

Submerged Plate Breakwater Composed of Horizontal Porous Plate and Slightly Inclined Solid Plate

S. T. Kee*

Department of Civil Engineering, Seoul National University of Technology, Seoul, Korea

A coupled mechanism of the wave energy dissipation effects by a submerged porous plate and the blockage effects by a submerged solid plate has been investigated in the context of linear wave theory. A series of configurations of a multi-plate breakwater was studied parametrically, and an optimized system has been chosen as a new breakwater that is plausible and desirable in costal engineering practice. The optimum performance has been validated through experiments in a 2-dimensional wave flume. The observed complicated wave deformations over, under and through the plates are discussed in detail. Wave reflection, transmission, dissipation coefficients, free-surface wave profiles and forces are calculated and discussed. A good use of the wave energy dissipation and blockage effects simultaneously stands on a resonance caused by the water wave interaction with the geometrical configuration of a system.

INTRODUCTION

Among the breakwaters used for coastal protection, a submerged horizontal solid or porous plate is an economical solution for steeply sloping shorelines. In many coastal regions, without a significant tidal range, this kind of structure is sufficient to reduce the transmitted wave energy (Brossard and Chagdali, 2001). It has the advantage of providing open scenic views as well as free water circulation in the sheltered region to prevent stagnations and pollutions, and of allowing sediment transports to generally keep partitioning the natural seabed.

In view of this, many researchers have studied the submerged plate breakwater for the sake of the aesthetics and eco-friendlier environments of the coastal region. Takaki (1988) investigated the characteristics of hydrodynamic forces on a submerged horizontal plate. Patarapanich and Cheong (1989) found that the optimum plate width may be 0.5~0.7 times that of the wavelength above the plate for the plate submergence of 0.05~0.15 times the water depth, for minimum transmission of waves. Yu and Chwang (1994) investigated the wave motion over a submerged porous plate and found that a proper porosity can greatly suppress the wave reflection and transmission thanks to the wave energy dissipation through the fine pores on the plate. Yu et al. (1995) predicted the breaking waves by a semi-empirical approach that was validated through the comparison with experimental results. The wave energy can also be dissipated by dispersing the incident wave into the higher harmonic waves. Brossard and Chagdali (2001) investigated experimentally the higher harmonic waves generated by a submerged solid plate as a result of the wave-structure interaction in the plate's wake. They found that vortices produced at the edges of the plate take part in the production of higher harmonics by nonlinear interaction with the free surface, but at the same time they involve a dissipation process that reduces the transmitted wave's amplitudes.

Usha and Gayathri (2005) investigated the wave motions over a twin-plate, based on the linear potential theory, for the var-

ious parameters such as the relative water depth, relative plate width and relative submergence spacing. They found the optimum spacing for the best performance; however, its performance is valid just for the limited higher frequency bend. Neelamani and Gayathri (2006) investigated experimentally the performances of the dual horizontal solid plates for a wide range of wave heights and periods in regular and random waves, and they found that a properly designed dual plate with a gap shows better performance than a single surface plate.

Kee et al. (2007) investigated the wave blockage effects and wave energy dissipations by multi-layered submerged plates based on the linear potential theory (multi-domain BEM) and the fully nonlinear Direct Numerical Simulation method (DNS). They found an optimum configuration of the plates for a practical engineering point of view. The breakwater was composed of a horizontally submerged porous plate and a slightly inclined solid plate in order to make good use of the blockage and wave energy dissipation effects simultaneously.

In this paper, the numerically predicted optimum performance of the proposed plates is further discussed based on the validation through the experiments. The observed complicated wave deformations over, under and through the plates are also discussed in detail. Free surface wave profiles and the distributions of wave forces along the entire length of plates are calculated and discussed. It is found that the wave energy dissipation and the blockage effects can be used simultaneously to employ a system resonance causing destructive interferences and stimulating wave energy dissipation.

PERFORMANCE OF OPTIMIZED TEST MODEL

A multi-domain boundary integral equation method based on the distribution of simple sources along the entire boundary is developed to investigate the diffraction of water waves by multi-layered submerged porous plates. Using a developed numerical code, the performance of multi-layered plates was evaluated for a range of wave and geometric parameters that illustrate the suitability of this type of structure as a barrier to wave action. A single submerged porous plate seems to reduce simultaneously the transmitted and reflected waves only when the structure is very lengthy in the direction of wave propagation. Multi-layer porous plates have a good performance at a much shorter length except

*ISOPE Member.

Received April 16, 2008; revised manuscript received by the editors August 9, 2008. The original version was submitted directly to the Journal.

KEY WORDS: Blockage effects, horizontal plates, porous plates, wave energy dissipation, pulsating flow, jet flows.