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A Study of the Dynamics of Miani Hor Coastal Lagoon, Pakistan and Failure of Damb Fish Harbour

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ABSTRACT

To manage the coastal environment and its ecosystem require a thorough understanding of the area and selection of best environmental and engineering solutions for coastal problems. Miani Hor coastal lagoon, a typical choked lagoon is situated in Lasbela, Balochistan Pakistan and has a surface area of 363 km^2 with single inlet connecting the lagoon with Arabian Sea. As a result of high fish yield not only from Miani Hor, but also from offshore, village Damb along the Miani Hor lagoon has been converted in to landing site for small fishing crafts. Provincial government planned and constructed a fish harbour at Damb but, the construction work could not be completed and had to be quit due to the siltation of harbour basin. In order to ascertain the factors that caused the fish harbour project to fail, a detailed study of the area was conducted for oceanographic and meteorological parameters.

The Miani Hor coastal lagoon comprises of narrow twisting channels influenced with tidal fluctuation and mangrove trees. The seawater velocity was 1.42 m sec^{-1} and salinity values ranged from 37.6 – 37.9 PSU (Practical Salinity Unit). The single inlet of lagoon attenuates short period waves but allows long period waves such as tide to penetrate in to Miani Hor lagoon. So the only dynamical force that keeps littoral drift is tide driven current. Fish harbour with a basin of 225 x 175 x -3.5 m, and breakwaters was constructed that silted up even during construction stage. The result of the study revealed that fish harbour was designed in such a way that used to protect the jetty from wave forces whereas, the jetty in Miani Hor it should had been designed to flush out the sediments with the natural hydrodynamical forces. The construction of breakwater allowed sediments to settle down in the calm basin with rate of accretion more than rate of excavation from basin. To ensure a technically successful coastal project, the involvement of coastal engineers is the ultimate fate. The coastal engineer can better pass his or her experience and judgment on to other decision makers, who may not have coastal expertise to plan and design a viable coastal project that is environmentally sound.

Keywords: *Arabian Sea, Miani Hor lagoon, chocked coastal lagoon, littoral drift, breakwater, accretion, satellite image processing, fish harbour, mangrove.*

I. INTRODUCTION

Coastal regions represent areas where a natural interaction between tidal movements, freshwater inputs from rivers and coastline result in a finely balanced ecosystem (Shore Protection Manual, 1984). The land – sea interaction make the area economically important, not just nationally due to importance of ports/harbours and industrial development, but also locally for fisheries and tourism. Therefore coastal zones ecosystems are managed in order to directly or indirectly benefit to human beings. As a result, managers of the coastal zones must understand the ecological basis of ecosystem sustainability and the inextricable interconnectedness of the human well-being (Miller, 2003).

Selection of the best environmental and engineering solution to a coastal problem requires a thorough understanding of the complexity and diversity of the coastal zone. A clear definition and cause of the problem as well as a comprehensive review of potential solutions are required to be considered. The principal environmental factors that should be considered in design and construction and techniques to attain environmental quality objectives should be discussed before initiating a viable coastal project.

Pakistan is fortunate that it has been bestowed with a vast coast of 990 km along the Sindh and Baluchistan provinces, of which 241 km is in the province of Sindh and 660 km coast (Figure 1) with highly productive sea, rugged and rough terrains with very low population density and hence negligible development work along the coast in the province of Balochistan (Baig & Iftikhar, 2007). Because of low population density, Baluchistan coast is habitated at three small towns; Ormara, Pasni and Gwadar and, at some fishing villages where fishermen could beach their catch and subsequently boats easily.

The coastal belt of Baluchistan contains two environmentally important coastal lagoons; Miani Hore in Lasbela and Kalmat Khor in Makran. Both of the coastal lagoons are full of bio-diversity life due to the existence of Mangrove forests; about 8500 acre at Miani Hor and 480 acre at Kalmat Khor (Qureshi, 2005) and seasonal fresh water runoff.

Miani Hor lagoon (Figure 1) is situated approximately 95 km west of Karachi in Sonmiani Tehsil district Lasbela, Balochistan (Quraishee, 1988). The lagoon is about 50 km long covering an area of 363 km^2 with an inlet of about 2000 m wide connecting the lagoon with Arabian Sea. Nearly 100 species of fish have so far been recorded from mangroves in Pakistan, of which 46 species were in fingerling or young stages while 52 in sub-adult or adult stages. In fact, more than 75 percent of commercially caught fish may inhabit mangroves at some point of their life (Baig & Iftikhar, 2007).

