Shoreline Evolution Due to Oblique Waves in Presence of Submerged Breakwaters

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Abstract: A major issue in Coastal Engineering is analyzing the effect of coastal structures on shoreline and beach morphology. Careful examination of these effects, coastal structures can be used significantly in order to improve protection of beaches. One of the structures that have been highly considered today is submerged breakwater. This structure has many advantages over other structures. The most important of them is coast protection without creating visual effects as it does not cause a visual barrier. This factor is particularly important for tourist beaches. In this study, the effect of wave angle to the breakwater on the shoreline changes is reviewed. To do so, first, the results of the laboratory model are examined. Then the numerical model is used to model wave and its effects on the coast. In all procedures, numerical modeling is performed by software package.

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1. Introduction

Human have long been associated with the sea intentionally or unintentionally, and the seas and oceans have always provided a large part of people's needs and are considered as an important economic source. The role of sea coasts have been more than sea, because the population density in coasts of seas and oceans is high, and human access to the sea is always through coast. Over 5,300 kilometers of shoreline in north and south borders of country on the one hand, and growth in industrial, trade and tourism plans in the region on the other one, requires particular attention to the protection and development plan of beaches. Coastal protection against erosion has always been one of the major issues facing coastal engineers. The phenomenon is mostly important in towns surrounding seaside as well as large sea ports.

Submerged breakwater is a new method to deal with beach erosion, which is built as a rock mass structure and like offshore breakwater, and its difference is immersion of breakwater crown below the surface of the water. The main function of this kind of breakwater can be stated in three cases:

- Reduction of wave energy in the coastal zone;
- Changing sediment transport regime and forming the desired shape of shore;
- Protecting heel for the beach slope.

Given the heightened sensitivity to the environmental impact of protective structures, researchers and coastal engineers has increased focus on the use of these types of structures in the past two decades. Distinctive advantages of submerged breakwaters to other beach protective structures can be named as follows:

- This structure acts as a relative barrier to the sediment flux and as a result is perfectly flexible against favorable morphological response.
- It makes less visual effects and does not cause a barrier to see the horizon. These factors are important in tourist beaches.
- Construction of a submerged breakwater structures makes an improved water circulation system in the back of structure, resulting in improved water quality and reduced environmental impact in the region (Mirzaei and Bargi 2008).

Breakwater will change the pattern of sediment transport and the morphology of the shore near structures or in areas away from structures will be influenced. About a submerged breakwater, it is much more complex because many factors can affect the sediment transport regime. Including:

- The structure of the wave;
- Wave diffraction around structures;
- Wave refraction over variable bed;
- Wave reflection by the impact of structure;
- Flow resulting from breaking of the waves on structures.

Due to the large number of variables and procedures governing the issue, the functional design of these structures is very difficult and complex. This paper presents background research done in this area. Then the modeling approach is described, and the results of running the model under different angles of wave radiation will be discussed. Finally, a summary of results is presented.

2. Literature review

In recent years, many studies have been done on the effects of submerged breakwaters on the beach. Watanabe et al (1986), using a numerical model, had anticipated three-dimensional beach deformation around a submerged breakwater(Watanabe, Maruyama et al. 1986). Cox, Tajziehchi (2005) studied hydrodynamic effects of submerged breakwaters experimentally and numerically(Cox and Tajziehchi 2005). Ranasinghe, Sato (2007) examined morphology of the beach in the back of submerged breakwater to the waves approach(Ranasinghe and Sato 2007). Their experiments was performed in a pool with dimensions of 11m × 6.5m × 0.3 m using Monochrometic waves. Vanlishout (2010) studied passing skewed waves from the submerged breakwater and the wave radiation coefficient (Vanlishout, Verhagen et al. 2010). Mirzaei and Bargi (2008) investigated Effective erosion processes around submerged breakwaters using a numerical model MIKE21(Mirzaei and Bargi 2008). Tajziehchi, Shariatmadari (2012) using a numerical model and based on the experimental results, given the changing distance of impermeable submerged breakwater from shore, presented a relation for the calculation of coastline development for different geometrical and hydrodynamic conditions (Tajziehchi and Shariatmadari 2012).

3. Modeling

Hydrodynamic processes on the banks are very complex for the variety of parameters. Any quantitative talk about issues such as hydrodynamic processes requires a detailed understanding and calculation of the process involved in the occurrence of this phenomenon. Basically, the methods to achieve the above parameters can be set in three main categories. The three categories are: field measurements, physical models and numerical models.

