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A New Technique For Estimating The Stable Weight Of Armor Units On A Submerged Breakwater In Wave-Current Coexisting Field

Ayman M. Mostafa, M. A. Hasan and Y. Marmoush
Dept. of Irrig. and Hydr., Cairo University,
Giza, Egypt

ABSTRACT

The stable weight of armor units on a submerged breakwater considering nonlinear interaction among waves, current and submerged breakwater has been investigated in this study. An integrated technique for estimating the nonlinear wave and current forces on armor units and their minimum stable weight have been developed for the case of non-breaking waves. The technique is mainly dependent on a numerical model, called BEM-FEM model. The model considers the wave deformation due to its interaction with porous but non-deformable structure over an impermeable seabed in a current filed. The results of the BEM-FEM model have been compared with some experimental results in order to evaluate the validity of the numerical model. The applicability of the BEM-FEM model has been used to evaluate the effect of using submerged breakwaters to improve the swimming conditions and decrease the net long shore transport of sand in the near shore zone in one of the Egyptian northern coastal resorts. The effect of breakwater size, hydraulic properties and current on the wave deformation and the dynamic forces on armor units has been examined. Also, the dynamic behavior of the submerged breakwater has been analyzed under different wave and current conditions to estimate the maximum wave forces acting on the armor units. Moreover, a new method has been proposed to estimate the distribution of the stable weight of the armor units on a submerged breakwater using Rufin stability models. It has been found that the factor of safety for computing the minimum stable weight using some traditional formulae ranges between 2 to 3.

KEY WORDS: Nonlinear waves; current; wave forces; submerged breakwater; stable weight; Egyptian coast; BEM-FEM coupled model.

INTRODUCTION

Coastal zones in many countries are of major concern by the virtue of being multi-functional regions. Their use as harbors, fisheries, recreational areas, source of minerals, water supply and excess water disposal gives them a very special interest. Also, the risk of low land flooding and excessive saltwater intrusion in the groundwater due to sea level rise, induced by the green house effect, has become a hot topic in much research. The use of coastal structures is the tool in many cases and, hence, the stability of marine structures for various waves, current and site conditions becomes of great interest.

The northern coast of Egypt has been suffering from several problems including erosion, strong rip currents, and overflow of the promenade and failure of some coastal structures. Submerged breakwaters have been introduced to improve the near shore conditions especially swimming conditions and erosion in several places. The breakwater causes large waves to break onshore or on the submerged breakwater, while smaller waves pass onshore of it allowing flushing of water. However, less attention is given to the stability of armor units on the breakwater under the effects of wave-current coexisting field considering porous breakwater and nonlinear interactions between water the structure.

Earlier researchers investigated the wave–current–structure interactions often with shortcomings. They either relied on laboratory experiments or on the use of simplified numerical schemes or focused on impermeable/small size structures, e.g., pipeline.

The use of analytica1 techniques to study the interaction between waves and permeable breakwater is normally older than the numerical ones. Sollitt and Cross (1972) linearized the wave and porous flow equations in order to develop an analytical solution for wave transmission through permeable structures.

Based on modified Navier-Stokcs equations, McCorquodale and Hannoura (1985) developed the flow equations inside the porous media and applied them to the case of rubble mound breakwaters. Analytical solutions analogous to the mild slope equations were also developed to estimate the wave transformation over a submerged permeable breakwater (e.g., Rojanakamthom et al., 1990; Izumiya, 1990).Cruz et al. (1992) derived a set of nonlinear vertically integrated equations similar to that of' Boussinesq to estimate the wave transformations past a submerged permeable breakwater. They found that their equations work well in the region of cnoidal waves, but the transmitted and the broken wave characteristics could not be well predicted.

The use of fully nonlinear potential flow wave models was limited to deep water waves (e.g., Longuet-Higgins and Cokelet, 1976; Vinje and Brevig, 1981; Dold and Peregrine, 1986). They used full nonlinear potential flow wave models with emphasis on deepwater plunging breaking. Dommermuth et aI. (1988) confirmed the validity of such models to simulate deepwater plunging breakers in a wave tank.

Cokgor and Avci (1998) conducted experimental investigations for estimating the hydrodynamic forces on a partially buried pipeline in the seabed laid in a co-existing wave and current field. They estimated the force coefficients for Reynolds number (R_e) of $0.8\text{-}2x10^4$ and