An investigation of alongshore sediment transport trend, using experimental relations, morphological landscapes and coastline changes in the Persian Gulf

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Abstract: Predict of sediment transport and sedimentation rates are one of the main affecting in coastal areas management. Many tries with emphasis on effective reasons in sediment movements has been done to decide the rate of sediment transport, including the CERC formula. But accurately predict sediment transport rates and trends were affiliated of different such as accuracy and precision statistics, basic and initial data's. Since that may not be possible such information in some areas, was necessary used other techniques such as coastline changes and morphology. In this paper, alongshore sediment transport trends were considered in parts of northern coast of Persian Gulf, by local wave data's, CERC formula, morphological landscapes and coastline changes at the headlands and breakwaters. Coastal morphology and coastline changes were expounded with CORONA (1964) and SPOT (2005) satellite imageries. Alongshore sediment transport was outcome by CERC formula. Based on results, all of morphological landscapes and coastline changes in the study area were confirmed alongshore sediment transport trends got from CERC formula. In some areas that have limit data or lack of substantial document and prepare field information should used coastline changes and morphological settings with empirical relationships, were impossible to inspect the output.

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1. Introduction

Coastal areas have various human activities potential, in the business for beach dwellers and very significant role in the world economies. Management and optimum utilization of these areas involves identifying the natural factors, which verified to the different perspectives of these factors of science related. In coastal engineering analysis of sediment transport issues have great importance. Determination of sedimentation rate and trend, and correct predict of coast changes is very sensitive and important in the construction of ports. A lot of damage associated with the incidence of sedimentation and erosion in coastal areas and especially in ports, despite of considerable advances in estimating the quantity and trend of deposition. Alongshore sediment transport from oblique waves fractures is the most important processes in the coastal morphology, erosion, sedimentation and indicated the beach stability. Although according to the wave specifications changes the rate and direction of sediment transport in certain parts of the coast, but the resultant rate of annual sediment transport, shows alongshore sediment transport predominant trend. To review and estimate alongshore sediment transport presented the various experimental relations such as, Kamphuis, Van der Meer and CERC [19, 28 and 10]. Considering that, alongshore sediment transport studies used CERC formula in Iran, coefficients of this formula have been done in relation and extracted with wave climate and sedimentation to other coastal countries. Taking of this formula needs more hesitated to use on the Iranian shores (Afsharkaveh, N. and Soltanour, M. 2010). To this purpose, sediment transport investigation was not enough with using these relationships and achievement of information is essential from the natural conditions of each region. In this field, many studies from various perspectives, has been done by the researchers such as, Wang and et al (1998), White (1998), Wang and Kraus (1999), Masselink and Pattiaratchi (2001), LaValle and et al (2001), Camenen and Larroude (2003), Soulsby and Damgaard (2005), Patsch and Griggs (2008), Brown and Davies (2009), Soltanpour and Kaveh Afshar (2010).

Coastline known as the boundary between land and water (Dolan, R., Hayden, B.P., May, P., May, S., 1980, and Horikawa, K., 1988). In fact, periodically change at time intervals in the beach location, due to alongshore and cross-shore sediment transport and these changes due to the dynamic movements of sea water in coastal areas, such as tide and waves. On the other hand, alongshore sediment transport is one of the influence factors to sediment supply along the coast. Any change in this trend, including changes in the quantity that cause the accretion and erosion trends in coastal areas. Changes of coastline are one of the important issues of coastal scientists and used in the coastal management and coastal engineering. Position and the history of coastline changes can be produce important information in the coastal protection, coastal development projects and to calibration and numericalization of coastal area models (Hanson, H., Gravens, M.B., Kraus, N.C., 1988). To analyse the trends and coastline changes, should be investigated those in time and space, based on fundamental principles coastal strip (Boak, E.B., Turner, I.L., 2005). Short-term changes in coastline are said to forward and backward displacement of the coast in decades timescale, usually due to erosion and sedimentation processes along the coasts and the changes in the beach profile. These changes are more pronounce in coastal structures limits and some morphological landscapes such as the capes. Thus, changing in coastline position could be used as an index to determine the alongshore sediment transport trend besides beach morphology changes. On changes in coastlines and its associated phenomena, can also mentioned to many studies such as, Frihy and Dewidar (1993), Camfield and Morang (1996), Storlazzi and Field (2000), Masselink and Pattiaratchi (2001), Gharibreza and et al (2004), Chen and Chang (2009) and Anfuso and et al (2011).

