J-Researchers

JOURNAL OF CIVIL ENGINEERING RESEARCHERS

Sediment Transport Rate Estimation in Pozm Fishery Harbor by Numerical Modelling and Empirical Formulas

Amin Gharibeshghi,[a*] Nima Ikani,[b]

a M.Sc in Coastal, Port and Marine Structures Engineering, Islamic Azad University of Central Tehran Branch, Iran

b M.Sc in Civil-Environmental Engineering, Sharif University of Technology, Iran

Abstract

Estimating the amount of alongshore sediment transport (LSTR) is an extremely important task for coastal engineers and coastal project managers to determine the probability of erosion and sedimentation in shores and ports. There are two popular empirical formulas, CERC and Kamphuis, that can be used to calculate the potential of the LSTR rate of the coast. In this study, sediment transport rate was calculated through experimental formulas and effective simulation in the Pozm Harbor is located in Oman Sea in the coordination of 25 ° 21 ° N and 60 ° 17 ° E. Using wave data and Specification of sediment. Also, the numerical simulation of this rate is calculated using numerical modeling. The numerical simulation results behind the groin have been compared with the new hydrography of data was collected in 2017. Furthermore, numerical model has been evaluated and general morphology has been identified. Based on sediment transport volumes calculated at Pozm harbor, a suitable sediment transport rate can be achieved using this numerical model and the Kamphuis formula.

Keywords: Alongshore Sediment Transport, CERC, Kamphuis, Gulf of Pozm

* Corresponding author: e-mail: Gharibeshghi1984@gmail.com

1. Introduction

In recent decades, despite substantial advances, estimating sedimentation rates still remains one of the most complex engineering issues of coastal areas. Moreover, sediment transport in coastal areas has been changed to an evolving science in the civil engineering field because, it depends on complex processes some of them have not been measured or fully understood. Therefore, according to [1], it is crucial for engineers to note that even the best predictions in sediment transport are broader than those expected in other fields of science and engineering. Also, according to [2],[3], sediment transport has been divided by two segments in coastal areas,

First; along shore flow caused by the failure of the oblique waves is the main cause of the LSTR in the declining zone and second; cross shore sediment transport. In this study, along shore flow in has been evaluated Pozm fishery harbor by numerical modeling and empirical formulas. Although the amount and direction of sediment transport in a particular part of the coast varies according to the characteristics of the waves, the net annual sediment transport rate represents the total amount of LSTR per year [4]. This transfer is actually the sum of suspended sediment and bed transport. To calculate the LSTR, empirical relationships including CERC, Kamphuis and Van der Meer formulas have been proposed by [5],[6] and [7] to calculate the LSTR. It should be noted that the Van der Meer theorem is applicable to sandy beaches and is less used in Iran due to the dominant aspect of the southern coast of the country. The CERC formula is able to estimate the rate of deposition caused by the waves only with respect to the wave characteristics [8], while the proposed formulation of Kamphuis also considers the effect of bed slope and provides more realistic values in the surf zone generated by breaking waves [9]. In order to identify the factors that lead to deposition behind the Pozm harbor groin, different marine parameters have been simulated such as current waves, wind speed, wave high and sediment size. According to waves and currents interaction simulation by using numerical modeling can be calculated sediment transport and bed sediment erosion.

2. Materials and Methods

2-1 Pozm case study

Pozm harbor is located on the southeastern margin of Pozm Bay in the vicinity of Chabahar Bay which is located in the oman Gulf as indicated in Figure 1.

Fig. 1. Pozm fishery location

In 1992, this port began operating with the construction long breakwater on the southeastern edge of Pozm Bay. Implementation of this plan and creation of the required harbor caused the problem of sediment sequestration on the northeast margin of the breakwater as it shows in Figure 2. To solve the problems various solutions were conducted to prevent sedimentation in the port and finally one of them has been performed in 2003 (Figure 3).

Fig. 2. Severe sedimentation in Pozm fishery in 1994

Fig. 3. Construction of a groin upstream of Pozm fishery in 2003

2-2 Sediment transport characteristics

In this study, the crucial parameters related to the transportation modeling have been considered such as area hydrography, regional wave characteristics and regional bed sedimentation which play a vital rule in sediment transport estimation. Therefore, deep water waves are estimated from using the output of the Iran Sea Waves Project conducted by the National Institute of Oceanography and Atmospheric Sciences from 2003 to 2011. Figure 4 shows the main direction of the waves is at an angle of 180 degrees and %45.72 of the wave's depth less than 0.6875 m which is called calm. Wave-rose analysis indicates dominant waves have moved from southeast, south and southwest (168 to 191 degrees) to the Pozm harbor which is expected to have the highest sediment transfer rate from mentioned angles.

