REVIEW OF HYDRAULIC MODEL STUDIES FOR PORT DEVELOPMENT

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Abstract - *the main problems that occur for coastal structures are due to wave, tides, silting, improper construction, etc. hence, to avoid these problems hydraulic models are constructed to study the stability of coastal structures in respect with these coastal phenomenons. Waves are generated due to the interfacial shear between the wind and the surface of water whereas tides are generated by the gravitational forces applied by the moon and sun. Most hydraulic system can be considered to be in a state of dynamic equilibrium between deposition and erosion. For the development of ports, it is of vital importance to ensure that the desired wave tranquility is achieved in the harbor area. . Silt and sediment deposition in navigation channel creates a problem of reducing the draft of navigation channel. Hence to maintain the appropriate draft of the navigation channel dredging is required and the deposition of dredged material at an appropriate location is performed. To study all these and to understand the effects of morphodynamic coastal processes, estuarine hydrodynamics an integrated model system is developed to simulate tides, waves, currents, winds, sediment transport. These models are also helps to understand the morphological changes in coastal and estuarine regions. Physical and numerical modeling and simulation form critical support tools for layout and structural design of ports, harbors and other related hydraulic structures.*

Keywords: - Hydraulic models, Tranquility, Navigation channel, Dredging, Silt, Simulation, Estuarine, Harbors

I. INTRODUCTION

Hydraulic modelling is a technical process which consists of reproducing free surface flow dynamics using physical and/or mathematical models. A physical model is a scaled representation of a hydraulic flow situation. Both the boundary conditions (e.g. channel bed, sidewalls), the upstream flow conditions and the flow field must be scaled in an appropriate manner. With advancement in computer technology and computation techniques, mathematical modeling is one of the preferred techniques of hydraulic modeling. Mathematical models are essentially based on conservation of mass and momentum equation. Similar to scale model there are tidal model as well as wave model. Physical hydraulic models are commonly used during design stages to optimize a structure and to ensure a safe operation of the structure. They have an important further role to assist non-engineering people during the decision-making process. A hydraulic model may help the decision-makers to visualize and to picture the flow field, before selecting a suitable design. In civil engineering applications, a physical hydraulic model is usually a smaller-size representation of the prototype (i.e. the full-scale structure). Other applications of model studies (e.g. water treatment plant, flotation column) may require the use of models larger than the prototype. In any case the model is investigated in a laboratory under controlled conditions.

Hydraulic models are used in planning and construction of ports, harbors, navigation channel, jetties/breakwaters, coastal protection structures, tidal inlets, cooling water circulation systems for power plants, water intakes and effluent outfalls etc. as well as to understand the coastal processes and associative sediment transport.

Coastal hydraulics is the study of the flow fields due to waves as well as tides. The wave models are based on short wave mechanics whereas tidal current simulations are based on long wave theory.

Hydraulic models in port development are tide as well as wave model. These models provide complete information about the hydrodynamics of the prototype. This information is very much essential to study the feasibility of development of ports and harbours and resulting morphological changes in adjoining coast. The morphological changes after the development in the coastal areas can be predicted by simulating sediment movements under the action of waves and tides.

II. OBJECTIVES

The aim of this paper is to study the wave and tidal hydrodynamics. Wave and tides causes the erosion and depositions of sediments along the coastal structures. Hence, to study the effect of these coastal phenomena on coastal structures, hydraulic model are developed and various studies are carried out and the results obtained by these studies are interpreted for prototype.

III. LITERATURE REVIEW

The period of solar day is 24 hr 00 min while the lunar day is 24 hr 50.47 min. The period of the vertical movement of water is 12 hr 25.23 min is known as tidal period. The flow of water (tidal flow) from land towards sea is from high tide to low tide called as ebb tide, while landward tidal flow from low to high tide is called flood tide. Time of no flow between ebb and flood tide is called slack water (period). The period with large tidal range is called the spring tide while the period with smaller tidal ranges is called neap tide. The tidal wave is however a long period wave having wave length as large as of the order of several hundreds of kilometres. A tide is generated by the force of attraction between the earth, moon and the sun. The hydraulic phenomenon involves tides, waves, density currents and the movement of sediments under the influence of tides and waves. Open coasts or wide bays are exposed to wave attack and often subject to cyclones/storm surges and tsunami effects. In regions like estuaries, unlike open coast and bays, generally tides and upland discharges play a dominant role. Most hydraulic system can be considered to be in a state of dynamic equilibrium between deposition and erosion. The general characteristics only change very slowly with time. Human interference with the governing phenomenon in such a delicate equilibrium will have morphological consequences with accelerated effects. To predict these consequences for a specific project, it is essential and important to have detailed knowledge of the local morphological variables such as the bed material size, the settling velocities of the suspended solids and sediment transport rates. [2]