Investigation of sedimentation behind breakwaters and coastal structures and review of erosion and sedimentation pattern on the adjacent coastal areas is a method for estimating alongshore sediment transport rate. Thus, field data; such as hydrographic data's in different years and their studies can be benefited and analysed conclude of them with the results of laboratory models and empirical formulas. Then exist of dredging information in courses and the volumes and removal of material from coastal sediments, as the output of the coastal zone is necessary in the study period (U. S. Army Corps of Engineering. 1994). Nevertheless, in some areas, doing of this process if it is not possible due to weakness of base data, such as recorded field data, other techniques must be use to measured accuracy of the output of experimental relations. Since most ports of the study area due to limited data or lack of substantial documented field information (or with poor information), such as hydrographic concepts and sediment exit data, only using empirical relationships for analysis of sedimentary processes will not be without critic. Therefore, in this research used the morphological landscapes and coastline changes, with alongshore sediment transport, as a natural constants and erosion and sedimentation functions.

2. Study area

In this research, has been investigated the mostly alongshore sediment transport rate by wave's data, satellite imagery, bathymetric maps, computing the sediment transport rate and GIS. Also, coastline changes investigated in the 41 years time-span, between the 1964 and 2005, during about 400 km of the north-eastern Persian Gulf coasts, from Berke Seflin Bay to Nayband Cape. These regions located between 53˚, 34' E to 55˚, 17' E and 26˚, 29' N to 27˚, 29' N, have morphology, geology and land use variation and several commercial and fishery port and, oil terminals (Fig. 1). These areas are one of the warmest in the Middle East (Anfuso, G. Pranzini, E. and Vitale, G. 2011), which has arid climate, with 80 to 200 mm mean annual rainfall (Meteorological yearbook of Iran. 2009). Theses coasts has Semi-diurnal tide, mean level was between 1.06 to 1.59 m (Aghtouman, P. 2008) and located along the Zagros mountain anticlines with the marls, siltstones, mudstones and limestones of Aghajari, Mishan and Gachsaran formations. In addition, conglomerates and limy sandstones of Bakhtiari formation and diapirs of salty Hormoz series have exposure in some coastal areas.

Widespread exploitation of these areas, including commercial, fishing, extraction and exploration of hydrocarbon, tourism and geotourism has caused, this part of the Persian Gulf coasts have remarkable growth and advances over the past decade. On the other hand, inattention to basic studies in these areas and do not implementation of comprehensive coastal zone management causes many problems among harmful coastline changes and sedimentation problem in ports.

3. Alongshore sediment transport trend

To estimation of alongshore sediment transport potential, has been used deep-water wave data, output of wave modelling Iran Seas project (General Directorate of Coast and Port Engineering. 2009). Extracted and used wave data parameters of 25 points that employed in CERC formula, such as wave height, wave period, occurrence and angle of waves. k coefficient in CERC formula considered 0.39 according to CEM recommendation (CEM Appendix A- Glossary of Coastal Terminology, 2003).

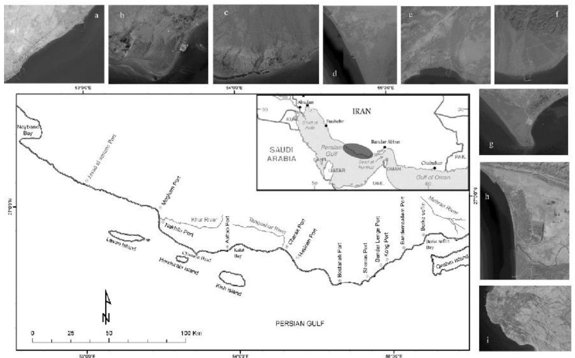

Fig 1: Study area and its major ports. a) Kong and Lenge ports coastal area. b) Sandy beach dunes and Shenas port. c) Bostaneh port coastal area. d) Hasineh port near the Hasineh salt domes. e) Charak port coastal area and Tangekhur river mouth. f) Aaftab port, Kalat salt domes and its alluvial fan. g) Chirouye coastal area and head. h) Mogham and Nakhilu coastal area and Khur river mouth. i) Nayband Cape in western of study area.

Thus obtained the net potential of alongshore sediment transport and extracted sediment transport overcome directions along the study coastal areas (Fig. 2). Based on the results, alongshore sediment transport pattern were divergent in Berke Seflin area so a trend is towards the East- South-east and the other one is to South-west. South-east trend were along to Shenas head and occurred convergence of currents in this region. This convergence pattern is because of the south-eastern current pattern between the Bostaneh coasts and Shenas head. Alongshore sediment transport pattern from the Eastern areas of Aaftab port is East and South-east and the trend seen to Bostaneh head that is converging currents. This divergence pattern causes Western alongshore sediment transport trend to the Chirouye head. Chirouye head is convergence location of this current trend with East South-eastern alongshore sediment transport current that flow from Nayband Cape. In addition, in Nayband Cape divergence of alongshore sediment transport currents occurred in to south-east and north to Nayband Gulf.