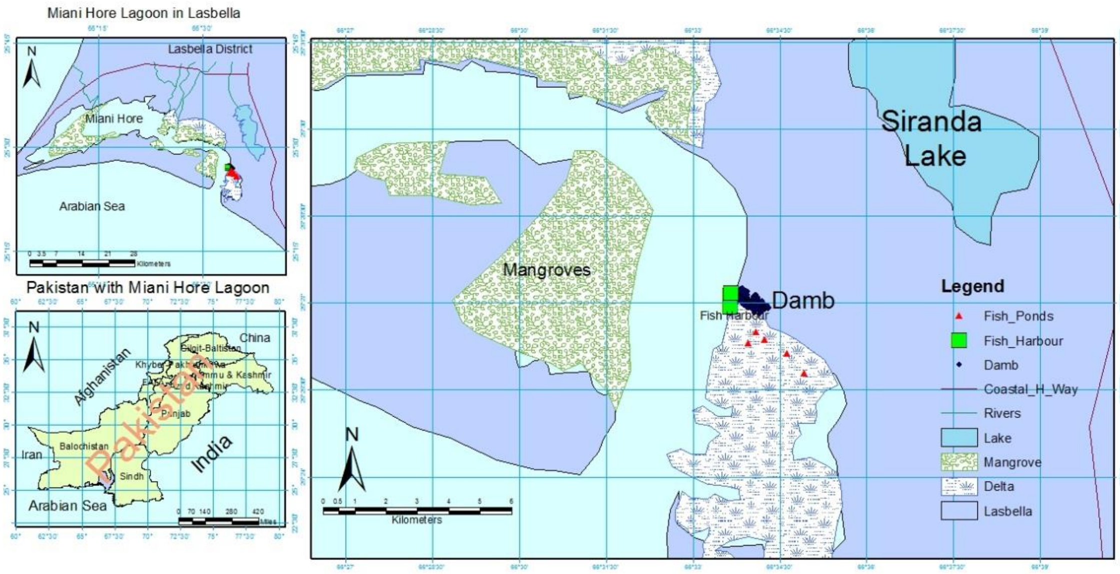

Figure 1. Location map of Miani Hor Lagoon in Balochistan, Pakistan and Damb Fish Harbour along Miani Hor Lagoon.

As a result of high fish yield from Miani Hor, at least three villages are situated on the coast of Miani Hor Lagoon; Sonmiani, Bheera and Damb. The village Damb has been converted in to landing site for small fishing crafts that catch fish stock offshore due to favourable landing condition and proximity to mega metropolitan city Karachi.

In 2005, the Government of Balochistan took steps to develop the modern fish landing facilities at different places along the provincial coast. Due to the importance of Damb village and Miani Hor coastal lagoon, a Fish harbour at Damb was planned and construction work was initiated. However, the construction work could not be completed and had to be quit due to the siltation of harbour basin even before the completion of dredging work.

There may be number of reasons for the failure of this fish harbour project relating to structural design. It is recognized that experienced coastal engineers are well aware of the concerns with the forces acting on the coastal structures and thus, are supposed to produce project plans based on professional judgment to make project sustainable.

The present research work concentrates on the hydrodynamical forces acting in the Miani Hor lagoon in District Lasbela, Balochistan in general and investigate the reasons in particular that caused the failure of fish harbour of Damb along Miani Hor coastal lagoon.

II. MATERIAL AND METHOD

The area of study is Miani Hor coastal lagoon along the Balochistan coast, Pakistan in general and Fish harbour at Damb on the coast of lagoon in particular (Figure 2). National Institute of Oceanography Karachi carried out oceanographic observation of the Miani Hor lagoon and site survey of abandoned fish harbour at Damb Lasbela, Balochistan. Data was collected sporadically spaced at three places inside the lagoon marked on the location map (Figure 2). The water samples for the analysis of seawater salinity were taken using Nisken sampling bottle while the velocity of the seawater was recorded with the help of direct reading Toho Denton Current Meter. Seawater salinity was computed in the laboratory by using digital display OSK made Salinometer from water samples collected and temperature with the help of ordinary thermometer. For the determination of sediments, van veen grab sampler was used and sediment samples were analyzed for grain size distribution.

