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Research Article

COASTAL PROCESS AND PORT DEVELOPMENT: A CASE STUDY OF PORT DEVELOPMENT IN NORTH KONKAN

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ABSTRACT
The coast of Maharashtrahas two major ports of Mumbai and Jawaharlal Nehru Port. Both these ports alone handle about 45% of the total maritime trade of India. These ports are presently reeling under pressure due to over congestion and increased turnaround time of ships and limited draft depths. With the idea of making Maharashtra a preferred destination for maritime trade, Maharashtra Maritime Board (MMB) was founded in 1996 with an aim to develop new ports to accommodate modern ships, which are bigger and need greater draft depths. The MMB has identified 43 sites to develop Multi Purpose Terminals and Captive Jetties to cater to the need of industries as well as reduce the burden on existing ports along the Konkan Coast of Maharashtra.

The sites selected for port development by the MMB are located at or near the entrances of estuaries. The sedimentation pattern in these estuaries is dependent on the physical configuration of the coast, seasonal characteristics of monsoon,which bring changes in the hydro-dynamic conditions and produce complex pattern of sedimentation in tidal creeks and estuaries. The littoral drift along the shore and the tidal influence further contribute to the distribution of these sediments. The sediment deposits in form sand bars and sand banks block the estuary entrances. These sand bars and banks change their orientation seasonally and restrict the draft depths available for the larger ships as well as pose hazard to navigation. Therefore it becomes necessary to look into the coastal processes and their influence on the sand deposits and the searching for solutions to overcome this problem.

This paper is an attempt to look into the coastal processes and their influence on the operational feasibility of these suggested port sites in terms of obtaining and maintaining draft depths needed to keep the ports operational.

Key Words: *Ports, Congestion, Sedimentation, Coastal Processes*

INTRODUCTION
The changing economic scenario after liberalization has brought about substantial changes in the international trade of India. With 95% of India’s foreign trade being sea-borne, ports become a crucial infrastructure to achieve these set targets. Ports are the dynamic nodes in the supply chain and are centers for integrated transport and logistics platforms in international trade (Ranade). Ports also stimulate trade and regional development.

The major ports in India are operating at more than their saturation levels. The major ports have handled a record traffic of 383.75 million tones 2004-05. The net result was increasing pressure on port infrastructure, congestion and high transport cost due to high pre-berthing detention and turnaround time of vessels.

To further compound the problems there is a question of increasing size of vessels and need for specialized cargo handling capabilities. Therefore, the ports should be geared up for deepening their draft for accommodating these larger vessels. In other words, if we have to compete with other ports of the region, ports must create handling facilities at par with the world standards.

The two major ports of Maharashtra, Mumbai and Jawaharlal Nehru Port handle more than 45% of India’s maritime trade. Both these ports are already reeling under pressure and have certain basic problems that have contributed to problems like traffic congestion and turnaround time. For example

Mumbai port had a turnaround time of 8 days where as the JNP again in Mumbai has a turnaround time of 4.8 days.

The Government of Maharashtra took initiative to develop ports in Maharashtra and formed the Maharashtra Maritime Board in 1996 with the purpose of developing minor ports. It aims at making Maharashtra into a preferred destination for maritime trade. It also aims at bringing in the development of ports with various facilities and aims to attain ensured balanced development along the coast with reference to industrial, social and human development by creating a world-class maritime infrastructure along the coast of Maharashtra. The MMB, for the purpose of developing minor ports, is all set to improve the existing 48 minor ports in the State. Over and above this, 35 creeks and rivers have been identified as having the potential for the construction of new ports.

The choice of these sites leads to some serious questions that need to be addressed to.

Study Area

Konkan is a narrow coastal plain adjoining the Arabian Sea. It stretches between, the Damanganga River (20^{o} 20' N) in the north and the Terekhol Creek (18^{o} 42' N) in the south over a length of 410 km as the crow flies. This is a long narrow coast along the western margins of Maharashtra, separated from the Deccan plateau by the Sahyadri escarpment with an average elevation of 1000 meters. The width of this coastal plain varies from 40 to 50 km. It is wider in the north as compared to its southern parts (Fig. 1).