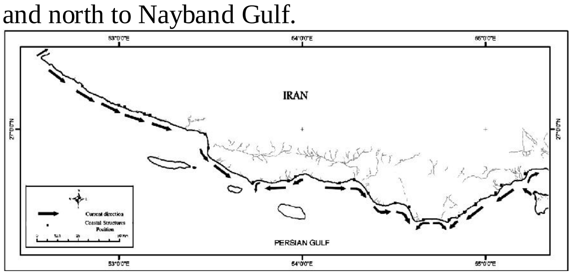

Fig 2: Pattern of alongshore sediment transport currents in coastal study area.

4. Coastline changes

The coastline changes have been considered in 41 years period between 1964 and 2005 by compared of CORONA and SPOT satellite imageries. CORONA is the first strategic management of Science and Technology Organization of United States satellite series, which has been built and used in cooperation with the USAF. At first, CORONA satellite was used with 24 inches camera, in height of 165 to 460 km from the earth that the cameras could be take images with less than 7.5 m resolution from the earth. This images out of the classified were reduces the accuracy at 2002 (NRO. 2010). CORONA and SPOT5 image that has 10 m spatial resolution have been based on compared periods shoreline positions. Noteworthy, 1964 CORONA images shows the coasts with the least interference of human impression such as ports and coastal structures, and this period have well capable of providing human effects in the coastal area. Coastline was considering the sea and land borders as exactly consistent mean high tides level (CEM Appendix A- Glossary of Coastal Terminology, 2003). The mean high tide level in different parts of the studied coastline is variable between 1.7 to 2.5 meters. Then, extracted mean high tide line from bathymetric maps and sketched waterline after corrections and cutting out errors from each one of the satellite images. These two lines were compared with separate and extract the shorelines. Mean high tide line provided by the interpolation of mean high tide levels in different parts of study area in the GIS tools, published by Iranian National Cartographic Centre (National Geographic center of Iran. 2004), and based on bathymetric maps zero line.

Accretion and regression pattern of shorelines has been obtain by comparison of two-term satellite imagery coastlines and set the critical points in the study area. Naturally, these critical points are located mostly at the limit of coastal structures such as breakwaters, and natural morphological landscapes such as heads and capes. In each of these points were calculated rate of coastline changes and used comply its results to alongshore sediment transport current trends. In this way were derived accretion and regression pattern of coastline at the limit of coastal structures and natural morphological landscapes (for example, Fig. 3). Based on these results have been determined the rate of shoreline accretion/regression within the meters scale (Table 1).

The results of coastline changes shows the accretion rate on the back of Javad al aemme, Mogham, Nakhilu, Charak, Hasineh and Shenas ports due to up drift (generally West - East) over the accretion rate due to down drift (generally East - West). Instead of this trend, the accretion rate due to up drift is less than the accretion rate due to down drift in Aaftab, Lenge and Kong ports (Table 1). Also left coast of Chirouye head has erosional pattern and right coast of that has accessional pattern. This pattern is a way the top of head be displaced to east in study time-span (Fig. 3).

Table 1: coastline accretion/regression at the critical points in the study area (positive and negative values were respectively accretion and regression of shoreline)

Down drift accretion (m)	Up drift accretion (m)	Location	Down drift accretion (m)	Up drift accretion (m)	Location
+19	+43	Charak port	+43	+105	Javad al aemme port
+35	+122	Hasineh port	+82	+300	Mogham port
+127	+116	Bostaneh port	+33	+56	Nakhilu port
+33	+48	Shenas port	+83(right)	-45(left)	Chirouye head
+115	+57	Lenge port	+85	+54	Aaftab port
+127	+59	Kong port	+64	+90	Old Charak jetty

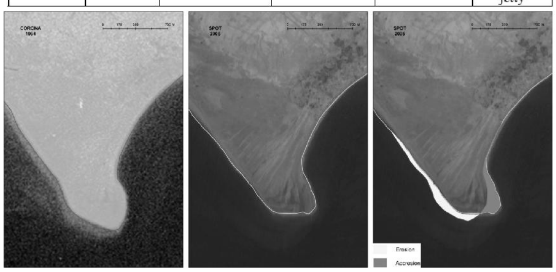

Fig 3: Extracted shorelines of Chirouye head base on CORONA (left), SPOT (mead) and sedimentation/erosion trend (right).

