DYNAMIC RESPONSE ANALYSIS OF SOIL-OFFSHORE STRUCTURE SYSTEMS

Yoshikazu YAMADA,	Professor,	Kyoto University
Hirokazu IEMURA,	Associate Professor,	Kyoto University
Kenji KAWANO,	Associate Professor,	Kagoshima University
Venkataramana KATTA,	Graduate Student,	Kyoto University

INTRODUCTION: This paper discusses the computation of the dynamic response of an offshore tower taking into account the dynamic interactions between soil-foundation and structure. The emphasis has been placed on the evaluations of the dynamic soil-structure interaction effects due to wave forces.

DYNAMIC RESPONSE ANALYSIS: Fig.1 shows the offshore structure model considered for study. The random waves around the tower are modelled to have stochastic properties of the zero mean Gaussian process, and are represented by the power spectral density functions of the Bretschneider type. The analysis is performed in the frequency domain using the mode superposition method[1]. The deformation of the pile head consists of a horizontal displacement component and a rotational displacement component. The governing equation of motion for the soil-offshore structure system is obtained by substructure method. The dynamic stiffness coefficients of the soil-pile foundation are interpreted as a generalized spring-dashpot system[2] [Fig.2]. Morison equation is used to define the forcing function. The equation of motion is

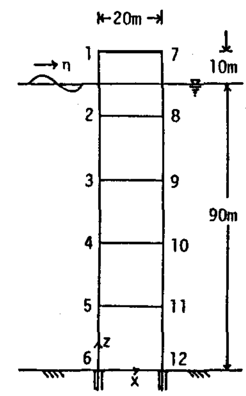

Fig.1 Offshore Tower Model

$$\begin{bmatrix}[\bar{M}_{aa}][\bar{M}_{ap}] \\ [\bar{M}_{pa}][\bar{M}_{pp}]\end{bmatrix}\begin{Bmatrix}\ddot{u}_a \\ \ddot{x}_p\end{Bmatrix}+\begin{bmatrix}[C_{aa}] & 0 \\ 0 & [C_p]\end{bmatrix}\begin{Bmatrix}\dot{u}_a \\ \dot{x}_p\end{Bmatrix}+\begin{bmatrix}[K_{aa}] & 0 \\ 0 & [K_p]\end{bmatrix}\begin{Bmatrix}u_a \\ x_p\end{Bmatrix}=\begin{bmatrix}[C_I]\{\dot{v}\}+[\hat{C}_D]\{v\} \\ [G]^T[L]^T([C_I]\{\dot{v}\}+[\hat{C}_D]\{v\})\end{bmatrix} \tag{1}$$

where $\{u_a\}$,$\{x_p\}$ are the displacement vectors for the tower and the pile; $[\bar{M}_{aa}]$ includes the added mass effect; the damping effect due to waves is contained in $[C_{aa}]$; $\{v\}$ and $\{\dot{v}\}$ are the velocity and acceleration vectors respectively of the water particles; [G] relates the deformations of pile head to the deformations of the bottom of the tower and [L] denotes the influence of the deformation of the pile on the tower. The eigenvalue analysis is carried out and the frequency response function $H(\omega)$ is determined. The modal response spectrum of the tower is given by

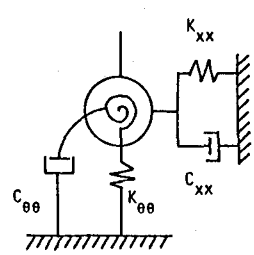

Fig.2 Pile Model

$$[S_{uu}(\omega)] = [\Phi][H(\omega)][S_{pp}(\omega)][H(\omega)^{*}][\Phi]^T \tag{2}$$

where $S_{pp}(\omega)$ is the generalized force spectrum; $H(\omega)^{*}$ is the conjugate of the frequency response function and Φ is the eigenvector. The auto correlation function of the modal response is obtained by the Fourier transformation of Eq.(2) and subsequently r.m.s. displacement is determined.

DATA ANALYSIS AND RESULTS: Fig.3 shows the spectral density function of the wave elevation in which $\overline{H}$ is the mean wave height and $\overline{T}$ is the mean wave period. As expected, higher frequency component spectra have low energy and lower frequency component spectra have greater energy. The r.m.s. velocity and acceleration of water particle at node 2 of the tower are plotted in Fig.4. The value of the r.m.s. velocity increases asymptotically with mean wave period. The dynamic response of the tower is computed for 2 cases: firstly, without considering the interaction effects of the soil-pile system i.e., treating the bottom of the tower as fixed, and secondly, considering the interaction effects. The values of the natural period for the first mode of vibration are 5.4 sec. for the first case and 7.1 sec. for the second case. The response is computed for the mean wave periods ranging from 4 sec. to 10 sec. The r.m.s. displacements of node 1 are plotted against mean wave period in Fig.5. The structural response is larger when the wave period is between 5 to 8 sec. For both cases, the maximum response is obtained when the wave period is nearer to the natural period of the structure. Further, the structural response is higher when the soil-pile interaction effects are taken into account.

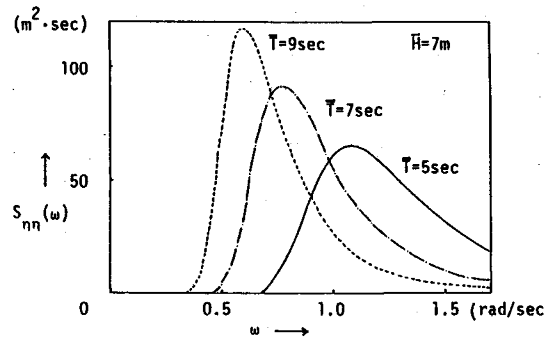

Fig.3 Wave Spectral Density Function

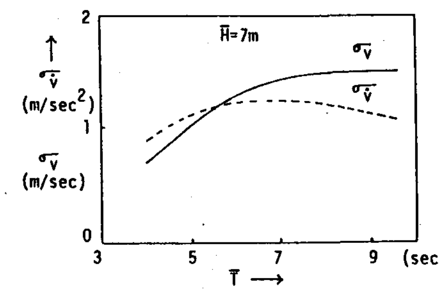

Fig.4 R.M.S.Velocity and Acceleration of Water Particle at Node 2

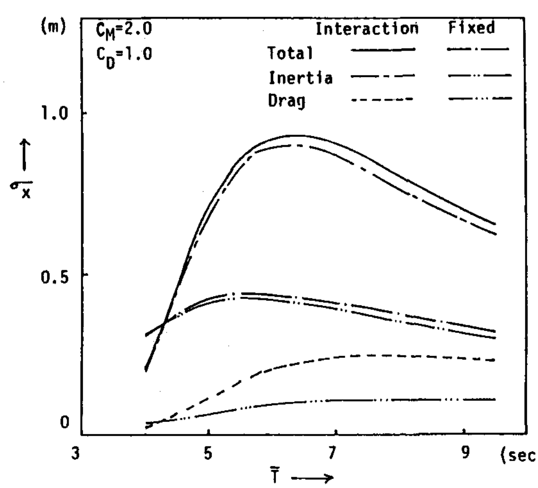

Fig.5 R.M.S.Displacement of node 1

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1) Malhotra, A.K. and Penzien, J., "Nondeterministic Analysis of Offshore Structures", ASCE, Vol.96, No.EM6, pp.985-1003, 1970.
2) Robert G. Bea, "Dynamic Response of Piles in Offshore Platforms", Proceedings of OTC., pp.80-109, 1981.