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Numerical Modeling to Determine the Groyne Field Dimensions for an Artificial Beach fill

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***Abstract*—The use of traditional hard protection structures for coastal protection has mostly proven to have long term disadvantages on eroding coastlines. This has led to the popularity of soft protection measures like artificial beach fill. However, to increase the longevity of such soft protection schemes, it is necessary to incorporate hard protection structures like groynes. This paper discusses a numerical modeling study done to determine the dimensions of a groyne field for an artificial beach fill. The MIKE 21/3 coupled model is used for this morphological model study. A conceptual artificial beach fill planned for an eroding beach in the Vishakhapatnam coastline in India is modeled for the present study. The simulations were carried out for only beach fill scenario and beach fill with single groyne scenario to ascertain the feasible dimensions for the groynes and further discuss dimensions for a groyne field. Useful inferences about the preliminary dimensions for a groyne field is derived from the post processed model results. This study will provide an insight into the two-dimensional numerical modelling technique that could be adopted for preliminary planning and design of combined soft and hard protection structures.**

Keywords— 2D Morphological model, MIKE 21/3 FM Coupled Model, Beach fill, Groyne field.

I. INTRODUCTION

Coastal erosion is a major concern and challenge in the field of coastal engineering. Over recent years, many coastal engineering projects have employed the use of soft solutions as these are generally less environmentally damaging than hard solutions [9]. However, in some cases, local conditions hinder the use of soft solutions, meaning that hard solutions have to be adopted or, sometimes, a combination of hard and soft measures is seen as optimal [9]. Traditional hard protection structures offer good protection against extreme wave climates but in long term it poses risk to the beach itself as the natural equilibrium of the beach gets lost and issues like severe downdrift erosion starts. The major disadvantage of soft solution is its longevity and comparatively low resistance to extreme wave climates. To increase the longevity of soft protection measures like artificial beach fills, hard measures like groyne field can be incorporated.

The planning of coastal protection structures for eroding coastlines is a major challenge for coastal engineers. One of the common tools used by coastal engineers these days for the planning and design of coastal protection structures is the numerical modeling technique. The aim of this paper is to present a numerical model study adopted for the preliminary planning of a groyne field incorporated to an artificial beach fill. A conceptual artificial beach fill planned for Visakhapatnam coastline is setup for a stretch up to Waltair point comprising of Ramakrishna beach on North side of Visakhapatnam Outer harbor. Being on the down-drift side of a major port with differential drift rates in the era of climate change and frequently occurring cyclones, this stretch is vulnerable to erosion particularly when beach nourishment quantities are not meeting the total requirement. Though south-west and north-east monsoons invoke littoral drift in two different directions northwards and southwards respectively, the impact of south-west monsoon is high in view of its higher intensity and duration making the net littoral drift direction towards the north [7].

The morphological model was setup using MIKE 21/3 Coupled model enabling dynamic coupling of Hydrodynamic (HD), Spectral Wave (SW) module and Sand Transport (ST) module. The HD and SW modules simulates the mutual interaction between waves and currents. The feedback on bed level changes is simulated using ST module. The morphological model was setup and run with speed-up factor to reduce the computational time as recommended by the MIKE software manual [3]. The several simulations were carried out to arrive at the best configuration of groynes for the proposed beach fill. Sharmila, Venkatachalapathy and Mugilarasan [10] has used the MIKE21/3 Coupled model to predict the morphological changes in Kakinada coast about 160 km southwest of Visakhapatnam. The validated coupled model was found to perform well in simulating the waves, currents, and sediment transport for the area of interest.

