SITE-DEPENDENT EARTHQUAKE SIMULATION

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SUMMARY

In this research work, one kind of realistic simulation has been carried out depending on soil conditions and frequency analyses of seventy one U.S. and twenty Japanese earthquake acceleration records. Simulated waves representing nonstationary amplitude and frequency characteristics, were generated in twenty five seconds. Two types of frequency content were employed and the charecteristics of simulated ground motions were examined through linear and nonlinear single degre systems.

INTRODUCTION

In the recent studies of the earthquake engineering, the effect of the frequency characteristics of the ground motion has been more important especially on the nonlinear structural response. Fintel, Derecho and Freskakis (1) have classified accelerograms in terms of damped velocity spectra as "broad band" and "peaking" types of accelerograms for the nonlinear analyses of isolated structural walls.Extensive and minor yielding which occured in the structure has greatly differed, although a rough basis for classification was proposed. Bertero, Herrera and Mahin (2) have shown that considerably larger deformations can be induced by the presence of just one, long pulse with an effective acceleration equal or just greater than that corresponding to yielding stregth of the structure.

On the other hand, the amplification factors to be applied to the maximum linear elastic response are generally controlled by the resonance phenomenon. For engineering purposes, the description of strong motion can be reduced to response spectra and frequency dependent of shaking.In the past, different types of spectra were suggested with many authers. (3,4,5,6).

However, it is not clearly considered to take into account the nonstationary frequency content of the earthquake strong motion records in the above studies. Since earthquakes release their energies in the different component waves with different frequencies, it is more resonable to consider that many uncertainties of the earthquake charecteristics might be lain down under the detailed investigations of the nonstationary frequency content. In this study it is attemped to seek resonable information about frequency contents and to employ them for simulation purposes.

Selection of the Earthquake Records for Analyses

For the analyses of the earthquake records, the selection was made from the work of Seed, Lysmer and Ugas (4) and same classification for the soil conditions was adopted as in previous study. Since corrected acceleration records (7) were used, some of very special records could not be found, the Number of accelerograms used in this study has been decreased and they are listed as follows:

(1) 26 records for rock sites
(2) 29 records for stiff soil sites
(3) 26 records for deep cohesionless sites
(4) 10 records for sites with soft to medium clay and sand.

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Physical Spectrum and Spectral Paremeters

Physical spectrum was first defined by Mark (8) in 1970 and successfully used for earthquake simulation in Japan (10). Physical spectrum of a random process x(t) is defined by:

$$S(\omega,t:W) = E\left[\frac{1}{2\pi}\left|\int_{-\infty}^{\infty} W(t-u).t(u).e^{-i\omega u}\,du\right|^2\right], -\infty < \omega < \infty \qquad (1)$$

where ω,t and W(t) are frequency,time and time window function selected as a Gaussian type respectively.

The frequency distribution of the each strong motion record is obtained by varying the time t. Before analyses, the duration of each wave was defined as the time needed to develope between 5 and 95 percent of Arias Intensity.First Eq. 1 was numerically solved and frequency content was obtained, then time dependent spectral values were normalized according the peak spectral value. In order to generalize the frequency contents, the shape function was assummed as a Gaussian type:

$$\dot{S}(\omega,t) = \frac{a(t)}{\sqrt{2\pi}\,\omega_s(t)}\exp\left\{-\frac{1}{2}\left[\omega-\omega_1(t)/\omega_s(t)\right]\right\} \qquad (2)$$

where a(t) is a proportion coefficient related with real frequency region, $\omega_1(t)$ and $\omega_s(t)$ are spectral paremeters (11,12), represent centroid and frequency dispersion of the spectrum density function at time t respectively. Spectral paremeters were simultaneously evaluated after the normalization of spectral values.

$\dot{S}(\omega,t)$ was statistically established first by the mean values and secondly 90 percentile of the values of the spectral paremeters (assuming t-distribution) for each group of soils.

Simulation Process

For simulation purpose, harmonic process model was adopted:

$$x(t) = z(\omega_i,t)\sum_{i=1}^{N}\text{Cos}(\omega_i t-\phi_i) \qquad (3)$$

where N is positive integer sufficient to express the nonstationary frequency properties; $z(\omega_i,t)$ is frequency dependent amplitude and ϕ_i is uniform random variable between 0 and 2π. Function $z(\omega_i,t)$ should be approximately related with the physical spectrum of x(t) through shape function as follows:

$$z(\omega_i,t) \cong \left\{4\dot{S}(\omega_i,t).\Delta\omega\right\}^{1/2} \qquad (4)$$

where $\Delta\omega$ is frequency increment, small enough. For this process first $z(\omega_i,t)$ was determined in Eq. 4, then substituting it in Eq. 3 x(t) was obtained. For each group of soils simulated ground motion records with first and second type frequency content were generated in 25 seconds with 0.02 sec. time range. In this manner eight strong motion records were obtained representing one ensemble.Normalized acceleration samples, S1 ME and S1 SD, describe first generated samples with 50 percentile and 90 percentile values of the spectral paremeters, are shown in Fig. 1 and Fig. 2 respectively.