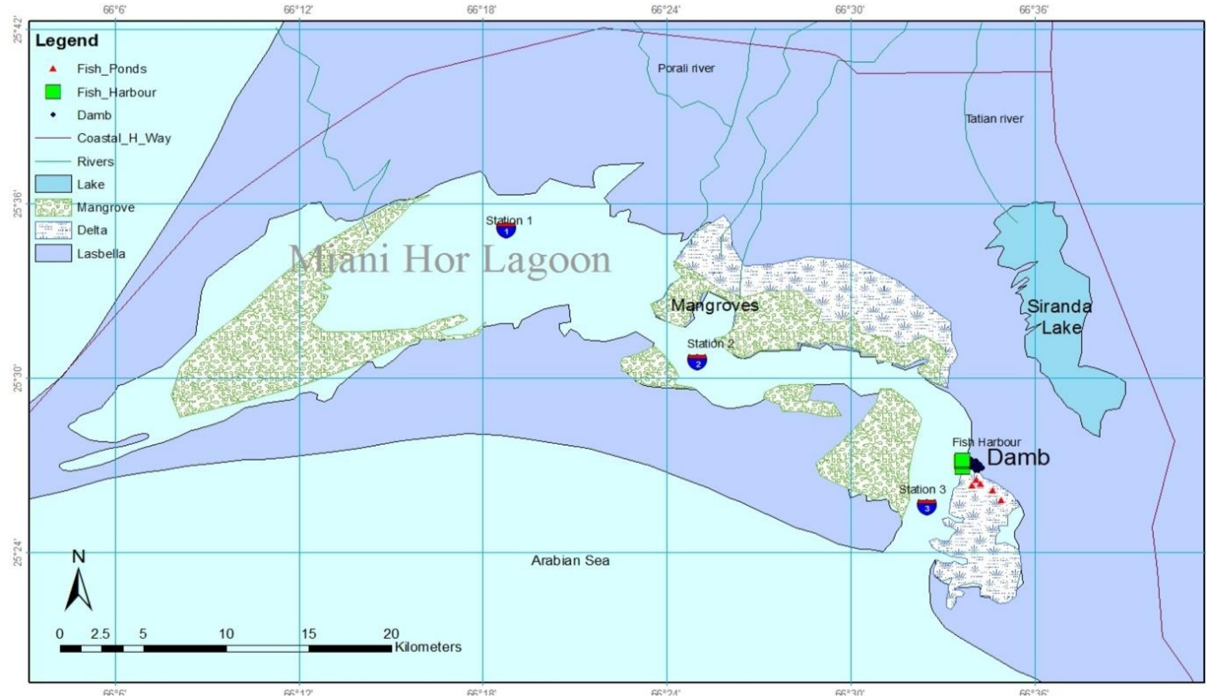

Figure 2. Location map of fish harbour at Damb village, mangrove forest in lagoon with Porali delta and oceanographic sampling sites in the Miani Hor Lagoon.

In order to determine the rate of evaporation, a meteorological observatory was established in summer for three months at Damb with standard Evaporation pan. Unfortunately tidal level could not be determined however, it was observed that tide levels and times predicted for Karachi matched with the water levels within the lagoon.

SPOT XS imagery for 3rd September 2005 level 2A was obtained and processed for tracing the signatures of sediment movement and identification of mangrove vegetation using on ER Mapper 7.1. Data was processed on Matlab and presented using ESRI ArcMap 10.1.

III. OBSERVATION

The Tract

Miani Hor tidal lagoon is situated approximately 95 km west of Karachi in Sonmiani Tehsil district Lasbela, Balochistan. The district Lasbela is bounded on the north by Khuzdar district, in the west by Hala, in the south by Arabian Sea and in the east by Dadu and Karachi Districts of Sindh (Figure 1). The tidal lagoon is about 50 km long covering an area of 363 km^2 (Baig & Iftikhar, 2007). The Porali River and its distributaries drain into the lagoon. However, Titian river, a distributary of Porali River drains in to Siranda lake east of lagoon.

Geographical and Physical Features

The district Lasbela consists of alluvial plain extending southwards up-to the bay of Somiani and the hilly regions situated east and west of the plain. The plain itself consists of alluvium deposits of Porali and other small seasonal rainwater rivers. At the edge of the plain, near the coast, lie raised sea-beaches, situated some 15 to 25 meters above sea level. The east of the alluvial plain exhibits the greatest variety of rocks forming the Anticlinal Ranges, which are separated by valleys. The hilly region is situated on the west of the alluvial plain of the Porali and extends along the Balochistan coast. The whole of the eastern part of the district is mountainous. The plain in the centre, comprising the greater portion of the district, is triangular shaped. The principal hill ranges are on the western slopes of the Kirthar mountains, as far as the north of Lak Phusi. The other side includes the main ridge of the Pub range with parts of the Khude or Khudo and part of the Pub range. The third side; comprises the lower slopes of the Balochistan coast (Figure 1).