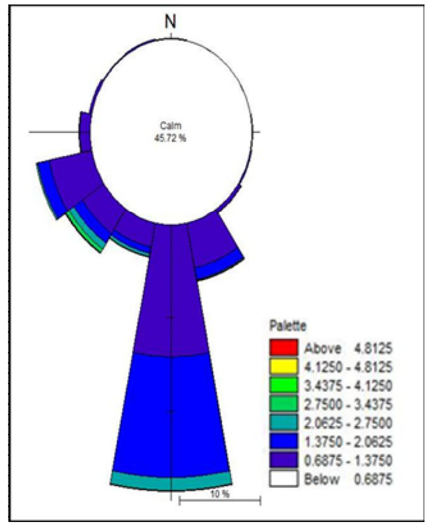

Fig. 4. Deep water wave rose from 2003 to 2011

2-3 Sediment transport formula procedure

The potential of LSTR depends on the amount of material available along the coast and is most closely related to the coastal component of energy flux or wave power. The CERC formula which is indicated in Eq 1 has been widely used in engineering applications [10], [11].

$$Q_l = K\left(\frac{\rho\sqrt{g}}{16\kappa^{\frac{1}{2}}(\rho_s-\rho)(1-n)}\right)H_b^{\frac{5}{2}}\sin(2\alpha) \quad (1)$$

The Kamphuis formula has been result from parameters such as the effects of wave period (wave sharpness), beach slope, and grain size, which is presented in Eq 2 [7]. This model is based on the assumption that the overall coastal sediment transport rate is proportional to the energy flux.

$$Q = 6.4 \times 10^4 H_b^2 T^{1.5} m_b^{0.75} D^{-0.25} \sin^{0.6}(2\alpha_b) \quad (2)$$

Where Q is volume transport rate, K is dimensionless coefficient (SPM=0.39), T_p is wave period, g is acceleration due to gravity, ρ_s is mass density of the sediment grains, ρ is mass density of water, n is sediment porosity (0.4), H_b means breaking wave height, m_b is beach slop, α_b means the wave breaker angle relative to the shoreline and D_{50} is sediment particle size

The numerical modelling simulation has been performed to find out the value of LSTR which corresponded to the sediment transport calculation. It has also been used in two conditions to investigate the effects of wind force using the extracted data from the European Centre for Medium-Range Weather Forecasts (ECMWF) in case of flow formation. Figure 5 illustrated the slight affect two parameters to run the simulation sediment transport with wind versus without wind force which can be irrespective this parameter. In other words, the current velocity is also not affected by wind despite of little fluctuation from 0.18 to 0.22 m/s.

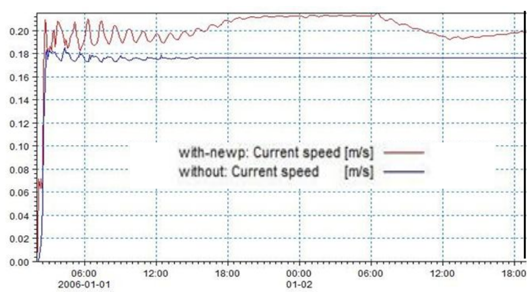

Fig. 5. Comparison of the flow velocity in two states with and without wind force

2-4 Sediment transport rate calculation

In this study, wave angles in shallow water, and wave height in the wave break zone have been calculated considering shoaling and reflection. The LSTR potential is then calculated using CERC and Kamphuis empirical Eqs 3 and 4 Where f' is the percentage of the wave frequency.

$$Q_{CERC\,(m^3/yr)} = \frac{I_i}{g(\rho_s - \rho)(1-n)} \times f' \times 24 \times 365 \times 3600 \quad (3)$$

$$Q_{Kamp\,huis\,(m^3/yr)} = 6.4 \times 10^4 H_b^2 T^{1.5} m_b^{0.75} D^{-0.25} \sin^{0.6}(2\alpha_b) \times f' \quad (4)$$

Figure 6 indicate a map that the area between the red line (with 665 m length and 100 m distances from the groin shown in hatch area) and groin has been considered to obtained the sediment transport rate calculation from numerical modelling simulation. Furthermore, comparison between CERC and Kamphuis with hydrographic maps has been evaluated to determine the accurate result.

Table 1 - Water temperature of Pozm fishery

Seasons	Average temperature	Water level	Zone	Temperature
June	Maximum	Surface water	41	31.44
January	Minimum	Surface water	41	21.98
August	Maximum	Close to bed	41	31.18
March	Minimum	Close to bed	41	21.76

Afterwards, numerical modelling has been compared hydrographic maps in the same area. By comparing hydrographic maps of pozm harbor over the last 10 years, from 2006 to 2017, the sedimentation rate at the behind of the groin was 77.611 m^3. Hydrographic maps have been compared with numerical simulations in a specific range at a distance of 100 meters behind the groin. The result comes from the comparison has been obtained an annual sediment of 32000 m^3.

