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Shoreline Evolution Due to The Development of Thangassery Harbour in Kerala

Kunhimammu Paravath* and Nasar T

Department of Water Resources and Ocean Engineering, National Institute of Technology, Surathkal, Karnataka, India

***Corresponding Author:** Kunhimammu Paravath, Department of Water Resources and Ocean Engineering,National Institute of Technology, Surathkal, Karnataka, India.

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Abstract

The shoreline, which is the boundary line between water and land is undergoing constant changes due to varying dynamic factors like, bathymetry, wave climate, currents, and coastal orientation. Shoreline movement causes erosion and accretion on the coast. The repeated storms and the rise in sea levels lead to coastal flooding and which contributes to erosion/accretion problem on the coast. For the present attempt, the shoreline evolution is analysed by using numerical method, due to the development of Thangassery harbour in Kerala coast in India. To predict the shoreline evolutions at Thangassery harbour Mike 21 SW and LITPACK modules are utilized. The studies reveal that after the harbour construction, there is tremendous accretion on the immediate south of leeward breakwater followed by erosion trend.

Keywords: harbour; breakwater; shoreline; erosion; accretion; LITPACK

Introduction

The boundary line between water and land can be considered as the shoreline (Dolan et al.1980). But the position of shorelines will change constantly with time, due to the dynamic aspects of water levels. So the shorelines can be taken in a temporal frame, and the time period adopted depends on the purpose and use of the data. The water-land border at one point of time is the instantaneous coastline at that point of time.

The main factors which influence the shoreline evolution are sediment movement, sea-level rises and interference on the coast. The hydrodynamics of the near-shore region, river conditions, the categories of coastal land forms and storm surges also influence the shoreline position (Narayana and Priju, 2006; Scott, 2005; Kumar and Jayappa, 2009). Shoreline evolution is directly connected to coastal erosion or accretion. The probable shoreline variations and the correct risk assessments during different time spans are the major necessity (Burgess et al. 2001). With regard to the supply of sediments, shoreline may be subjected to three situations like surplus balanced, or deficit situation in sediment budgeting system. The considerable deviations in the supply of sediments, with shorter or stretched time period, leads to surplus or deficit sediment budget causing shoreline oscillations (Mukhopadhaya et al. 2012). Generally, the rise in sea level following storms, global warming etc. will cause flooding on the coastline and erosion/accretion phenomena occur along the shoreline (Dattatri et al. 1997).

Study Area

The Kerala coast in India is having 590km length. This coast is characterised with a low lying strip of land sandwiched with a number of lagoons and backwaters on the eastern side and the Arabian Sea on the western side. These lagoons and backwaters have openings to Arabian sea at many points. In this coast, the main economic activities, major industries and agricultural activities in Kerala are situated. There are forty one west flowing rivers in Kerala. All these rivers flow in westerly direction and enter into the lagoons and backwaters along the Kerala coast. These lagoons or backwaters have 34 openings into Arabian sea. In these 34 inlets, only 21 inlets are perennial and the remaining inlets are ephemeral, that means they will remain open during the monsoon period only and will get closed for the remaining part of the year mainly due to the littoral transport (Kunhimammu et al, 1997). The fishery harbours established on Kerala coast can be grouped into three. They are: harbours at the river estuaries, harbours at natural bays and harbours on open sea coast. The harbour locations are generally selected based on the factors like, technical, political and social aspects Three types of harbours can respectively be called as estuarine harbours, bay harbours and sea harbours (Kunhimammu et al, 2007). For the present study, Thangassery harbour, a bay harbour, is considered. Fig. 1 presents the location of this harbour on Kerala coast.

At Thangassery, a bay type fishery harbour is developed by constructing a main breakwater with a length of 2100m and a leeward breakwater of 500m length. It is located at 8°52’35”N and 76°34’00”E and constructed on the open coast in Kollam district of Kerala state in India(CWPRS, 1984; HED, 1985). The construction was started during the year 1990 and completed during March 2001 (Fig. 2).

Figure 1: Location of Thangassery harbour on Kerala coast.

Methodology

MIKE 21 Spectral Wave (SW) module is the tool used for the transformation of wave data from deep water to shallow water. This software is capable of transforming the wind generated waves and its growth and decay. This module considers unstructured meshes and the main factors like wave growth due to wind, dissipations due to white-capping, interaction of non-linear waves, friction from bottom and wave breaking. The module also takes into account the wave diffraction, wave shoaling and refraction in the nearshore region (DHI, 2011, 2017).

Figure 2: Present view of Thangassery harbour.

