Improving Method of Estimating Irregular Wave Overtopping Rates

Changliang Li1, Xiaolin Huan2

1. College of Petroleum Engineering, China University of Petroleum (East China), QingDao, Shandong Province, China
2. College of Civil and Architecture Engineering, Shandong University of Technology, QingDao, Shandong Province, China

ABSTRACT

This paper reviewed and extended the Shore Protection Manual (SPM) method and Coastal Engineering Manual (CEM) for estimating the wave overtopping rates under irregular waves. An improved formula of applying a monochromatic wave overtopping equation to random waves is presented. When the freeboard is zero, the overtopping rate is related to not only wave height, but also wave velocity. The assumption made by the SPM method is not practical, leading to the overtopping rates are underestimated or overestimated. This paper improves the unreasonable assumptions. Furthermore, the effects of the statistical distribution of ocean wave are taken into account. The results are compared with SPM method, CEM method, Experimental data and Numerical results and other empirical method. One concludes that the improved method is analytically correct, and suggested to be a reference design principle.

KEY WORDS: overtopping rate, weibull distribution, irregular wave, directional spectrum, breaking parameter, wave runup.

INTRODUCTION

When water waves reach seawalls or revetments, they usually go through the physical processes of dissipation, reflection, runup, and sometimes overtopping of the structure. The wave overtopping is a violent phenomenon which may cause the failure of coastal structures and damages to the properties and lives. Wave overtopping significantly affects the functional efficiency, safety of transit, mooring on the rear side and, to some extent, the structural safety of coastal structures. Although overtopping can be reduced or even eliminated by increasing structure heights, the better structure design in term of function, aesthetics, and cost is often one that allows overtopping under extreme conditions. On the other hand, in the design of the crest elevation of a seawall, usually a tolerable wave overtopping rate is applied (Owen, 1980; Goda, 1985; van der Meer, 1994). Accurate estimation of overtopping rates is therefore critical to the designs and the analyses of failure probability of the structure.

In general speaking, prediction the overtopping rate of random waves is difficult, because not every wave can overtop the structure, only the fraction of waves that runup beyond the freeboard can lead to overtop. Furthermore, the overtopping of a single wave in an irregular wave train is strongly affected by the interaction of wave and wave. A very good discussion about the influence of various physical parameters on wave overtopping under irregular waves was presented by Jensen and Juhl (1987).

Now, there are three main methods available to predict overtopping rates for irregular waves include numerical modeling, physical model testing and empirical formulas. Goda et al. (1975) presented design diagrams for estimation of the overtopping rate of seawalls based on results from small-scale model tests. Takayama et al. (1982) derived an empirical formula from Goda’s design diagrams to predict the average overtopping rate. Hayashi et al. (2000) tried an approach of the Lagrangian gridless analysis to simulate wave overtopping events for an upright seawall. Uemaya(1993) used both the theoretical and experimental analyses to investigate the wave overtopping on a vertical boundary. Wijayaratna er al. (2000) simulated wave overtopping on gentle slope seawalls by using 2D Large Eddy Simulation (LES). Okayasu et al. (2005) performed experiments on wave overtopping for gentle slope seawalls in a laboratory flume, and applied 3D LES to evaluate instantaneous overtopping discharge. Yu et al. (2007) studied the wave overtopping performance of sloping seawall under oblique and multi-directional irregular waves by 3D physical model test. The numerical models have been validated only by small-scale tests with limited structural and incident wave conditions. Physical model testing is impractical for preliminary design due to time and expenses involved. As a result, design engineers rely heavily on empirical overtopping formulas for preliminary design.

These existing empirical formulas associated with the Shore Protection Manual (SPM) (1984), Goda (1985) and Battjes (1972) are based on monochromatic wave data. Owen (1982) developed a design equation relating the mean overtopping discharge to incident wave conditions. By analyzing a large number of observed overtopping data under irregular waves, van der Meer and Janssen (1995) developed an empirical method to predict the wave overtopping rate. It had been