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Investigation of the effects of rubble mound structures on coastal bed profile over the Southern Coasts of Caspian Sea (Field study: Astara Port)

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ABSTRACT

Coastal protection engineering works may result in changes in characterization of the hydrodynamics and bottom topography of the near shore domain. Since measuring the changes in underlying bathymetric is very costly, developing equilibrium beach profiles which can demonstrate the important features of the bottom topography is of importance. In order to assess the bottom topography of the Caspian Sea in vicinity of Astara Port, some field measurements of beach profiles were carried out. The purpose of this paper is to investigate the influences of the breakwaters of Astara Port on beach morphological evolution in the vicinity of them to identify how the extension of breakwaters altered the sea bed topography. To describe evolving cross-shore profiles in the study area, beach profile surveys were conducted by a single-beam echo sounder. Results showed that the breakwaters considerably affected their surroundings. Furthermore, comparisons of measured beach profiles with Dean's profile model for the equilibrium beach profile illustrated that: while the Dean's profile can precisely represent the time-mean profiles in the coastal area, it must be used with care in the structure vicinity. As a result, the coefficient, A, in Dean's equilibrium equation in the front of the breakwater will be about two or three times more than as when it used for the coast without the structure. It is because of the presence of coarser grains in front of the breakwater. It is while the power term in Dean's equation is the same for both the cases without and with the structure which is 2/3.

1. Introduction

Coastal protection engineering works, such as breakwaters, influencing waves, wave-induced near shore currents, and sediment transport, are carried out to protect coasts or harbors against the effects of waves and long shore drift [19].The structures can affect bottom topography and the shoreline contour, resulting in overall and local deformations that would not evolve without the presence of them [13].Overall deformations can cause morphological evolution owing to the disturbance of long shore sediment movement, and the second ones can bring about changes in movements of sediments in the vicinity of the coastal structures during a given storm event [8,15].In an article [18] showed that the strongest coastal current prevails in the autumn season and the calm current prevails in the summer in the coastal area of Astara. 93% of the days of the year the waves come from the northeast and the prevailing current is from north to south.differences of Hydrodynamic factors cause a variety of coastal conditions in the northern and southern coastal regions of Iran. In this research, the morphodynamic classification of Iranian coasts has been investigated [17].Analysis of wind, sea Current characteristics, and wave height on the southern shores of the Caspian Sea, especially on offshore shores It was done in the north of Iran. According to the main factors Affecting the waves caused by the wind, the atmospheric framework in the studied area with High pressure was identified as the main factor that should be considered in the formation of waves [14] . [10] showed that As the wave's steepness rises, the location of the formation of the bars moves toward the coast, and the depth of water decreases at the beginning and the ends of the bars; also, in terms of lowering in the water level with the change in the height of the waves, the position and the geometric shape of the bars will not follow a certain trend. Numerous investigations have been carried out to evaluate the effects of coastal structures on beach morphologies [15]. Identified how breakwaters with different layout alter asymmetry of the salient [1]. Based on 14 years of data, they found that the berm lowering rate was marginally larger at sea walled sections in comparison to dune/beach sections. Also, they didn't find any convincing evidence to prove the claim that seawalls had caused higher shoreline recession rates in the study area. However, measuring changes in underlying bathymetric is so expensive that numerous reliable numerical models have been developed to simulate morphological changes. As a result, many numerical studies have been performed to understand the morphological evolution around coastal structures. Since waves, wave-induced nearshore currents have decisive effects on sediment transport, these studies have placed considerable importance on correctly modelling waves and wave-induced nearshore currents. The results obtained from this approach look encouraging [2,5,9]. Furthermore, an understanding of equilibrium beach profiles may be useful in some problems of coastal engineering [7]. Using equilibrium beach profiles, which approximately demonstrate the important features of cross-shore profiles a beach, the response of beach profiles under changing hydrodynamic conditions can be shown [12].

The best known and most commonly used equilibrium beach profile form is Dean's profile, which determines the shape of equilibrium beach profile with regard to the distance from the coastline and the sediment size. The profile does not consider the effects of wave climate, and coastal currents [7,11]. Some equilibrium beach profiles have been characterized to represent cross-shore profiles subject to different conditions [3,7].

Beach profiles are likely to stay the same under long-term wave climate and persistent sediment size, which means that the long shore sediment transport is equal to zero[4]. [6] proposed the power law approach, most used form of equilibrium beach profile, but it is commonly known as Dean's profile. It can mathematically define the shape of equilibrium beach profile:

$$h=Ax^{2/3} \quad (1)$$

Where h is water depth, x is seaward distance from the shoreline and A is the sediment-dependent scale parameter[7].