The shoreline evolution and littoral movement can be numerically simulated by utilizing the LITPACK software module. The regular as well as irregular waves, currents, wind stress, friction from botton, refraction, shoaling and wave breaking in shallow waters are taken into consideration in this module. The littoral movement is calculated from the wave data, data on sediment and current. This is called intra-wave period sediment transport model. The suspended load and bed load distribution with time within the wave period is considered. The combination effect of wave, current and wave breaking is also taken into account in the model.(DHI, 2022).

LITPACK module for prediction of shoreline evolution, considers the coastal response to gradients in alon shore sediment transport capacity in relation to the existing natural situations and and exitsing structures on the coast. For arriving at the shoreline evolution, LITPACK module solves a continuity equation for the sediment movement in littoral zone. The important input data for finding solution by utilizing the model is the alignment of the coastline, bathymetric data, cross-shore profile data, active transport depth, angles of contours, data on wave and tidal currents, data on water level, size of coastal structures, etc. (DHI, 2022).

Data Used

For deep water bathymetry, C-Map data has been utilized in the model. The Harbour Engineering Department (HED) and Hydrgraphic Survey Wing of Kerala Governmnet carry out periodic bathymetric surveys and takes soundings along the Kerala coast and at harbour locations. These field survey data is also used for the present study. For two staions, 160km away from shore located off Thiruvananthapuram and Kasaragod districts, the deep water wave data are collected and used for the model study. The depth of this data available is 10yrs , that is from 2007 to 2017.

Flexible mesh is adopted for the present study. At deeper water the mesh size is 20km, for water depths ranging from -1000m to -50m the mesh size is a mesh size is 10km for -50m depth to shoreline mesh size is 5km. This adopted mesh size resolution is suitable for different water depth ranges and results obtained for model calibration and its further validations are observed to be good. Fig.3 shows the mesh diagram.

Results and Discussion

Model Calibration

The model is calibrated with the field wave data available with Harbour Engineering Department. The department had observed wave data at 8m depth by using Directional Wave Recorder (DWR) in 2012 at South Paravur in Kollam district. This collected field wave data was taken for calibrating and further validating the results obtained from SW model. It is observed that for a bottom friction of 0.15 and with wind data incorporated in the model, the results are very well matching with the field observed data (Fig. 4). This model setup is used for further analyses of shoreline evolutions at other locations on the coast. For the present attempt, the field wave data obtained during the year 2017 is considered.

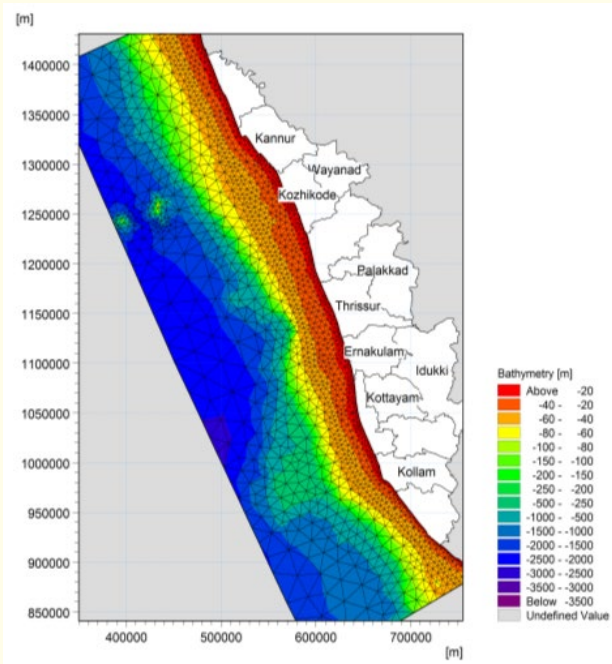

Figure 3: Bathymetry and mesh adopted in modelstudy.

At Paravur, the field wave data is also collected during the period from 9th to 29th July of 2012 and this field data are used for the further validation of the calibrated model. The predicted and observed results for Paravur location matches very well. The results are presented below (Fig. 5 & 6).

Figure 4: Results of calibration for bottom friction 0.10 and 0.15.

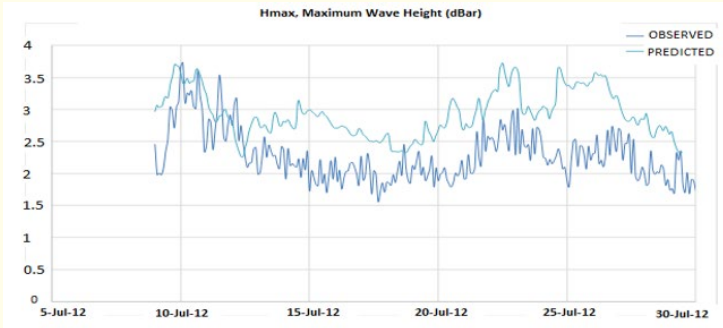

Figure 5: Results of validation for Paravur site– Hmax.

