ON THE RELIABILITY ANALYSIS OF OFFSHORE STRUCTURES

Yoshikazu YAMADA, Professor, Kyoto University
Hirokazu IEMURA, Associate Professor, Kyoto University
Kenji KAWANO, Associate Professor, Kagoshima University
K.VENKATARAMANA, Graduate Student, Kyoto University

INTRODUCTION: Dynamic response of offshore structures to random sea waves and strong earthquake motions is investigated. Emphasis is placed on the evaluation of the dynamic soil-structure interaction effects. Response quantities are compared by employing the principles of first-passage probabilities across specific barriers.

RELIABILITY ANAYSIS METHOD: Fig.1 shows the elevation of a tower model resting on pile-soil foundation. Random sea waves are represented by Bretschneider's wave energy spectrum and Morison equation is used to define the wave forcing function. Earthquake ground motions are modelled stochastically using Tajimi-Kanai power spectrum for stationary conditions. The equation of motion is derived by the substructure method separately for sea waves and earthquake motions. Response analysis is carried out using frequency-domain random vibration approach.

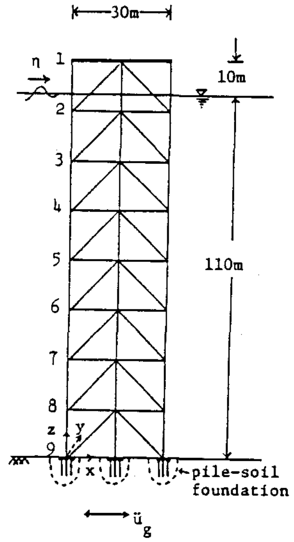

Fig.1 Analytical model of structure-pile-soil system

For a zero-mean Gaussian process x(t) with spectral density function $G_x(\omega)$, a bandwidth parameter q_x is defined as:

$$q_x = \left[1 - \frac{\alpha_1^2}{\alpha_0 \alpha_2}\right]^{\frac{1}{2}} \quad \text{where} \quad \alpha_i = \int_0^\infty \omega^i G_x(\omega)\,d\omega \qquad 0 \leq q_x \leq 1$$

The reliability $L(\lambda)$ of the structure corresponds to the probability of x(t) not exceeding the critical barrier λ and is given as:

$$L(\lambda) = \exp\left[-\frac{1}{\pi}\sqrt{\frac{\alpha_2}{\alpha_0}}\, t_0 \exp[-\frac{\gamma^2}{2}]C_1\right] \quad \text{where} \quad C_1 = \frac{1-\exp[-\sqrt{\frac{\pi}{2}}\, q_x \gamma]}{1-\exp[-\frac{\gamma^2}{2}]}$$

in which t_0 is the duration of the input excitation and $\gamma = \lambda/\sqrt{\alpha_0}$ is the reduced level.

Yoshikazu YAMADA, Hirokazu IEMURA, Kenji KAWANO and Katta VENKATARAMANA

RESULTS AND DISCUSSIONS: The values of natural periods for first vibration mode are 3.32sec (rigidly supported base condition) and 3.36sec (soil-structure interaction condition). Fig.2 shows the rms response displacement at node 1 for different sea states. The responses are generally larger when the interaction effects are included.

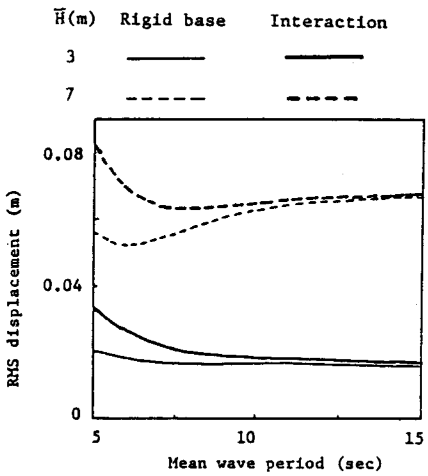

Fig.2 RMS displacement at node 1

Fig.3 shows the rms displacement at node 1 for earthquake loadings, expressed using rms ground acceleration $\sigma_{\ddot{u}_g}$. The dynamic response for the soil-structure interaction condition is generally smaller than that for the rigidly supported base condition because of the energy dissipation of the pile-soil foundation system. Since the response velocity of the structure is small, the nonlinear drag force has few contributions on the response.

The reliabilities on the first passage are presented in Fig.4 for the soil-structure interaction condition. The duration time t_0 is expressed in terms of the first natural period T_0 of the structure-pile-soil system. Since, the wave motion has the duration time of a few hours, reliable displacement can be evaluated for a large value of peak factor. On the other hand, the corresponding displacement may be caused by very severe earthquakes because earthquake ground motion has comparitively short duration time of less than a few minutes. Therefore, it is seen that the reliabilities of seismic responses are higher than the wave responses for the numerical examples of this study.

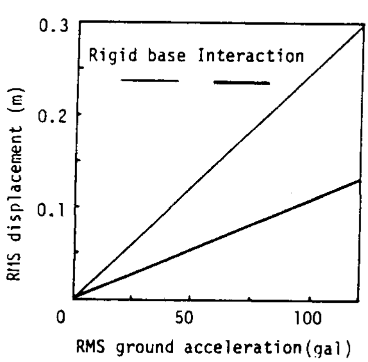

Fig.3 RMS displacement at node 1

Barrier Level $\lambda=3.5\cdot\sigma_x$ where σ_x is the response displacement at node 1 for wave loading

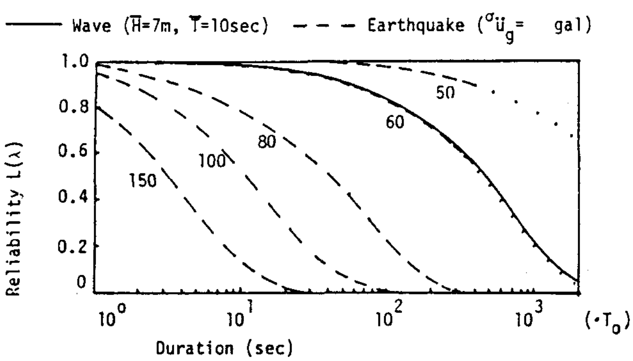

Fig.4 Reliability of wave and earthquake loadings (Interaction)