2. Study Area

Astara port (38.4069 °N and 48.8815°E) is located at the southwest of the Caspian Sea, North of Iran (Figure 1). In 1996, Astara port was mainly built as a port for fishing, trading, and travelling. Due to the positive effects the port had on the development of the region, it has been enlarged. As a result, the northern breakwater with a length of 470 m and the southern breakwater with a length of 187 m have been built (Figure 1).

Figure 1. **Location of Astara Port**

The study area is exposed to Mediterranean climate with warm summers, moderate and rainy winters. The annual prevailing winds in the area are northerly, northwesterly, and northeasterly. The water level of the port, like that of the Caspian Sea, is currently around 27 m below the level of open seas. Since there are no tides in the Caspian Sea [16] the tidal water-level fluctuations are negligible in the port. Wave rose for study site shows that the prevailing wave direction is from the north-east. In addition, the dominating current direction is southward (Figure 2).

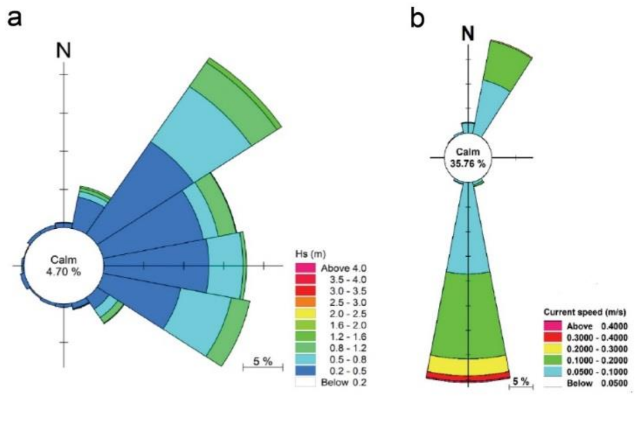

Figure 2. (a) Wave rose and (b) current rose for study area

The sea bed in the study area is mostly sand, with grain size changing from 0.02 to 4 mm. To investigate the effect of sediment size on the bed profile, about 22 samples were taken and tested for grain size distribution. Figure 3 shows the grain size distribution of bed sediment for samples 1-5 and 1-6 typically. Then, the average sediment size, D_{50}, was computed for all samples (Figure 4).

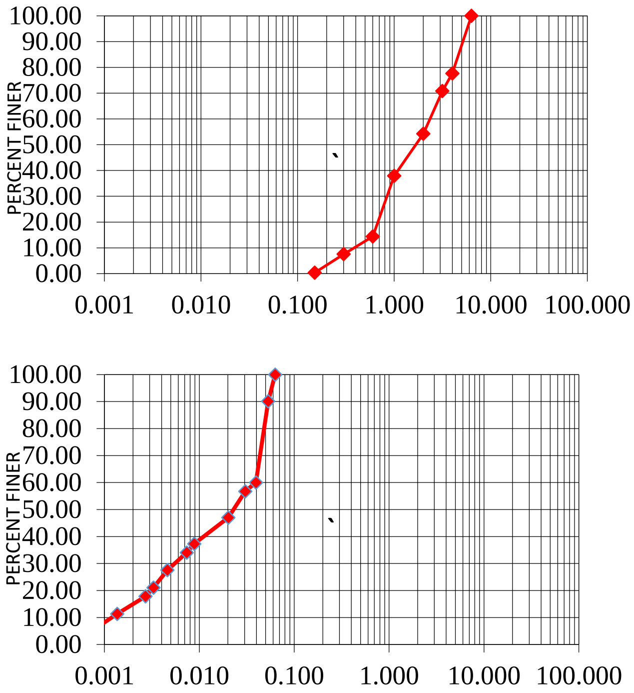

Figure 3. **Typical Grain size distribution of sediments: Samples 1-5 (left) and 1-6 (Right)**

Sample ID	D50 (mm)
1-1	0.28
1-2	1.7
1-3	0.08
1-4	0.05
1-5	1.7
2-1	0.16
2-2	0.16
2-3	0.12
2-4	0.09
2-5	0.11
2-6	0.10
3-1	0.10
3-2	0.15
3-3	0.11
3-4	0.09
3-5	0.52
3-6	3.4
4-1	0.2
4-2	0.11
4-3	0.1
4-4	0.11
4-5	0.15