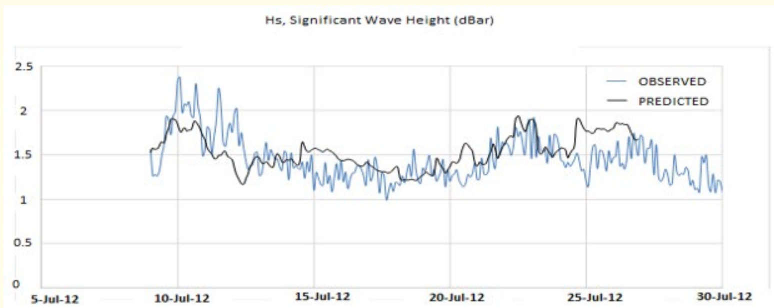

Figure 6: Results of validation for Paravur site – Hs.

The SW transformation results are presented in Fig.7 below. These ransformed results on wave for monsoon period (July 2017) is shown in the figure. These results from SW model is considered as the input for running the LITPACK for shoreline evolution.

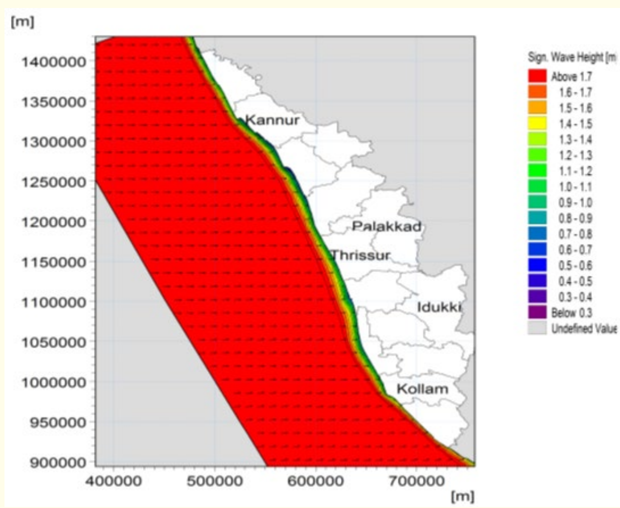

Figure 7: Transformed wave climate for monsoon (July 2017).

Thangassery Harbour

The extracted results from SW transformation for Thangassery harbour site are shown below (Fig. 8). These extracted values are used in the LITPACK model for obtaining shoreline evolution results.

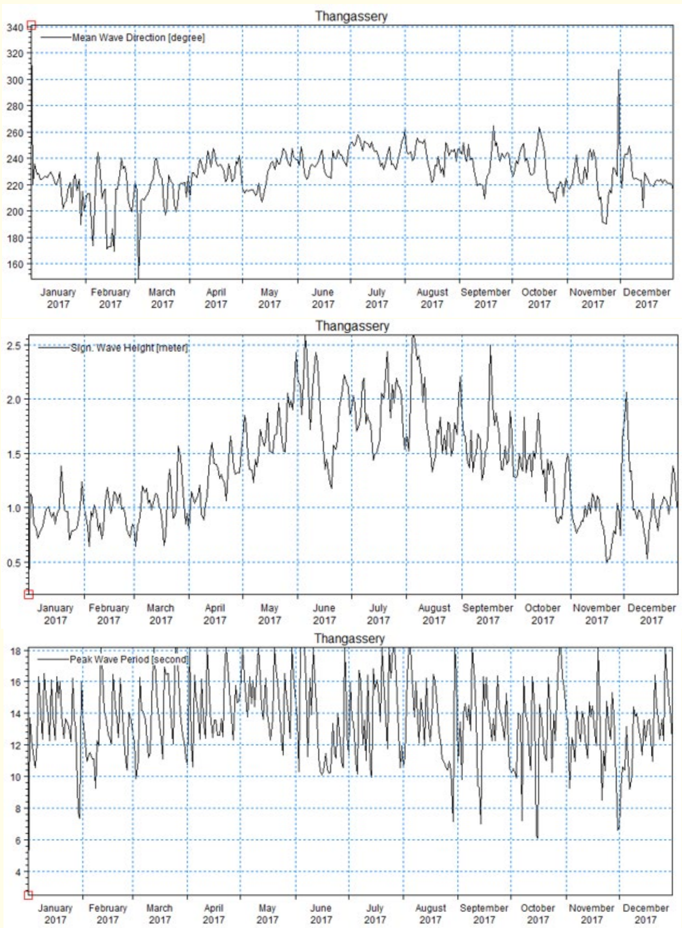

Figure 8: Transformed wave climate from deep-water to 25m depth near Thangassery harbour.

