Three-dimensional Formulation of Multiple Pile-restrained Floating Breakwaters Connected by Hinges

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ABSTRACT

The overall performance of an array of multiple pile-restrained floating breakwaters connected by hinges is investigated under the action of monochromatic incident waves in the frequency domain. The numerical analysis of the array is based on a 3D hydrodynamic formulation of the floating body. The effect of the configuration of the array of multiple floating breakwaters on its effectiveness and deflections as well as on the loads imposed on the restraining piles are investigated through extensive parametric study. Moreover, the performance of the various configurations of multiple floating breakwaters examined is compared with the performance of a single pile-restrained breakwater with no hinges.

KEY WORDS: Multiple pile-restrained floating breakwaters; fluid structure interaction; hydroelasticity; hinge joints; effectiveness; response; deflections.

INTRODUCTION

The traditional type of breakwaters is the bottom-founded one. The construction of this type of breakwaters is not always economical, especially for large water depths; furthermore, breakwaters of this type are potentially associated with environmental problems. The aforementioned disadvantages motivated the search for an alternative type of breakwaters, namely the floating ones. The application of such kind of structures is continuously increasing, because of their fast and inexpensive construction as well as their mobility and relocation possibility. The floating breakwaters are usually pile-restrained or cable-moored. Their design must aim at satisfactory reduction of the transmitted energy, and the non-failure of the restraining piles or mooring lines as well as their interconnections (Loukogeorgaki and Angelides, 2005). Piles are used for water depths less than 10 m and for favorable sea-bottom conditions, while mooring lines can be used for deeper water depths irrespective of the bottom conditions (McCarty, 1985).

Reviews of the general design of floating breakwaters are presented in McCarty (1985), Werner (1988), Cammaert et al. (1994) and Isaacson (1993); furthermore, Isaacson (1993) provides an overview of wave effects on floating breakwaters. As far as the hydrodynamic analysis of the floating body, different linear two dimensional models have been developed to describe the complete hydrodynamic problem of the floating body interaction with the wave field by Isaacson and Nwogu (1987), Isaacson (1993), Isaacson and Bhat (1996), Bhat (1998), Williams et al. (2000), Fugazza et al. (1988), Garrison (1984). While a three dimensional model for V-shaped floating breakwater was used by Briggs et al. (1999).

In addition to the above investigations that consider rigid floating body, hydroelasticity has also been investigated in various studies. According to Chen et al. (2006) hydroelasticity theories can be classified into the following categories; (i) two-dimensional linear, (ii) two-dimensional non-linear, (iii) three-dimensional linear and (iv) three-dimensional non-linear theories. An extended review of the hydroelastic theories and studies is presented in Chen et al. (2006). In each of these hydroelastic studies the floating body is assumed to be free.

Besides free floating bodies, pile-restrained ones have also been investigated by several researchers, assuming rigid body conditions. In particular, they have been investigated numerically and theoretically (Kim et al., 1994; Isaacson and Baldwin, 1998; Bhat, 1998), numerically (Koutandos et al., 2004).

In this paper, the performance of an array of multiple pile-restrained floating breakwaters connected by hinge joints under the action of monochromatic incident waves is investigated in the frequency domain. The array of multiple floating breakwaters experiences deflections along its length and is held in place by piles that allow only vertical displacements to take place. The performance is defined here as the response (deflections) of the array, its effectiveness in terms of the reduction of the transmitted energy behind it and the reduction of load level exercised on the restraining piles. The total number of degrees of freedom needed to describe the array of multiple floating breakwaters are the six conventional body modes (surge, sway, heave, roll, pitch, yaw) when it moves as a rigid body, plus the extra generalized modes, equal to the number of the hinge joints. The generalized hinge modes are introduced to facilitate the representation of the deflections due to the hinges. The six rigid-body modes are defined with the assumption that all the hinges permit each module to pitch independently. The numerical analysis of the array is based on a three-dimensional hydrodynamic formulation of the floating body. An extensive parametric study is carried out in order to investigate the effect of the configuration of multiple pile-restrained floating breakwaters on the performance of the array. The performance of the various configurations examined is also compared with the corresponding one.