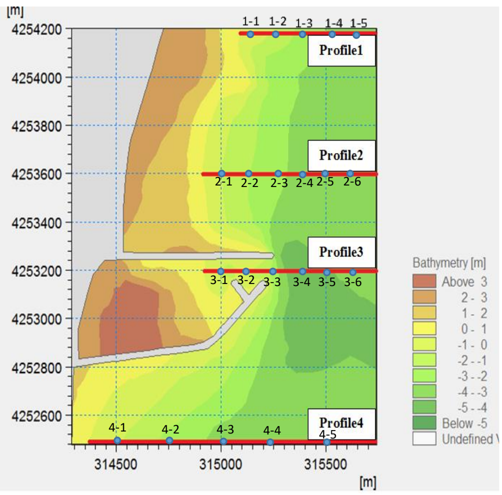

Figure 4. **Average diameter of sediment size along the Profile 1 to 4**

3. Methodology

In this study, morphological evolution in the vicinity of the breakwaters constructed in Astara Port was monitored to investigate the effects of the structures on beach morphological evolution. For this purpose, changes in the bottom topography around the structure were observed in different years. Besides, measured profiles were compared with Dean's profile in the study area. In order to assess changes in the bottom topography due to the extension of breakwaters of Astara Port, bathymetric surveys which surveyed by the Iran National Cartographic Center (INCC) in 2009, 2011 and 2012 were used. Then four cross-shore bathymetric profiles were extracted for each year to represent the cross-shore profiles of the study area (Figure 5). The data had a vertical accuracy of ± 5 cm and a horizontal accuracy of 1 m. The profiles are spaced at intervals of approximately 400 m, with an offshore extension of 1400 m.

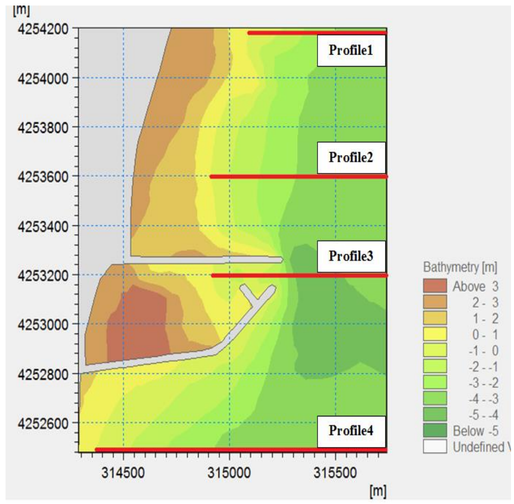

Figure 5. **Locations of transects where cross-shore profiles were measured**

4. Results

Figures 6 to 8 compare cross-shore measured profiles with relative Dean's profiles which were determined based on the best fit to measured profiles . The equations for the best-fit profiles were extracted which obey the Dean's equation with different 'A' coefficients (Figures 6 to 8). As can be seen from Figure 6, the cross-shore profiles for sections 1, 2, and 4, in the year 2009, are closed to each other which can be represented by the Dean's equation $y=A\ x^{2/3}$, where A=0.047 for these cases. While, for Section 2 which crosses the port structure, the shape of the profile is completely different. It shows a deposition area inside the port basin, and a desertion area outside the basin in front of the breakwater (Figures 6 and 9). In this case, the bed profile inside the port basin cannot be represented by the Dean's equation, while outside the basin it is well represented by Dean's equation with parameter A=0.156 (Fig 6). Figure 9 also shows an active area which extends about 700 meters from the coastline toward the sea, where the depth is about 3.7 meter and all bed profiles meet each other.Like the year 2009, the profile pattern was repeated for the years 2011 and 2012. As shown in figures 7 and 8, the bed profiles for sections 1, 2, 4 can fairly be represented by Dean's formula, however, for section 2 which crosses the port structure, the Dean's formula is only applicable to the offshore part of the profile which is steeper and completely submerged. As shown in these figures, the coefficient 'A' of Dean's formula is increasing when we're getting closer to the port structure along the coast. Especially, for the sections crosses the breakwater, the coefficient 'A' increased rapidly. Since the A value depends on the sediment size (D), it can be concluded that the size of sediments in the neighborhood of the port structure is greater than the area located far from the port. This fact is shown in Fig.10, which is a plot of A versus D. As shown in this figure, the position on A-D plot for profiles 1, 2 and 4 (sections which are far from the port structure) are apart from for profile 3 (which is close to port breakwater).

