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Ocean Engineering 32 (2005) 1073–1097

www.elsevier.com/locate/oceaneng

On the radiation and diffraction of linear water waves by a rectangular structure over a sill. Part I. Infinite domain of finite water depth

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Received 1 January 2004; accepted 7 July 2004

Available online 19 December 2004

Abstract

The effects of a bottom sill on the hydrodynamic coefficients, wave force, and reflection and transmission coefficients of a rectangular structure floating on the free surface are analyzed in this paper by use of a semi-analytical method. Linearized water wave theory and the method of separation of variables are applied to obtain analytical expressions for the diffracted and radiated wave potentials. The unknown coefficients in the obtained expressions are determined by use of the eigenfunction expansion matching method. To verify the obtained expressions and the proposed method, a comparison of the analytical results with those obtained by the boundary element method is made and very good agreement is achieved, which shows that the analytical expressions for the radiated and diffracted potentials are correct. By use of the present analytical solution, several results for the hydrodynamic coefficients, wave force, reflection and transmission coefficients are given.

Keywords: Radiation and diffraction; Linear water waves; Analytical method; Hydrodynamic coefficients; Wave force; Reflection and transmission coefficients

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doi:10.1016/j.oceaneng.2004.07.011

1. Introduction

Floating structures are often used in ocean engineering, such as breakwaters, wave energy devices and ocean platforms. One of the most common floating breakwater types is the pontoon or box-type which has been proven effective in moderate conditions (McCartney, 1985). The hydrodynamic properties of floating structures are of interest of designers. Many research papers have been involved in the hydrodynamics of floating structures and lots of important results have been obtained.

To obtain the hydrodynamic coefficients, wave forces, and reflection and transmission coefficients of two-dimensional rectangular structures, various numerical and analytical methods have been used. In analytical or semi-analytical studies, Black et al. (1971) applied the Schwinger's variational formulation to the radiation of surface waves due to small oscillations of horizontal rectangular structures. Radiated wave amplitudes and wave forces were computed. Drimer et al. (1992) presented a simplified analytical model for a floating rectangular breakwater in water of finite depth. The hydrodynamic coefficients, exciting forces, and reflection and transmission coefficients are computed. Williams (1994) analyzed the Froude–Krylov force coefficients for the case when a rectangular body is located close to the free surface or sea bed based on the linear diffraction theory. Lee (1995) presented an analytical solution to the heave radiation problem of a rectangular structure, and by use of the solution, he calculated the generated waves, added mass, damping coefficients and the hydrodynamic effect of the submergence, width of the structure. Wu et al. (1995) used the eigenfunction expansion-matching method to analyze the wave-induced responses of an elastic floating plate. Wave-induced responses such as the displacement, bending moment and shear force of the structure were obtained. Cheong et al. (1996) extended the eigenfunction expansion method to analyze a submerged platform breakwater. Yang et al. (1997) used the eigenfunction expansion method to explore the interaction of a linear water wave in a channel of constant depth impinging on a vertical thin porous breakwater with a semi-submerged and fixed rectangular obstacle in front of it and made wave flume experiments to verify the correctness of the general solution.

In numerical studies, Anderson and He (1985) presented a simple Green's function technique to calculate the two-dimensional hydrodynamic coefficients of one or two infinitely long, arbitrary cylinders forced to oscillate in or below the free water surface. The hydrodynamic parameters for different cases and oscillation modes were obtained. Hsu and Wu (1997) applied the linear water wave theory and the Boundary Element Method (BEM) to the hydrodynamic coefficient for an oscillating rectangular structure on a free surface with sidewall, and negative added mass, sharp peaks in the damping and resonant behavior have been found. Hsu and Wu (1999) used again the boundary element method to the scattering of water wave by a submerged horizontal plate and a submerged permeable breakwater. Sannasiraj et al. (1995) applied the finite element technique to study the interaction of oblique waves with freely floating long structures. The hydrodynamic behavior of two-dimensional horizontal floating structures under the action of the multi-directional waves has been investigated, and the motions and forces on a rectangular floating structure experiencing unidirectional and multi-directional wave fields were computed. Sannasiraj et al. (1998) adopted a two-dimensional finite element