The dimensions of lagoon change greatly between high and low tides twice a day due to tidal water fluctuation that enters into lagoon from single inlet connecting the lagoon with the sea. The rise and fall of the tide in the sea causes flow of water into and out of inlet that in turn causes fluctuation of water level of the lagoon. The steep mud banks are visible at low tide surrounded by numerous flat islets of mud covered with mangrove. As a result of occasional fresh water runoff into the lagoon, a small Porali delta has been developed which is enriching the mangrove forest in the vicinity. The Porali river runs over a stony course and has low banks as far as Mangia, where it passes through clay soil. About 89 km north of Shah Lakhra, a branch of the Porali river, known as the Titian river, takes off and eventually flows into the Siranda lake.

The analyses of sediment samples indicate that lagoon bed is consisted of silty clay with few sandy patches. Beach material is composed of medium and fine sand with some stones. The soil of Lasbela up to Miani Hor Lagoon is alluvial, and is composed of light loose clay, mixed with fine sand with saline ingredients. The main minerals are shale, marble, lime stone, barite and serpentine while basalt and magnesium are also found in the district. At the head of the valley above Bela, there are numerous streams and watercourses which drain either in to Lagoon or directly to the sea.

Climate

The coastal area of Miani Hor lagoon like other coastal areas of Balochistan is moderate and moist. The winter extends from October to January, with the minimum temperature reaching to 8.3 ºC in the month of January. The average annual minimum temperature was 18 ºC, however, in February and March the climate is moderate. April to September constitutes summer, during which the hottest months of May and June are observed. Miani Hor lagoon often faces the highest temperature (43 ºC) in the month of May (Ajmal & Bilqees, 2002).

Table 1. Monthly meteorological observations as recorded at Sonmiani by NIO.

Month	Relative Humidity (%)	Average Daily Maximum Temperature (ºC)	Daily Mean Minimum Temperature (ºC)	Average Wind (Kts)	
				Speed	Direction
JAN	64	25.8	10.4	2.5	NW
FEB	68	27.7	12.7	3.1	NW
MAR	73	31.5	17.6	3.9	NW
APR	76	34.3	22.3	5.9	NW
MAY	75	35.2	25.9	8.6	W
JUN	76	34.8	27.9	8.2	W
JULY	80	33.1	27.4	7.8	W
AUG	82	31.7	26.1	8.3	W
SEP	81	32.6	25.2	6.9	W
OCT	84	34.7	21.0	3.2	NW
NOV	65	31.9	15.9	2.7	NW
DEC	**62**	**27.4**	**11.6**	**2.2**	NW

The north-western wind (locally called Gorich) prevails from October to February and becomes particularly strong towards the end of the cold weather season. The Gorich becomes a burning hot wind during April and May, when it is known by locals as Liwar. The wind roses for summer (Figure 3) and winter (Figure 4) are given bellow.

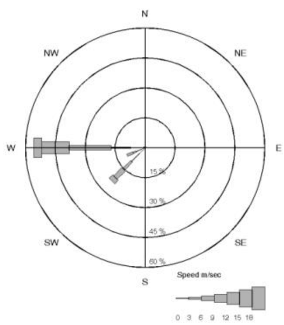

Figure 3. Wind rose plotted for the wind speed and direction recorded during summer showing the dominant direction with maximum velocity from west.

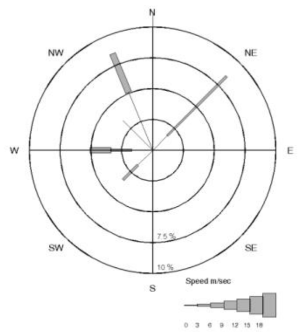

Figure 4. Wind rose plotted for the wind speed and direction recorded during winter showing the dominant wind from northwesterly.

Rainfall is unreliable and uncertain however, most rain falls in summer during June, July and August and with little rain in January and February. The total annual rainfall of 205.6 mm is reported by Pakistan Meteorological Department in the Lasbela district (Ajmal & Bilqees, 2002). The rate of evaporation computed during observation of three months is 2.21 m $year^{-1}$ which is less than 3 m $year^{-1}$ on average. The seawater velocity data collected during ebb tidal stage (Table 2) revealed that maximum ebb velocity was 1.42 m sec^{-1} whereas salinity values are normal to seawater salinity values ranging from 37.6 – 37.9 PSU (Quraishee, 1988).

Table 2. Oceanographic observation taken during summer in the Miani Hor coastal lagoon.

Station	Observation Depth (m)	Seawater velocity (m sec^{-1})	Seawater Direction (ºN)	Air Temperature (ºC)	Seawater Temperature (ºC)	Seawater Salinity (PSU)
1	0.5	1.05	200	29.2	28.3	37.61
	4.0	1.0	210			
2	0.5	1.4	210	29.4	27.7	37.91
	7.0	1.42	210			
3	0.5	0.5	220	29.9	29.4	37.6
	8.0	0.4	220			

Aviciennia marina, Rhizophoras mucronata and Ceriops tagal are three common varieties of mangroves present in the Porali delta and in Miani Hor (Figure 5) lagoon (Baig & Iftikhar, 2007).