The wind energy in the offshore region is transferred to the coast in the form of waves, which constantly agitate the coastal region. The wave's dynamic impact on coastal structures, which they must withstand. Also, the waves influence the navigation of ships as well as ship motion at berth affecting the operations at berths. At the coast, the waves result in movement of sand along the shore causing erosion or accretion of the shore line. The waves stir up the sediments at the bed and bring them into suspensions which are transported by currents, which may lead to siltation in harbours and approaches. Therefore, understanding of the mechanism of waves is important to coastal engineering [6]. In this paper he also led us to the importance of dimensional analysis and dynamic similitude. The fluid flow problems involve a number of complex factors. Analytical methods in general are not sufficient to derive solutions. Engineers largely depend on empirical formulae, experience and intuition for solving problems associated with design and construction of hydraulic structures. Subsequently, physical models were employed in studying fluid flow problems. Scale modelling technique used in physical model is based on similitude principles. Dimensional analysis is used to obtain a functional relationship between the dependent and independent variables. The principle of dynamic similitude is used to solve flow problems where exact analytical solutions are not possible using analytical methods. At different fluid than one in prototype can also be used. Selection of fluid and model scales depends upon practical considerations. [4, 5]

A beach is a landform along a body of water. It usually consists of loose particles, which are often composed of rock, such as sand, gravel, shingle, pebbles, or cobblestones. The particles comprising a beach are occasionally biological in origin, such as mollusc shells or coralline algae.The beach is under a state of dynamic equilibrium with the environmental parameters of waves, tides, currents, winds, etc. which are prevalent in the coastal area. The response of the beach is a function of shoreline configuration, beach profile and sediment characteristics. Also the coastal processes are influenced by sources/sinks of sediment material. Thus, the morphological processes in coastal areas are quite complex and need comprehensive understanding of the various coastal processes involved. The coastal engineer has to plan development activities duly considering the coastal processes and sedimentation in the region that will have a direct bearing on:

- Prediction of environmental quality and impact.
- Habitat stability.
- Public health risks.
- Marine hazards such as ship grounding, oil spills, etc.
- Access to ports, sea bed scouring.
- Siltation in harbours, infill of reservoirs and artificial lakes.
- Coastline protection.[1]

By the means of the physical process-based modelling approaches to computing coastal and estuarine hydrodynamic and morphodynamic processes, an integrated model system was developed to simulate tides, waves, currents, winds, sediment transport, and morphological changes in coastal and estuarine regions. In his paper he presents an overview of this integrated morphological process modeling system consisting of modules for simulating random wave deformations, tidal and shortwave-induced currents, sediment transport and morphological changes. The individual modules included in the integrated model system were validated by simulating hydrodynamic and morphodynamic processes in laboratory experiments and field study cases. An example for model application to an estuary is presented to demonstrate the model's effectiveness in simulating comprehensive impacts of combined storm waves, typhoons (or hurricanes), river floods, sediment transport, and morphological changes in its coastal and estuarine area. This modeling system provides engineers and researchers with an efficient and effective numerical software package to facilitate better coastal erosion protection, flood and inundation prevention, coastal storm water management and infrastructure protection against hazardous storms, typhoons, and hurricanes.[10]

The causes of coastal erosion are broadly classified as natural and human causes. The natural causes are:

- Increased rate of net littoral drift due to change in wave conditions.
- Erosion during extreme wave and storm surge condition.
- Loss of sand into canyons.
- Sea level rise.
- Deflation- sand movement due to wind.
- Subsidence- lowering of the surface in certain region.
- Variation in supply of sand from rivers due to droughts.

