Study Of Sedimentation & Erosion in Astara Port Coastal Region (Iran, Caspian Sea)

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Abstract

Study of coastal sediment transport in order to determine the amount and the depth of erosion and sedimentation pattern in the coastal regions of port, is one of the most significant subjects in ports design and coastal engineering .basically, an exact calculation of sedimentation requires periodical hydrography in details of the region and specification of border circumstances such as flows speed, pattern of natural flows ,waves characteristics ,percentage of water salinities, size of pores, and ingredient of bottom materials, concentration of sediments, grain size of sediment ,speed of settlement of sediment suspending particles ,and study of erosion depth. in the present research ,sedimentation and erosion in coasts of Astara port were studied. for this purpose, the rate of coastal sediments transport along the coast was measured by taking into consideration existence of Astara chay river and the waves characteristics in shallow water up to the breaking zone, also measured depth of erosion by different techniques in site zone, the laboratorical study investigated base of sediment in basin and out basin. and also by utilization of Astara chay hydrography plots and in port basin ,procedure of sediments movement were drawn on three-dimension, and the obtained results lead us to more correct design of coastal dikes and also break waters of the port.

Introduction

Astara is a city port of Iran, located at west coast plain of Caspian sea, longitude of northern 38^{O} and 26'. Situation of Astara coast in Caspian sea, adjacent to conjunction of Astara river, is shown in Figure 1 and also situations of breakwater and Astara port have been shown in figure 2. Length of Astara coasts, as it is seen in Figure 2, has a seasonal and semi seasonal river named: Astara Chay, located at border of Iran and Republic of Azerbaijan. Considering that this river is fluvial or semi fluvial, it will make sediments at estuary and also coasts of this port.

Along the coast up to the river and also after the river, from swamp to breakwater of the port, coastal dikes have been established, existence of which makes some changes in sedimentation and beach erosion. Also the oscillation of sea level in Caspian sea which causes regression or encroachment of sea, have usually a direct contact with estuary of rivers and in the coasts of the estuary. All these cases create a very complex process in the coasts of this port. Finally, breakwaters of the port have been established in the direction that have changed natural order of sedimentation process, so that firstly, by cutting the flows carrying local sedimentation, they hinder ordinary distribution of sediments and increase rate of sedimentation, behind the northern breakwaters and

secondly, they increase the amount of erosion behind the southern breakwater. Furthermore, at the entrance harbor basin, accumulation of sediments is observed which may cause this fishing harbor lose its uses in future. This research try to study the rate of sediments transport at coast of Astara and determination of erosion and sedimentation patterns in Astara port.

Theory

Establishment of ports and coastal structures will change the nature of near shore phenomena, which the most important of them is change of pattern of the flow and consequently, change of erosion pattern and transfer of sediments and sedimentation. Problem of sedimentation inside the basin of ports, and sedimentation, and erosion of coasts around the coastal structures is very significant, so that awareness of circumstances for production of sediment and flows carrying sediments and determination of base of sediments imposed on the surroundings of port, will play an important role in calculation of their suitable life. Astara Chay river, located at coast of Astara is a seasonal and rather permanent river and total regime of river's flow follows seasonal falls. Short-term morphology of the river follows the seasonal floods and its long-term morphology follows the floods with rather long return terms. In the total regime of seasonal rivers, the dominant factor belongs to suspending sedimentation materials. In stormy or semi stormy conditions of sea, sea water level comes up to the limit of storm surge and sea waves breaks in the surf zone. This makes the sea penetrate in the river much. If the river has a semi torrent status, due to reaction of waves and river flows, the sedimentation materials have to be accumulated around the estuary to Astara Customs Bridge. Existence of many sedimentation islands in this area, proves this case. It can be said that much sediments are emptied from Astara Customs Bridge toward the river estuary and sea. In different circumstances of the seasons with low or high water, the amount of sediments carried by the river and its mechanism are approximately different. Figure 3 shows the changes of water level of Caspian sea from 1921 to 1995. It is observed that balance of sea water from 1978, when it began its increasing procedure, has increased about 2,3m. to 1995. It means that, sea level has risen about 14cm. Per year. Coastal dikes were established from southern side of Astara Chai river to the swamp and from southern side of swamp to northern breakwater, to prevent the coastal regions to go beneath the water. From the beginning of 1996-97, Caspian sea level, began to regress the coasts, so that mean figures of sea water level decreased in this year for about 20cm. in comparison with the previous year. The most important impact observed in estuary of Astara Chay river after regression of sea, is high amount of sediments remained by decrease of balance of sea water. Moreover, against the coastal dikes, much sediments have been remained. Establishment of breakwaters, commenced from 1995, is the other reason for change of natural order of sedimentation processes in coasts of this port. After breaking line, the flow caused by the waves are divided into two components perpendicular on coasts and parallel with coast. Parallel flows of coast carry about 80 to 90% of sediments that are taken from the

