International Journal of Offshore and Polar Engineering
Vol. 4, No. 4, December 1994 (ISSN 1053-5381)

Control of Incident Waves into a Harbor by L-shaped Structures

Yusaku Kyozuka
Department of Earth System Science and Technology, Kyushu University, Kasuga, Japan

Kazunori Kitano
Pacific Consultants Inc., Osaka, Japan

ABSTRACT

A fundamental study was carried out on L-shaped structures constructed near a harbor mouth to reduce the entry of waves into the harbor, which is an important aspect of ship safety and the efficiency of loading/unloading at a berth. Incident waves through the harbor mouth interact with diffracted waves and cancel out as a result of the placement of the L-shaped structure near the harbor mouth. Wave diffraction problems by vertical structures in constant water depth are solved by the boundary element method in the linear theory. Optimal size and location of the L-shaped structures for the reduction of waves into a harbor are determined by the nonlinear programming for a given objective function. Some wave patterns near the harbor mouth for optimized configurations of L-shaped structures are presented graphically. Variations of the performance as functions of incident wave length and incident wave angle are presented. From those numerical results, it is confirmed that L-shaped structures are effective in reducing the entry of waves into the harbor.

INTRODUCTION

Propagation of light, sound, water waves and elastic waves is described by a wave equation and the fundamental characteristics are found to be similar. This means that we can apply the engineering methods developed in other fields to water wave problems (Bessho, 1981). A water wave is characterized by its dispersion and the phase velocity changes dependent on the depth of shallow water. The velocity potential is governed by the Helmholtz equation, however, if the problem is restricted to the interaction between vertical cylinders and waves, which is the same as the two-dimensional sound wave.

This paper presents fundamental studies on the reduction and control of ocean waves entering into a harbor. Incident waves entering through the harbor mouth interact with diffracted waves due to L-shaped structures placed near the harbor mouth, and they may cancel each other out. This idea was originally developed for sound waves and is now used in some sound absorption devices such as Calmzon (Bridgestone IPK Ltd., 1992).

The principle of this device is such that waves through a channel between the L-shaped structure and a straight breakwater cancel out the direct waves entering the harbor if the length of the L-shaped structure l is chosen as half of the incident wave length. However, the diffraction wave field around such structures is not simple, so that an exact analysis is needed to determine the most effective structure to minimize the waves entering the harbor.

In the previous report (Kyozuka and Kitano, 1992a), we confirmed the good performance of L-shaped structures of $l = \lambda/2$ in reducing the waves entering the harbor. But it was found that it would be more effective for waves twice as long. This is convenient from a point of view in the real application, because we can choose a smaller L-shaped structure $l = \lambda/4$ for the reduction of the same waves. In this report, the performance of an L-shaped structure of $l = \lambda/4$ is studied, and the optimal location for minimizing the waves entering the harbor is obtained by nonlinear programming.

Received January 26, 1994: revised manuscript received by the editors August 15, 1994. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.
KEY WORDS: Wave entry, wave control, wave diffraction, nonlinear programming.

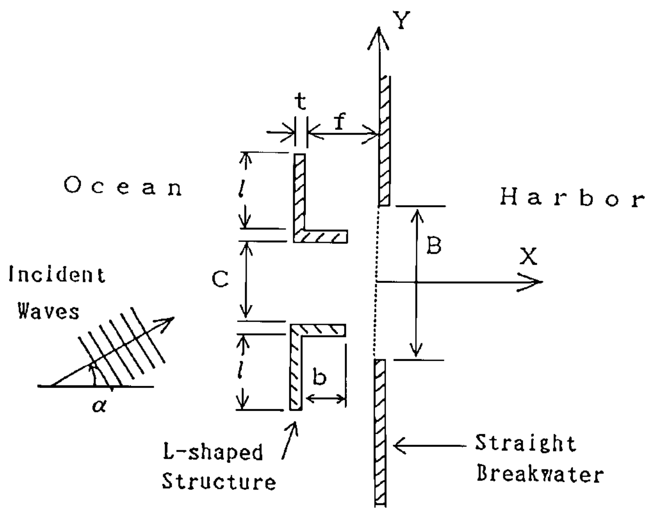

Fig. 1 L-shaped structures near harbor mouth

INTERACTIVE WAVE CONTROL STRUCTURE

The interactive wave control structure in this study is L-shaped and constructed near the harbor mouth as shown in Fig. 1. We choose B as a reference length as it is regarded as the effective width of the harbor mouth for a ship to pass through. We assume B = 100 m in this study, which may correspond to some local harbor. Routes for ships should be straight inside and outside the harbor mouth following the requirements of ship maneuverability and safety.

We consider the wave diffraction problem by a pair of straight breakwater and vertical cylinders near a harbor mouth in a constant water depth. Therefore, the velocity potential is described by a boundary integral using the same Green function as in sound-wave problems of two dimensions. The position (x_p, y_p) and the angle θ of an L-shaped structure as shown in Fig. 2 are optimized for a given thickness t and the proportion of L-shape d_1/d_2 in the case of