5. Morphological landscapes influenced of alongshore sediment transport

Coastal morphology directly affected by sedimentary processes, such as sediment supply by rivers and streams from land and coastal sediment transport currents. Alongshore currents as one of sediment transporters along the shorelines were putting order some natural morphological landscapes such as, alluvial sediments complex on drains mouths, river deltas, coastal sandbars and ridges. Thus, those be inclined over the time along the longshore currents and/or will have been special erosion or sedimentation patterns. These landscapes can be easily interpreted evaluation of satellite images. In this process have been used spot images. Therefore, morphological landscapes from Nayband cape to Chirouye head coasts indicate general alongshore trend to east. In these areas, small deltas of seasonal drains mouth (Fig. 4a) and some beach rims (Fig. 4b) have eastward trend. The morphological landscapes Between Chirouye head and Kalat bay coasts indicate general alongshore trend to west, so convergence of these trends causes Chirouye head (Fig. 4c). In these areas, small deltas of seasonal drains mouth of Kalat bay western coast have westward trend (Fig. 4d). Kalat bay eastern coast observed reverse trend, as deltas of seasonal drains mouth have eastward trend (Fig. 4e). This eastward trend was observed to Bostaneh head coastal morphology. This scape evident clearly in the Tangekhur river mouth, Charak estuary (Fig. 5a) and drains leaded to the sea from Hasineh salt dome (Fig. 5e). The same evidence can be seen to Bostaneh head. In addition, morphological landscapes of Shenas western coast show the eastward trend, so that the drains mouth have eastward trend in this area. The arrangement pattern of transverse sand dunes at Shenas head indicate converge two currents and south-eastward growth of sand dune system and creation of this head (Fig. 5d). In the coastal areas from Shenas head to Berke Seflin bay, some morphological landscapes have eastward trend, so can be cited the deposition pattern of drains mouth (Fig. 5b). Morphological coastal landscapes such as mouth and bars of estuaries and spits are inclined to the east from Berke Seflin bay Eastern coast toward east to Khuran area at Mehran river delta (Fig. 5c).

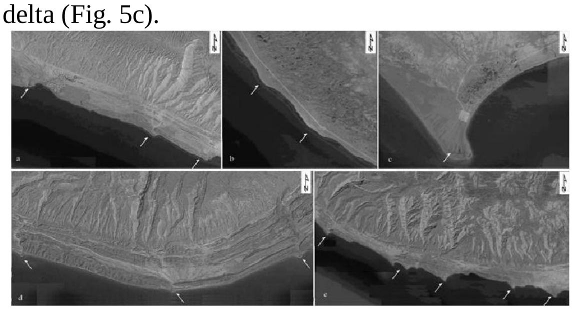

Fig. 4: a) eastward trend of seasonal drains mouth of the Nayband Cape eastern coasts. b) Eastward trend of Chirouye northwestern sandy beaches. c) Growth pattern of Chirouye head due to convergence alongshore sediment transport currents. d) Westward trend of seasonal drains mouth of the Kalat bay western coast. e) Eastward trend of seasonal drains mouth of Kalat bay eastern coast.

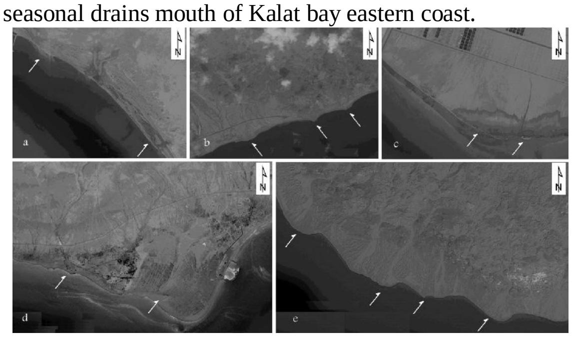

Fig. 5: a) Eastward trend of seasonal drains mouth and bars of Charak estuary. b) Westward trend of leaded to the sea seasonal drains mouth from Kong salt dome. c) Eastward pattern of estuaries bars and spits of Khuran area. d) Eastward trend of seasonal drains mouth of Shenas head western coast and arrangement pattern of transverse sand dunes. e) Eastward trend of leaded to the sea seasonal drains mouth from Hasineh salt dome.