bottom and are floating in water. When there is any obstacle in the path of such flows, such as breakwater, the sediments will be trapped behind it. Consequently, shape of coastal line and sea bed will change. Arm length of northern breakwater of Astara port is about 260m. (commercial part) and arm length of middle breakwater is about 520m. (fishing part), thus they dominate on width of breaking zone and much sediments of long shore may not pass the breakwater head and are collected behind the breakwater to settle. Field studies and photos taken in 2001 and 2003 clearly show that sedimentation behind the northern breakwater had an increase every year. Much sediments are carried to basin and study of hydrographic drawings of several years reveals that a sever erosion is seen at entrance of basin's cross, which is observed in the form of a cavity in three dimensional drawings and is quite tangible at entrance of sedimentation which may cause some problems for the ships in future. There is also a coastal erosion, behind the southern breakwater, with length of 580m., main branch and 90m. secondary branch. The above-mentioned cases reveal that with existence of seasonal rivers and coastal dikes, and port's breakwaters, coasts of this city, the coasts have a very complex process and changes of Caspian sea level has made another factor we know that there exists no pattern for complex analysis from river's coast to dike and basin. Therefore, we try to find a separate pattern for their combination analysis by a separate study.

Local Measurements

By taking some samples of estuary of Astara Chay river and left side coasts (Azerbaijan) and right side coasts (Iran), it is perceived that, we have coastal flows with powerful origin and total procedure of decrease of particles diameter continues in Iranian coast, but, existence of spit at the mouth of Astara Chay river makes presence of particles having bigger diameters in the sediments of the region. By study of grading curve for accumulation of sedimentation particles, the following cases are concluded:

1. There is a similarity and commonality in size of sediment particles of left and right coasts which reveals sediment transfer by the coastal flows and sea currents of sediments from left side coasts toward the right side coasts in the area of waves breaking.
2. Since, right side coasts are protected by coastal dikes and coastal profile has accelerated in this part, there is more energy density of sea waves in this region of the coast, resulted by intervention of reflective waves when sea is stormy. There is slight difference in size of sediment particles between left and right sides occurred by the same phenomenon.
3. Existence of another river (Mordab Rood) and evacuation of smaller particle sediments toward right side coasts at the time of flood has also augmented the distribution of sediment particles. Also, by taking sediment samples from port's basin and out of it, from depths: 2.5 and 5 and 7.5 m it was observed that the base of sediment in basin is most from, the rivers and long shore sediment transport.

Since, there is no measurement or compiled statistics in respect to specifications of waves in deep and shallow waters of Caspian Sea in the scope of Astara Port, thus, by

analysis of wind statistics, specially the speed measured and the direction of regional winds during the year, by utilization of experimental formulas specifications of waves in deep water can be obtained. Having the speed and direction of wind (table 1) and by considering length of blow and impact of wind (Figure 4), the height and period of waves can be obtained.