CONCLUSIONS

The charecteristics of simulated ground motions were examined through linear and nonlinear single degree systems. In Fig. 3 the ensemble averages of the normalized accelération response spectra were drawn for both first and second type frequency contets and results were compared with Ref. 5. The tendency of the amplifications for all soil types was seen as being approached to 84 percentile response spectra. For stiff soils, first and second type simulations mainly coincides with 50 percentile response spectra in all periods except very short period range. The amplification rates slightly drops from rock to medium clay and sand. Almost one standard deviations of the frequency paremeters affected spectral accelerations being greater than averaged ones; except for soft soils. Only for soft soils,the frequency variation gave higher amplification response for than the others. Dominant periods of the averaged response spectra are also increasing from rock type to medium clay.

Origin-oriented model was used for nonlinear calculations and resulțs were compared in terms of ductility with the work of Murakami and Penzien (12).in which β is stregth paremeter and A,B,C,D types earthquakes are defined by Housner and Jennings as simulated earthquakes. Although the results are not exhibited here,but as an example, medium clay soil simulation gives higher ductility requirements than the others.When the period is 0.5 sec.and β=0.5 , the ductility is 7.11 for Stiff Sl ME and 33.44 for Med. Sl ME and 12,8,7,5 for A,B,C,D types of eartquakes respectively. Since the long periods of the pulses of the first and second type of simulated waves are increasing from rock to medium clay soils,their effects which have been noted in Ref. 2 mainly coincides with results.

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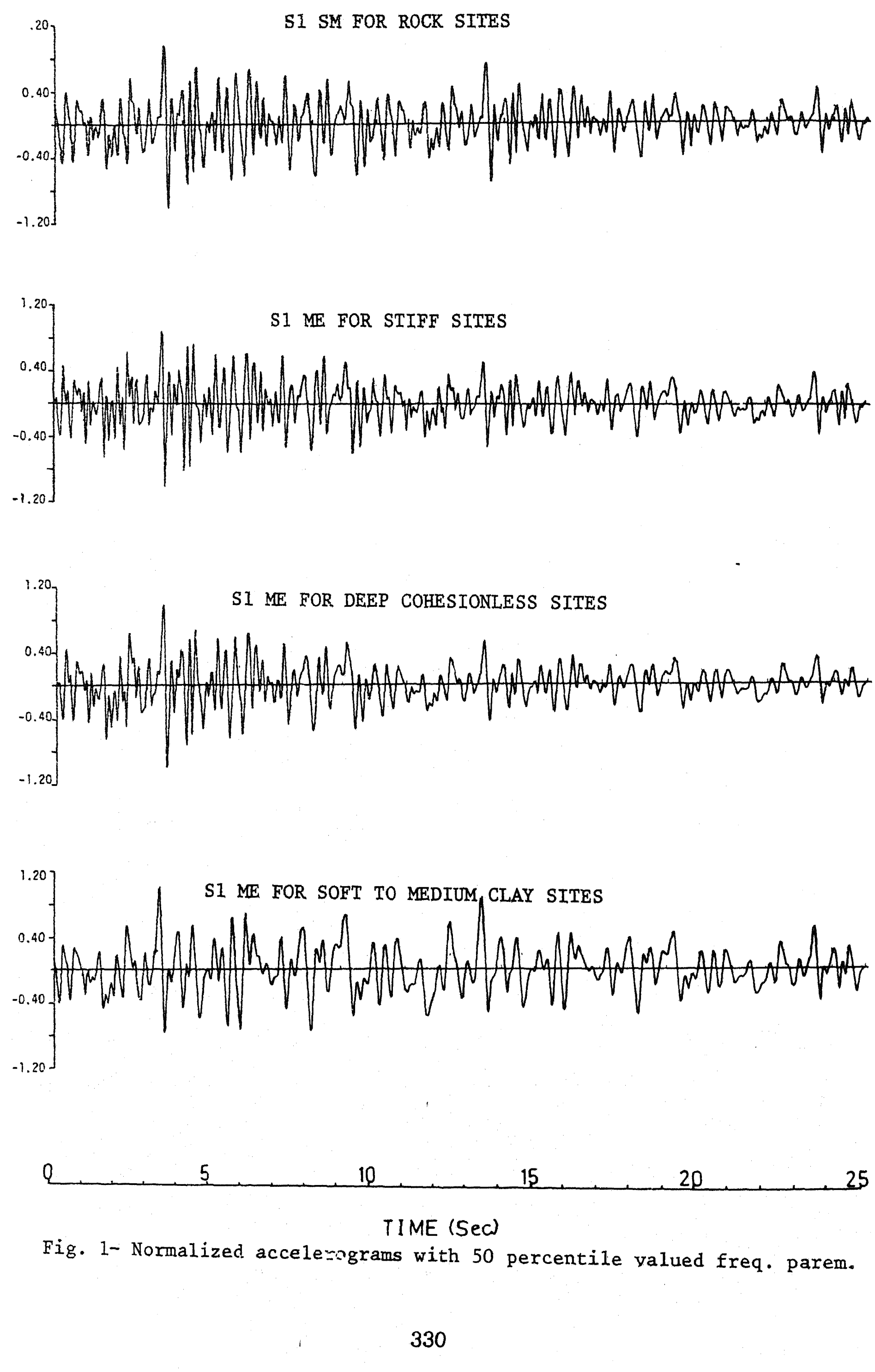

