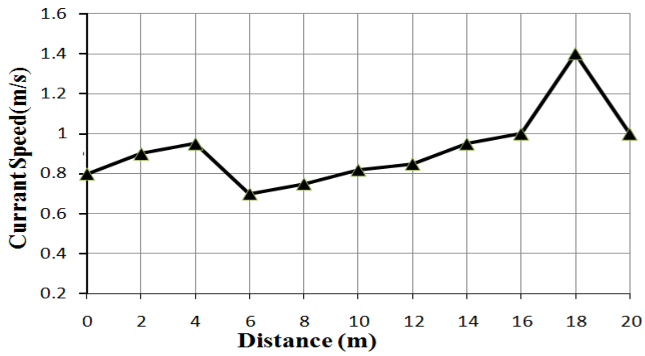


Fig 12. The current speed on the West Coast after the construction of the structure

According to the comparison between the graphs shown above, splitting currents occur with higher speed in the case without the construction of the structure, and the speed of these currents exceeds 1.5m/s and 2.4m/s in some cases, which is highly hazardous, but construction of breakwater reduces this speed. Therefore, a reduction in splitting current speed leads to a decline in sediment displacement towards the sea.

Effects of deep-water wave height on the current speed with determined coordinates

The current speed is examined in different modes regarding the height of deep-water waves in this part of the study. It is worth noting that the considered coordinate is similar to the previous case of the eastern and western sides.

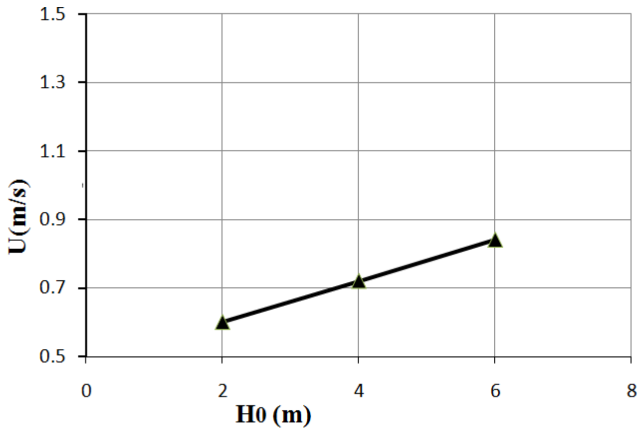


Fig 13. Height of deep-water waves relative to current speed on the west side of the breakwater

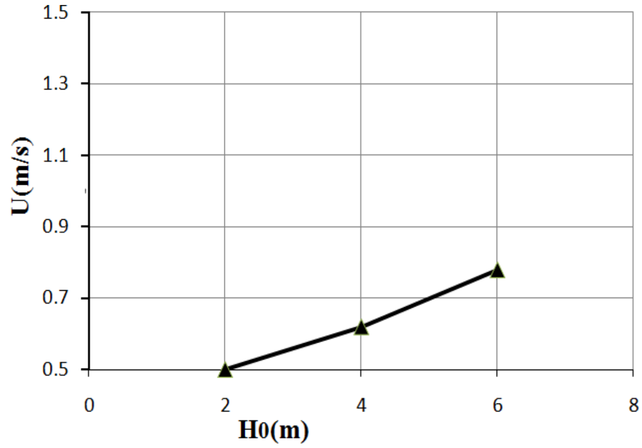


Fig 14. Height of deep-water waves relative to current speed on the east side of the breakwater

As shown in the graphs above, when the height of transmission from deep water becomes higher, then sea current speed will be increased. Thus, it can be stated that there is a linear relationship between current speed and the height of waves in the deep water. According to the wave pattern changes after the construction of the structure, wave height will be decreased after the structure is built. This case can be effective in sediment transmission because the decline in height and speed of the wave, which are two important factors for sediment transmission and displacement can leave a highly important effect.