The human causes are:

- Interruption to littoral drift by construction structures such as breakwaters, navigation channels.
- Dredging and disposal of sand while maintaining the navigational depths in channels and harbors.
- Removal of the sand from the beach.
- Obstruction to natural supply of land from rivers.[6]

The development of ports, it is of vital importance to ensure that the desired wave tranquillity is achieved in the harbour area. The disturbance due to the combined effect of refraction, shoaling, diffraction, non linearity, partial reflection from pier, breakwater etc. should be considered while assessing the wave tranquillity.[3]

The physical and numerical modeling and simulation form critical support tools for layout and structural design of ports. Physical models are still essential as modeling tools, whilst having the following advantages:

- Complicated internal processes do not have to be known exactly to obtain reliable results.
- The hydrodynamic processes are being visualized.
- Cause and effect can be observed directly for optimization.
- Models provide an overview of proposed future realizations.[7]

Physical models constructed and operated at reduced scale offer an alternative for examining coastal phenomena that are presently beyond our analytical skills. Dalrymple (1985) pointed out two distinct advantages gained by using physical models to replicate near shore processes.

1) The physical model integrates the appropriate equations governing the processes without simplifying assumptions that have to be made for analytical or numerical models.
2) The small size of the model permits easier data collection throughout the regime at a reduced cost, whereas field data collection is much more expensive and difficult, and simultaneously field measurements are hard to achieve.

The main three goals that can be pursued using a physical model are as follows:-

1) Seek qualitative insight into a phenomenon not yet described or understood (e.g., turbulence formation by wave breaking, formation of scour holes at coastal structures).
2) Obtain measurements to verify or disprove a theoretical result (e.g., nonlinear waves on a uniform current, or interacting nonlinear waves).
3) Obtain measurements for phenomenon so complicated that so far they have not been accessible for theoretical approaches (e.g., stability of rubble-mound breakwaters, or sediment suspension over a rippled bed).[8]

The model calibration and validation is a very important aspect after the model is completed and it is done by comparing the values of all the model parameters that have been adjusted (e.g. roughness coefficient, eddy viscosity, etc). For the evaluation work the values should be submitted such as water level difference diagram and velocity difference diagram. After the calibration is done verification is the next major aspect which is carried out by comparing the predicted water levels and current velocities to actual measured values. The average differences in speed and direction shall not be more than 30% and 450 respectively. [9]

IV. CONCLUSION

Hydraulic models play a vital role in decision making while constructing coastal structures as these models can give us the information about the actual prototype conditions. Many studies can be done on these models such as tranquillity conditions, flow of the water, stability of the coastal structures, etc. Different types of physical models are to be used depending upon the nature of studies to be carried out. Hence, the use of hydraulic models is very important for the studies of coastal phenomenon such as waves and tides, it is also very important to know the stability of the coastal structures.

REFERENCES

1) H.B. Jagadeesh, (2016), “Coastal processes and sedimentation”, CW&PRS, lecture notes, 14-15 September 2016
2) J.D. Aggarwal, (2013), “Wave and Tidal hydrodynamics”, CW&PRS, lecture notes, 9-10 October 2013
3) K.H. Barve, Shri L.R. Ranganath, and Shri M.D. Kudale, (2014), “Assessment of Wave Tranquillity in the proposed Harbour with Ro-Ro Jetty” ”. Published by Hydro 2014 International, 19th Conference on Hydraulics, Water Resources & Environmental Engineering – 18- 20 Dec 2014.
4) M. Phani Kumar,(1991), “Physical Modelling” CW&PRS, lecture notes, 14-15 july 1991
5) M. Phani Kumar,(2011) “Wave Hydrodynamics”, CW&PRS, lecture notes, 16-19 September 2014

6) M.D. Kudale, (2013), "Coastal erosion and protection", CW&PRS.
7) Prof. Hans Moes, Prof. Dave Phelp, Prof. Marius Rossouw, Stellenbosch, (2005), "Hydraulic Model studies for Port Structures and Development" Published by Railway and Harbour Development.
8) Steven A. Hughes, (1993), "Physical Models and Laboratory Techniques in Coastal Engineering", Volume 7
9) T. Nagendra, (2013)" Coastal processes and sediment transport", CW&PRS, lecture notes, 9-10 October 2013
10) Yan Ding and Sam S. Y. Wang, (N.A.), "Development and Application of a Coastal and Estuarine Morphological Process Modelling System". Published by Journal of Coastal Research, Special Issue 52: pp. 127 – 140.