Geomorphologic Impact of Construction of Breakwaters at Ponnani Fishery Harbour in Kerala

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Abstract. Coast belonging to one particular stretch happens to be versatile because of its dynamicity. This dynamicity is attributed to both natural and anthropogenic activities. Hence, it is important to monitor any fragile coastal stretch’s dynamicity in a temporal basis. In the present study, an attempt is made to analyse the shoreline changes using Digital Shoreline Analysis System (DSAS), by calculating Linear Regression Rate (LRR), in response to the construction of two breakwaters at Ponnani which is a major fish landing centre in Malappuram district of Kerala state in India. Shorelines were extracted from field data, satellite imageries, LANDSAT (1979-2002) and Google earth (2010-2016). From the detailed analyses, before the construction of breakwaters, it is inferred that erosion at the rate of 1.5m/yr and 5.3m/yr was observed on north and south sides of Ponnani estuary respectively. But after construction, an accretion at the rate of 3m/yr on either side of estuary is observed.

1. Introduction
An idealized definition of shoreline is that it coincides with the land and water physical interface [1]. Despite its apparent simplicity, this definition is a challenge for practical application. Really, the shorelines change continually throughout time, due to the dynamic nature of water levels at the coastal boundary (e.g., waves, tides, groundwater, storm surge, setup, run up, etc.). The shoreline is therefore considered in a temporal frame, and the time scale adopted will depend on the context of the investigation. Coasts are most dynamic in nature as it is subjected to different wave characteristics with time and dynamics of erosion or accretion [2].

Method used to study the dynamicity of one coastal stretch cannot be subjected to another coastal stretch. This is due to the varying geomorphology and wave climate, prevalent adjacent to the coast. Coastal areas are very important to humans since olden times due to its abundant natural resources, leading to rapid urbanization along the coastlines. Coastal zones are mainly complicated ecosystems with a very high number of living and non-living resources [3]. Coastal zones are highly dynamic and their change causes loss of life and property, threat to harbours and depletion of coastal land resources. Coastal zone monitoring is therefore a significant task in terms of national development and environmental conservation, in which extraction of coastline is the fundamental study [4].

Coastal erosion and accretion is a global problem. Sea and oceans will continuously cause erosion of coastal rock particles along the shores. However, erosion and accretion by sea mainly takes place by the hydraulic action of sea waves, abrasion of rock particles, attrition of rock particles and corrosion. In addition to above mentioned phenomenon, the sea level rise and frequent occurrence of storms will lead to coastal flooding and hence, erosion/accretion problems that occur along the coastline. In the present study, an attempt is made to analyse the shoreline changes using Digital Shoreline Analysis System (DSAS), by calculating Linear Regression Rate (LRR), in response to the construction of two
estuarine breakwaters at Ponnani which is a major fish landing centre located in Malappuram district of Kerala state in India. The rubble mound breakwaters were constructed during the period 2002 to 2010.

2. Study area
Ponnani harbour in Malappuram district of Kerala state in India is considered as the study area (Fig.1) for the present work. The geographical location of harbour is 10°47'12.81"N 75°54'38.62"E and it comes under the administration of Ponnani Taluk in Malappuram District of Kerala state. Two rivers namely, Bharathapuzha and Tirurpuzha join together in the confluence and their discharge passes through a common river inlet at Ponnani.

Fig. 1 Location of study area

Ponnani was an established estuarine port for a long period. The commercial importance of this port started dwindling since the last four decades due to the formation of shoals in front of port wharf and shallow outer bars at the river mouth. Apart from this, the development of additional facilities at Cochin Port, the construction of New Mangalore Port and improvement in the road network has resulted in the diversion of cargoes from Ponnani to other places. As a result there is no cargo traffic through Ponnani port for the last four decades [5]. The two rivers joining at Ponnani were rather shallow and the bathymetry at the entrance was complicated due to shallow water depths causing shift in the natural channel and frequent modifications in the adjoining beaches connecting the shallow bars. The inlet had very limited area of cross section. Due to the complicated bathymetry and inlet shifting, the fishermen were facing considerable difficulties in manoeuvring their vessels. In Kerala coast, even though 21 inlets are permanently open, most of them are found to be unstable under its natural conditions [6]. They are not suitable for maintaining a safe navigational channel due to the unfavourable stability conditions. It is therefore imperative to provide proper protection to vessels using these inlet. For developing Ponnani estuary into a fishery harbour, the detailed investigations, model studies, planning, design, etc. were carried out. The model studies were carried out in CWPRS, Pune during 1998. From the model studies it has been found that the coastal inlet at Ponnani under its natural conditions will not be suitable for maintaining a navigational channel due to the unfavourable stability conditions. It was evolved from detailed studies that for maintaining a safe and navigable entrance channel, two breakwaters of 780m (north) and 570m (south) are to be constructed with centre to centre distance of 270m. The proposed approach channel is to be with 3m draft and 60m wide and the harbour basin is with 2.5m draft. Accordingly the construction was commenced in the month of May 2002 and got completed in the
month of February 2011 (Fig. 2). As many as 6,500 fishermen were expected to benefit by the harbour
directly and 25,000 others in same vending sector indirectly.