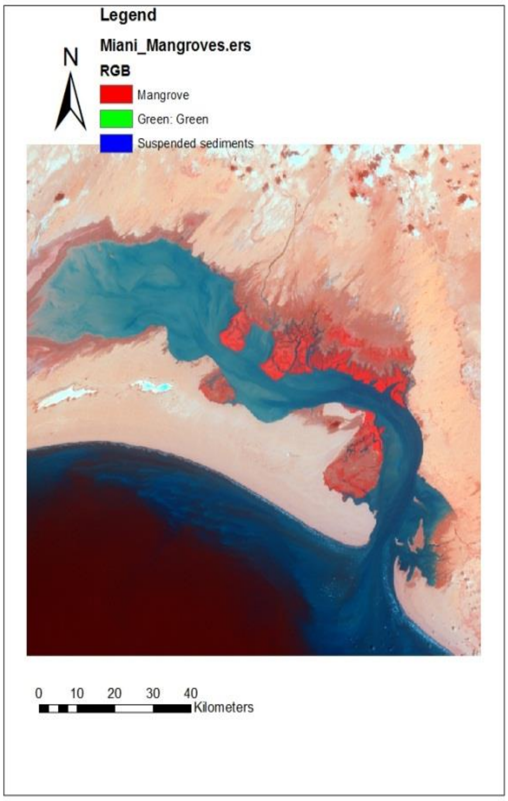

Figure 5. The FCC of the SPOT XS processed for classification and identification of mangrove forest using NDVI algorithm in the Miani Hor lagoon. The processed imagery clearly show the dominant sediment movement as well as mangrove forest.

Layout and Design of Fish Harbour as Constructed

A fish harbour with a basin of 225 x 175 x -3.5 m and a precast RCC jetty of 4.5 x 40 m on 9 pairs of 0.6 m diameter piles spaced 4.5 m and penetrated 18 m deep in to the bed is designed and constructed with breakwaters and small harbour entrance (Figure 6). The jetty was designed 3.12 m high from chart datum which is zero of tide level. All the 18 piles were completed, whereas, precast slabs could only be placed upto 20 m.

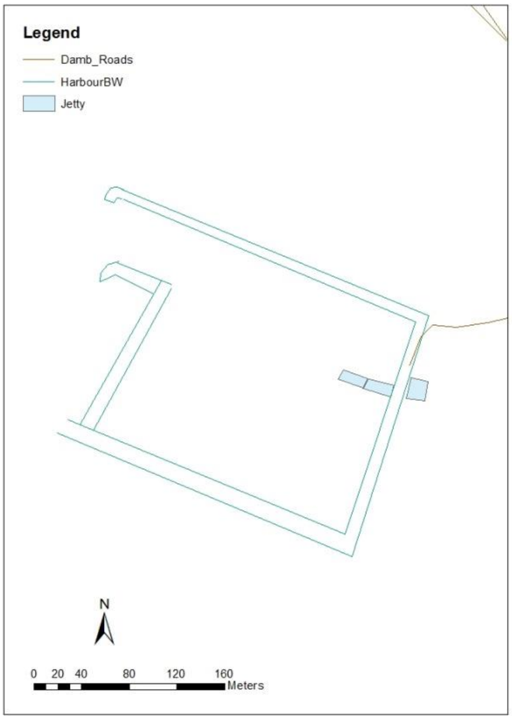

Figure 6. Layout and Design of constructed fish landing jetty and breakwater in the Miani Hor lagoon, at Damb village.

IV. RESULT

Miani Hor tidal lagoon is about 50 km long covering an area of 363 km^2 with an average depth of 6 m that varied from 8 m near the lagoon inlet to 4 m near the tail of lagoon (Quraishee, 1988). The Porali River and its distributaries drain into the lagoon. The dimensions of lagoon change greatly between high and low tides twice a day due to tidal water fluctuation that enters into lagoon from single inlet connecting the lagoon with the sea.

Although there is no tide measurement data is available for the lagoon, however, visual observations made at the time of recording the oceanographic observation revealed that due to the sufficient width and depth of inlet (2000 x 4 m) there is no difference of timing and levels between Karachi tide and tide at Damb. The rise and fall of the tide in the sea causes flow of water into and out of inlet that in turn causes fluctuation of water level of the lagoon. The Miani Hor lagoon area comprises of narrow twisting channels, with steep mud banks visible at low tide surrounded by numerous flat islets of mud covered with mangrove trees (Figure 4).