The mathematical model for simplification of the process has better relative accuracy. Therefore, data obtained from these tests, are the best and most numbers available. Meanwhile, disadvantages and difficulties of this method is also considered. The major shortcoming of this method is the inability to answer questions such as the rate of sediment transfer for making structure in their path, the morphological changes of coastline and more. The mechanism of the test is not without difficulty and probably problems (Hu, Ding et al. 2009).

In this study, the Delft3D numerical model developed by the Delft University of Technology in Netherlands is used. For modeling wave propagation Wave module and to simulate the flow regime Flow module is used (Delft 2009a & Delft 2009b). The model used in this study is based on the experimental model of Ranasinghe & Sato (2007). They did laboratory tests in a pool with dimensions of 11m x 6.5m x 0.3m. The pool had a slope of approximately 1/20 an in average was filled with 4cm sand with uniform D_{50} = 0.2mm (Ranasinghe and Sato 2007).

In the laboratory simulation by software Delft3D, many errors occur. So, to get better results and more realistic, dimensions of model in the software Delft3D, is increased 10 times. In other words, a basin with dimensions of 110 x 53 x 3 mm is modeled. Laboratory surge and conditions of modeled wave are indicated in Table 1.

Table 1: Experimental wave conditions

Wave characteristics	h_i(cm)	h_b(cm)	T(s)	θ(deg)	γ_b
Laboratory	3.4	5.6	1.25	20	0.98
Modeling	34	56	4	20	0.98

In this model the longitudinal boundaries (the direction perpendicular to the coast) are considered as or free boundary. In boundary parallel to the coast, wave height is defined in such a way that it meets the conditions of the experiment. The computational grid for the model is created with dimensions of 1m x 1m by regular lattice.

For modeling the back of submerged breakwater module Flow-Roller is used. In this model, the refraction index is calculated according to the formula of Cox, Tajziehchi (2005). In setting up the model, testing time according to the laboratory test duration of Ranasinghe & Sato (2007) is equivalent to 8 hours. Also, the particle density is elected equal to 2650 kg / m^3 and deposition diameter (D_{50}), according to the entrance to the laboratory is 0.2 mm (Ranasinghe and Sato 2007). The formula for sediment election is of Van Rijn (1993) (Van Rijn 1993).

The modeling process to investigate is this: first the pool is modeled without the breakwater to determine how changes in the shoreline occur without breakwater. Next, the pool is modeled with submerged breakwaters, and by changing the angle between zero and 70 degrees to the wave of foreshore and seabed, and shoreline changes due to these changes are studied.

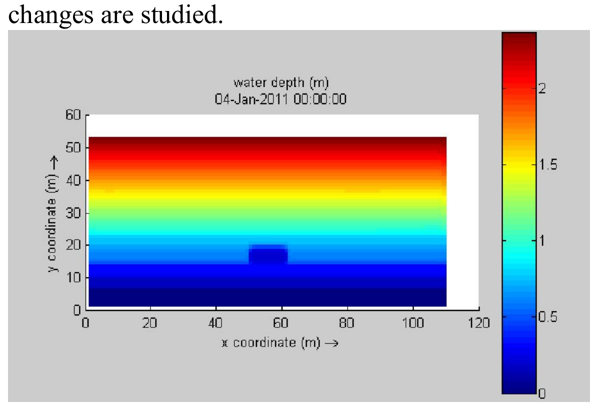
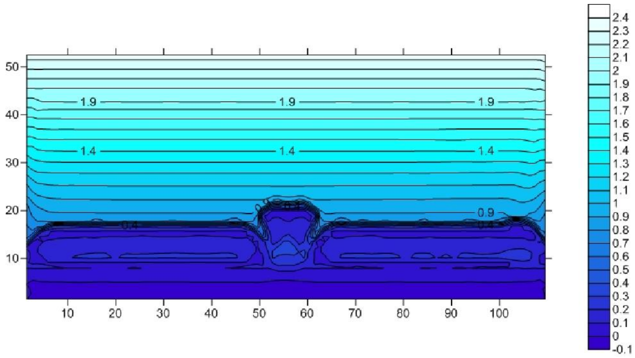


Figure 1 indicates the layout of the breakwater and the water depth in the model



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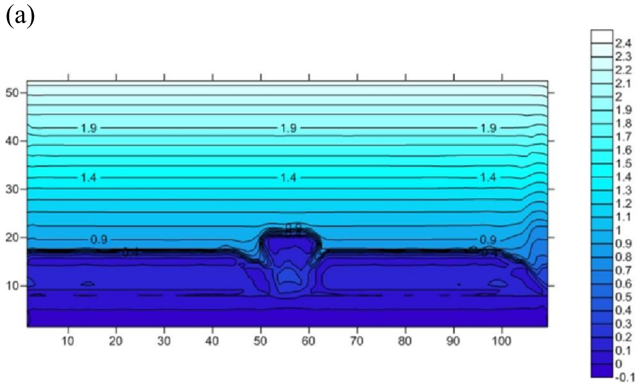