II. METHODOLOGY

A baseline model representing the existing conditions of the project area was setup initially for calibration. The artificial beach fill was setup and modelled in subsequent simulations. Finally, the modelled beach fill was tested out with a single groyne in the mid portion to understand the effect of the single groyne on beach fill. The offshore bathymetry data was taken from MIKE C-MAP database and nearshore survey data available at Central Water and Power Research Station (CWPRS), Pune was used for the creating the model bathymetry. The wave data for the offshore boundary was taken from CWPRS database. The offshore wave boundary was imposed from available site-specific data. The tide data for the model boundaries were extracted using the Global tide

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model in MIKE21. The Q3D sediment transport table used as input for the ST module was generated using the MIKE21 Toolbox. The baseline model was calibrated and validated with the available wave and current speed data. The beach fill and beach fill with single groyne scenario were setup by incorporating the respective elements to the model domain of the calibrated baseline model. Once the retention effect of groyne was determined from the simulation results, the dimensions of groyne field was finalized.

A. Model Description

The model domain extends from Yarada beach on the south side to Lawson's Bay on the north side. The model domain extends for up to 6 km to the offshore east boundary and 18.6 km from the south to north boundary. The wave climates used as input represents the south-west monsoon season which is the predominant season for Visakhapatnam coast (from June to October). The extreme monsoon wave climate causes northerly drift and hence gives an idea about the maximum impact that the waves afflict on the shoreline. The input waves are forced from the offshore East boundary. Fig. 1 shows the model domain with the offshore boundaries and study area location.

B. Modelling of Beach Fill and Groyne

The conceptual artificial beach fill proposed for the model study was total of 4km stretch from North side of Catamaran harbour covering Ramakrishna beach up to Waltair point. The beach fill has a flat straight portion and two dove tailed tapered ends. The beach crest is fixed at +5m elevation. The frontal slope of the beach was chosen to be 1 in 30 slope as it is more stable than steeper ones. The straight beach fill portion has a width of 200 m and is 3 km in length. The tapered ends have 500 m length and joins with the existing natural bathymetry on both sides.

To study the retention effect of a groyne on the beach fill, a single groyne was planned for the mid portion of beach fill. The groyne length extends for 500 m from the existing shoreline extending perpendicular to the beach fill until -2m depth. The groyne terminates at -2m depth so that it does not completely block the longshore sediment transport. The width of the single groyne was taken as 40 m. The location and dimensions of the beach fill and single groyne is shown in enlarged view in Fig. 1.

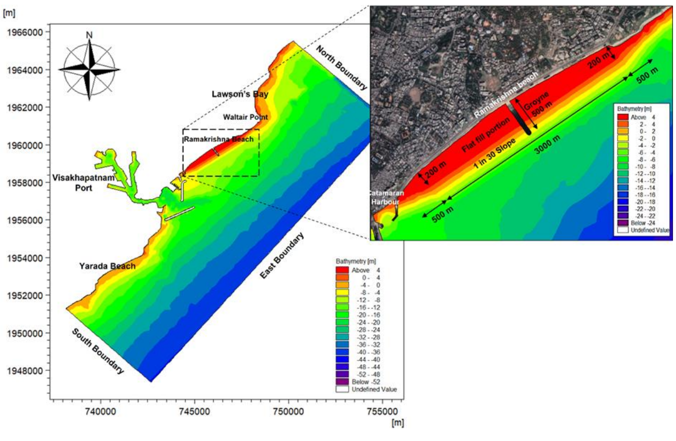

Fig. 1. Model Domain and Dimensions of Beach fill with Groyne

III. RESULTS

The model simulations for only beach fill and beach fill with single groyne were carried out successfully and the results were post processed. The main parameters analyzed was the bed levels and bed level change. The results were analyzed by extracting profile data and creating 2D plots to arrive at a conclusion.

A. Bed Level

The variation in bed level for the portion at the updrift side and downdrift side of the single groyne scenario was analyzed. The spatial plot of final bed levels for both simulations were overlayed to get an idea regarding the extent of erosion and accretion that took place at the updrift and downdrift areas. The final bed level contours in 2D plots for both the cases are shown in Fig. 2 and Fig. 3 below.