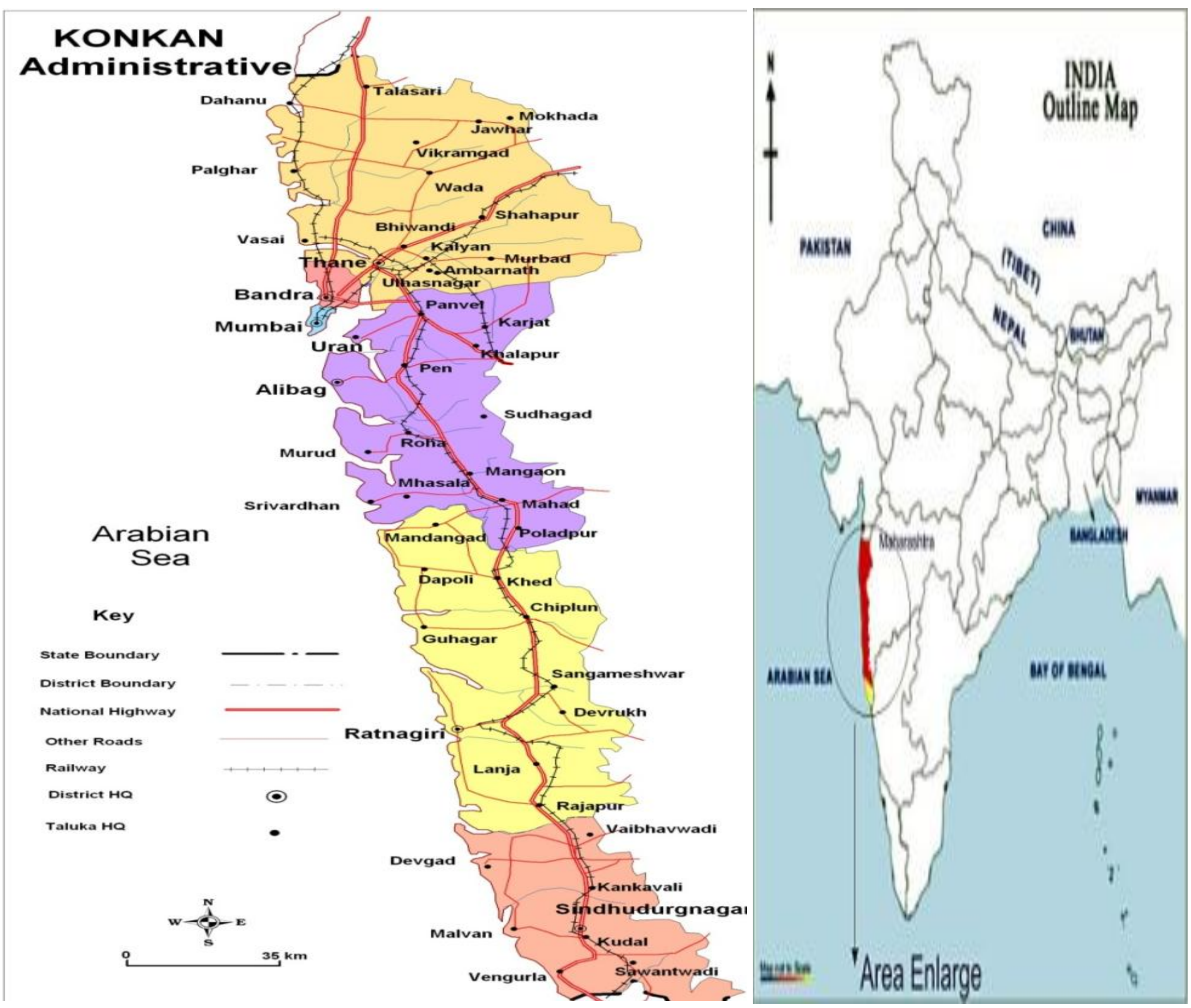

Figure 1: Study Area

New Ports of Konkan

The 43 identified by MMBsites along the Konkan coast of Maharashtra to develop alternate port sites will be of three types;Intermediate ports, Multi Purpose Terminals (MPT), minor ports and Captive Jetties (CJ)to cater to limited services. Most of the sites selected are at estuary mouths or inside the estuaries in protected bays. Therefore selection of these sites will have to be investigated carefully keeping in mind the difficulties in operational feasibility in terms of having the required draft depths as well as maintaining the draft depths to accommodate the ships. These depths are influenced by sedimentation. The sedimentation process is influenced by surface and sub-surface forces like geology and climate,the physical configuration of the coast, the seasonal characteristics of monsoon and the tidal influence on sedimentation.