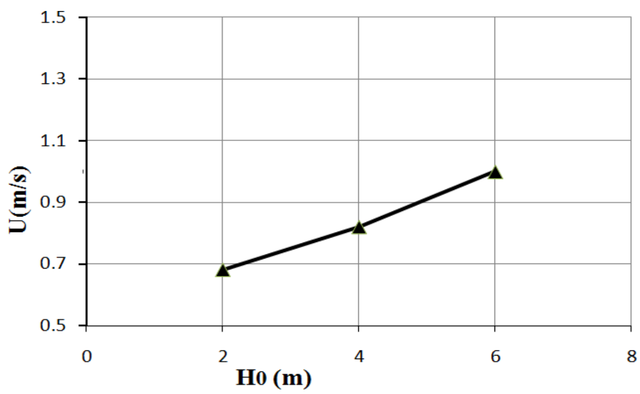


Fig 15. Height of deep-water waves relative to current speed on the west side without the construction of a breakwater

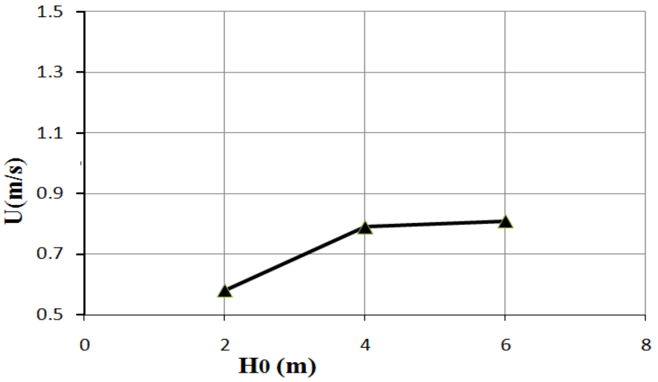


Fig 16. Height of deep-water waves relative to current speed on the east side without the construction of the breakwater

The velocity of eastern currents is less than the effect of western currents; however, when the height of transmitted waves increases, it will have a direct relationship with current speed. It is worth noting that the higher height of waves results in an increase in current speed in both cases with and without the construction of the structure.

Manual Computations:

According to formulas (2-25) and (2-27) that are used for determining the type of profile and erosion creation and available data based on the conducted computations, the summer profile will appear in the coastal area of the breakwater in Anzali Port. The summer profile indicates that sediment accumulation appears in the coastal area. Regarding the assessments conducted through MIKE Software and manual computations, breakwater construction can be effective in improving and protecting the coastal line. The computational process has been explained herein [6].

Computational Operations:

The problem data are as follows:

$H=5m$, $T=10_S$, $h=12_m$, $D_{50}=0.2_{mm}$, $S=2$, $g=9.81$, and $\gamma = 10^{-6}\frac{m^2}{s}$

$$L=\sqrt{gd}\,T \longrightarrow \sqrt{9.81\times 12}\times 10 = 108.498_m$$

$$U_r=\frac{H/L}{\left(\frac{d}{L}\right)^3} \longrightarrow U_r$$

$$=\frac{5\times(103.498)^2}{(12)^3}=34.061>25$$

$U_r > 25$ is a Ursell number that is greater than 25, meaning that water has highly approached the coast, so Conoidal theory (single-wave) is used.

Particles settling speed by using equation (2-25) [5].

$$W=\frac{10\gamma}{D_{50}}\left[\left(1+\frac{0.01(S-1)g\ {D_{50}}^3}{\gamma^2}\right)^{0.5}-1\right]$$

Erosion creation condition by using equation (2-27)

$$D_0=\frac{H_0}{TW}>0.85 \longrightarrow$$

$$K_s=\sqrt{\frac{1}{\tan h(Kd)\left(1+\frac{2kd}{Sinh(2kd)}\right)}}>1 \longrightarrow$$

Scheduling coefficient

$$K_s=\sqrt{\frac{1}{\tan h\left(\frac{2\times3.14\times12}{108.498}\right)\left(1+\frac{\left(\frac{2\times3.14\times12}{108.498}\right)}{\sin h\left(\frac{2\times3.14\times12}{108.498}\right)}\right)}}=0.978$$

$$H=K_s.H_0 \longrightarrow 5=0.978.H_0 \longrightarrow H_0=5.112_m$$

$$W=\frac{10\times10^{-6}}{0.2\times10^{-3}}\left[\left(1+\frac{0.01(2-1)\,9.81\times(0.2\times10^{-3})^3}{10^{-12}}\right)^{0.5}-1\right]=1.770\times10^{-7}$$