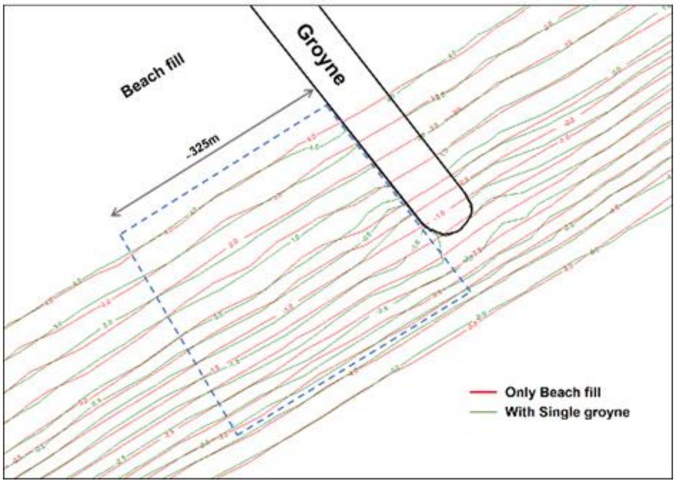

Fig. 2. Final Bed Level in Updrift Portion of Groyne

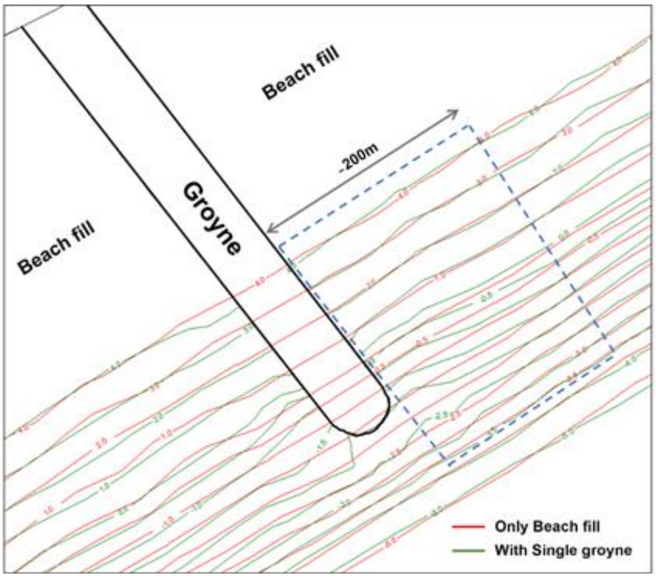

Fig. 3. Final Bed Level in Downdrift Portion of Groyne

From Fig. 2 it is noted that the accretion zone at the updrift portion was extending for almost 325 m. The Fig. 3 shows the extent of downdrift erosion that took place due to groyne. The erosion zone at the downdrift portion was observed for almost 200 m distance.

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B. Bed Level Change

The statistical mean of bed level change for the entire simulation was taken to get a detailed understanding regarding the erosion and accretion zones near the groyne. The 2D spatial plots showing the statistical mean bed level change is shown in Fig. 4 and Fig. 5.

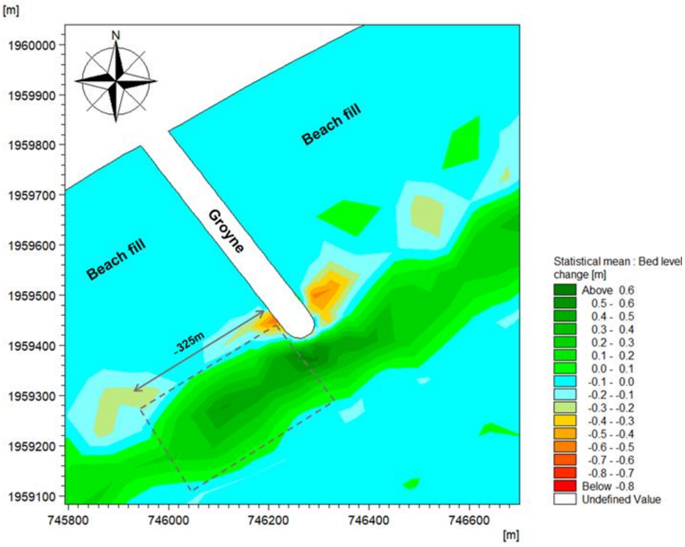

Fig. 4. Statistical Mean Bed Level Change – Accretion Zone for Determination of Groyne Spacing

