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Dynamic response analysis of an offshore platform due to seismic motions

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ABSTRACT

A three-dimensional (3D) numerical model for dynamic response analysis of seismic-induced motions is developed using the modal analysis and substructure methods. The developed model and an impedance function method are applied to an offshore platform with a pile–soil foundation system. The Newmark β method is used as a time integration scheme. The displacement and bending stresses at selective nodal points on the structure are computed for various maximum seismic accelerations and the shear-wave velocities of soil. Using a reliability index obtained by the Monte Carlo Simulation method, we successfully performed a reliability evaluation at the critical points of the structure for various seismic motions and soil conditions.

1. Introduction

It is of great importance to utilize ocean spaces and marine renewable energies, as land-based resources are increasingly depleted. Ocean structures such as offshore platforms and basins may provide opportunities for the development and utilization of ocean resources. Incident wave is a primary concern for the safety of structure and an array of cylinders as a common shape of offshore platform is used to predict the wave excitation forces [1]. In active seismic zones near the Pacific Rim, however, seismic-induced ground motion is one of the most critical excitation loads to carefully evaluate when ensuring that platforms retain proper seismic resistance.

Several studies have been carried out on the seismic responses of offshore structures. A zero mean ergodic Gaussian process of finite duration [2] or Kanai–Tajimi power spectrum [3–5] was used to determine horizontal ground acceleration due to earthquakes. Two primary techniques can be used to analyze the structure–foundation system and its characteristics, direct and substructure methods, both of which are outlined by Wolf [6,7]. Aydinoglu [8,9] developed mathematical formulations for both methods. Three sub-schemes have been developed for the dynamic interactions of soil and pile groups on the seabed: the equivalent single pile scheme, the elasticity scheme, and the general three-dimensional load transfer scheme. References for these methods can be found in Park et al. [10].

Loads on the foundation due to earthquakes involve uncertainties when the dynamic characteristics are determined using time histories of the data [11]. Thus, for accurate dynamic structure response, uncertain parameters such as seismic motions and shear-wave velocities of soil may be considered using the Monte Carlo Simulation (MCS) method, which is an efficient way to detect uncertainties. Several studies of jacket structures have been reported regarding reliability evaluation of uncertain seismic motions, e.g., [12–15]. In particular, the use of the MCS method in a nonlinear system including seismic motions is necessary to calculate the reliability index for the evaluation.

In this study, using modal analysis a three-dimensional (3D) numerical model is developed for the dynamic response induced by various standardized maximum seismic accelerations measured in Japan. The newly developed model was applied to a bottom-mounted offshore platform with a pile–soil foundation system. The interactions of the structure and foundation systems were also considered using the substructure method. The Newmark β method as a time integration scheme for 3D cases, which was formulated by Park et al. [10], was applied to the present case. The offshore platform considered in this study is illustrated in Fig. 1. The platform consists of two structural subsystems; the superstructure and the pile–soil foundation subsystems, which are connected at the nodal points between the pile heads of the foundation and the bottom of the superstructure. The lower part of the superstructure is a truss-type structure, and the upper part

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