As a result of occasional fresh water runoff into the lagoon, a small Porali delta has been developed enriching the mangrove forest in the vicinity. Since Porali is a seasonal river that drains only when there is rain in its catchment area so very seldom it makes any impact on the water quality of Miani Hore lagoon, thus most of the time due to excessive rate of evaporation (3 m year^{-1}) the salinity of lagoon remains higher than the open sea to serve as negative estuary diluted by seawater mixing during flood tide. The depth at the inlet is relatively smaller than the average depth of lagoon therefore there is exchange of water during tidal fluctuation.

The wave condition off lagoon is considered as high energy waves with 90% wave ranged between 1 – 2 m (Figure 7) and period of 6 – 10 sec (Figure 8) with dominant wave direction from southwest, however, inside the lagoon as a result of single and 4 m deep inlet, these waves get attenuated with no significant height. The only dominant force that keep the bottom sediment of lagoon in suspension is tidal driven circulation. During peak flood and ebb velocitie, sediments are suspended and carried away and during slack periods they are deposited (Figure 9).

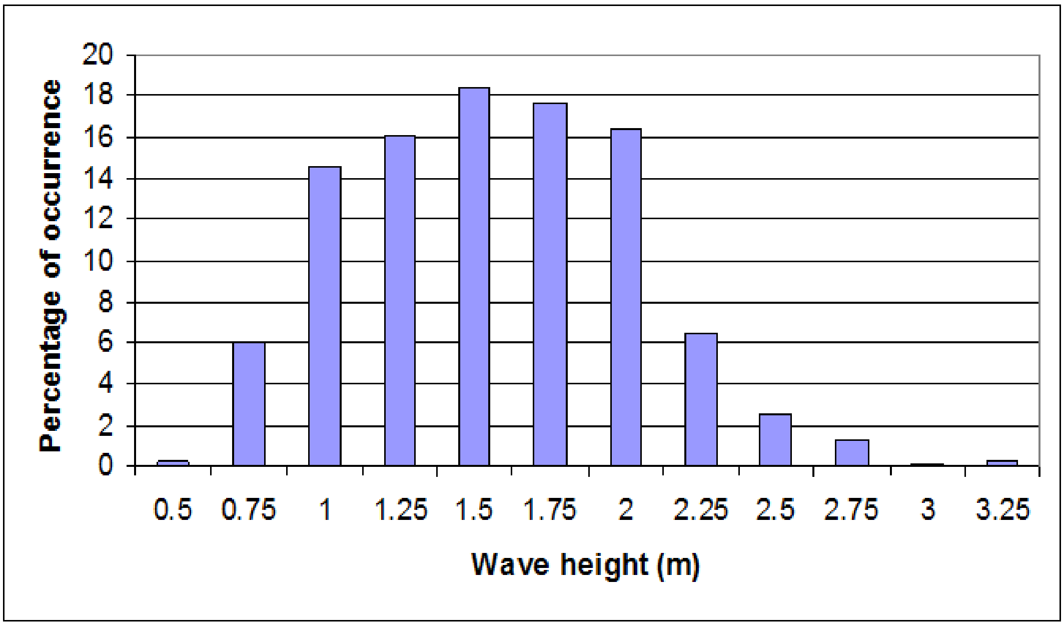

Figure 7. Percentage of occurrence of significant wave height offshore Balochistan coast recorded during summer season. Graph depicts that 90% of the waves ranged between 1 – 2 m.