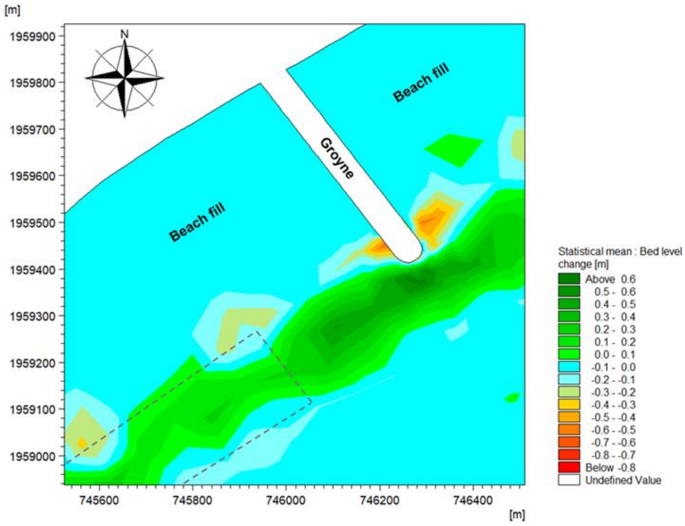

Fig. 5. Statistical Mean Bed Level Change – Portion Beyond Accretion Zone for Determination of Groyne Spacing

From Fig. 4 it was observed that the accretion zone on the updrift side of the groyne extends for almost 325 m, same as inferred from final bed level plots. The reduced accretion beyond the 325 m portion on updrift of the groyne is shown in dotted lines in Fig. 5. So, it is evident that the groyne's retention effect is valid for almost 325 m on its updrift side. Hence the spacing between the groynes in the groyne field should be around 325 m.

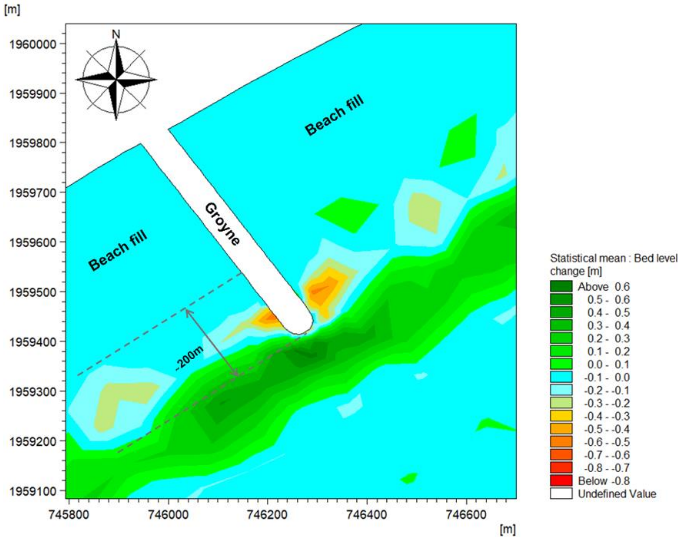

Fig. 6. Statistical Mean Bed Level Change – For Determination of Groyne Length

On analyzing the maximum erosion/accretion zones surrounding the groyne, it was clear that these zones do not extend beyond 200 m length of the groyne as seen in Fig. 6. So, it can be concluded that the effective groyne length can be reduced to a length of around 200 m. Localized erosion expected near the groyne has been noted and this would require periodic maintenance to avoid toe failures.

IV. DISCUSSION

The results discussed above section have given a clear idea regarding the retention effect of the groyne on beach fill. Based on the observations made, the dimensions of the groyne field were finalized as shown in Fig. 7.