Sedimentation on River mouths and Coastal Littorals of Konkan

Rivers of Konkan are short and swift and seasonal in nature. They follow a short straight course with steep gradients through middle Konkan to enter the Arabian Sea through estuarine heads. Due to the short length that these rivers possess the proportion of tidal length to the non-tidal freshwater length is as high as 1:1. The tidal range also increases from about 3 meters in the south to 5 meters towards the northern end of Konkan. There is also a reasonable ground to suspect that during the pre-historic and historic period the location of the tidal heads has shifted downstream, due to permanent blocking of the river mouths by sand banks and bars and partly by occasional spits protruding across the mouth almost to the mid-stream level (Table 1).

Table 1: Konkan-River Mouths and associated Geomorphic Features

River	Length (km) and Orientation	Drainage Area Basin Km2	Associated Geomorphic Features
Vaitarna	146, E-W	3647	Estuarine with thick sediment accumulation at mouth
Ulhas	140, E-W	3804	Estuarine and Sand bar at mouth
Amba	69, NE-SW	907	Estuarine, with thick sediment accumulation at mouth
Kundalika	45, E-W	778	Thick Sediment accumulation at the mouth.
Savitri	97, E-W	2299	Thick layers of sediment at mouth old bars beaten back into mouth and new bars constantly in formation.
Vashisti	80, E-W	2215	Thick Sediment at mouth, thickness 8-26 m, silty sands
Shastri	65, E-W	2296	Sand bar at mouth
Kajvi	64, E-W	524	Sand bar at mouth
Muchkundi	62, E-W	825	Sand bar at mouth
Kodavli	54, E-W	588	Sediment accumulation at mouth
Vagotan	68, E-W	894	Sediment accumulation at mouth
Gad	74, E-W	973	Sand spit at mouth
Karli	75, E-W	816	Sand spit at mouth

(Source: Gujar A.R. NIO 1995)

The transport and trapping of sediments are controlled by tidal dynamics, river discharge and particle dynamics throughout the estuarine system. Sediment budget is a quantitative inventory of all the sediment inputs, outputs and storage within the system. Estuarine processes control the distribution and transportation of suspended sediments. These processes vary in a systematic manner within tidal and weather cycles. During a periodic event such as the monsoon season, estuaries can carry high amount of suspended sediment loads and this can drastically change the pattern of sediment transport and dispersion in the system (Nichols, 1977). The increased suspended sediment into the estuarine ecosystem is causing enormous economic burden by way of increased investment the infrastructures for navigation and flood mitigations.

This poses two major problems; one that estuaries are navigable only at high tides and second the high tides submerge some of the bars at the estuary mouths thus posing a threat to safe navigation.

It is therefore necessary to study the processes governing the sediment movement in order to understand contemporary problems in estuarine environment such as reclamation, harbour development and dispersal of pollutants.

The factors that influence the sedimentation process include;

Changing sea levels: Sea level is subject to short term changes either due to daily tides, or annually consistent with the latitudinal movement of the sun over the year. Apart from short term oscillations, long term oscillations are caused by worldwide changes that are global glacio-eustatic changes. There are also regional changes that are restricted to limited stretches of the coast due to tectonic movements. The two may at times coincide enhancing the rise or fall of sea level.

Since the end of the last of the Ice ages, the sea level has been rising initially rapidly but later slowing down to reach a nearly stable level at or around the present sea level about 6000 BP (4000 BC). These changes leave their imprints on the shore landforms as well as near-shore underwater features.

