Dynamic Response and Reliability Evaluations of an Offshore Platform with Pile-soil Foundation System due to Wave and Seismic Forces

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ABSTRACT

For the reliable design of an offshore platform, it is very important to accurately evaluate the effects of both wave and seismic forces on the platform. The eigenfunction method was applied to calculate the wave force on the offshore platform having permeable cylindrical structures. Especially, it has been well recognized the importance of dynamic soil-structure interaction for several structures founded on soft soils. In order to examine the effects of soil-structure interaction, the substructure method is applied to the dynamic response evaluations of the platform. For the idealized three-dimensional platform with the pile-soil foundation system, the dynamic response evaluations were carried out through the modal analysis.

On the other hand, the uncertainty effects of dynamic forces and structural properties play very important roles on the reliability evaluations of the platform. The Monte Carlo Simulation (MCS) method is very effective to access these influences. If the limit state function is given by the most critical situations of dynamic responses, the reliability evaluations of the platform can be effectively calculated by the reliability index with the results obtained from MCS. The uncertainty evaluations of offshore platform influenced by severe waves and seismic forces were examined from the reliability index. Since the uncertainty of the wave and seismic forces is important for dynamic response evaluations, it is necessary for the reliable design of the offshore structure to clarify the effects of uncertainties.

KEY WORDS: eigenfunction expansion method, offshore platform with pile-soil foundation system, wave and seismic forces, MCS method, substructure method

INTRODUCTION

An offshore platform with a large deck area is a new concept of offshore structure for developing ocean space which may be used as residence areas, airports, and power station, etc. To perform the reliable design of an offshore structure in ocean, it is necessary to examine severe wave forces and seismic forces acting on the offshore structure. In addition, since large offshore platforms have heavy dead loads, the reaction forces on the foundation become severe and very firm foundations should be required (Kawano et al., 1996). Therefore, the importance of dynamic soil-structure interaction for offshore platforms founded on soft soils has to be well recognized. If the severe reaction forces of the offshore structure can be reduced by the way such as large diameter members of buoyancy-type or having porosity, it is very useful to develop the large scale offshore structure.

On the other hand, the uncertainty of dynamic forces and structural properties plays the important roles on the reliability of the structure. If the uncertainty is limited within small variations, the sensitivity of uncertainties can be effectively evaluated by the perturbation method. If the uncertainty involves relatively large variations and the structure response is nonlinear motions, the Monte Carlo Simulation (MCS) method would be very effective to account for these influences (Guan, et al(2000), Kawano, et al(2004)). The reliability estimation has been performed with the static response analysis, and there are only a few estimations with the dynamic responses (Kardeniz, 2005). It is important to clarify the effects of the uncertainty due to dynamic forces for the reliability estimation of the offshore platform.

In the present study, the eigenfunction method after Williams & Li (2000) is applied to evaluate the wave force on an offshore platform with N porous cylindrical structure. Numerical results are presented the variation of various wave forces and wave run ups through changing the porosity rate of structure. It is found that the increase of porosity rate is significantly effective to reduce the effects of wave force and wave run up. By using the wave forces obtained by the present method, the dynamic response of offshore platform is examined through the modal analysis which can be solved by step-by-step integration such as Newmark \( \beta \) method (Kawano, et al(1990)). In order to evaluate the effects of soil-structure interaction, the substructure method is applied to the dynamic response evaluations of the offshore platform. The present three-dimensional offshore platform consists of two subsystems: structure and pile-foundation subsystems, which are connected at the nodal points between the pile heads of the foundation and the bottom of the superstructure. The equation of motion for the superstructure is represented with the finite element method and that for foundation system is obtained by the impedance function method for the pile-soil foundation system. For the idealized three-dimensional offshore platform with the pile-soil foundation system, the dynamic response evaluations for seismic and wave forces is carried out using the reliability index based on the results obtained from MCS method.