Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Overtopping and Hydrodynamic Forces on Seawalls of Arc Crown Wall in Regular Waves

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ABSTRACT

Hydrodynamic loads on the arc crown wall of seawalls are studied numerically and experimentally when overtopping appears. Considering the flow of incompressible liquid, the primary governing equations are the well-known Reynolds-averaged Navier-Stokes (RANS) equations associated with the turbulence model. The volume of fluid method (VOF) is used to trace the free surface. An analytic relaxation approach is developed to implement wave generation and absorbing in the numerical wave flume, which is validated comparing the computed overtopping discharge with the experimental data and numerical results in literature. The physical model tests on hydrodynamic load on the seawalls are carried out in a wave flume in which the time series of hydrodynamic forces acting the crown wall are measured by a three component balance. The numerical results are compared with the physical model results. A good agreement is found.

KEY WORDS: seawalls; crown wall; regular wave; hydrodynamic force; overtopping; violent breaking; numerical wave flume.

INTRODUCTION

When coastal buildings or roads are threatened, the typical response is to harden the coast with a seawall. Seawalls run parallel to the beach and can be built of concrete, wood, steel, or boulders. When storms attack the coastal areas, waves break against seawalls throwing water and spray over the top. Violent overtopping events can be extremely dangerous with people, cars and facilities in coasts. Waves generated by storms, either locally or offshore, exacerbated by high tides and low air pressure lead to the disruption of road services, flooding, structural damage and occasionally loss of life. For the design and maintenance works of coastal structures, reliable predictions of wave overtopping are required. Empirical formulae exist for dikes, rubble mound breakwaters and vertical breakwaters, however, often there are no suitable theoretical or numerical methods available for structures that deviate from standard shapes in appearance.

Traditionally, physical model experiment approaches have been used to evaluate the overtopping over some seawalls for specific projects and a large data set obtained from numerous physical model tests can be found in literature. On the other hand, in order to optimize the seawall profiles for low construction cost, it would be a potential approach to decrease the level of seawalls using the arc drown wall to return the incoming waves to ocean. Overtopping of waves over such seawall of low level is a violently natural phenomenon that may cause the coastal structural failure. Owing to the presence of returning jet and breaking waves, flows become highly turbulent. Numerical simulation of overtopping of waves in complex flows with high turbulence and hydrodynamic loads on the seawall is one of the challenging topics.

Development, refinement and applications of the Numerical Wave Tanks have been recognized as one of most intensively studied topics in the field of coastal and ocean engineering. One kind of the numerical models is based on the depth averaged Navier-Stokes equations, including the shallow water equations and the family of the Boussinesq equations. These models are suitable for describing hydrodynamic flows with the free surface in the sense of the hydrostatic assumption based uniform distribution of horizontal velocities and the specific distribution of horizontal velocities from the Boussinesq approach without hydrostatic assumption. The depth averaged hydrodynamic model is no long valid for the flows with violently distorted free surface, such as breaking waves and overtopping, even though there are several papers concerning the numerical simulation of overtopping by the use of the shallow water equations. Hu *et al* (2000) proposed a systematic comparison of overtopping over seawalls of simple slope profile among the experimental data and the numerical results obtained by the nonlinear shallow water equations. Even though it turns out that the shallow water equations based numerical model works well for prediction of overtopping, it is hard to extend this kind of mathematical models to simulate violent overtopping when wave breaking and air entrainment appear.

Another kind of mathematical models is the numerical solution of the Reynolds averaged Navier-Stokes equation for turbulent flows of incompressible fluids in which the specific approach is used to simulate the changes of the free surface. In the passed ten years, there is significant progress in the development and application of the RANS based numerical wave tanks, including the numerical schemes and algorithm of the Navier-Stokes equations, the numerical approaches for the violent deformation of the free surface and the of numerical and methods, and the specific method for setting up the wave generation