Data Analysis

By referring to diagram of regional winds (Figure 5), it is observed that direction and amount of blow of regional winds are from north, north west, north east. Waves resulted by the wind were influenced by Baku cape and have no direct effect on Astara site. But, because such waves are dominant in Caspian sea, the design is based on such waves, with regard to the effective fetch from NW region. Calculation of the effective fetch length and also the specifications considered, are extracted based on experimental relations of SMB. Length of effective fetch was calculated for the directions of N, NE, E, SE and drawn up according to (table 2). Due to special location of Astara site behind Baku cape, it is essential to correct the waves mostly from the direction of NW on this site. For the same reason, correction of different parameters of wave from west side direction to Baku cape will have a decrease for about 40% in length of the wave. Having this relative presumption, specifications of the waves are based on the above-mentioned cases in compliance with (table 3). After calculation of parameters of waves at different directions, by consideration of return periods concerned and regarding the breaking phenomena and depth decrease impact (shoaling), specifications of waves in shallow water were calculated up to breaking zone and then for the directions concerned, mentioned in (table 4). Using the waves specifications in deep water and shallow water and helping the CERC formula and rate of sediments transfer can be calculated. **CERC** Formula:

$$S_{ls} = 0.14\, H_0^2\, C_0\, K_{br}^2 \sin\varphi_{br} \cos\varphi_{br} \qquad (1)$$

In which, $K^2_{br} = \cos\varphi_0 / \cos\varphi_b$, H_0 deep water wave height, H_{br} breaking waves height, φ_0 wave angle, φ_b breaking wave angle, K_{br} refraction coefficient and S_{ls} long shore sediment transport. The amount of annual sediments carried by Astara Chay River was calculated for about 39000 m^3/year or 104357^{ton}/year. Since, most of the times of year, wind blows from northwest (Figure 5), thus, coastal flows are influenced by such waves in playing a significant role in transfer of sediments. The waves of north also produce flows from northwest to southeast, but blowing frequency of such waves is less powerful in proportion with northwest flows. also The waves blowing from northeast with their frequency have also the waves are blowing from NE with their less frequency are effective in currents from north to south coast. Referring to radius shape of angles effective on Caspian sea, in Astara site it is observed that the waves are effective from East direction in creating the coastal flow toward the sea, vise versa, not in creation of coastal flows of waves. The waves from southeast create diverse coastal flows. Mean

rate of transfer of coastal sediments were calculated from different aspects bye of CERC relation, mentioned in Table 5. Using the wave specification in Astara zone and helping the lower furmula, erosion depth can be calculated.

$$d_{cr} = \frac{97.9U_w^{2.08}}{T^{1.08}\left[g(s-1)\right]^{2.08}} \quad (2)$$

In which, $S= \rho_s / \rho_0$, $U_w = wa_b$, U_w the orbital velocity amplitude, T wave period, ρ_s sediment density, ρ_0 water density, w fall velocity, a_b the amplitude of the water displacement near the bottom and d_{cr} erosion depth and effect on the siltation and erosion in Astara coastal region in the order of 10 to 30 cm in depth. Using hydrographic drawings of different years and extracting depth points at estuary of Astara Chay and also inside the port's basin and by utilization of surfer, sedimentation in estuary of river and port's basin were drawn on two dimensional and three dimensional basis, shown in Figures 6, 7, 8, 9. In three dimensional drawings related to the river, accumulation of sediments and erosion are quite specified in the scope of estuary and it's expansion towards the coast is determined and in three dimensional drawings of port's basin, erosion is observed at entrance and sedimentation is observed inside the basin. If it continues this way, it will create some problems for entrance and exit of ships and suffer the navigation of the harbor.

Conclusions

1-the rate of coastal sediment transports and the amants of river sediment discharges. show, a complex interactions between the river and long shore flow which makes deposition in river mouth.
2-the analysis of deep and near shore waves dynamics shows a predominant waves directions from NW, and effect on the siltation &erosion in Astara chay coastal region in the order of 10to 30 cm in depth.
3-the field analysis of sediment grain size in the surf-zone by taking in to account the existence of sea dike shows to that the severs erosion in beach profile occurs, which the river discharge. sonee how balance the erosion phenomena in the site area.
4-the results of models shows a good agreement, in scouring and siltation , in comparison by field measurement and calculations, in the western parts and harbor basin, and also the depth of scour in the head of break waters.

References

1. H. Morovvati, "Roughness effect on waves & currents combined flow", 2000, Ph.D. thesis submitted to IAU, Tehran, Iran
2. W.W.MASSIE. PE. 1986, Coastal Engineering. Volume II.

