Numerical Investigation of a Novel Wave Absorbing Method Based on Gap Resonance

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A new wave absorbing approach based on the mechanism of gap resonance is proposed in this work. The wave absorber is designed by placing a fixed box in front of the end of a physical wave flume, thereby forming a gap between the box and the end wall. To facilitate matching between the resonant frequency and the incident wave frequency, the gap width, box draft, and box breadth are jointly adjustable. A slatted screen is introduced into the gap to obtain the appropriate damping effect, if necessary. Numerical examinations are conducted to investigate the efficiency and applicability of the proposed resonant wave absorber based on a fully nonlinear finite element numerical wave flume within the modified potential flow theory. The numerical results confirm that the resonant wave absorber can achieve a high efficiency for a wide range of wave frequencies. Small reflection coefficients of $K_r < 5\%$ are obtained for all wave conditions examined in this work. Moreover, the size of the wave absorber (measured in the wave propagation direction) is less than 40% of the incident wave length (for example, the wavelength $\lambda \in [1.02 \text{ m}, 6.55 \text{ m}]$ and the water depth $h = 0.5 \text{ m}$). The main advantage of the present method is that it can lead to fairly small reflection coefficients for extremely long waves even with relatively small flume sizes, for which the widely used artificial sloping beach generally fails.

INTRODUCTION

Waves reflected from the end of a physical wave flume or basin have negative effects on the accuracies of laboratory tests. Hence, the installation of a wave absorber is generally required to reduce undesirable reflected waves. The wave absorbers developed thus far can be roughly divided into two categories: active wave absorbers and passive wave absorbers. The former, which are incorporated into the wave generation module to eliminate reflected waves within test models, are not widely used because of their high cost and the complexity of the control system required. Passive wave absorbers are mainly referred to as artificial beaches and cages. Normally, passive wave absorbers require at least one wavelength to achieve effective wave absorption (i.e., a reflection coefficient of $K_r < 0.05$). Indeed, such a requirement remains challenging for long wavelengths, especially when the existing wave flume is not long enough.

Lean (1967) conducted investigations on the reflection of linear waves from three types of permeable sloping beaches and concluded that the length of the absorber can be reduced if an optimal parabolic profile is adopted. However, it is not possible to attain reflection coefficients below 0.10 for a shaped absorber if its length is shorter than approximately 1/2 to 3/4 of the wavelength. As shown by Ouellet and Datta (1987), a parabolic profile seems to be the most efficient choice for wave absorption, although it is generally limited to a narrow range of wave parameters. Chegini (1993) conducted experiments with sloping wave absorbers covered with a layer of horsehair and tested wave absorbers at three slopes of 0.10, 0.15, and 0.20. They showed that the reflection coefficient increases as the wave steepness decreases for a specific slope.

Alternative methods to the artificial beach for absorbing wave energy have been proposed to conserve the lengths of flumes. Le Méhauté (1972) first proposed the concept of a progressive wave absorber, in which a number of thin, perforated vertical screens are adopted with a porosity that decreases toward the rear end of the absorber. Analytical solutions and experimental measurements quantitatively confirmed the validity of the proposed wave absorber. An experiment was conducted for a specific wave with a wavelength $\lambda = 1.08$ m, wave period $T = 1.0$ s, wave height $H = 0.04$ m, and water depth $h = 0.15$ m, and a minimum reflection coefficient $K_r = 0.02$ was achieved when the total length of the wave absorber was 1.0 m. Furthermore, Jamieson and Mansard (1987) conducted experimental studies on an upright progressive wave absorber comprising multiple perforated vertical metal sheets. Chwang and Dong (1984) investigated the trapping of waves by a thin porous plate located near the end of the flume. Experimental results indicated that the reflection coefficient reached a minimum when the porous plate was located at a distance of $m/4$ times the wavelength ($m = 1, 3, 5, \ldots$) in front of the vertical wall. Twu and Lin (1990, 1991) extended the method proposed by Chwang and Dong (1984) to evaluate the reflection of waves from multiple porous plates and found that a set of six porous plates with an appropriate distance ($0.88$ times the water depth) can achieve a wave reflection coefficient below 0.04 for the wave frequency range $0.40 < \omega^2 h/g < 2.80$, where $h$ is the water depth and $g$ is the gravitational acceleration. Under a similar arrangement, a 10-sheet wave absorber can work even more effectively for a wider frequency range of $0.095 < \omega^2 h/g < 3.13$. 

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