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Investigation of Sediment Transport Pattern and Beach Morphology in the Vicinity of Submerged Groyne

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ABSTRACT

Groynes are one of the most prominent structures that are used in shore protection to control the littoral sediment transportation. This structure can be used submerged providing the necessary beach protection without negative aesthetic impact. Although submerged structures adopt for beach protection, the shoreline's response to these structures is not well understood at present. The objective of this study is to predict sediment transport in the vicinity of submerged groyne and comparison with non-submerged groyne with focus on a part of the coast at Dahane Sar Sefidrood, Guilan Province, Iran where serious coast erosion has occurred. The simulations were obtained using a one-line model, in this paper; a linear model is presented to estimate shoreline deformation in the presence of these structures. The results of the present study show that using submerged groyne can have a good efficiency to control the sediment and beach erosion without causing severe environmental impact to the coast. The important outcome from this study may be employed in optimum design of groyne systems in marine projects. Comparison of the predicted results with those obtained through field measurements shows the efficiency of the proposed model.

KEYWORDS:

Submerged Groyne, Sediment Transport, Shoreline Deformation, One-line Model, Dahane Sar Sefidrood

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1- Introction

Understanding shoreline erosion and developing effective protection strategies is a complex subject. However, studies of the shoreline change in the vicinity of submerged groynes in a coastal area has received little attention. Since the problem of coastal stabilization is of high importance, there is a need for more research. After extensive research on a part of the coast at Dahane Sar Sefidrood, it has been revealed that this area is at high risk for beach erosion; therefore, it was selected for this study. It is noteworthy that the coastal villages of Astaneh Ashrafieh, due to sea-level rise, are at risk of flooding. Sea-level rise in some village of this city i.e., Dahane Sar Sefidrood are very serious as many houses have been exposed to destruction. In addition, rising sea-levels have caused massive damage to hunters in these areas. Sea level rise in the coast of the city is an important issue that must be considered; otherwise, the city will face further damage and if sea-level rise continues on the coast of this city, residents will be facing a lot of problems in future. Threat and endangerment of human life due to sea level rise at Dahane Sar Sefidrood are shown in Figs. 1 to 2.

Fig. 1. Submerging wheat silos due to sea level rise

Fig. 2. Coastal road exposed to waves

2- Methodology

2- 1- Data collection

The data used in this study include geographic location of area and bathymetry that is rare in Iran. The other data are information related to characteristics of deep-water waves which include period, direction and wave height [1].

Moreover, beach sediment grain size is one of the main date for determining beach deformation. The data for maximum wave height and period in the deep water and grain size diameter are presented in Table 1.

2- 2- Modeling of submerged and non-submerged groynes using Mike-21

Modeling of coastal structures are utilized with mesh generator of Mike-21 and coastal structures are drawn before creating the mesh file, after creating bathymetry that can be used in other modules of this software, all required information is derived from the study area. The remarkable thing is that the modeling of submerged structures is more complex than non-submerged structures in Mike-21 and it requires more attention, so non-submerged structures are defined as Beach Ridge and mesh is done on them. Bathymetry of non-submerged and submerged groynes is shown in Figs. (3) and (4).

2- 3- Determine the coastal sediment transport rate using a numerical model Mike-21

Mike-21 Flow Model-ST describes erosion, transport and deposition of sand under the action of currents and waves or pure current. It is specifically suited for application to coastal engineering problems for studying sediment transport studies of non-cohesive sediments. The hydrodynamic basis of ST modul is calculated using the HD module of Mike-21 Flow Model FM. The sand transport calculations are carried out using a mean horizontal velocity component.

In the model with combined waves and currents, sediment transport tables need to be generated for

