Proceedings of the Eighth (1998) International Offshore and Polar Engineering Conference
Montréal, Canada, May 24-29, 1998

ISBN 1-880653-34-6 (Set); ISBN 1-880653-38-9 (Vol. IV)

Simplified Earthquake Response Analysis Modeling of Offshore Structures

T. Nakamura
Shinozuka Research Institute
Tokyo, Japan

Y. Tanaka
Taisei Corporation
Tokyo, Japan

ABSTRACT

A simplified method of the seismic response analysis using the hydrodynamic restoring force coefficients for an arbitrary shaped three dimensional offshore structure with multiple degrees of freedom has been developed. The present method was verified through the comparisons with the more rigorous numerical solution using Green's function. The frequency characteristics of the hydrodynamic restoring force coefficients were investigated. The response of twin cylindrical structures were analyzed, and the structure interaction effects due to the fluid compressibility were discussed.

KEY WORDS : Earthquake response, Offshore structure, Hydrodynamic restoring force coefficient, Boundary integral method

INTRODUCTION

A gravity-type oil production concrete platform and a foundation of a strait bridge in deep water usually have multiple columns. Seismic design for such structures is required to take into account the elastic deformation in water and the hydrodynamic interaction between the structure and the surrounding fluid.

Several different solutions for response analysis of a flexible circular cylindrical structure in water have been presented by Liaw and Chopra (1974), Williams (1986) and Tanaka and Hudspeth (1988). Liaw and Chopre (1975), and Kokkinowrochs and Tharos (1988) have obtained a solution for the hydrodynamic pressure on arbitarily shaped bodies of revolution with a vertical axis. Nakamura and Tanaka (1993) have been developed a method of the dynamic response analysis for arbitrarily shaped offshore 3-D structures in deep water based on a Green's function approach. Their method rigorously satisfies the body surface boundary condition by applying it directly on the integral equation, hence it is complicated to reduce to the matrix form in the integral equation. Many reliable computer codes on the market for 3-D frame structures are available to use so called 'USER SUBROUTINE' to add new functions such as hydrodynamic interaction. It could be convenient if such computer codes are used for the response analysis of the structure in water. Hence, the idea of the hydrodynamic restoring force coefficient is useful to solve the interaction problem of 3-D offshore structures due to earthquake. The similar methodology using the hydrodynamic restoring force coefficients has been applied for the response analysis of the floating structures in waves.

In this paper, the simplified method for the response analysis of offshore structures due to earthquakes using the hydrodynamic restoring force coefficient has been developed. In order to investigate the interaction of the structures which are in close to each other, the numerical implementation of twin cylindrical structures were carried out. Based on these numerical results, it was clarified that the present numerical model can calculate properly the interaction behavior between each member and that the compressive propagating waves generated from each member influences the response of the peak values and the resonance frequencies in water.

MATHEMATICAL FORMULATION

Methodology Outline

Let hydrodynamic restoring forces considering the interaction between the structure and fluid be taken into the equation of motion. The equation of motion with multiple degrees of freedom may be written in the matrix form.

$$[M]\{\ddot{d}\}+[C]\left(\{\dot{d}\}-\{\dot{a}\}\right)+[K](\{d\}-\{a\})+[F]\{d\}=0 \quad (1)$$

where $[M]$, $[C]$, and $[K]$ are the mass matrix, the structural damping matrix, and the stiffness matrix, respectively. $\{d\}$ is the absolute displacement vector of the structure, and $\{a\}$ is the ground