Numerical Investigation of a Novel Wave Absorbing Method by Gap Resonance

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ABSTRACT

A new wave absorbing approach based on the gap resonance principle is proposed in this work. The wave absorber is designed by placing a fixed box in front of the end of the wave flume, which forms a narrow gap between them. Numerical examinations are carried out to investigate the feasibility of the proposed wave absorber based on a fully nonlinear finite element wave flume within the modified potential flow theory. The numerical results show that the wave absorber can work with high efficiency. The reflection coefficients are absolutely smaller than 0.05 for the wide range of wave lengths (1.60 ~ 6.55m) considered in this work. Moreover, the working region of the wave absorber is less than 40% of wave length. Compared with the classical wave absorbers, the main advantage of the present method relies on the fact that it can work with small reflection coefficient for extremely long waves, even with a fairly small size of the working region.

KEY WORDS: wave absorber; narrow gap resonance; reflection coefficient; Finite Element Method.

INTRODUCTION

The reflection waves from the end of physical wave flume or basin have negative effects on the accuracy of laboratory tests. Hence it generally requires the installation of wave absorber to reduce the undesirable reflections. The wave absorbers developed so far can be roughly divided into two categories: active wave absorbers and passive wave absorbers. Because of the high cost and complex control system, the active wave absorbers are mainly adopted for the wave generation module to cancel the reflected waves from the tested structures. Passive wave absorbers are mainly referred to as artificial beaches with constant or varied slopes and cages filled with porous materials. Normally, the length of passive absorbers for effective wave absorption, i.e., the reflection coefficient $K_r < 0.05$, should be at least one wave length. Indeed, such a requirement remains challenging for long waves, especially for the case when the wave flume is not long enough.

Lean (1967) conducted investigations on the reflection of waves from three types of permeable sloping beach for linear waves. It was concluded that using optimal parabolic profile is helpful to reduce the absorber length. However, it does not appear possible to attain reflection coefficients below 0.10 for shaped absorbers with its length shorter than about 1/2 to 3/4 wavelength. As shown by Ouellet and Datta (1987), the parabolic profile seems to be the most efficient one to absorb waves. However, this type of wave absorber is still limited to a narrow range of wave parameters. Chegini (1993) conducted experiments with sloping wave absorbers covered by horse hair layer. The wave absorbers were tested at three slopes of 10%, 15% and 20%. It was shown that the reflection coefficients increased as the wave steepness decreased for a specific slope.

Besides the artificial beach as a means to absorb wave energy, an alternative method has also been proposed to save flume space. In this method, a number of thin perforated vertical screens were adopted, in which the porosity decreased towards the rear end of the absorber. Le Méhaute (1972) first proposed the concept of the progressive wave absorber. The analytical solutions and experimental measurements qualitatively confirmed the validity of the designed wave absorber. For a specific wave with wavelength $L=1.08m$, wave period $T=1.00s$, water depth $d=0.15m$, and wave height $H=0.04m$, the low reflection coefficient of $K_r \approx 0.02$ can be achieved with the total length of the wave absorber being 1.00m. Jamieson and Mansard (1987) conducted experimental studies on an upright progressive wave absorber comprising multiple rows of perforated vertical metal sheets. Chwang and Dong (1984) investigated wave trapping by a thin porous plate located near the end of a semi-ininitely long open channel. The experimental results indicated that the reflection coefficient reaches its minimum value as the porous plate is located at a distance of $m/4$ times the wave length $(m=1, 3, 5, ...)$ in front of vertical wall. Twu and Lin (1990, 1991) extended Chwang's method to evaluate the wave reflection from a wave absorber containing several porous plates. It was found that a set of six porous plates with appropriate distance could offer a wave reflection coefficient below 0.04 for the wave range 0.40 < $\omega h/\sqrt{g}$ < 2.80. Under a similar arrangement a ten-sheet wave absorber could expand the effective range to 0.095 < $\omega h/\sqrt{g}$ < 3.13. The corresponding absorption length is 5.28 and 8.80 times water depth, respectively.

In addition to the artificial beach and porosity structures, the resonance mechanism is also applied to develop wave absorbers. Kamphuis (1984) presented a wave absorber which is made of a superposition of horizontal plates and a space left between the structure and the near vertical wall. The reflection coefficient is smaller when the resonance chamber is excited so that the incoming wave and the water rushing out the chamber meet near the seaward end of the structure. Lebey M et al. (2002) proposed a Superposed Inclined Planes Wave Absorber (SIPWA) based on the three mechanisms to consume the wave energy: i) viscous dissipation, ii) breaking wave and iii) the resonating mechanism. It was reported that the proposed device can lead to nearly complete dissipation of the swell energy with the short sizes. However, this work did not provide information about how it works for a certain range of wave periods.