Bragg Scattering of Waves Propagating over a Series of Poro-elastic Submerged Breakwaters

Yuan-Jyh Lan, Tai-Wen Hsu *, Jian-Wu Lai, Chen-Chen Chang, Chia-Huan Ting
Department of Hydraulic and Ocean Engineering, National Cheng Kung University
Tainan, TAIWAN, China

ABSTRACT

In this study, the Bragg scattering of waves propagating over a series of poro-elastic submerged breakwaters is investigated by theoretical derivation and experimental tests. An analytical solution is developed for waves propagating over a series of poro-elastic submerged structures. Water waves are described using the linear wave theory. The poro-elastic structures are assumed to be homogeneous, isotropic, and can be elastic. Based on the improved poro-elastic medium theory using Biot’s theory and the turbulent fricative effect, the governing equations are theoretically developed. Continuity of dynamic pressure and flow flux at the interfacial structures surface are used to solve the problem. The general solutions of the wave motions and poro-elastic submerged structures are also derived. Experiments are also conducted in a wave flume to compare the theoretical results. The comparison shows good agreement between theoretical values and laboratory observations. Using the present analytical solution, effects of elasticity, permeability and the breakwater height of the series of poro-elastic submerged breakwaters on Bragg reflection are studied. Calculated results show that the softer poro-elastic structures can induce higher wave reflection and lower transmission.

KEY WORDS: poro-elastic structures; a series of submerged structures; analytical solution; Bragg reflection.

INTRODUCTION

The use of porosity, surface friction and flexibility characteristics of artificial structures in coastal engineering for harbor and coastal protection has gradually increased, as they can effectively reduce the wave forces acting on, wave reflection and run-up in front of the structure. Instead of impermeable reflective concrete structures, these structures clearly decrease loading and impact on natural environment. Due to the flexibility of soft material, the structural deformation induced from water wave disturbs flow field in the vicinity. Subsequently, the waves can be influenced by the flexibility structure and the characteristics of wave reflection, diffraction, transmission and energy dissipation will be different. Hence, to deal with the Bragg reflection by a series of submerged breakwaters, it is more completed to consider the effects of porous and flexible structures on Bragg scattering of water waves.

In the past decade, many researchers have studied surface wave scattering caused by the patches of bottom undulations. These studies include theoretical formulation, laboratory experiments, and numerical simulations. On wave propagating over a series submerged breakwaters, caused by the patches of bottom undulations with various shapes were studied theoretically (Kirby, 1986; Chen, 1991; Bailard et al., 1992). An analysis of wave scattering over a series of rectangular rigid submerged structures with porous media was revealed by Twu and Liu (2004). The numerical model provides an alternative to determine wave reflection for the problem of Bragg scattering of water waves (Yueh, et al., 1998). The studies mentioned above only concerns the Bragg scattering of surface waves over rigid structures, which the permeability is considered or not. For the problem of elastic structures, Lan and Lee (1999) proposed a theoretical solution on waves passing over a poro-elastic submerged breakwater. Their solution is shown to be applicable for not only poro-elastic medium structures but also rigid and near impermeable ones. Based on the aforementioned studies, an analytical solution for wave propagating on a series of poro-elastic submerged structures was presented by Lan (2007). Using the analytical solution, the effect of elasticity of two poro-elastic submerged structures on wave reflection and transmission were investigated.

In this paper, the problem of waves propagating through a series of poro-elastic submerged structures is studied theoretically. Comparisons between the analytical results and laboratory experiments were made to examine the capability of the present theory. Properties of Bragg scattering affected by the influence parameters of submerged breakwaters, the number of structures and the structural height are discussed.

THEORETICAL FORMULATION

A number of J poro-elastic submerged structures with rectangular shapes which are placed on an impermeable flat seabed. Monochromatic wave trains propagate normally from the right-hand side toward the submerged structures. The schematic diagram is illustrated in Fig. 1, where \( d \) is the water depth. A two-dimensional Cartesian coordinate system is used with the origin located at the