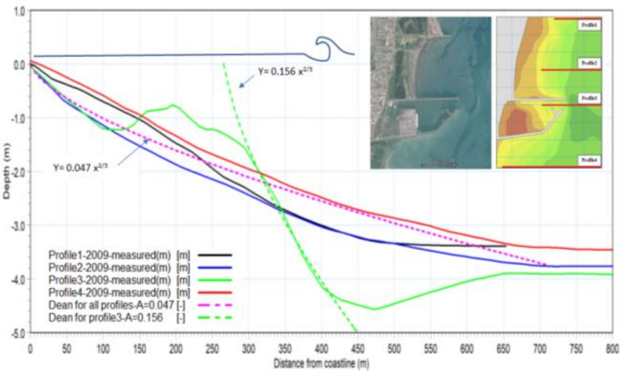

Figure 6. Measured Bed Profiles around the Astara Port (Year 2009) in Comparison with Dean's Formula

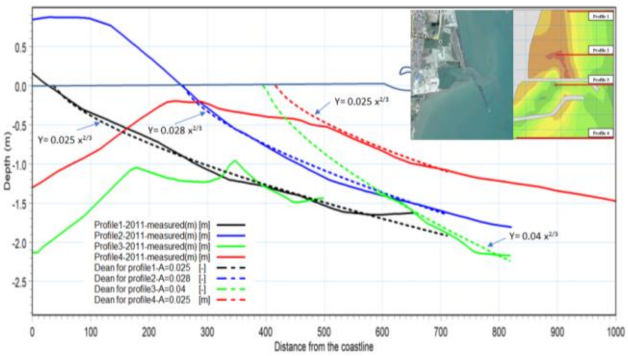

Figure 7. Measured Bed Profiles around the Astara Port (Year 2011) in Comparison with Dean's Formula

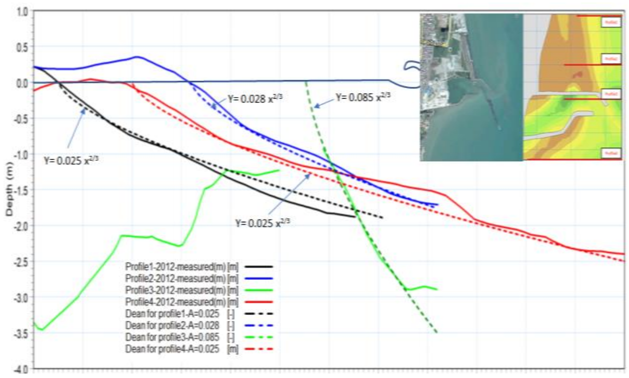

Figure 8. Measured Bed Profiles around the Astara Port (Year 2012) in Comparison with Dean's Formula

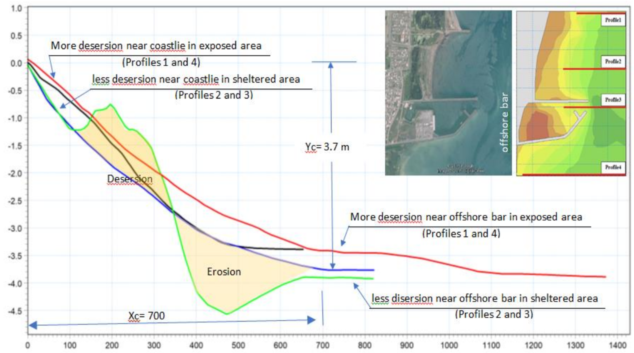

Figure 9. Erosion and Deposition in cross-shore Profiles (Year 2009)

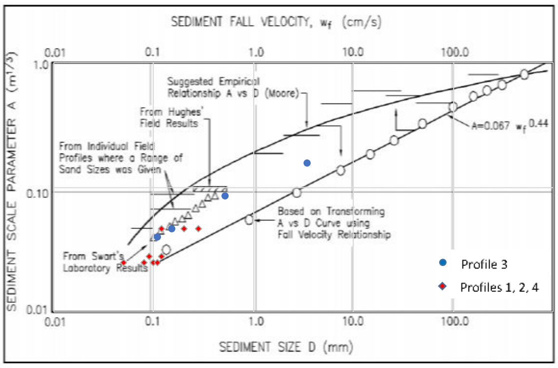

Figure 10. A-D plot for Profiles 1,2,3 (far from the structure) and Profile 3 (in front of the structure)

5. Conclusion

Coastal protection engineering works may result in changes in characterization of the hydrodynamics and bottom topography of the nearshore domain. Since measuring the changes in underlying bathymetric is very costly, developing equilibrium beach profiles which can demonstrate the important features of the bottom topography is of importance. In order to assess the bottom topography of the Caspian Sea in vicinity of Astara Port, some field measurements of beach profiles were carried out. The agreement between the profiles and the equilibrium profile described by Dean was investigated. In addition, investigating profiles in the vicinity of Astara Port showed that the breakwaters have caused the disturbance to the southward long shore sand transport, leading to beach accretion on the northern side and shoreline erosion in the lee of the structures. It can be concluded that, the Dean's formula ($y=A\,x^{2/3}$) can be applied for all parts of the coast even for the areas in vicinity of the coastal structures, while the power term in the formula is (2/3) for all cases but the coefficient 'A' for structure neighborhood is inherently more than the other areas. The shape of bed profile in structure neighborhood is steeper than the other areas which resulted from the accumulation of bigger sediments around the structure.