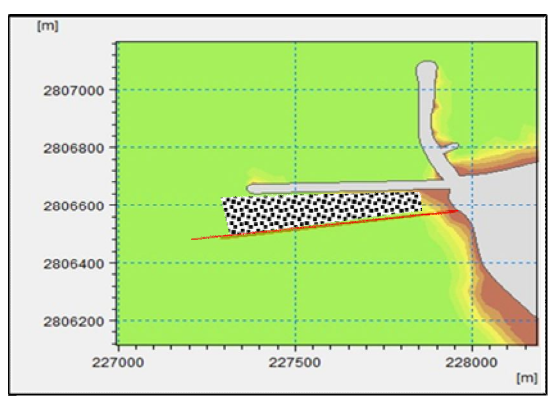

Fig. 6. Comparative analysis area behind the groin and red line

Water temperature also has been considered as one of the parameters in simulation numerical seasons average temperature have been used in this study which are shown in table 1 from [12] Eynali's study.

According the table 1 maximum and minimum average temperature in different months has been considered and suggested in water surface level and depth water close to bed.

Table 3 shows the comparison between the two formulas, CERC and Kamphuis. Compared to the Kamphuis Formula, the CERC seems to be the best formula for calculating the LSRT. Although the CERC formula is simpler compare with Kamphuis because there are fewer parameters has been used.

Also, in the CERC formula beach slope and grain size has been not considered. Furthermore, it can be providing overall volume and considering wave as the only factor to move sediment particles. According to [13] in the CERC formula, the total volume sediment cannot be calculated accurately without considering coastal structures in transitional sedimentation. Therefore, the result of the CERC formula has been not precise in the port of Pozm rather than the Kamphuis formula.

Table 3 - Comparison of sediment transport rate values with empirical relationships

Wave Angle (Degree)	Kamphuis m^3/year	CERC m^3/year	Numerical Modelling m^3/year
146.25	1103	18589	431
168.25	57784	1000000	21030
191.25	11127	209578	3849
213.75	8222	118226	2129
236.25	6995	-112785	2472
258.75	3285	-97963	592
281.25	152	-5443	11

3. Results and Discussion

According to the Table 2, the sediment transport rate of Pozm fishery in seven angels has been investigated and calculated in the Kamphuis, CERC formula and numerical modelling simulation. Result manifest that the highest sediment transport rate which is obtained from CERC, Kamphuis and Numerical modelling are 1000000, 57784 and 21030 m^3/year respectively with 168.25 wave angle degree.

Table 2 - Sediment transport rate of Pozm Fishery

Volume transport rate (Q) m3/year	Result
Kamphuis	88669
CERC	1132247
Numerical modelling	30514
Measured of hydrographic maps	77611
Kamphuis/Measured	1.14
CERC/Measured	14.58

As can be seen in Table 3, the sediment transport rate according to the total measured hydrographic maps is 77611(m^3/year), which is close to the rate obtained by Kamphuis formula as 88669 (m3/year). According to the numerical modelling results, however, the total annual sediment transport rate in the area behind of groin has been estimated to be 30514 (m^3/year). Numerical modelling is useful methods for achieving the sedimentation pattern in the Pozm bay and suggested acceptable prediction of the annual sediment transport rate.

Yazdanparast indicated in his study that the coastal rock erosion is definitely the main source of sediment production in the area correspondent to cliff height estimation and satellite imagery usage. Hence,

Time

the sediment volume obtained from rock erosion has been estimated to be 23000(m^3/year). On the other hand, he finds out the dominant current and sediment transport along the Oman Sea coast from the east to the west. Consequently, approximately %100 of the sediments reaches the behind of the groin from the east coast. The sediment rate obtained from numerical simulation is 30514 m^3/year which is very close to 23000 (m^3/year) from [14].

Figure 7 shows the counter plot which is scattered the flow velocity behind the groin and along the coast so that the surface elevation behind the groin increased to the highest sediment rate. Also, based on the numerical simulation result, LSRT have been reached the behind the groin from the east coast. Flow velocity direction near the groin is indicated that vortex has been formed due to the decreased velocity Also, suspended particles eventually settle.

