International Journal of Offshore and Polar Engineering
Vol. 6, No. 3, September 1996 (ISSN 1053-5381)

Interaction Between Tsunami and Artificial Floating Island

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ABSTRACT

The interaction between a tsunami wave and a large floating artificial island is studied in this paper. Modified three-dimensional Boussinesq equations which represent long waves beneath a floating elastic plate are derived. These equations do not take the mass of the plate into account because of the long wave assumption. Applying the matched asymptotic expansion method, conditions for a connection between the ordinary Boussinesq equations for long water waves and the modified Boussinesq equations are obtained. These sets of equations are solved by the finite difference method. Numerical results demonstrate the significance of nonlinear and three-dimensional effects which strongly affect the propagation of tsunami waves beneath a large artificial island floating on a shallow sea.

INTRODUCTION

Building artificial islands is one of the most promising future targets for ocean engineers and civil engineers. There are two types of artificial islands. The first one is the reclaimed land, and its typical example is the 4-km-long, 1.3-km-wide Kansai International Airport. Through existing examples, it seems that technical difficulties for reclaimed islands have been overcome. But a significant problem with reclaimed islands is the destruction of the environment; to get the soil for reclamation, a part of a mountain with vegetation must be destroyed. The possibility of liquefaction caused by an earthquake may be another problem.

The second type of artificial island is the floating type made of metal or concrete, whose advantages are water permeability and safety against earthquake excitation. A typical shape is the semisubmersible type, whose motions in waves are very small. But it is expensive to build and to protect from erosion damage. To overcome these shortcomings, a barge-type floating island is proposed because of its simple structure and small wetted surface area. This paper covers fundamental research into the behavior of a barge-type artificial island in tsunami waves generated by an earthquake.

It is well-known that a very large structure behaves like an elastic plate. Since a tsunami is described as a solitary wave in shallow water, we considered a thin elastic plate floating on shallow water subject to a solitary wave.

Long waves beneath a floating elastic plate were first investigated by Stoker (1957, p. 438). He was concerned with the transmission of waves beneath a floating breakwater in the linear theory. His work has since been extended by Evans and Davies (1968) to the case of three dimensions. Recently, two-dimensional periodic waves beneath an elastic plate resting on the surface of an infinitely deep fluid have been investigated by Forbes (1986, 1988), using a high order series expansion technique. Lu (1991) discussed the transmission and reflection of a plane soliton on a two-dimensional structure by the matched asymptotic expansion method, which gives a relation between the outer solution governed by the Boussinesq equations and the inner solution governed by the Laplace equation.

With a two-dimensional model, the author (1996) derived the Boussinesq class equations for a long wave motion beneath a two-dimensional floating elastic plate, and discussed matching conditions between the ordinary and modified Boussinesq equations by employing the matched asymptotic expansion method.

In the present paper, this theory is extended to the three-dimensional case, and the three-dimensional Boussinesq class equations and matching conditions are discussed. A finite difference scheme is applied to solve the obtained Boussinesq class equations.

THEORY

As shown in Fig. 1, the problem is divided into three parts. The first is an ordinary shallow water wave problem which is defined in region I. The second is a problem in a particular region covered with an elastic plate. The third is defined at the intersection between the free surface and the edge of the elastic plate which is a singular point of the first two regions. The first two are called outer problems; the third is an inner problem. The overall solution

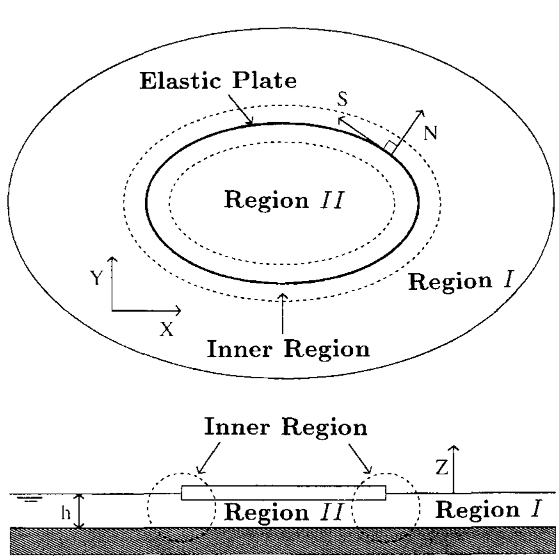

Fig. 1 Coordinate system

Received February 6, 1996: revised manuscript received by the editors July 22, 1996. The original version (prior to the final revised manuscript) was presented at the Sixth International Offshore and Polar Engineering Conference (ISOPE-96), Los Angeles, USA, May 26-31, 1996.

KEY WORDS: Nonlinear waves, solitary wave, hydro-elasticity, floating island.