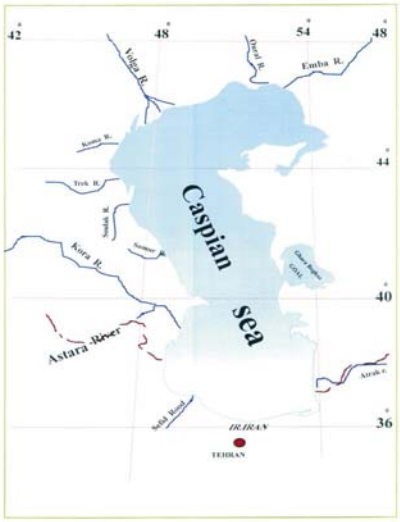


Fig 1: Caspian Sea & Astara harbour. Site Area

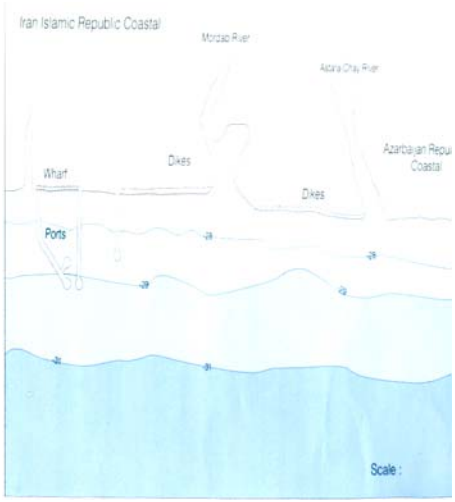


Fig 2: Site plan of Astara Coastal Area

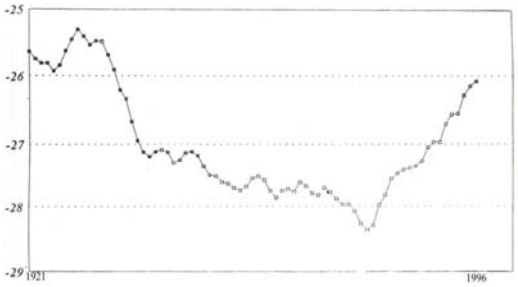


Figure3: sea level changes curve of Caspian sea between 1921 – 1996

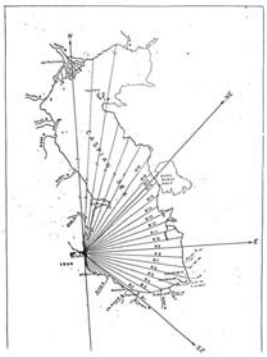


Figure4: effective fetch are Caspian sea in Astara port

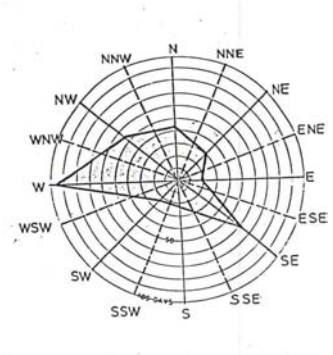


Figure5:windy days for difference direction in during year In Astara site

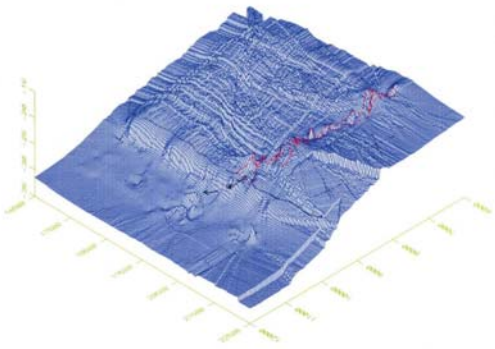
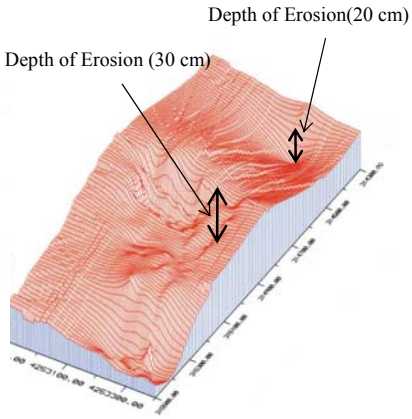


