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Modeling of cable-moored floating breakwaters connected with hinges

Ioanna Diamantoulaki *, Demos C. Angelides

Department of Civil Engineering, Aristotle University of Thessaloniki, University Campus, Thessaloniki 54124, Greece

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ABSTRACT

In the present paper, the overall performance of a cable-moored array of floating breakwaters connected by hinges is investigated under the action of monochromatic linear waves in the frequency domain. The performance is defined here as: (i) demonstration of acceptable levels of both response of the array and its effectiveness and (ii) non-failure of the mooring lines. The numerical analysis of the array is based on a 3D hydrodynamic formulation of the floating body coupled with the static and dynamic analyses of the mooring lines. The motions of the array of floating breakwaters associated with the hinge vertical translations are considered in the hydrodynamic analysis with the implementation of appropriate generalized modes. The stiffness and damping coefficients caused by the mooring lines in both rigid and generalized degrees of freedom are derived here in the general form. A rigorous parametric study is carried out in order to investigate the effect of different configurations (number of hinge joints and number of mooring lines) on the performance of the cable-moored array of floating breakwaters. Moreover, the performance of the various configurations of cable-moored floating breakwaters connected by hinges examined is compared with the performance of a single cable-moored floating breakwater with no hinges. It is found that the number of hinge joints and mooring lines have a direct effect on the performance of the cable-moored array of floating breakwaters.

1. Introduction

The traditional type of breakwater is the bottom-founded structure. The construction of this type of breakwater is not always economical, especially for deep water depths; furthermore, breakwaters of this type are potentially associated with environmental problems, such as intense shore erosion, water quality problems and aesthetic considerations. The aforementioned disadvantages motivated the search for an alternative type of breakwater, namely the floating ones. The application of such kind of structures is continuously increasing, because of the fast and inexpensive construction as well as the possibility of mobility and reallocation. The floating breakwaters are usually pile-restrained or cable-moored. Reviews of the general design of floating breakwaters are presented in [1–4]; furthermore, Isaacson [4] provides an overview of wave effects on floating breakwaters. As far as the hydrodynamic analysis of the floating body is concerned, 2D models have been developed that describe the complete linear hydrodynamic problem of the wave–structure interaction [4–14]. These 2D models use four methods: (i) finite element method, (ii) boundary integral method, (iii) finite differences using Boussinesq type equations, (iv) volume of fluid and (v) particle methods. Analytical solutions of the hydrodynamic problem are available for simple geometries and regular waves [15]. Loukogeorgaki and Angelides [16] and Diamantoulaki et al. [17] used a 3D hydrodynamic model to investigate the performance of floating breakwaters. A 3D analysis for a V-shaped floating breakwater was used by Briggs et al. [18], including hydroelasticity.

The phenomenon of hydroelasticity has also been investigated in various studies using (i) 2D linear theories [19–22], (ii) 2D non-linear theories [23,24], (iii) 3D linear theories [25–28] and (iv) 3D non-linear theories [29,30]. Bishop and Price [31] used free undamped "wet" bending modes, while Gran [32] used orthogonal modes of a uniform beam to express the vertical translations of a slender ship. Newman [33] extended the linearized frequency domain analysis of wave diffraction and radiation for a 3D body in a fixed mean position to a variety of deformable body motions using an expansion in arbitrary modal shape functions. Jensen and Pedersen [23] developed a non-linear quadratic strip theory formulated in the frequency domain for predicting wave loads and ship responses in moderate seas. Du [34] presented a complete frequency domain analysis for linear 3D hydroelastic responses of floating structures moving in a seaway and Fu et al. [35] used 3D linear hydroelasticity theory to predict the response of flexible interconnected structures. Finally, Wu et al. [29] used a 3D non-linear hydroelasticity theory for both frequency and time domain analyses. Many researchers have dealt with the application of hydroelasticity theories in the analysis of VLFS [36–40], since hydroelasticity is very important for this kind of structures. A comprehensive review of hydroelasticity theories

* Corresponding author. Tel.: +30 2310 995702; fax: +30 2310 995740.
E-mail address: idiamant@civil.auth.gr (I. Diamantoulaki).

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