Geology: The predominant rock is solid basalt with variations like amygdular and vesicular basalts and intermediate basic–acidic rocks. The geology of Konkan undergoes a change as one goes from south to north. Except in the extreme south (south of Malvan), Konkan is dominated by the Upper Traps of the Tertiary period. As one proceeds north, the lowland trap landscape of the south gradually changes primarily due to the increasing occurrence of acidic traps. The underlying geology of North and Central Konkan rivers dominates erosion on a larger scale due to heavy monsoon and steep slopes and relatively wide river valleys as compared to shorter rivers of southern Central and South Konkan. Here the predominant lithological surface being laterite, the rain water seeps through it, thus reducing its surface run-off and erosional potentials.

Near-Shore Circulation: One other important force that influences the sedimentation pattern is the coastal circulation of the south-west monsoon along the Konkan coast. The annual rhythm of monsoon cycle commences due to drastic change in the atmospheric pressure and wind distribution north of the equator during April with the setting in of stronger, moisture-laden southwest monsoon winds.

The general circulation of the south-west monsoon and the northeast wind season sets off littoral drifts which are responsible for many coastal depositional features. The long-shore littoral drift contributes to coastal erosion and accretion along the west coast. Long shore net drift direction is known from various coastal landform indicators and off-shore turbidity distribution pattern. Studies of landform indicators suggest that during the south-west monsoon period, strong southerly currents and dominant south-westerlies erode protruding headlands, and deposit eroded material, though partially, along varying sectors to the south of the headland. During the rest of the year, under the influence of the northerly currents, accretion takes place along retreating sectors as reflected in the development of beach ridges. The turbidity pattern distribution as exhibited by satellite imagery analysis suggests bi-directional shore drift depending upon the period of the season. Although sediment transport is bi-directional, net major sediment transport is southward, and is reflected in large spits along the southern part of the west coast.

Climate, drainage and sediment budget: The prevalent seasonal rainy climate gives rise to perennial rivers, ubiquitous vegetal cover and deep chemical weathering which plays a significant role in detaching weathering resistant material from the outcrops. Konkan is drained by a dozen larger rivers, which originate in Sahyadri. There are 36 minor rivers and creeks which drain directly into the sea. Lithological differences govern the longitudinal profiles of the river and the erosion. The rivers in the central area are of medium length flowing in an east-west direction, showing control of topography and have steeper gradients with more fluvial erosion in scarp zone and greater weathering of basalts. However, the amount of erosion in the lateritic caps is less as the water tends to seep into the porous rocks and the overall sediment budgets remain low in this area. The rivers of north Konkan and southern Sindhudurg are long and show control of tectonic lineaments and have graded profiles. The basalts are well-eroded and therefore the sediment budget on them is high.

Many of the rivers on north and central Konkan like Vaitarna, Ulhas, Kundalika, Savitri, and Shastri are bar- ridden at their sea-entrances. Most of these bars are formed on the northern deeper side of the estuary and leave a narrow passage to the south, which forms the entrance channel to the river estuary. Studies conducted by Victor Rajamanickam and Gujar (1984) on "Effects of waves on redistribution of sediments along the Konkan coast", mention the bar on the mouth of Shastri river, that is generally parallel to the coast. This bar, they state, attains a change in its orientation during the months of Southwest monsoon. It becomes almost perpendicular to the coast. This is due to high wave activity of monsoon runoff. When an offshore bar has been built up sufficiently high, breakers sweeping over the crest of the bar transfer bar material from the seaward face causing migration of the bar landwards. Dean and Walton (1975), state that the seaward transport of sand is due to tidal currents, whereas the landward movement of sand is probably due to wave forces. Since the channel is close to the natural barrier, no material is transported inside strong erosion exposes a non-scouring hard rock bottom at the channel. Since the bar is formed in the wave divergence zones, it becomes a permanent feature and acts as a barrier for the mixing of river sediments with the bay sediments.

