I-504 NONLINEAR SEISMIC SOIL-STRUCTURE-INTERACTION STUDY by HYBRID EXPERIMENT

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Nonlinear effects in seismic soil-structure-interaction can not be treated in detail analytically because of simplified idealizations in system's geometry and mechanical properties. Although experimental methods for soil-structure-interaction studies cover the problem of nonlinearity, yet they introduce secondary problems in interpreting the results because of using small scale models. Hybrid experiment method in which relatively large scale models may be utilized remains the most reliable means to study nonlinear seismic soil structure interactions.

A hybrid study has been made of nonlinear seismic soil-structure-interaction by numerical analysis of the governing differential equations by on-line computer. During this analysis the nonlinearity of the stiffness of the system was measured experimentally by means of pseudo-dynamic tests and fed back to the computer at each successive step. The other dynamic characteristics of the system were treated analytically. Different parameters affecting nonlinearity in seismic soil structure interactions were considered choosing different combinations of following parameters as; two types of foundation structures (footing and caison), three cases for embedment (surface, shallow and deep), three soil models for the half-space (constant coefficient, virtual mass and frequency dependent), two seismic record frequency contents (Taft and Hachinohe), five maximum amplitudes for the strong ground motions (from 60 to 300 Hz every 60 Hz). Fig.s (1) and (2) show the actual and lumped mass modeling of the soil-structure system. Mechanical properties of the above soil structure systems were determined in advance by means of static and forced vibration tests. A set of results from these tests are shown in Fig.s (3) and (4). Frequency dependent dynamic characteristics measured through these tests were taken into account in formulating dynamic equations of equilibrium of the system. We developed a new time domain numerical integration scheme that is based on Hilbert Transformation of frequency dependent stiffness and damping which leads to time dependent impedance function for the soil structure system. Equation of motion of the system using the above modeling for one degree of freedom system becomes as;

$$M*\ddot{X}(t) + L*X(t) = - M*\ddot{U}g(t)$$

$$L = [\ Co - (2*A*W1)/\pi\ ]*d/dt + Ko + \int_0^t S(t-s)*ds$$

here L is the operator of soil dynamic reaction, X is generalized displacement, M is mass, Ug is seismic ground acceleration, Co and Ko are the initial damping and stiffness of the system, A is parameter of parabolic approximation of damping, W1 is limit of frequency within which we consider damping frequency dependent, and s is dummy of integration. Fig.(5) show time history of the system's response to Taft-120 gal input with virtual mass soil model. Also are presented hysteresis loops for sway and rocking modes. Fig.(6) presents a comparative study of analytic linear response of the system with initial and linear-equivalent stiffness respectively against hybrid experimental response.

Conclusions :

- we developed a time domain integration scheme based on Hilbert Transformation of dynamic characteristics of the system,
- Versatile Modeling was used in Identification of system respons and hysteresis loop,
- contribution of the system response in sway and rocking decreases with embedment, indicating increase in stiffness due to embedment.
- resonant frequencies increase with embedment.

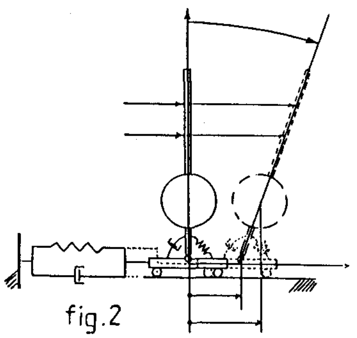


fig.2

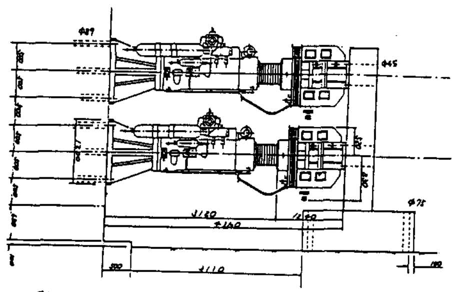
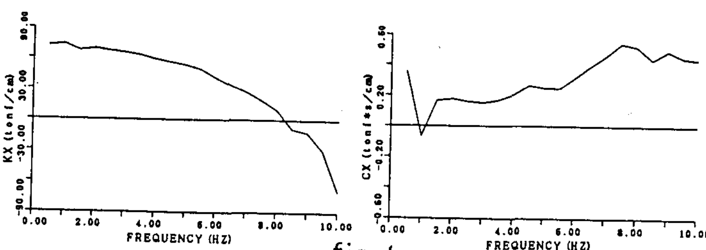


fig.1



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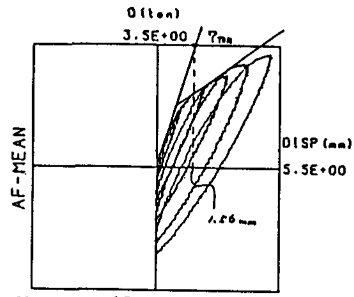
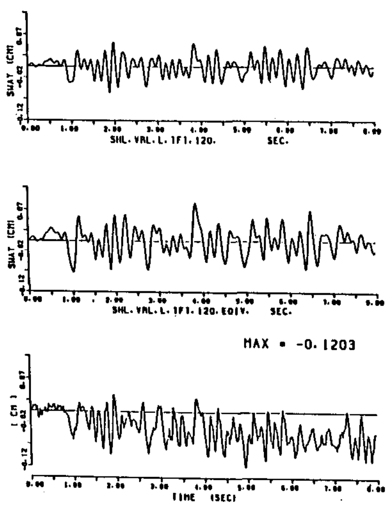
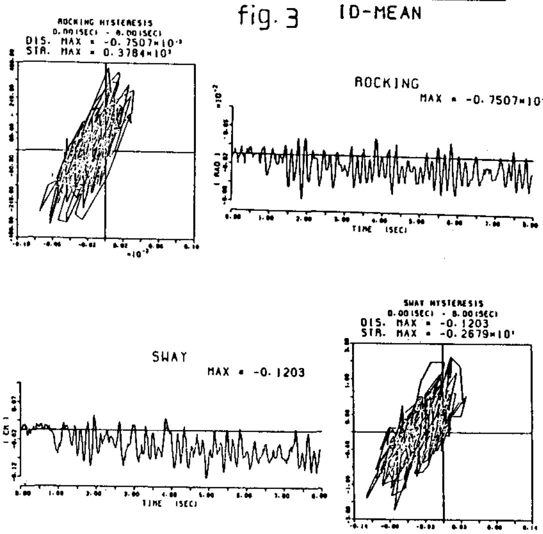


fig.3



Shallow Foundation, Virtual Mass Model
Taft (S69E) 120.gal
up)time domain linear analysis
md)time domain linear analysis with equivalent stiffness
dn)result from Pseudo-Dynamic Test

fig.6



Shallow Foundation.
Virtual Mass Model.
TAFT S69E 120.gal

fig.5