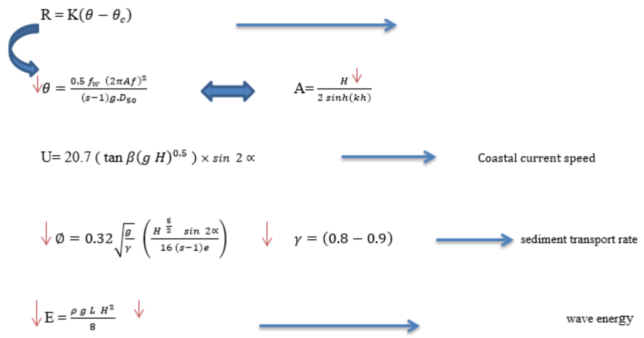
$$D_0=\frac{5.112}{10\times1.770\times10^{-7}}=2.888\times10^{-6}$$

$$D_0<0.85 \longrightarrow \textit{lack of erosion}\ [6]$$

According to the results obtained from the abovementioned computations, no erosion has occurred in the coastline. Because $D_0<0.85$, the summer profile will occur on the coast so sediment accumulation appears on the coastline.

According to the information obtained from the analyses mentioned above (doing manual computations and MIKE Software), wave height will be decreased after the destruction of the breakwater. Subsequently, hydrodynamic scour depth (R), coastal current speed (u), sediment transport rate (Q), and wave energy (E) will be directly and indirectly reduced. The mathematical equation of the cases mentioned above is shown in the equation below in which, the role of wave height is seen [5].

Hydrodynamic scour depth [6]



Hence, it is concluded that a reduction in wave height leads to a decrease in hydrodynamic scour depth, coastal current speed, sediment transport rate, and wave energy which are among the important parameters for creating coast erosion.

CONCLUSION:

- ✓ See current speed has been examined in different time steps with and without the construction of the breakwater structure, and the maximum sea current speed equals 2.5 m/s before the construction of the breakwater and the current speed on the west coast within the time step equals 1.6m/s after the construction of a breakwater in west coasts. Thus, the probability of rip current occurrence on the west coasts is higher than east costs. According to the results obtained from the case without structure construction, splitting currents occur rapidly and the speed of these currents exceeds 1.5m/s-2.4m/s in some cases, which is highly hazardous. However. This speed will be slower when the breakwater is built.

- ✓ As we know, when the height of weights transferred from deep water is increased, sea current speed will be increased. The results of this study confirm the subject, and for this specific case in the breakwater area of Anali port, the results imply that eastern currents' speed is slower than the effect of western currents. However, when the height of transmitted waves increases then it has a direct relationship with current speed.
- ✓ It is worth noting that the shape of the coastal line and seabed in the area near the coast affects the growth of splitting currents. The speed of sea currents will be indeed different before and after the construction of the structure.
- ✓ According to the computations (manual computations) for determining the profile, it is concluded that the summer profile exists in the area of Bandar Anzali Port. This shows that sediment accumulation is possible in the coastal line.
- ✓ According to the assessments done through MIKE Software, wave height will be decreased after the construction of the breakwater, which subsequently leads to a direct and indirect decline in depth of hydrodynamic scour (R), coastal current speed (u), sediment transport rate (Q), and wave energy (E).

RESULT:

This study that is derived from the assessment of information and observations within modeling in the adjacent coast area of Anzali Port shows that the volume of sediment deposited in the coastal area has increased after the construction of the structure. According to the current pattern graphs and considering this case that sea currents' speed decreased after the construction of the breakwater within different time steps, we will see a decline in the wave height having summer profile and sediment accumulation mass in the coastal line.

REFERENCES:

1. Khoshravan, H. (2010). Erosional hazards of sediments in southern coasts of Caspian Sea, Proceedings of 8th International Conferences on Coasts, Ports and Marine Structures (ICOPMAS 2008).
2. DHI (Danish Hydraulic Institute). (2007). MIKE 21 user guide and reference manual." Horsholm Denmark: DHI.
3. Binam, (2011). General Directorate of Coastal Engineering of Ports, Ports and Maritime Organization, Data and results of Iran's seas wave modeling (ISWM).
4. Nafezi, A. (2015). "Study of the formation of splitting waves around the breakwaters," MS Thesis on Coasts, Ports and Marine Structures Engineering, Gilan University.
5. Afsoos Biria, H. (2014). Analysis and comparison between effects of the geometrical shape of floating breakwaters' layout on the efficiency of quite a zone (open-closed), floating repairs in waves with a maximum 6-second period, Research project of Maritime Industries.
6. Lashte Neshaie, A. (2017). "Coasts engineering principles," Textbook of Coasts, Ports and Marine Structures Engineering, Gilan University.