Conclusion

According to the results of the coastline changes, can be settle the main alongshore sediment transport current along the coastal study areas. Attention to Javad al aemme and Nakhilu ports position, which sedimentation due to up drift was more than down drift in both of them, have eastward alongshore sediment current at Javad al aemme and Mogham areas and southward at Nakhilu area. Also eastward inclinations of morphological landscapes confirm this result in these areas, thus were established the result of the CERC formula. The arrangement pattern of transverse dunes, confirmed the regressional trend in the western coast and accretional trend in the eastern coast and this caused south-eastward accretion of the Chirouye head. This causes rotation of south-eastward sediment current along the eastern; towards the western coast and convergence with the south-westward sediment current in this head. This convergence was causing sedimentation and thus Chirouye head and its western coast has existed accretional model. Further, the results of the CERC Formula have shown convergence of these two currents within the Chirouye head. Attention to more accretion rate of shoreline due to down drift than up drift in Aaftab port and westward trend of mouths and small deltas of seasonal drains in western coasts of this area, the mostly sediment transport current in this region has east to west direction. Therefore, these settles conform to CERC formula results. Sedimentation within the Aaftab port pool also confirmed this trend (Fig. 6a), so the pool entrance built facing alongshore sediment transport current. However, coastal accretion trend and morphological landscapes have showed the west to east mostly sediment transport current in Hasineh and Charak areas. Based on morphological evidence, this current and westward current in Aaftab port area, divergence at Kalat bay. Thus, based on coastal accretions and sediment masses, alongshore sediment transport current were west-northwest to east-southeast in Charak port area, Tangekhur river mouth and Charak estuary and north to south in the Hasineh port area, which conform to current patterns resulted by CERC formula.

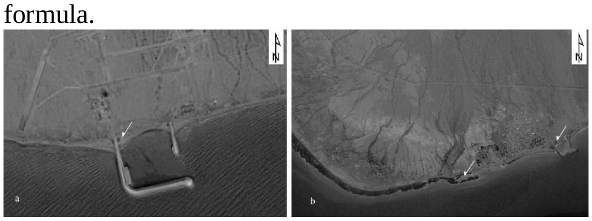

Fig 6: a) Sedimentation within the Aaftab port pool. b) Eastward trend of sand ridges on west coasts of Bostaneh port and sedimentation within its pool.

Westward mostly alongshore current was distinguished by more accretion rate of shoreline due to down drift than up drift and sedimentation on base of main breakwater in Bostaneh port conform to CERC formula results. On the other side, eastward morphological landscapes between Bostaneh port and head can sign up the west to east alongshore current (Fig. 6b), inconsistent with the CERC formula and coastline changes results. Noteworthy, the morphological landscapes such as sand ridges formed during the coastline changes study time period and inexistent in CORONA satellite image. This matter can be justified with build Bostaneh port, thus build that at 4 km away the Bostaneh head, and cutting the westward littoral drift by port, caused intensifies eastward currents effects, and the ridges formed after builds harbour. Eastward morphological landscapes from eastern coasts of Bostaneh to Shenas areas and arrangement pattern of Shenas head sandy dunes (Fig. 5d) point to occur alongshore current towards the east. Convergence of this current and south-westward current from the south-east coast of Shenas area, was created progressive shore with transverse dunes and formation of sedimentary Shenas head. All the morphological landscapes (Fig. 5b) and coastline changes from Shenas head to Berke Seflin bay (Table 2, coastline changes in Shenas, Kong and Lenge ports) conform to CERC formula results and despite the south-westward mostly alongshore currents. Meanwhile, construction of Shenas port facing to the south-westward alongshore currents has causing sedimentation in the pool. Turbulence between pool waters and waves is clearly visible in Fig. 5d. Because of the related to Qeshm island and existence of Mehran river great delta at the south-east and east of Berke Seflin bay, pattern of alongshore currents were shown rotation and dispersion in to south-east and south-west directions. Estuaries bars and spits were shown the existence of south-eastward current on the eastern coasts of Berke Seflin bay (Fig. 5c).

Attention to results, in some area that limited data or lack of substantial documented and preparing the field information were impossible, to inspect the output should used coastline changes and morphological settings with empirical relationships. In-attention to vital and citing only empirical relationships may cause wrong conclusion in analysing the sediment transport currents. In this case, implementations of coastal construction projects and coastal protection programs have risks such as damaging erosion or sedimentation. Including such events, can be mentioned in the Aaftab and Shenas ports. Other benefits of combining the studies of morphology and coastline changes along the empirical relationships, was taken the results from natural processes that shape the coast over the time.

These reasons were results from the reacting all effective processes in coastal area, which referring and use such results would be useful. Thus, can interpret any of coastal area contexts, such as littoral sedimentary cell boundaries and effect of human. Meanwhile the use of tools GIS is affordable because of high-speed, low cost and good accuracy in the information against such interpretations of field data.

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