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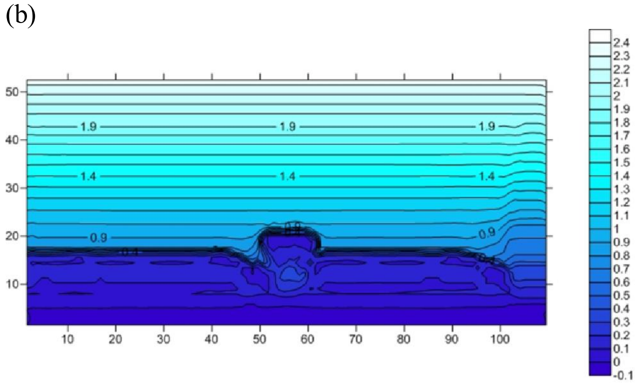

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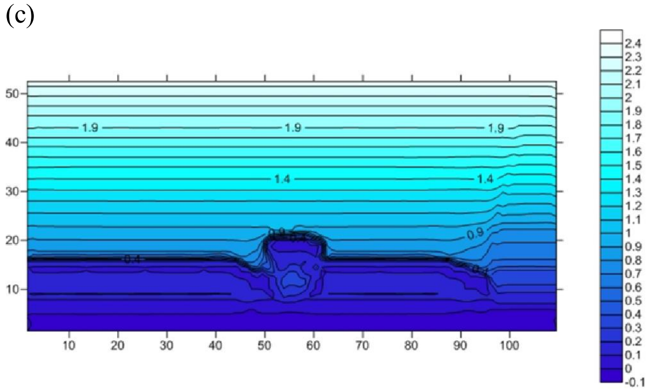

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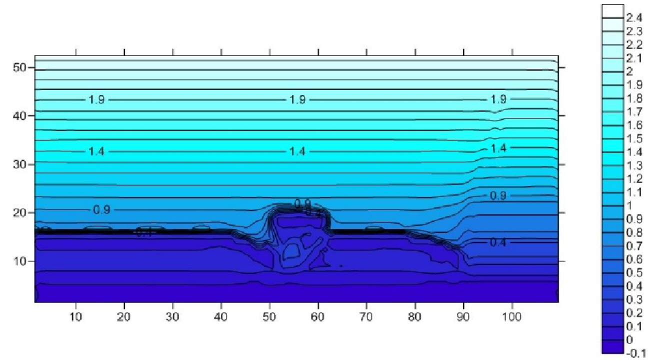

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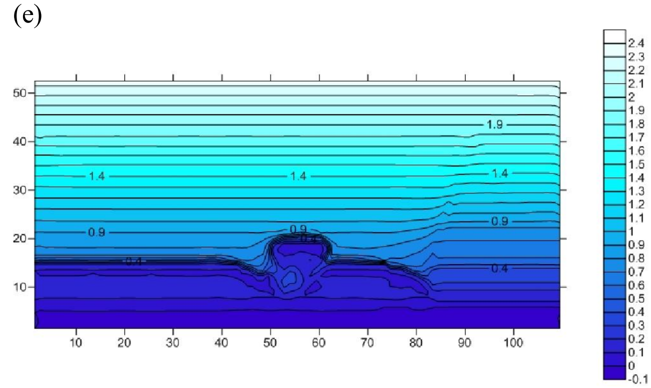

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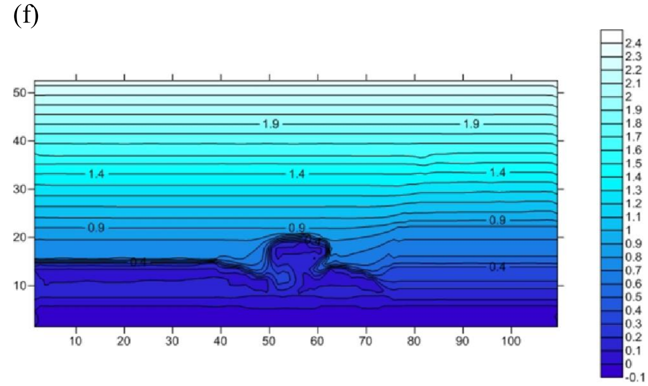

