Experiments on Submerged Pitching Plate Under Water Waves

T.L. Yip and Allen T. Chwang
University of Hong Kong
Hong Kong

ABSTRACT

A submerged pitching plate was suggested as an active wave control device by Yip and Chwang (1996, 1997) (Figure 1). Based on the linear wave theory, they determined the plate performance in terms of reflection and transmission coefficients versus other physical parameters of wave, plate, porosity and pitching. The experimental investigation on a pitching plate is conducted to compare the theoretical analysis with the laboratory results in order to verify the linear theory and to determine its application range, especially for the variation of pitching and porosity. To meet the theoretical conditions, experimental tests are carried out in a wave flume with a reflection-absorbing wavemaker. The pitching plate is submerged in water while its submergence depth, pitching amplitude and phase are adjustable. Two pairs of wave gauges are placed in front of and behind the plate and used to determine the reflection and transmission coefficients by employing the Goda and Suzuki (1976) method. Under various combinations of steady conditions, the overall agreement between experimental and theoretical results is satisfactory. Discrepancy occurs only when the wavelength is relatively short or the depth of submergence is shallow.

KEY WORDS: experiment, porous plate, pitching plate, water waves, wave scattering

1. INTRODUCTION

In order to broaden the application of a submerged plate as a breakwater, pitching as an element of active control was introduced by Yip and Chwang (1996). In addition, to further improve the wave control, porous material was utilised by Yip and Chwang (1997) to dissipate wave energy and to reduce the force. As the theory is newly proposed for the pitching plate, experiments are conducted to validate the theoretical results. Moreover, the experimental investigation may provide some clues for further development of the proposed theory.

There are several experimental works done to investigate the wave scattering by a horizontally submerged plate. The first experiment seems to be done by Dattari, Shankar and Roman (1977). They demonstrated that the wave transmission decreases generally with the decreasing submergence of the plate, and also pointed out that the minimum transmission occurs at a moderate depth of submergence, rather than at the water surface. After a lapse of time, Takaki (1988) investigated the wave scattering by a horizontal plate and conducted another series of experiments. He found likewise that the wave transmission is minimum at a moderate depth of submergence, not at the water surface. He further argued that the wave reflection and transmission are not just due to the existence of the plate like other problems of wave scattering by a simple obstacle. By observation with the aid of a video recorder, Takaki (1988) discovered a backward flow at the rear end of the plate and it is caused by the difference between the flow velocities above and below the plate. A direct comparison between experimental and numerical results was first made by Patarapanich and Cheong (1989). The experimental and numerical results generally agreed with each other. Based on their experimental data, they discussed the effect of the incident wave height and found that, as the incident wave height increases, the reflection continues to increase slightly and the transmission decreases slightly. Yu, Isobe and Watanabe (1990) found the linear theory satisfactory to predict the wave conditions and meanwhile observed a discrepancy between experimental and theoretical results for relatively short waves. They insisted that most discrepancy is caused by the nonlinearity and argued that the linearization of free-surface boundary conditions is not appropriate for the high ratio of wave height to wavelength or water depth. They further developed nonlinear equations solved by a numerical method and showed that the nonlinear theory has a better agreement with experiments than the linear theory. Neelamani and Reddy’s (1992) experiments covered a wide range of submergence depth and incident wave height and demonstrated that the wave height is a weak parameter of wave scattering. Graw (1992) considered the plate as a wave filter for irregular waves, because his experimental study disclosed that a horizontal plate can efficiently reflect waves of wavelength less than certain ratio to the plate length. He used an ultrasonic 3D-probe to explain the principal phenomenon by visualising the flow. He observed how the wave propagates into the subregions above and below the plate and the backward flow around the lee of the plate.