I-561 OBSERVED SEISMIC DATA ON A MODEL PILE GROUP

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INTRODUCTION Because of computational complexities, highly simplified mathematical models are often employed in seismic analysis of soil-structure systems. Having seismic observed data available for a foudation, a good comparison between the computed and measured motions, if achieved, would provide confidence in understanding of the foundation mechanism and in the usefulness of employed simplified modeling. An opportunity to have seismic observation data of a pile group foundation was provided when an earthquake occurred at the site of a series of hybrid experiments on pile group foundations.

SET-UP AND MODELING A three-pile group foundation, named PL3 and schematically shown in Fig.(1) is modelled as an elevated mass concentrated at the center of gravity of the foundation being connected to a sway-rocking spring at its base. Pile spacing was determined according to Japanese seismic code and a gap of $5cm$ isolated the foundation cap from any probable cap-soil interaction. Six meter long steel piles were driven into a soil deposit its upper three meters were replaced by well grained sand. Free-field site was at a distance of 70 meters far from the foundations and no major topographical disturbance was present, thus assumed,in the study. For this pile group foundation forced vibration test was conducted to produce sufficient data to define three mathematical models for use in the soil-foundation interaction study. Results of the tests appear in Fig.(2) in that amplitude and phase spectra are shown against cyclic frequency. Obtained from amplitude and phase shift study, shown in Fig.(3), are frequency dependent stiffness and damping of the foundation-soil system in swaying modes. Three models with different dynamic characteristics as constant(CNS), virtual added mass(VRL), and frequency dependent(FRQ) based on Hilbert transformation were used,[1]. Following equations show the dynamic equilibrium of the system, when different CNS, VRL and FRQ models are employed respectively.

$$M\ddot{X}(t) + C_{ini}\dot{X}(t) + R(t) = -M\ddot{U}_g(t)$$

$$M\ddot{X}(t) + C_{ave}\dot{X}(t) + R(t) = -M\ddot{U}_g(t) + M_{vrl}\ddot{X}(t)$$

$$M\ddot{X}(t) + C_{ini}\dot{X}(t) + R(t) = -M\ddot{U}_g(t) + C_{exc}\dot{X}(t) + \int_0^t S(t-\tau)K_{ini}^{-1}R(\tau)d\tau$$

where M is mass matrix, M_{vrl} added virtual mass matrix, C_{ini} initial viscos damping matrix, C_{ave} matrix of average viscos damping C_{exc} matrix of excess damping due to satisfaction of conditions of causality,[Ref.1], $S(t)$ inverse Fourier transformation of $\bar{S}(\omega) = K_\omega(\omega) + i\hat{K}_\omega(\omega)$ with $K_\omega(\omega) = K - K_{ini}$, i.e., the frequency dependence of stiffnrss, K_{ini} initial stiffness matrix, R either measured restoring force vector in PDT or any presumed linear or nonlinear force-displacement relationship, $U_g = (u_g, 0)^T$ with $\ddot{u}_g$ being the input seismic accelerogram, X displacement response vector, τ dummy of integration, 'bar' and 'hat' stand for Fourier and Hilbert transformations respectively, and the dots denote differentiation with respect to time.

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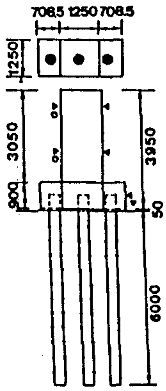

Fig.(1): 3-Pile Group Foundation

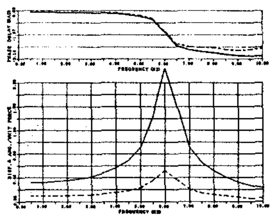

Fig.(2): Dynamic Test Results
Amplitude(down) and Phase(up)
Sway(line) and Rocking(dashed)

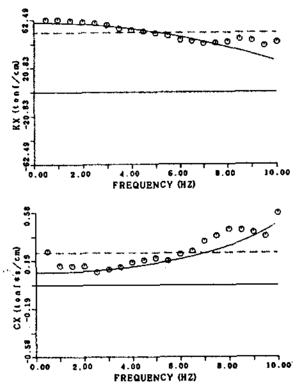

Fig.(3): Dynamic Characteristics
Stiffness(up) and Damping(down)
Test(circles) and Modeling(line)

OBSERVATION Fig.(4) plots the recorded East-West acceleration of the foundation and the free-field site during the observed earthquake. Using CNS, VRL and FRQ models of the soil-foundation interaction, we carried out linear numerical simulations in them the recorded accelerogram at the free-field site was employed as base excitation. Response absolute acceleration of the foundation in swaying mode are presented in Fig.(5) for FRQ, VRL, and CNS modelings.

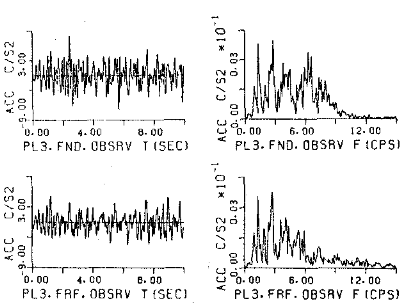

Fig.(4): E-W Observed Acceleration
Foundation(up) and Free-field(down)

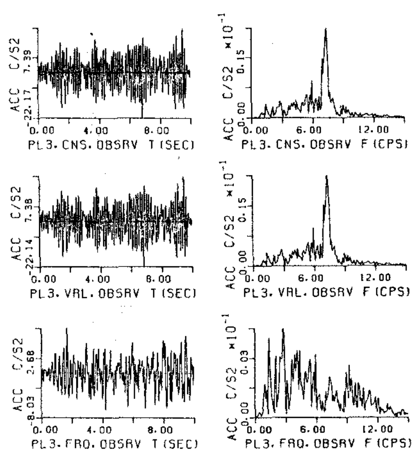

Fig.(5): Simulated Acceleration
CNS(up), VRL(middle) and FRQ(down)

CONCLUSIONS Although some correlation is seen comparing recorded and simulated accelerations on the foundation, even for this very low amplitude recorded accelerogram there existed some discrepancies between the behavior of the actual soil-foundation system and that predited by different frequency dependent models. Yet, the study shows that one can count on the employment of such models provided that, due to an earthquake, the system does not undergo appreciable nonlinear deformations.

REFERENCES

1: "Hybrid Experiments on Nonlinear Earthquake-induced Soil-Structure Interaction", K.Toki, T.Sato, J.Kiyono, N.Kishi Garmroudi S.Emi and M.Yoshikawa, International Journal of Earthquake Engineering and Structural Dynamics, will be published in summer 1990.