International Journal of Offshore and Polar Engineering
Vol. 8, No. 4, December 1998 (ISSN 1053-5381)

Wave Propagation Past a Pile-Restrained Floating Breakwater

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ABSTRACT

The present paper describes a numerical and experimental study of wave propagation past a pile-restrained floating breakwater. The numerical model is based on two-dimensional wave diffraction theory for wave interaction with a long horizontal cylinder and is applied to the common case of a rectangular-section breakwater subjected to normally incident waves. Comparisons with experimental measurements show excellent agreement and the effect of a gap between the piles and the breakwater is discussed. Relevant results for the wave transmission and heave motion of the breakwater in deep water are presented as functions of the relative wave frequency for various beam to draft ratios.

INTRODUCTION

Floating breakwaters are being used increasingly at coastal locations where open water wave conditions are not unduly severe and water depths are relatively large. A variety of floating breakwater designs has been used, including concrete caisson breakwaters, A-frame breakwaters, scrap-tire breakwaters and log bundles. General reviews of floating breakwaters include those by McCartney (1985), Werner (1988) and Cammaert et al. (1994), and an overview of wave effects on floating breakwaters has been given by Isaacson (1993). Typically, floating breakwaters have been used at locations where wave periods range up to about 4-5 s and wave heights range up to about 1 m.

Numerical methods describing the response of floating breakwatersto waves have originated largely from ship hydrodynamics (e.g., Newman, 1977). For caisson-type breakwaters, a hydrodynamic analysis based on potential flow theory is generally employed and has been reviewed by, for example, Sarpkaya and Isaacson (1981), Chakrabarti (1987) and Sawaragi (1995). Several authors have treated the corresponding two-dimensional problem of wave interaction with a fixed or floating horizontal cylinder at the water surface (e.g., Bai, 1975; Garrison, 1984; and Isaacson and Nwogu, 1987). Comparisons of field data with laboratory tests and numerical models have generally indicated that the response of breakwaters can be modelled reasonably well.

Floating breakwaters have generally been restrained by either piles or mooring lines. Mooring lines are typically used in deeper water or where bottom conditions are unfavourable, while piles are used in shallower water where water depths are less than about 10 m (McCartney, 1985). Piles offer particular advantages with respect to avoiding drift motion of the breakwater, while maintaining underwater clearance for circulation. The hydrodynamic performance of moored breakwaters is reasonably well documented, and in the usual case of relatively slack mooring lines the restraint provided by the mooring lines has relatively little effect on wave transmission and breakwater motions (e.g., Natvig and Pendered, 1980; Drimer et al., 1992; and Isaacson and Baldwin, 1996). In the case of pile-restrained breakwaters, very few studies have been reported (e.g., Kim et al., 1994). The restraint provided by the piles is significantly greater than that provided by mooring lines and the effects of this on the wave transmission and breakwater motion have not been well established.

In the above context, the present paper describes a numerical and experimental study of wave propagation past a pile-restrained floating breakwater. The numerical model is summarized and is applied to the common case of a rectangular-section breakwater subjected to normally incident waves in deep water. Relevant results for the wave transmission and breakwater motion are presented as functions of relative wave frequency for various beam-to-draft ratios, and comparisons with experimental measurements are carried out. The effect of a gap between the piles and the breakwater is also discussed.

NUMERICAL MODEL

The problem under consideration corresponds to normally incident waves interacting with an infinitely long horizontal cylinder restrained by piles as indicated in Fig. 1. A numerical model has been developed (Isaacson and Nwogu, 1987) to treat this problem on the basis of 2-dimensional linear wave diffraction/radiation theory. Thus, the fluid is assumed incompressible and inviscid, and the flow irrotational, so that potential flow theory is used. The velocity potential Φ of the flow is considered to be made up of components associated with the incident waves, scattered waves, both of these components being proportional to the incident wave height H, and forced waves associated with each mode of motion of the cylinder, corresponding to sway, heave and roll (Fig. 1). The latter potentials are proportional to the corresponding amplitudes of the motion. Thus the total velocity potential Φ is expressed in the form:

$$\Phi = \left[\frac{-i\omega H}{2}(\phi_0+\phi_4)+\sum_{j=1}^{3}-i\omega\xi_j\phi_j\right]\exp(-i\omega t) \quad (1)$$

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Received March 23, 1998: revised manuscript received by the editors September 15, 1998. The original version was submitted directly to the Journal.
KEY WORDS: Breakwaters, coastal engineering, coastal structures, hydrodynamics, wave transmission, waves.