Konkan estuaries have been formed after the rise of sea level post- Holocene and are therefore non-marine in origin (Karlekar, 2008). The sediment input gives rise to a variety of bed forms in the estuaries and creeks. These include tidal inlet dunes, sand waves, sand lenses, and sand bars. The bed forms in Konkan estuaries are associated with cuts and scoops in tidal channel. Sediments here range from fine to medium sand and gravel. In contrast, clay constitutes a major part of sediments in the northern estuaries, particularly to north of Mumbai, where tidal range is more than 4mts.The suspended sediments quantum is also equally high making these estuaries more turbid as compared to those in South Konkan (Karlekar,1993).

In the estuaries of Raigad, Ratnagiri and Sindhudurg, the zonation of sediments is distinctly visible. Fine sediments are deposited in upper and middle reaches of the tidal sectors. Coarse fraction, gravel and pebbles usually are found at the tidal mouth. This variation in size is indicative of fluvial origin of bed in upper reaches and tidal origin in lower reaches. Sedimentation on river beds and banks take place immediately after floods. In a normal season with slow steady flow or still waters practically no sedimentation takes place. During heavy rains and consequential floods boulders are rolled or tumble down steep gradients. Coarse grains and sands are dragged along the bed of the river and the finer silts, mud and clay are carried in suspension in the water itself. Soon after the flood subsides, velocities and volume of flow come down drastically and material in suspension settles wherever it is on the stream path. During successive floods, the material in transport is carried downstream till it reaches the mouth, or enters the sea, where it is subject to different types of treatment, transport and assortment. The Konkan river mouths are active zones of constant redistribution of the sediment material in different depositional forms. Since heavy rains and floods take place only over a few days, about a dozen during the peak of the South-west monsoon season, heavy sedimentation is confined to a few days in the year, the rest of the year being devoted to dispersal and redistribution of the sediments in the mouth along the coast by littoral drift and rarely into deeper parts of the sea-floor.

Sedimentation at the river mouth and the lower reaches of river basins depends on;

- Annual discharge
- Tidal inflow
- Extent of blockade at and across the river mouths at the sea-entrance by long-shore drift and development of underwater bars and banks, occasionally rising above water level during the ebb tide
- Development of sand spits extending from the beach on one or both the banks across the river in cases even directing the flow into the sea, either to one side of the river mouth or diversion.

Inspite of large annual flow drawn from larger catchments, North Konkan rivers both Vaitarna and Ulhas mouths, have bars at the mouth that rise above water level during ebb tide. What is even more distinctive is the fact that both these river mouths that were characterized by insular topography till late mediaeval time are now part of the mainland, partly due to reclamation processes. These mouths have a number of islands just upstream of the mouth reflecting the extent of sedimentation. In fact, the lower reaches of the both rivers have a large number of legal and illegal dredging operations over last few decades for building sand-reflecting the high rate of sedimentation.

Spits at Kalbadevi, Achra, and Devbag characterize smaller river mouths, Achra being the longest. These spits have actually diverted the mouths southwards. North to South littoral drift along the shore contributes to this spit building. Bars and banks are noted in Kundalika, Savitri, Vashisti and Shastri valley mouths. Though the course is not diverted the flow in the river is on the south side, north side being exposed to inflow of high tides.

Field-work in the Savitri mouth indicates bar development on the north side of the sea-entrance of the river. The bar as it develops is pushed inland by the flood tide on one hand, and eroded on the sea-face on the other to form yet another bar on the sea-front, ahead of the bar is that is pushed inland. Thus a series of parallel bars develop one behind the other.

CONCLUSION

The fact that the proposed port sites to be developed lie at or near the entrance of estuary mouths in Konkan poses some serious questions. The sedimentation processes undergo a changedue to seasonally changing hydro-dynamic conditions and produce a complex pattern of sedimentation within the estuary, their mouths and along the coast. Therefore when the choices of sites for development of new ports in Konkan are being made there is a need to look carefully at the sedimentation processes which are influenced by numerous forces as discussed above. The new ports are expected to accommodate larger ships and keeping in mind the facts that these estuary entrances are blocked by sandbars and sand banks and face complex sedimentation pattern, it will be necessary to dredge the approach, navigational channels as well as the port in itself, in the initial stages as well as in subsequent stages to maintain the required draft depths. This will incur considerable costs and the basic question of operational feasibility will remain.

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