Table 1. Data used in modeling

Grain size (*mm*)	Wave period (*s*)	Wave height (*m*)
0.16	13	6

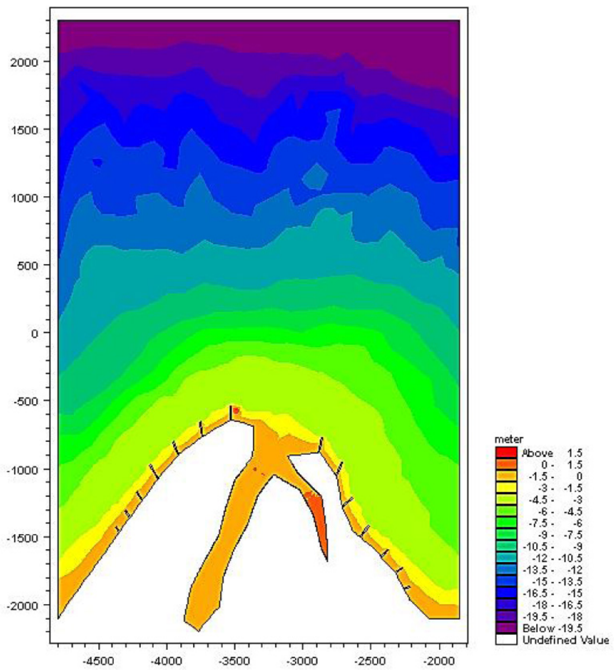

Fig. 3. Bathymetry after construction of non-submerged groyne

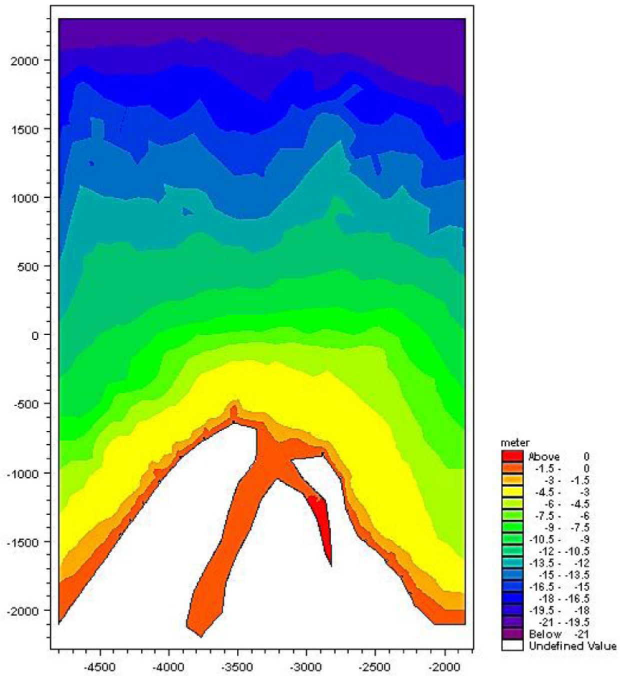

Fig. 4. Bathymetry after construction of submerged groyne

the general spectrum of wave field. These are then used in the calculations to find transport rates using linear interpolation. Currently only one fraction of sediment input is allowed in both cases. There is also a provision for including the effects of morphological changes on the hydrodynamics of the area which in turn affect the sediment transport pattern [2,3].

2- 4- Theory of beaches deformation in the vicinity of the groyne

Therefore, due to wave breaking, transport of sediment along the coast begins to move and if a barrier to be built along this current, sedimentation happens behind the beach and finally beach deformation is changed. Relationship to estimate the deformation of the beaches in the vicinity of the groyne has been expressed in Eq. (1):

$$Y = \phi' \sqrt{\frac{4at}{\pi}} \left[e^{-u^2} - u\theta\sqrt{\pi} \right] \quad (1)$$

In Eq. (1), variable a, u and θ are obtained from the following relations:

$$a = \frac{Q}{\phi' d} \quad (2)$$

$$u = \frac{-x}{\sqrt{4at}} \quad (3)$$

$$\theta = \frac{2}{\sqrt{\pi}} \int_{u}^{\infty} e^{-u^2} du = 1 - \frac{2}{\sqrt{\pi}} \int_{0}^{u} e^{-u^2} du \quad (4)$$

In the above equations; $Q(m^3/s)$ is the discharge along the coast, $d(m)$ is the water depth at the toe of groyne, $x(m)$ is the groyne spacing and $t(s)$ is time. θ is noteworthy that no analytical solution and must be solved on the table. A very important point in solving Eq. (1) is attention to relationship between φ and $\partial y/\partial x$, indicates that the wave angle with beach deformation is changed [4,5].

2- 5- Simiulation results

The results of sediment discharge were presented in Table 2 from approximate relations [6]. The results of sediment discharge between submerged and non-submerged groyne with Mike-21 were presented in Table 3.

The results of predicted beach deformation show that when submerged groyne construct in the beach, sediment accumulation will be slightly less than the non-submerged groyne; because transfer coefficient

Table 2. Calculated discharge from approximate equations in the study area

Row	Used the approximate relations	Discharge (m^3/yr)
1	Q_{CERC}	30763368
2	$Q_{Kamphuis}$	11941288

Table 3. Calculated discharge from Mike-21 between submerged and non-submerged groyne

Row	Numerical model for groyne	Discharge (m^3/yr)
1	Non-submerged	2850
2	Submerged	2325

for the submerged groyne is more than non-submerged groyne. This result will cause more sediment passing on submerged groyne.

Beach deformation in the vicinity of the constructed groyne was measured over a period of 15 months in the Dahane Sar Sefidrood coast.

The updated shorelines obtained from filed study, experimental equations and numerical model for submerged and non-submerged groyne are given in Fig. 5.

The important outcome from this study may be employed in optimum design of groyne systems in marine projects.

3- Refrences

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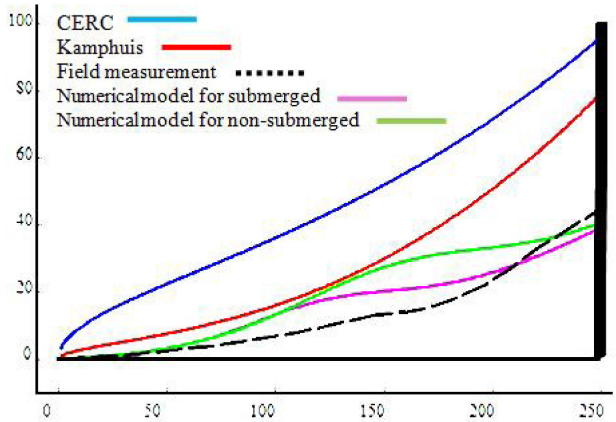

Fig. 5. Comparison of updated shorelines in the vicinity of groyne and discussions

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