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Shoaling of Periodic Waves over Barred-Beaches in a Fully Nonlinear Numerical Wave Tank

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ABSTRACT

A numerical wave tank based on fully nonlinear potential flow theory is used to calculate changes in local properties of periodic waves shoaling over barred-beaches (wave height, celerity, front-to-back asymmetry). Results show that strongly nonlinear wave decomposition phenomena occur in a modulation region beyond the bars. These are analyzed in detail and discussed in the paper.

INTRODUCTION

Bars on beaches are important topographic features for many coastal engineering problems. For sufficiently high incident waves, bars with shallow berms and steep side slopes induce large wave modulations, mostly on their onshore side. As a result, significant variations occur with depth for parameters such as wave height H, celerity c, and front to back asymmetry s_2/s_1 (Fig. 1). We will show that these modulations result from strongly nonlinear wave decomposition phenomena occurring when nonlinear waves propagate into the deeper-water region beyond the bar.

Such decomposition phenomena have been well observed, over submerged obstacles, shelves or bars, in the field (e.g., Byrne, 1969; Young, 1989) and in the laboratory (e.g., Beji and Battjes, 1994). They were analyzed and modeled using weakly nonlinear and weakly dispersive Boussinesq equations (BE) (e.g., Freilich and Guza, 1984; Seabra-Santos et al., 1987) or low-order Stokes-type expansions (e.g., Massel, 1983; Rey, 1992; Rey et al., 1992). Driscoll et al. (1992) and Ohyama and Nadaoka (1994) used models based on Fully Nonlinear Potential Flow (FNPF) theory to calculate periodic wave propagation over submerged rectangular obstacles. They showed that, to correctly describe wave decomposition, a fully nonlinear method must be used, in which no approximations are made on wave shape and celerity, because of the large wave height-to-depth ratios occurring over the obstacles, leading to strong nonlinearities in the wave field. Similar conclusions were reached by Grilli et al. (1994) who studied the propagation of large solitary waves (breaking and nonbreaking) over submerged trapezoidal breakwaters, using both an FNPF model and laboratory experiments. For waves propagating over steep obstacles on a flat bottom, Driscoll et al. (1992) and Ohyama and Nadaoka (1994) showed that higher harmonics are generated as bound waves in the shallower-water region over the obstacle, and then released as free waves beyond the obstacle, where wave nonlinearity is weaker due to the deeper-water depth. The initial harmonic generation depends on the dimensions of the obstacle (i.e., berm depth and width) and on incident wave period (i.e., wavelength) and height (i.e., incident steepness).

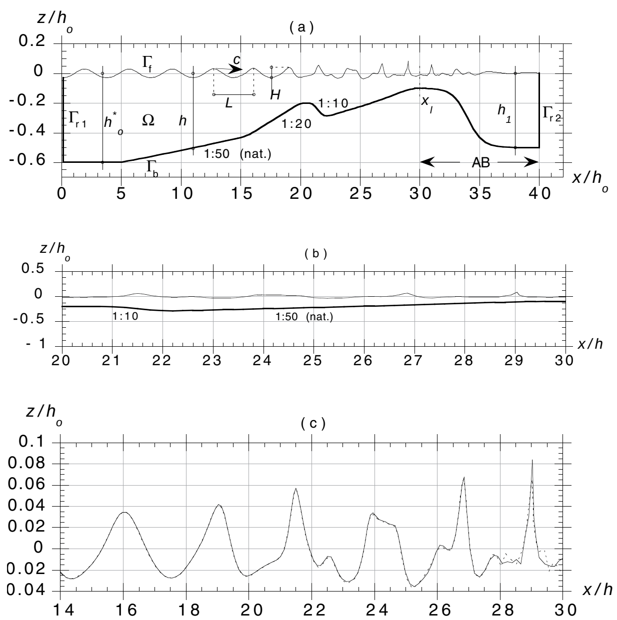

Fig. 1 Sketch of computational domain and typical free-surface elevation for 2D-FNPF computations of a periodic wave, of height H_o and period T in depth h_o, shoaling over a beach with Dean's equilibrium profile (1:50 average slope; with $h(x) \propto (x\text{-}x_o)^{2/3}$) and a bar. (a) NWT set-up; (b) blow-up of free-surface shape in undistorted scale (case 1, Table 1); (c) free-surface shape for case 1 (Table 1) at, $t' =$ (——) $15.75T'$; (- - - - -) $16.75T'$.

Grilli and Horrillo (1996, 1998) used an FNPF Numerical Wave Tank (NWT) to calculate nonlinear properties of periodic waves, of height H_o and period T in deep water, shoaling over cylindrical beaches, i.e., beaches with monotonously decreasing and mildly sloping depth variation $h(x)$. Their two-dimensional (2D) NWT combined (Grilli et al., 1989; Grilli and Subramanya, 1996; Grilli and Horrillo, 1997): (i) a higher-order Boundary Element (BEM) solution of FNPF equations; (ii) an exact generation of finite amplitude periodic waves (Streamfunction Waves) at the deeper water extremity (Γ_{r1}); and (iii) an Absorbing Beach (AB) at the far end of the tank (featuring both free-surface absorption on Γ_f and lateral active absorption on Γ_{r2}; Fig. 1). A feedback procedure was developed to adaptively calibrate the beach absorption

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