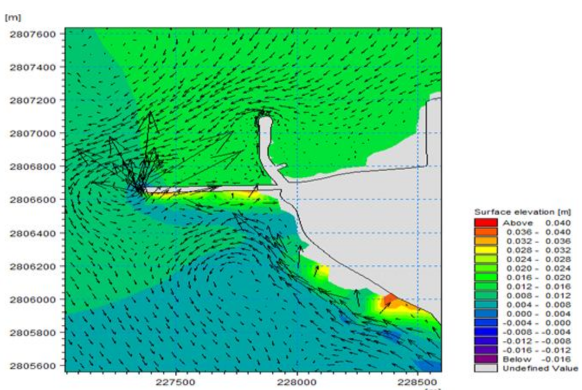

Fig. 7. Velocity interaction behind the groin and along the coast

4. Conclusion

According to parameters such as beach slope and grain size, the Kamphuis formula provides the most accurate estimate. Azarmsa examined the accuracy of the Kamphuis formula using several empirical relationships [15]. Using information in Pozm port including wave height, wave period, breaking wave angle, grain size and shore slope, sediment transport behavior has been calculated with empirical formulas CERC and Kamphuis. Then the volume of sediment obtained from hydrography and empirical formulas has been compared.

The CERC formula has been estimated to be 14.58 times higher than the real volume (Eq 5). For Pozm harbour area, it is recommended that a coefficient has been determined specifically for the CERC formula to estimate the annual LSTR. Using K = 0.0267 for the Pozm coast is a suggested method for correcting the dimensionless constant coefficient of the CERC formula which is K = 0.39.

$$Q_{C.E.R.C} = 14.58\, Q_{observation} \tag{5}$$

Also, the Kamphuis formula estimates the amount of annual sediment by 1.14 times higher than the measured volume (Eq 6). The difference between the value result of Kamphuis formula and the measured value is due to the lack of calibration range of the areas. The value of the constant coefficient has been suggested in the Kamphuis formula in terms of m^3/s by K_{re} which is reformative the formula to value 0.875 to modify it in the port of Pozm.

$$Q_{Kamphuis} = 1.14\, Q_{observation} \tag{6}$$

Furthermore, the numerical modelling is suitable method to predict the sedimentation annual pattern of the sediment transport rate. On the other hand, according to the wave classification, the highest sediment transport rates have been calculated from not only the empirical equations but also the numerical model.

Moreover, the highest sediment transport potential in the port of Pozm based on the angel has been evaluated in 168.75, 191.25, 213.75 and 236.25 angles.

References

[1] Soulsby, R. L.; Damgaard, J. S., Bedload sediment transport in coastal waters. Coastal Engineering 2005, 52 (8), 673-689.

[2] Deigaard, R., Mechanics of coastal sediment transport. World Scientific: 1992; Vol. 3.,

[3] Fredsøe, J., Modelling of non-cohesive sediment transport processes in the marine environment. Coastal Engineering 1993, 21 (1-3), 71-103.

[4] Cherif, Y. S.; Mezouar, K.; Guerfi, M.; Sallaye, M., Nearshore hydrodynamics and sediment transport processes along the sandy coast of Boumerdes, Algeria. Arabian Journal of Geosciences 2019, 12 (24), 1-17.

[5] Manual, S. P. US Army Coastal Engineering Research Center, Department of the Army, Corps of Engineers, US Govt. Printing Office, Washington, DC, USA 1984, vols, 1and2

[6] Van der Meer, J. In Static and dynamic stability of loose materials, Short course on Coastal Protection at 22 Intern. Conf. on Coastal Eng., ASCE, Delft. Balkema, Rotterdam, 1990; pp 157-195.

[7] Kamphuis, J. W., Alongshore sediment transport rate. Journal of Waterway, Port, Coastal, and Ocean Engineering 1991, 117 (6), 624-640.

[8] Toldo Jr, E.; Nicolodi, J.; Almeida, L.; Corrêa, I.; Esteves, L., Coastal dunes and shoreface width as a function of longshore transport. *Journal of Coastal Research* **2006**, 390-394.

[9] Bayram, A.; Larson, M.; Hanson, H., A new formula for the total longshore sediment transport rate. Coastal Engineering 2007, 54 (9), 700-710.

[10] US, A. Coastal Engineering Manual. Chapter II-2, Meteorology and Wave Climate, Engineer Manual 1110-2-1100. US Army Corps of Engineers, Washington, DC 2006

[11] King, D. B. Influence of grain size on sediment transport rates with emphasis on the total longshore rate; ENGINEER RESEARCH AND DEVELOPMENT CENTER VICKSBURG MS COASTAL AND HYDRAULICS LAB: 2005.

[12] Eynali, A. C., vahid. Investigation of temporal and spatial variability of physical parameters (temperature, salinity and density) of the Gulf of Pozm. Journal of Marine Science and Technology 2017, 16: 111-124.

[13] Bosboom, J.; Stive, M. J., Coastal dynamics I: lectures notes CIE4305. 2012.

[14] Yazdanparast, S. Analysis of sediment produced by coastal rock erosion on Sediment Port of Pozm, Khaje Nasir al-Din Tusi University of Technology 2011

[15] azarmsa, S. Forecasting the position and how the shoreline changes in the Gulf of Pozm by 2010. Journal of Earth and Air Physics, 36: 89-98