The model calibration is carried out by taking the shoreline of 1990 (baseline), just before the starting of breakwater work and calibration is carried out against 2017 shoreline. The observed as well as predicted shorelines of 2017 are more or less the same. Immediate south of southern breakwater shows tremendous deposition followed by erosion when compared to baseline (Fig. 9).

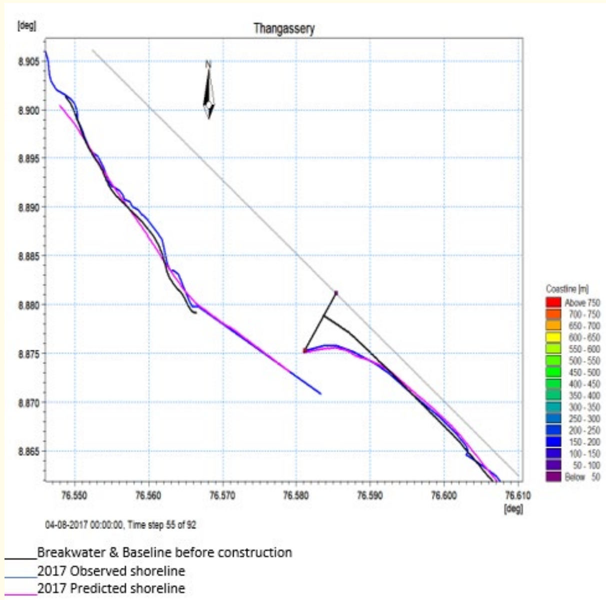

Figure 9: Thangassery model calibration.

The calibrated model is used for the prediction of shoreline oscillations around the breakwaters constructed for the harbour at Thangassery. The shoreline evolution results are predicted after 5th, 10th and 15th years. The final result is presented in Fig. 10.

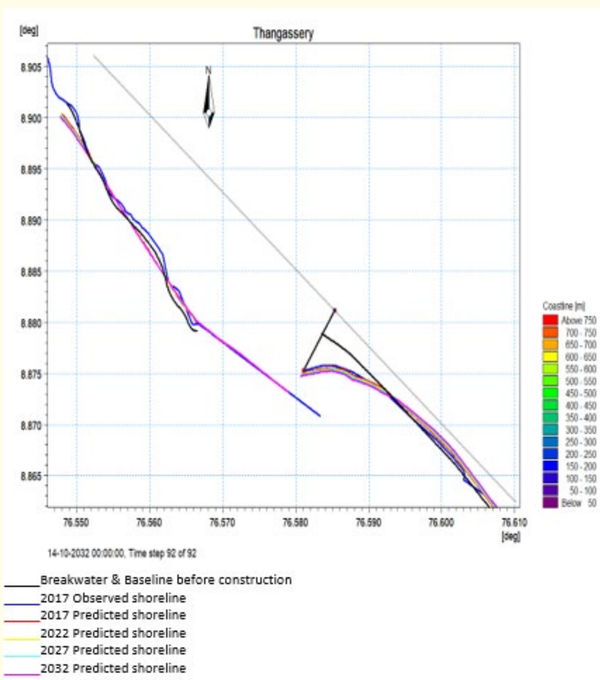

Figure 10: Shoreline evolution at Thangassery harbour.

The predicted results show that tremendous deposition has occurred in the immediate south of leeward breakwater for some extent after its construction. But after some distance the trend reverses and erosion trend is observed when compared to the baseline. The deposition on the south has reached upto the tip of the leeward breakwater. The predicted results also reveal that that the accretion on the immediate south of leeward breakwater is considerable and shoreline is showing net advance whereas on further south shoreline is showing net retreat/erosion. To arrest further erosion on the southern side a groin field is constructed and to avoid bypassing of the deposited material around the tip of leeward breakwater into the harbour basin, periodic dredging and removal of spoil are taken up.

Conclusions

The shoreline evolution due to the development of Thangassery harbour in Kerala is studied using SW and LITPACK modules of Mike 21. The main conclusions are:

- At immediate south of leeward breakwater, tremendous accretion is observed after the construction;
- After some distance on the south of leeward breakwater, the coast is subjected to erosion trend;
- The predicted and observed shoreline chnges are found to be well matching; and
- The shoreline evolution during 5^{th}, 10^{th} and 15^{th} years after calibration is predicted and presented.

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