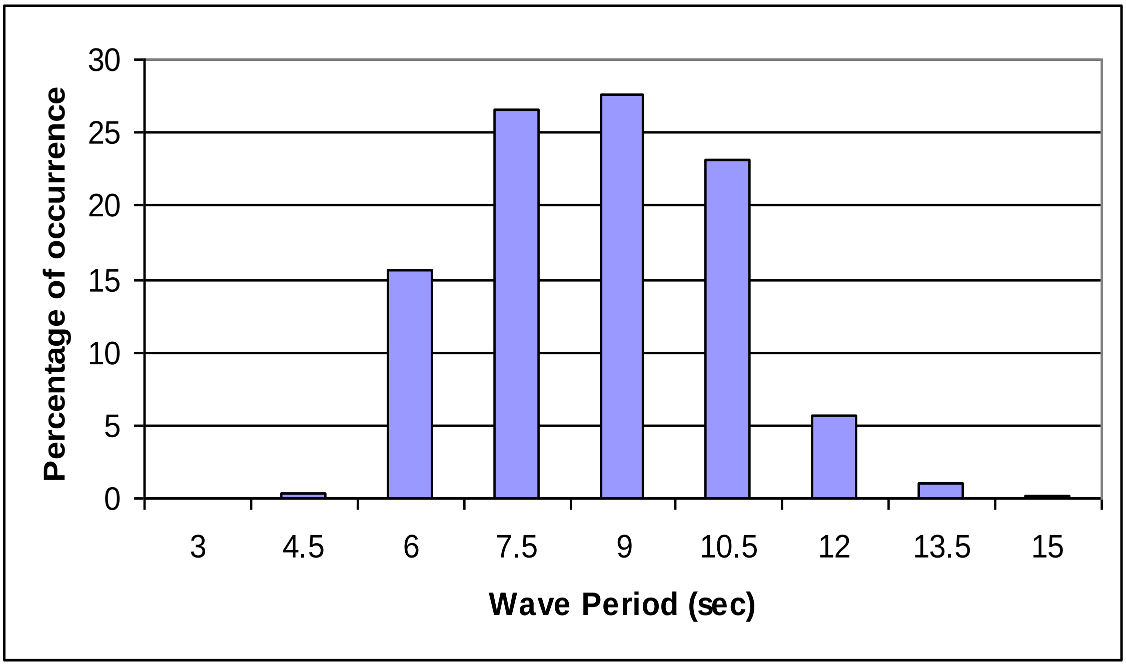

Figure 8. Zero crossing wave periods recorded offshore Balochistan coast during summer season.

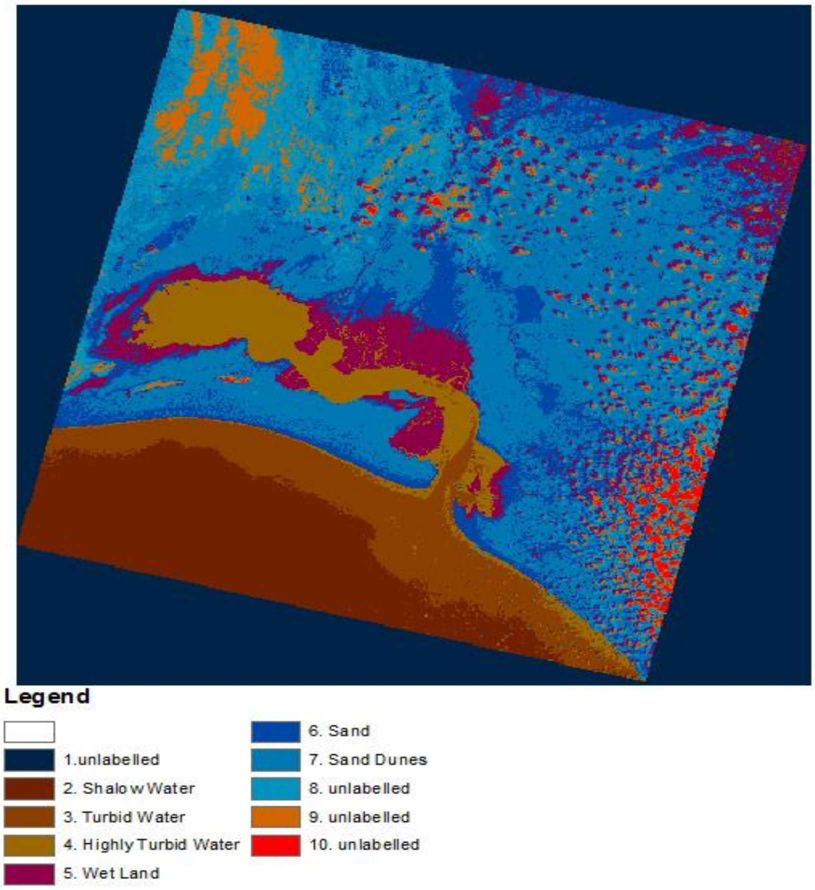

Figure 9. SPOT XS imagery of 3rd September 2005 processed for sediment transport in and around Miani Hor lagoon. The figure show that sediments brought form lagoon are deposited offshore keeping inlet open as a result of jet flow water.