Figure6: three dimensional diagram scour changes Calculated in Astara chay river and estuary



Figuer7:three dimensional diagram scour changes Calculated in Astara port basin(2002)

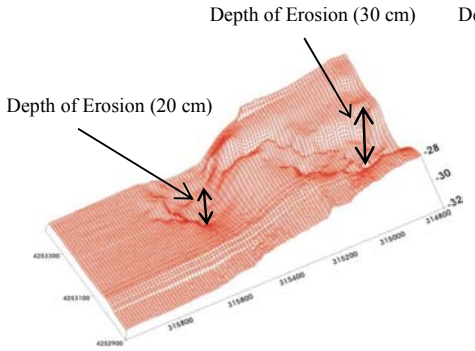
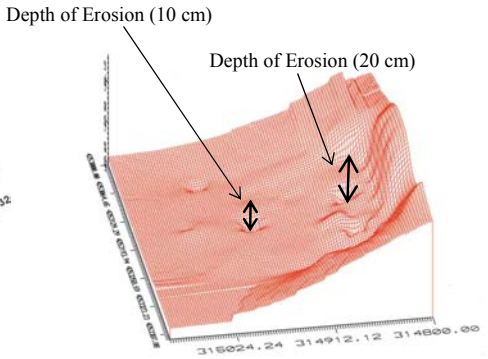


Figure8: three dimensional diagram scour changes Calculated in Astara port basin(2002)



Figur9: three dimensional diagram scour changes Calculated in Astara port basin (1998)

Table1: Direct effect winds data In southern Caspian sea in Astara site

Dir / Ret	5	10	20	30	40	50	60	70	80	90	100	200	300	400	500	600	700	800	900	1000
W	15	17.57	20.5	21.49	22.47	23.29	23.91	24.43	24.89	25.30	25.67	28.09	29.48	30.46	31.23	31.85	32.42	32.83	33.24	33.60
E	11.5	15.10	18.14	19.48	21.08	22.01	22.78	23.45	24.02	24.48	24.94	27.88	29.58	30.77	31.70	32.47	33.09	33.65	34.17	34.58
NW	13.40	16.39	19.27	20.97	22.11	23.04	23.76	24.43	24.94	25.41	25.87	28.65	30.30	31.44	32.31	33.09	33.71	34.22	34.69	35.15
NE	9.38	10.98	12.52	13.45	14.07	14.53	14.94	15.30	15.56	15.82	16.08	17.57	18.45	19.07	19.53	19.94	20.25	20.56	20.82	21.03
N	11.5	13.57	15.51	16.49	17.21	17.73	18.19	18.55	18.86	19.17	19.43	21.13	22.11	22.78	23.35	23.76	24.12	24.48	24.74	25
SEE	10.41	14.53	15.30	18.19	18.91	19.48	20.20	20.67	21.23	21.80	22.21	22.93	24.07	24.27	24.43	25.10	25.87	26.44	27.01	28.55

Table 2. length of Effective fetch for difference direction in Astara

Direction	Length effective fetch(KM)
N	360
NE	408
E	380
SE	372

Table3 .wave characteristics in deep water in Astara site

Direction	Wave period in deep water (sec)	Wave length in deep water (m)	Wave height in deep water (m)	Wave angle in deep water (deg)
N	8	100	2.83	85-90
NE	6	56.16	1.51	45
NW	8	100	5.2	60

Table4. wave characteristic in shallow water in Astara site

Direction	Wave angle in deep water (deg)	Wave breaking height (m)	Wave breaking angle (deg)	Water depth in breaking (h)
N	85	1.037	23	1.525
NE	45	1.399	22.17	2.058
NW	60	2.345	28	3.448

Table5. coastal sediment transfer in Astara site

Direction	Yearly coastal sediment rate $^{m3}/_{year}$
NW	$3*10^5$
N	$6*10^4$
NG	$9*10^4$
SE	$14.6*10^4$