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# Potential Use of an Oscillating Water Column Located inside Perforated Caisson

*Yong Liu*
College of Engineering, Ocean University of China.
Qingdao, Shandong Province, China.

*Yucheng Li*
Stat Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology.
Dalian, Liaoning Province, China.

## ABSTRACT

This study proposes a potential use of an oscillating water column (OWC) located inside a perforated caisson breakwater. Based on the linear potential theory, the interaction of water wave with the OWC is decomposed as a diffraction problem and a radiation problem as usual. This study only gives the analytical solution of the diffraction problem by means of the matched eigenfunction expansion method. Three parameters of engineering interest, the reflection coefficient, the vertical flux inside the OWC and the wave force acting on the whole structure, are examined. Some useful results are presented. The present study may provide an alternative low reflection OWC for engineers.

KEY WORDS: Perforated caisson; oscillating water column; diffraction; wave energy.

## INTRODUCTION

Recently, various technologies of sea wave energy utilization have been extensively studied all over the world. A latest review on this topic has been given by Falcão (2010). The oscillating water column (OWC) is one of widely used wave power extraction devices. It generally includes a partially-immersed chamber with bottom open and with one or several Wells turbines. The incident wave induced oscillating motion of water surface inside the OWC can push the air through the Wells turbines, and then an electrical generator is driven by the turbines. In practice, the OWC devices are often installed on the coast or coastal structures rather than offshore, for reducing the costs of construction, maintenance, storage and so on. Especially, installing OWC devices on breakwaters seems to be a fine idea (e.g., Boccotti, 2007; Martins-Rivas and Mei, 2009).

Perforated caisson breakwater is often used as a new type structure. It is initially proposed by Jarlan (1961) and consists of a perforated front wall, a solid rear wall and a wave absorbing chamber between the two walls. The advantages of perforated caissons are the lower reflection coefficient and smaller wave force (Li, 2007). The reflection coefficient of perforated caisson is mainly determined by the ratio of the chamber width to the incident wavelength ($B/L$). Theoretically, the reflection coefficient $C_R$ of the original fully perforated caisson will attain a minimum (even zero) at $B/L = 0.25$, and unity at $B/L = 0.5$ if ignoring the inertial effect of the perforated front wall (Chwang and Dong, 1984). When $C_R = 0$ with $B/L = 0.25$, the surface elevations at the leeside surface of the perforated front wall equals zero. But the surface elevation at the the solid rear wall equals the incident wave amplitude. At $C_R = 1$ with $B/L = 0.5$, the perforated front wall has no effect on the wave motion, and standing waves are formulated inside the chamber. It can be seen that there are considerable wave energy inside the wave chamber of perforated caisson. In other words, the wave chamber with suitable size may serve as an effective wave energy capture device. Thus we may set an OWC device inside the chamber. For this concept, the construction and maintenance of OWC should be easier. Moreover, the low reflection of the whole structure can reduce the scouring in front of the caisson. Also it is safer for vessel navigation near the breakwater.

The main objective of the present study is to examine theoretically the possibility of setting an OWC inside the chamber of a perforated caisson. We know that the interaction of water waves with OWC devices can be decomposed as the sum of a diffraction problem and a radiation problem (e.g., Porter and Evans, 1995; Martins-Rivas and Mei, 2009). The diffraction problem is due to the mere existence of the structure in the wave field, and the radiation problem is due to the oscillating air pressure inside the OWC. At the present stage, we only consider the diffraction problem. In the following section, an analytical solution of the diffraction problem is developed by means of the matched eigenfunction expansion method. In section 3, the reflection coefficient of the breakwater, the diffraction-induced vertical flux inside the OWC, and the wave force acting on the structure are calculated and examined. Finally, the main conclusion is drawn.

## FORMULATION AND SOLUTION

The idealized sketch of the present problem is shown in Fig. 1. A perforated caisson is located in a water channel with uniform depth $d$. The wave absorbing chamber width of the caisson is $B$. An oscillating water column is installed in the wave chamber. The width of the OWC is $b$, and the draft of the OWC's front wall is $a$. The Cartesian-coordinate system is used with the $x$-axis directing out of the fluid domain, and the $z$-axis vertically upwards along the chamber rear wall. Here we only consider the diffraction problem, and examine the