3. Methodology
In this present study, Digital Shoreline Analysis System (DSAS) is used to understand the influence of
two breakwaters on coast adjacent to it. DSAS is a software extension to ESRI ArcGIS that computes
rate of change statistics from historic shoreline vector data.
To extract shoreline configuration during different phases of time, data have been collected from
various sources. The study emphasizes on studying the temporal dynamicity of shoreline configuration
and for same, historical set of shoreline data have been collected from Harbour Engineering
Department, Government of Kerala and remote sensing data from various sources (Table 1).
Shoreline (vector format) extracted from field survey data for the period of 2002-2010 during the
construction of the breakwaters, satellite data (LANDSAT) for a period of 1979-2002, Google earth
and LISS IV for a period of 2010-2017 were used to study shoreline change rate before, during and
after construction of breakwaters. The extracted shoreline was fed into DSAS and inter annual
variation of shoreline was estimated by calculating Linear Regression Rate (LRR). A linear regression
rate-of-change value can be determined by fitting a least-squares regression line to all the shoreline
points for a particular transect line. The regression line is placed in such a way that the sum of the
squared residuals is minimized [7]. The computation was carried out 10 times viz. once for pre-
construction (1979-2002), 8 times during the phase of construction (2002-2010) and once for post
construction (2010-2017). Intra annual change for the period of construction (2002-2010) was also
computed by calculating End Point Rate (EPR) between consecutive months from field survey data
(Fig. 3). The end point rate is calculated by dividing the distance of shoreline change by the time
elapsed between the oldest and the latest shoreline [7].

Fig. 2 Ponnani Harbour - After the construction of breakwaters
Table 1. List of input data and its source

| SL. NO | DATA                          | SOURCE           |
|-------|-------------------------------|------------------|
| 1     | Satellite data                | Google earth     |
| 2     | LISS-III & IV Satellite data  | NRSC             |
| 3     | Landsat – MSS, TM, ETM+       | USGS             |
| 4     | Field survey data - shoreline configuration | Harbour Engineering Dept. |

Fig. 3 Workflow to analyse the dynamicity of shoreline configuration - pre, during and post construction

4. Results and discussion
Table 2 depicts the results of LRR obtained for different phases of time (pre, during and post construction of breakwaters). It is understood that the considered coastal stretch of Ponnani has dynamically changed its configuration over a period of 38 years (1979-2017). On comparing the LRR values among the shorelines during construction, it is observed that the shore has stabilised along with the construction (Fig. 4). The dwindling nature of shoreline has been stabilised, on studying the pre- construction and post- construction shoreline configuration (Fig. 5). Before the construction of breakwaters, the shoal formation is the main reason for choking the river inlet and further hindering the fishing activities. It is learnt (Fig. 4) that the breakwaters constructed has served its purpose as expected, i.e. a retreat in the formation of sand bars/spits has been observed.

Fig. 4 LRR - During construction
4.1 Shoreline changes prior to construction
From the analysis of shoreline data for the period 1979-2002 that is before the commencement of the breakwaters, it is observed that extreme shoal formation on both north and south sides of river inlet, reducing the width of inlet’s mouth, and it is measured about 85 m. On southern side, extreme erosion observed at a distance of 136 m from river mouth for a stretch of 360 m. In addition, at river inlet there is an accretion at a rate of 1.5 m/yr. The average rate of change of shoreline configuration dynamicity before construction of breakwaters, along northern side is calculated as 0.72 m/yr and southern side is calculated as -3.8 m/yr. (Table 2).