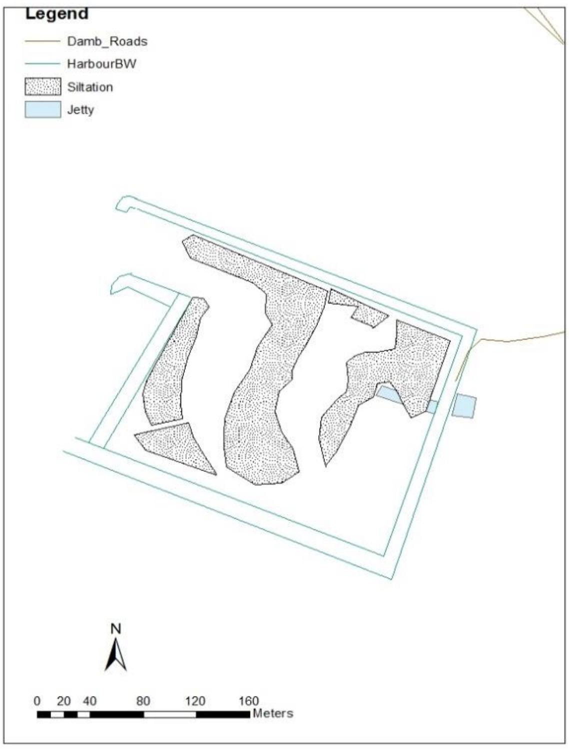

Figure 10. The silted fish harbour at Damb, Balochistan showing the areas of accretion in the harbour basin that forced the development work to abandon.

The survey of fish harbour revealed that it has been silted up and construction work has been abandoned halfway and turned into a playing ground for local children even in high tide. In order to map the silted area in the basin, satellite imagery was used in ESRI ArcMap and shown in figure 10.

V. DISCUSSION

The geomorphological condition of Miani Hor lagoon depicts that lagoon is typically choked coastal lagoon due to its single inlet because a choked coastal lagoon is an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets which remains open at least intermittently, and have water depths which seldom exceed a couple of meters. Further to that, choked lagoons usually connected by a simple long, narrow entrance channel, along coasts with high wave energy and significant littoral drift (Kjerfve, 1986; Kjerfve, 1994). The coast facing the sea off Miani Hor is a high wave energy coast with mean tidal range of 2.5 m and characterized as mixed tide.

In confirmatory to Smith (1994), Miani Hor lagoon inlet also plays a central role in the lagoon-sea exchange phenomenon, and acts as dynamic filter to eliminate the short period wind generated waves (Kjerfve, 1986; Kjerfve et al, 1990; Kjerfve & Knoppers, 1991). The narrow Inlet of the lagoon, attenuates the short period oscillations that are produced offshore and approach lagoon inlet. Hence, the circulation in the Miani Hore lagoon is predominantly, tidal driven. The morphology of the Miani Hor lagoon inlet allows the long period waves such as tidal wave to penetrate into the lagoon and keeps the lagoon - sea exchange in action. The orientation of the lagoon does not coincide with the local and non-local wind direction. Hence, winds that blows during winter from northwest, forces the lagoon water out of lagoon, while summer winds can have less than 2 km fetch length which is insufficient to produce any wave of significant height and remains negligible.

The only hydrodynamical force that produces the circulation with in Miani Hor lagoon and lagoon – sea circulation is the tidal water fluctuation which causes seawater to move in and out of lagoon with the variation in water levels. The salinity values as recorded also confirm the circulation pattern due to small difference with in lagoon and offshore.

The high velocities of ebb tidal currents maintain the main channel of inlet to remain open and deposit sediments offshore. Ebb tide the bed erodes with accelerating flow and accretes with decelerating flow. This fact is clearly depicted by the SPOT imagery processed for littoral drift movement and sediment transport as a result of seawater current. Therefore, Miani Hor lagoon is the area where natural interaction between tidal movements, freshwater inputs from seasonal rivers and coastline result in a finely balanced ecosystem. In addition, it is economically important, for prospective and well-designed ports, harbours, fisheries, tourism and industrial development if the hydrodynamical forces acting in the lagoon are properly studied and taken in to account.

Hence, the fish harbour embarked upon along the coast of Miani Hor, lacked the understanding of hydrodynamical forces that play in the area, in this case tidal current and sediment circulation. The fish jetty at Damb is wrongly protected with the rubble-mound breakwaters with small allowance for boat entrance even though the lagoon is well protected from wave penetration from seaward and there is no chance for waves to develop with in the lagoon due to inadequate length of fetch. The breakwater wall around the jetty, not only zeroed the wave action but also seawater current, and provided a calm water basin to fluctuate with tidal movement. The design of calm water basin deprived the basin to naturally flush out the sediments that are being brought in during flood tide and hence embellished the sediment accretion process due to availability of manmade sediment pocket. Therefore, the designing of breakwater around fish lending jetty at Damb is unnecessary, it should had been designed in such a way that sediment should have been flushed out naturally with force of tidal current.

To ensure a technically successful coastal project, the involvement of coastal engineers is the ultimate fate. The coastal engineer can better pass his or her experience and judgment on to other decision makers, who may not have coastal expertise to plan and design a viable coastal project that is environmentally sound.

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