

Blockage Effects and Wave Energy Dissipation by Submerged Porous Plates

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ABSTRACT

Wave motions over and under the submerged porous or solid plates is studied by the multi-domain boundary element method and by the direct numerical simulation (DNS) for the fully nonlinear wave interactions with structures. The mechanism of the blockage effects by a submerged solid plate or the wave energy dissipation effects by porous plates has been investigated and discussed. It is found that the both effects are incompatible against each other. A series of multi-plates were studied parametrically, and a dual system has been chosen for the optimum performance as a new breakwater that is plausible and favorable in the coastal engineering practice. The system design parameters are properly tuned against the incident waves so that the incompatible effects become to be complementary to each other, having outstanding performances over the wide range of frequencies.

KEY WORDS: Blockage effects; submerged horizontal porous plate; standing wave; wave energy dissipation; pulsating flow.

INTRODUCTION

Application of the submerged horizontal solid or porous plate as breakwaters has been studied by numerous researchers for last several decades as a promising alternative means against conventional breakwaters for the aesthetics and environments of the coastal region, especially of the steeply sloping shorelines with a less tidal range. Since it insures open scenic views, free water circulations in the sheltered region to prevent stagnations and pollutions, and sediment transports to keep in general partitioning the natural seabed.

Stoker (1957) triggered the study of hydrodynamic performance (reflection and transmission) of long waves passing over a horizontal single surface solid plate fixed at the free surface. Siew and Hurley (1977) obtained an analytic expression for the reflection and transmission coefficient for long waves propagating past a submerged plate in shallow water. Patarapanish (1978) has examined the average energy flux passing around the submerged plate and found that the reflection coefficients varied with plate length. Takaki (1988) also investigated the fluid phenomena around a horizontal submerged-plate

and investigated the characteristics of hydrodynamic forces on submerged plates. Patrapanich and Cheong (1989) found that the optimum plate width may be about 0.5–0.7 times that of the wavelength above the plate for the plate submergence of around 0.05–0.15 times the water depth, for minimum transmission of waves. Neelamani and Reddy (1992) experimentally investigated the transmission, reflection and the energy dissipation of waves by a rigid fixed surface and submerged horizontal plate.

One of typical studies for the wave blockage effects by the pulsating flow under a submerged solid plate was studied by Graw (1992), and that could be used as wave energy converter (Graw, 1993). Another was the wave motion over a submerged porous plate (Yu and Chang, 1994). They 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. A submerged solid plate generates pulsating flow seaward beneath the plate mainly due to the differences of the phase velocity propagating over and beneath the plate. The pulsating flow seaward blocks the oncoming incident waves at the some narrow specific frequency band, especially low frequency region where a resonance condition can occur based on the length of a plate and a submergence depth. After imposing porosities on the plate, the blockage effects quite decreases since the kinetic energy of the orbital motion of water particle can be dissipated through pine pores on the plate due to the fluid viscosity. The wave energy dissipation reduces the transmitted waves for the higher frequency regions. In addition, the additional wave energy can be further dissipated by the vortices at the ends of the plate, and by the wave breakings over the plates. That phenomenon is widely favored by practical engineers. Yu etc (1995) predicted the breaking waves by semi-empirical approach that was validated through the comparison with experimental results. The wave energy can also 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 wake of the plate. 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 involve, at the same time, a dissipation process that reduces the transmitted wave's amplitudes.