4.2 Shoreline changes during construction
The breakwater construction began during 2002, during this year, preliminary coastal survey was conducted. It was observed that at a distance of 240 m from inlet’s mouth on northern side there was severe erosion at a rate of 162 m/yr (Fig. 4). During the year 2002, the average shoreline configuration dynamicity rate, along northern side is calculated as -21.5 m/yr and southern side is calculated as 59.91 m/yr (Table 2). A maximum erosion of -12.78 m/yr was noticed on the south side during October-November and a maximum accretion of 111.56 m/yr was observed on the northern side during

| SHORELINE PHASE | YEAR | LRR - NORTHERN SIDE (m/yr) | LRR - SOUTHERN SIDE (m/yr) |
|----------------|------|-----------------------------|-----------------------------|
| PRE | 1979-2002 | 0.72 | -3.8 |
| D | 2002 | -121.5 | 59.91 |
| U | 2003 | 30.231 | -32.15 |
| R | 2004 | 18.094 | -3.32 |
| I | 2005 | -184.133 | -243.89 |
| N | 2006 | -30.86 | 59.46 |
| G | 2007 | 18.43 | 31.86 |
| | 2008 | -7.08 | -38.51 |
| | 2009 | 32.15 | 23.56 |
| | 2010 | -55.26 | -1.302 |
| POST | 2011-2017 | 4.5 | 2.36 |
August-September. Southern side of river inlet is observed to be stable but northern side is observed to have severe erosion during the month of July-August.

Field survey data collected during 2003 showed that the river inlet’s mouth has migrated towards south for a distance of 230m. Away from inlet on both sides of the mouth at a distance of 300-350m, erosion is observed at a rate of 40m/yr. The average shoreline configuration dynamicity rate along northern side is calculated as 30.231m/yr and southern side is calculated as -32.15m/yr (Table 2). A maximum erosion of -282.749m/yr was noticed on the southern side during February-March and a maximum accretion of 66.22m/yr was found on the northern side during August-September. Southern side of river inlet is observed to be stable except for the month of August-September where, the erosion appears to be severe. But the northern side is observed to be stable except for a good amount of accretion next to the inlet during the month of May-June.

During 2004, on the north side, the shore is stable and there is negligible erosion at a distance of 860m from the river inlet and also a significant accretion at a rate of 17m/yr is observed. On the southern side, the erosion was contained to a greater extent and the rate of erosion has been reduced to 3m/yr (Fig. 6). The average rate of shoreline change dynamicity, along northern side is calculated as 18.094m/yr and southern side is calculated as -3.32m/yr (Table 2). A maximum erosion of -26.89m/yr was observed on the south side during July-August and a maximum accretion of 29.33m/yr was observed on the south side during June-July (Table 3). Southern side of river inlet is observed to have accretion during pre-monsoon and erosion during post monsoon. Wherein, northern side is observed to be stable after 100m from inlet except for a good amount of accretion next to the inlet during the month of June-July (Fig. 6).

In 2005, severe erosion was observed on either sides of the river mouth at a rate of 250m/yr. A maximum erosion of -18.932m/yr was observed on the north side during February-March and a maximum accretion of 58.328m/yr was observed on the south side during January-February. The average rate of shoreline configuration dynamicity, along northern side is calculated as -184.133m/yr and southern side is calculated as -243.89m/yr (Table 2).

Table 3. EPR values during the year 2004

| MONTH    | NORTHERN EPR(m/yr) | SOUTHERN EPR(m/yr) |
|----------|--------------------|--------------------|
| JAN-MAR  | 4.39               | 10.48              |
| MAR-APR  | -0.54              | -4.77              |
| APR -MAY | -3.84              | -1.04              |
| MAY-JUN  | -7.56              | -7.14              |
| JUN-JUL  | 11.48              | 29.33              |
| JUL-AUG  | 20.83              | -26.89             |
| AUG-SEPT | -5.29              | 16.96              |
| SEPT-OCT | -2.19              | -4.51              |
| OCT-NOV  | -4.16              | 25.94              |
| NOV-DEC  | -4.41              | -28.35             |
Fig. 6 EPR – During the year 2004