Fig. 1- Normalized accelerograms with 50 percentile valued freq. parem.

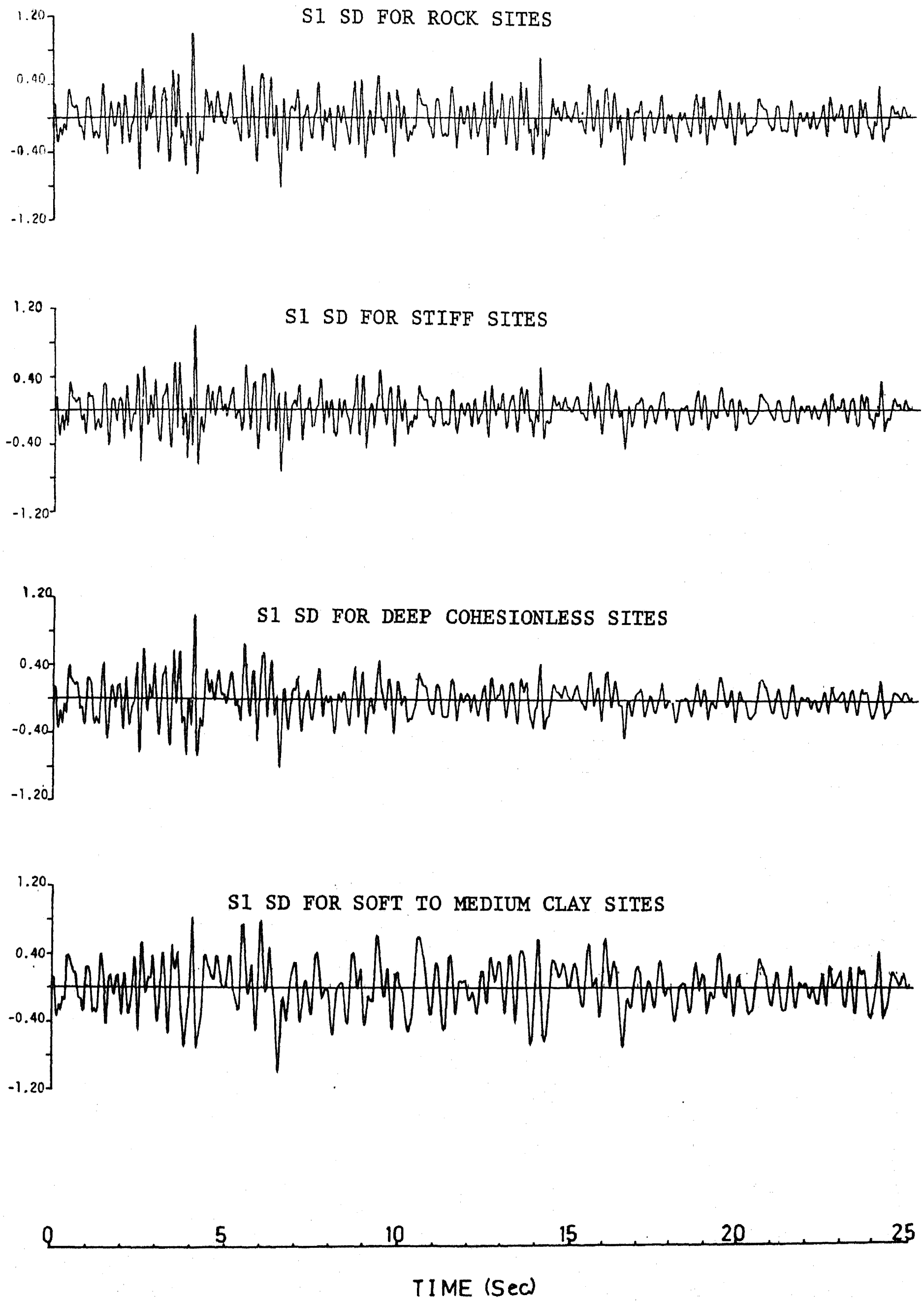

Fig. 2- Normalized accelerograms obtained with 