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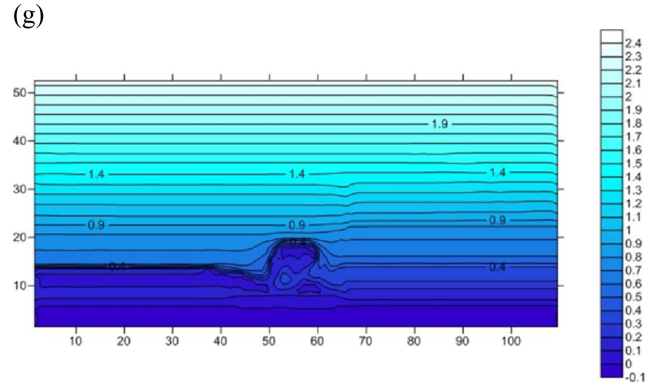

(h)

Figure 2: Topographic map of water depth for radiation angles: (a): 0 °, (b): 10 °, (c): 20 °,(d): 30 °, (e): 40 °,(f): 50 °,(g): 60 ° and (h): 70 °

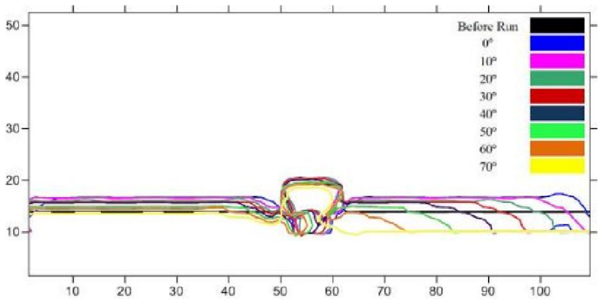

Figure 3: Comparison of water depth corresponding to lines 0.4 m for different angles of radiation

Verification of modeling and the difference in results of Delft3D numerical model with physical model have been investigated by Tajziehchi and Shariatmadari (2012) (Tajziehchi and Shariatmadari 2012).

4. Shoreline changes

Changes in the nature of a beach, will affect the natural process of mutual influence of the sea and the shore, among them the marine sediments can be noted. The nature of this behavior is based on the principle that changes made on natural factors, are mainly considered as an interference with the normal routine of the accounts. Interactions are repulsive and ruin balance between all elements in a long time on this phenomenon and the nature of the project area. Accordingly coastal projects not exempt from this principle and coastal areas will be subject to continuous developments and irregularities. This process will continue until a stable and balanced state is obtained. Sediment types and how to consider them in terms of behavior in mathematical model is of great importance, and besides the regional currents is of the most important factors in determining the sedimentation and erosion pattern.

To investigate the effect of wave radiation angle of shoreline, it is required to have a standard to measure shoreline change. Changes in water depth can be a useful and trusted indicator in this regard. Therefore, in this study the submerged breakwater is modeled under wave angles of 0, 10, 20, 30, 40, 50, 60 and 70 degree, and water depth data in different parts of the network are obtained. Decreasing water depth represents beach restore and increasing water depth means beach erosion. The topographic maps related to water depth is given to any angle. It should be noted that the angle of 0 ° to the vertical breakwater is intended and as a clockwise angle is increases. Figure 2 (a to h) shows variation of water depth for each angle individually.

For a better understanding and a clearer view of shoreline change, in Figure 3 the lines correspond to the depth of 0.4 m for different angles are shown. As is evident with increasing angle the shoreline retreats. The retreat is more intense right in the foreshore areas that have been exposed to waves.

Moreover, according to Figure 3 it can be seen that for angles greater than 50 degrees, gradually effect of submerged breakwater on the coast recovery in the opposite direction of wave is also reduced. In general, by the output results are presented in Figure 1, we can say that if the angle of wave approach to submerged breakwater along a line perpendicular to the line is more than 40 degrees, breakwater is not effective, and according to modeling in this study, it is not justifiable to be implemented.

5. Conclusion

This article examines impact of radiation angle of wave and breakwater on changes in shoreline by numerical modeling. Considering the direction of the waves hitting the submerged breakwater, along the line perpendicular to the shore, shoreline erosion begins in the direction that the wave is close to the beach. With increasing angle of wave radiation, the erosion is greater, so that for angles more than 50 degree, the submerged breakwater has almost no effect. Comparing lines aligned, it is determined by increasing the breakwater wave radiation angle, and depth of field behind a submerged breakwater in the opposite direction of wave approach gradually increases. Generally, it can be said that is more than 40 degrees, breakwater is not effective, and according to modeling in this study, it is not justifiable to be implemented.

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