6. References

[1] Basco, D. R., Bellomo, D. A., & Pollock, C. (1992). Statistically significant beach profile change with and without the presence of seawalls. In *Coastal Engineering 1992* (pp. 1924-1937).

[2] Birben, A. R., Özölçer, İ. H., Karasu, S., & Kömürcü, M. İ. (2007). Investigation of the effects of offshore breakwater parameters on sediment accumulation. *Ocean Engineering*, *34*(2), 284-302.

[3] Bodge, K. R. (1992). Representing equilibrium beach profiles with an exponential expression. *Journal of coastal research*, 47-55.

[4] Bowen, A. J. (1980). Simple modes of nearshore sedimentation beach profiles and longshore bars. *The coastline of Canada*

[5] Broker, I., Johnson, H. K., Zyserman, J. A., Ronberg, J. K., Pedersen, C., Deigaard, R., & Fredsoe, J. (1995). Coastal profile and coastal area morphodynamic modelling. MAST 68-M Final Workshop, Gdansk.

[6] Bruun, P. (1954). *Coast erosion and the development of beach profiles* (Vol. 44). US Beach Erosion Board.

[7] Dean, R. G. (1991). Equilibrium beach profiles: characteristics and applications. Journal of coastal research, 53-84.

[8] DOLPHIN, T., TAYLOR, J., VINCENT, C., BACON, J., Pan, S., & O'CONNER, B. R. I. A. N. (2005). Storm-scale effects of shore-parallel breakwaters on beaches in a tidal setting (LEACOAST). In Coastal Engineering 2004: (In 4 Volumes) (pp. 2849-2861).

[9] Du, Y., Pan, S., & Chen, Y. (2010). Modelling the effect of wave overtopping on nearshore hydrodynamics and morphodynamics around shore-parallel breakwaters. Coastal Engineering, 57(9), 812-826.

[10] Ghanbari, F., Adjami, M., & Ataei H, S. (2019). An Analytical Study on the Formation of Submerged Bars in the Southern Coasts of Caspian Sea. International Journal Of Coastal, Offshore And Environmental Engineering, 4(3), 1-8.

[11] González, M., Medina, R., & Losada, M. A. (1999). Equilibrium beach profile model for perched beaches. Coastal Engineering, 36(4), 343-357.

[12] Holman, R. A., Lalejini, D. M., Edwards, K., & Veeramony, J. (2014). A parametric model for barred equilibrium beach profiles. Coastal engineering, 90, 85-94

[13] Kristensen, S. E., Drønen, N., Deigaard, R., & Fredsoe, J. (2013). Hybrid morphological modelling of shoreline response to a detached breakwater. *Coastal Engineering*, *71*, 13-27.

[14] Lama, G. F. C., Sadeghifar, T., Azad, M. T., Sihag, P., & Kisi, O. (2022). On the Indirect Estimation of Wind Wave Heights over the Southern Coasts of Caspian Sea: A Comparative Analysis. Water 2022, 14, 843.

[15] Jackson, N. L., Harley, M. D., Armaroli, C., & Nordstrom, K. F. (2015). Beach morphologies induced by breakwaters with different orientations. Geomorphology, 239, 48-57.

[16] Ranjbar, M. H., & Hadjizadeh Zaker, N. (2018). Numerical modeling of general circulation, thermohaline structure, and residence time in Gorgan Bay, Iran. *Ocean Dynamics*, *68*, 35-46.

[17]Shiea-Ali, M., & Valipour, A. (2021). Morphodynamic Classification of Beaches in some parts of the Iranian Coasts. International Journal Of Coastal, Offshore And Environmental Engineering, 6(3), 26-39.

[18]Sh.Hazrati, M.Torabi, K. Lari, A. A.Bidokhti, (2018). Numerical simulation of coastal currents caused by wind on the coast of Astara port. Journal of Meteorology and Atmospheric ciences,271-258.

[19] Tang, J., Lyu, Y., Shen, Y., Zhang, M., & Su, M. (2017). Numerical study on influences of breakwater layout on coastal waves, wave-induced currents, sediment transport and beach morphological evolution. Ocean Engineering, 141, 375-387.