During 2006, northern side was still prevailing as an erosional coast; southern side has stabilised and has started behaving as an accretional one. Available set of data indicates that severe accretion and erosion occurred on either sides of inlet during consecutive months. The average shoreline configuration dynamicity rate, along northern side is calculated as -30.86m/yr and southern side is calculated as 50.46m/yr (Table 2). On the north side, a maximum erosion of -6.08m/yr and a maximum accretion of 8.974m/yr were observed during the months of September-October and July-August, respectively. Immediate next to inlet for 100m on both sides there is immense erosion during the month of July-August, however, during June-July and August-September accretion is noticed. In 2007, both the sides of river mouth have stabilised and the sediments had accreted at a rate of 55m/yr. The average shoreline configuration dynamicity rate, along the northern side is calculated as 18.43m/yr and southern side is calculated as 31.86m/yr (Table 2). A maximum erosion of -11.11m/yr was observed on the south side during July-August and a maximum accretion of 22.31m/yr was observed on the north side during July-August. Southern side of inlet seems to be stable but northern side seems to have severe erosion immediate next to inlet for 1.5km and later severe accretion is identified for remaining length during the months of October-November.

During 2008, there was minimal erosion at northern side at a rate of 8m/yr, but on the southern side, there was severe erosion at a rate of 102m/yr (Fig. 7). The average rate of shoreline change dynamicity, along northern side is calculated as -7.08m/yr and southern side is calculated as -38.51m/yr (Table 2). A maximum erosion of -8.37m/yr was observed on the north side during April-May and a maximum accretion of 11.72m/yr was observed on the south side during March-April (Table 4). By analysing the intra annual scenario for the year 2008, a minimal accretion is observed during post monsoon on the north side, but, erosion is identified during pre-monsoon. Wherein, post monsoon shows an erosional trend on the south side (Fig. 7).

Table 4. EPR values during the year 2008

| MONTH       | NORTHERN EPR(m/yr) | SOUTHERN EPR(m/yr) |
|-------------|--------------------|--------------------|
| JAN-FEB     | 4.08               | -0.75              |
| FEB - MAR   | 7.30               | -2.58              |
| MAR-APR     | -0.73              | 11.72              |
| APR - MAY   | -8.37              | 5.63               |
| MAY-JUN     | -0.44              | 5.45               |
During 2008, the previous year erosion had contained and an accretional coast is formed during this year on either sides of the river inlet at a rate of 30m/yr. The average rate of shoreline change dynamicity, along northern side is calculated as 32.15m/yr and southern side is calculated as 23.56m/yr (Table 2). A maximum erosion of -84.39m/yr was observed on the south side during September-October and a maximum accretion of 26.94m/yr was observed on the north side during June-July. The entire coast acts stable throughout the year with the erosional and accretional values fluctuating between ±20m/yr except for the months of June-July on both sides and September-October on the south side.

There is negligible erosion on both sides of the river mouth, throughout the coast, during the year 2010. The average rate of shoreline change dynamicity, along northern side is calculated as 5.00m/yr and southern side is calculated as -1.40m/yr (Table 2). A maximum erosion of -9.51m/yr was observed on the north side during June-July and a maximum accretion of 2.95m/yr was observed on the south side during May-June. The coast is observed to be stable and has an erosional trend during the month of June-July at a rate -15m/yr.

4.3 Post- construction shoreline changes
The construction activities were completed by the year 2010. From the analysis it is inferred that significant accretion at a rate of 5m/yr on north side and negligible erosion on south side of the river mouth is observed. The river inlet is trained with a width of 270m and after the construction of breakwaters; a clear navigable channel is maintained. The average rate of shoreline change dynamicity, after construction of breakwater, along northern side is calculated as 4.5m/yr and southern side is calculated as 2.36m/yr. (Table 2).
5. Conclusion
From the analysis on dynamicity of shoreline configuration at Ponnani fishery harbour, the following main conclusions are drawn:
1) Before the construction of breakwaters, northern side is observed to be accretional and southern side is erosional coast;
2) The average shoreline configuration dynamicity rate before construction of breakwaters, along northern side is calculated as 0.72m/yr and southern side is calculated as -3.8m/yr.
3) During the construction period, it is observed that there is tremendous accretion on the northern side and on south there is severe erosion tendency except during the year 2005. During the year 2005, it is observed that there is severe erosion trend on both the sides;
4) The accretion during the construction period has never exceeded the rate of 60m/yr;
5) During post construction period, it is noticed that on the north side there is significant accretion and on the south side there is negligible erosion; and
6) The construction of two breakwaters at Ponnani river estuary has paved the way to create a safe and navigable channel for the fishing vessels.

6. References
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