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Performance of Moored Floating Breakwaters

Eva Loukogeorgaki and Demos C. Angelides*
Department of Civil Engineering, Aristotle University of Thessaloniki (AUTh), Thessaloniki, Greece

In this paper the performance of moored floating breakwaters under the action of normal incident waves is investigated in frequency domain. A 3-dimensional hydrodynamic model is coupled with a static and dynamic model of the mooring lines, using an iterative procedure. The models are validated through comparison with numerical and experimental results. An extensive parametric study is performed. The initial draft of a base case floating breakwater is modified through the appropriate modification of the mooring lines' length, directly affecting the mooring lines' stiffness and damping. The existence of an "optimum" configuration (length of mooring lines and draft) for the frequencies examined, in terms of wave elevation coefficients and mooring lines' forces, is clearly demonstrated.

INTRODUCTION

Floating breakwaters present an alternative solution to conventional fixed breakwaters and can be effectively used in coastal regions with mild wave environment conditions. Poor-foundation or deep-water conditions as well as environmental requirements, such as phenomena of intense shore erosion, water quality and aesthetic considerations, advocate for the application of such structures.

Floating breakwaters have many advantages compared to the fixed ones, e.g., flexibility of future extensions, mobility, and real-location ability. As a result, many types of floating breakwaters have been developed, as described by McCartney (1985). However, the most commonly used are the rectangular pontoon-type breakwaters, which are moored to the sea bottom with cables or chains.

A moored floating breakwater should be properly designed in order to ensure: (a) effective reduction of the transmitted energy, hence adequate protection of the area behind the floating system, (b) non-failure of the mooring lines, and (c) non-failure of the floaters themselves and their interconnections. The satisfaction of these 3 requirements represents the overall desired performance of the floating breakwater.

Isaacson (1993b) provides a brief review of the design process for floating breakwaters and related design criteria, both with respect to wave effects. Linear 2-dimensional models that describe the complete hydrodynamic problem (diffraction and radiation) have been developed by Isaacson and Nwogu (1987), Isaacson (1993a), Isaacson and Bhat (1996), Williams and Abul-Azm (1997), Bhat and Isaacson (1998), Sannasiraj et al. (1998), Williams et al. (2000), and Lee and Cho (2003). The effect of mooring lines' stiffness is modeled with the appropriate modification of the hydrodynamic equations (Williams and Abul-Azm, 1997; Sannasiraj et al., 1998; Williams et al., 2000; and Lee and Cho, 2003). Bhat and Isaacson (1998) performed an iterative coupled procedure between a hydrodynamic model and a mooring analysis model in terms of convergence of steady drift forces. Isaacson and Nwogu (1987) and Bhat (1998) properly modified the 2-D hydrodynamic model in order to take into account the effect of finite floating body length. Isaacson and Garceau (1997) investigated the response of a freely floating breakwater by superposing 2-D solutions for the diffracted and radiated waves, and they compared this simplified approach with 3-D results. Briggs et al. (1999) implemented a 3-D analysis of a V-shape floating breakwater. Finally, Kim et al. (1994) investigated theoretically and experimentally the effect of the initial constraining forces of a pile-restrained floating breakwater and indicated the existence of optimum initial values of these forces in terms of wave transmission.

In this paper the protection effectiveness and dynamic response of a moored floating breakwater is investigated in frequency domain under the action of regular waves. A 3-D model of the hydrodynamic analysis of the floating body is coupled with a model of the static and dynamic analysis of the mooring lines, using an appropriate iterative procedure in terms of the steady drift forces and the response of the floating breakwater. The floating body analysis is based on a 3-D panel method utilizing Green's theorem. The analysis of the mooring lines includes the computation of mooring lines' stiffness and damping imposed on the floating body. An extensive parametric study is performed in order to investigate the effect of the stiffness and damping of the mooring lines on the dynamic response and effectiveness of the floating breakwater as well as on the mooring lines' loads. The initial draft of a base-case floating breakwater is properly modified through the appropriate changes of the mooring lines' length; this directly affects mooring lines' stiffness and damping. The existence of an "optimum" configuration (length of mooring lines and draft) for the frequencies examined, in terms of wave elevation coefficients and mooring lines' forces, is clearly demonstrated.

NUMERICAL MODELS

The 2 components of the analysis of the behavior of a moored floating breakwater are briefly described here. Fig. 1 shows the geometry of the problem, the coordinate system and the definition of some basic quantities mentioned below. The origin of the coordinate system is placed on the still water level.

Hydrodynamic Analysis of Floating Body

The hydrodynamic analysis of the floating body subjected to incident regular waves is conducted in the frequency domain and

*ISOPE Member.

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