The Numerical and Experimental Simulations of Wave Evolution near Islands

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ABSTRACT

The characteristic of waves near islands is quite different from that in the open sea and is crucial for the safety of offshore platforms. In this paper, Wave evolution near specific islands is investigated by numerical simulation and model experiment. Based on the spectral third-generation wind-wave model WAVEWATCH, the near islands wave evolution of regular and irregular waves at open sea are simulated to acquire the variation of wave parameters and energy spectrum on the route of wave propagation. To reveal the shallow water features and validate the numerical scheme, model tests are carried out in wave basin with similar seabed. The numerical and experimental results are compared with each other and good consistencies are obtained. This work might be valuable for the responses prediction of floating bodies near the islands in next step.

KEY WORDS: Near islands; wave evolution; WW3; model experiment.

INTRODUCTION

Wave environment near islands plays an important role in determining hydrodynamic loads, motions and structural responses of a moored floating body. However, the waves near islands are affected greatly by the complex seabed conditions and possess the characteristics of non-uniform distribution in space scale, which are greatly different from those in open deep sea. The wave environmental datas at specific islands near southeast coast of China are rarely referred by researchers in the past. In this paper, a numerical scheme based on third generation ocean wave prediction model (WW3) is developed for simulating the wave evolution near islands (Mo, 2014; Zhong, 2014). Meanwhile, model tests are conducted in a wave basin with the same scaled seabed as the specific area of the interested islands to investigate the propagating phenomena (Wang, 2014). A set of wave gauges are arranged in the tests to measure the regular and irregular waves. The wave parameters obtained from the simulation and tests at different positions on the route of wave propagation are compared with each other, and favorable consistency is presented. Finally, some valuable conclusions are drawn to predict wave evolution around islands.

Numerical Model

Waves around islands are extremely complex, among which there are over-top flow and three-dimensional flow accompanied by refraction, diffraction, reflection, dispersion, degradation, diffusion, breaking and climbing. The wave characteristics near islands can be simulated by various numerical models. According to their capability of distinguishing wave phenomenon, these models are classified into three scale sizes: mega-scale models, middle-scale models and small-scale models(Tian, 2014). Mega-scale models are based on phase-averaged model such as WAM, SWAN and WW3 (Wave Watch 3)( Hasselmann et al, 1988). Middle-scale models are based on phase-resolved model, such as mild-slope equation(Berkhoff, 1973), Boussinesq equation(Peregrine, 1967) and Green-Naghdi equation.(Demirbilek, 1992) Small-scale models include viscous models such as FVM-VOF model(Hirt, 1981), SPH model(Gingold, 1977), etc. This kind of models are built based on RANS equation and potential solvers such as WAMIT, WADAM, AQWA and etc., considering the adaptability of numerical model, WW3 is applied to simulate the wave evolution near islands.

The balance equation for the spectrum N (k, ω, x, t) used in WW3 is given as

\[ \frac{\partial N}{\partial t} + \nabla \cdot (\mathbf{k} N) + \frac{\partial}{\partial \omega} (\mathbf{u} \cdot \mathbf{k} N) + \frac{\partial}{\partial \theta} \mathbf{D} \frac{\partial N}{\partial \sigma} = \frac{S}{\sigma} \]  

(1)

\[ \dot{x} = C_s + U \]  

(2)

\[ \dot{k} = -\frac{\partial \sigma}{\partial \theta} \frac{\partial d}{\partial \sigma} \frac{k}{s} \cdot \frac{\partial U}{\partial s} \]  

(3)

\[ \dot{\theta} = -\frac{1}{k} \left[ \frac{\partial \sigma}{\partial \theta} \frac{\partial d}{\partial \sigma} - \frac{k}{s} \frac{\partial U}{\partial m} \right] \]  

(4)

Where, \( C_s \) is given \( C_s \) and \( \theta \), \( s \) is a coordinate in the direction \( \theta \) and \( m \) is a coordinate perpendicular to \( s \). \( d \) is the mean water depth and \( U \) is (depth- and time-averaged) current velocity. \( \sigma \) is relative frequency.

The net source \( S \) is generally considered to consist of three parts,