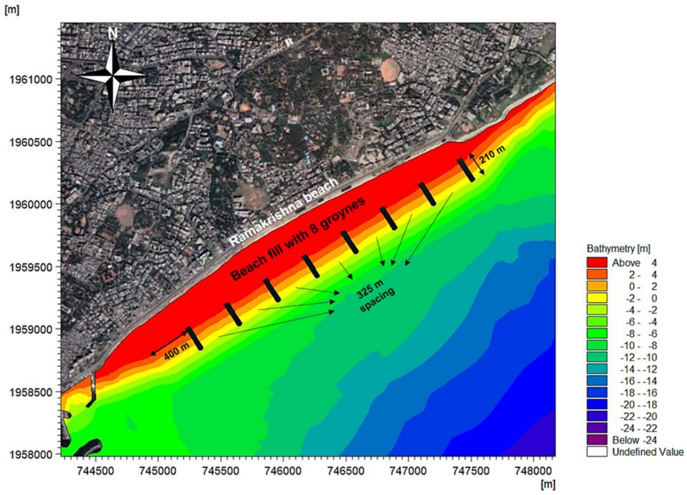

Fig. 7. Dimensions of the Proposed Beach fill with Groyne Field

The first groyne from the South end of flat beach fill portion was placed at distance of 400m as the North breakwater of Vizag outer harbour offers protection to some extent in that region. The remaining flat fill portion was divided equally to accommodate a total of 8 groynes of 40 m width. This arrangement was possible by providing a groyne spacing of 325 m which satisfies the minimum spacing requirement discussed in previous section. The lengths of the groynes were reduced to 210 m as the flat fill portion at +5m elevation was found to be undisturbed in extreme wave climates. The extra

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10m length has been provided as a buffer for the groyne and maybe extended further using sand filled geo bags if required.

The general groyne spacing rules are mentioned in Kraus et. al [5], SPM [11], Fleming [4], CEM [1]. Kraus et. al [5] reported that groynes on sandy beaches perform well when the spacing is two to four times the groyne length. Fleming [4] cited the survey results of groyne and found ratio of groyne spacing to length to be varying between 0.8 to 2.7 for wave reflecting timber groynes used widely in UK during 1993. SPM [11] recommends spacing ration of two to three, whereas CEM [1] suggests spacing ration of two to four. In the present study, based on the dimensions of groyne field derived using model results, a groyne spacing to length ratio of 1.5 was found. This confirms with the Fleming's findings, even though it falls short of the other guidelines, the groyne field dimensions are highly dependent on the site-specific conditions and the present model results can however be used as a preliminary judgement tool. The groyne lengths maybe extended to meet the guidelines at a detailed design stage, however this is not considered or discussed further in this numerical model study.

V. CONCLUSION

An attempt to find out the feasible dimension of groyne field on the artificial beach fill was successfully done in the present model study. The 2D flexible mesh model was setup using MIKE21/3 Coupled model which involved dynamic coupling of HD, SW, and ST modules. The model simulation runs carried out includes the baseline model, only beach fill model and beach fill with single groyne model. The outputs were analyzed to derive the suitable results and conclusions. The beach fill with single groyne simulation gave an idea regarding the extend of retention provided by a single groyne. It was observed that groyne spacing should be a minimum of 325 m to have a stable condition when implementing multiple groynes. This would ensure that the downdrift erosion of one groyne will be counteracted by the updrift accretion offered by the subsequent groyne in the groyne field. However, periodic nourishment and maintenance would be required for the downdrift portion beyond the terminal groyne at the north end. The effective length of groyne was found to be 200 m as the flat fill beach crest portion was found to be undisturbed with extreme wave climate. The length of the groyne was decided to be fixed as 210 m accounting for a buffer length of 10 m. Based on the modelling results, a groyne field with eight groynes at 325 m spacing and 210 m lengths were formulated for the proposed artificial beach fill.

The present model study has provided an insight into the use of 2D morphological models that can be adopted for a preliminary planning and design of combined soft and hard protection measures. However, the detailed design procedures considering the design life of structures should be carried out in subsequent stages in real-life scenario. Physical model studies can also be carried out to arrive at an agreement with the findings of the numerical model study.

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