90 percentile valued frequency paremeters.

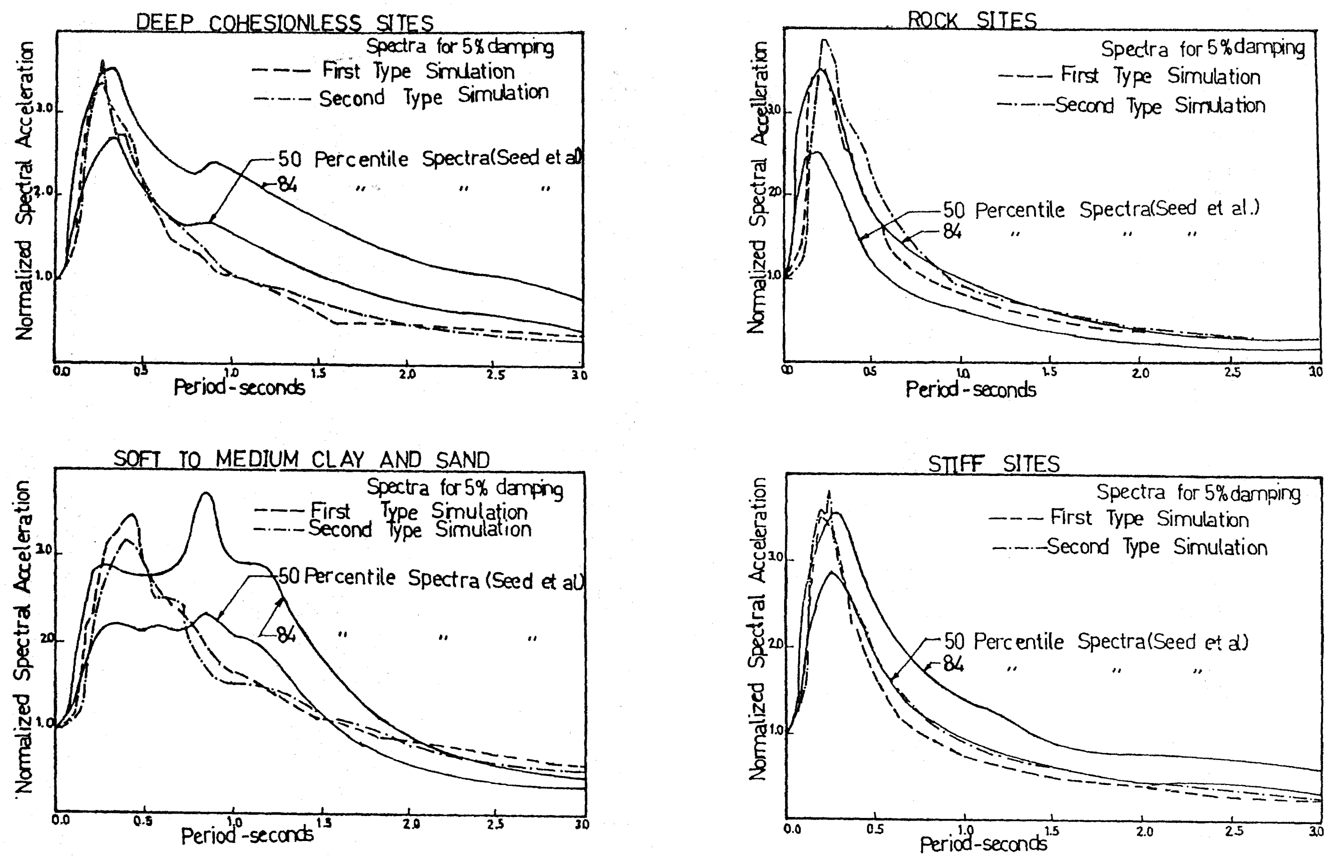

Fig. 3- Normalized Acceleration Response Spectra with the comparison of Ref. 4.