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STOCHASTICALLY BASED STUDY OF RESPONSE SPECTRA SPATIAL VARIABILITY

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ABSTRACT

The present study investigates the contribution of soil layers stochasticity in spatial variation of seismic response spectra. Numerical examples showed that this stochasticity could affect seismic response of structures since the response spectra can be applied as input motions at the supports of structures or buried lifelines in their seismic resistant analysis and design. On other hand, spatial variation of response spectra may induce significant additional forces in the multiply supported structures than those obtained if it is assumed that the motions at all supports are identical.

Keywords: RTV, stochasticity, response spectra, power spectral density, spatial variation.

INTRODICTION

Stochasticity of soil properties can cause amplification of surface ground motion more important than when the properties are assumed deterministic (Zerva and Stephenson, 2011; sadouki et al, 2012). In addition, ground motion spatial variation is associated with wave passage effect, coherency loss effect and different local site effect, and is generally obtained from the analysis of seismic recordings of the same event at several locations at the ground surface. So, in areas with or without strong ground motion recordings, the random vibration theory (RVT) is the main method used to estimate the ground motion, and is a computationally fast to estimate the characteristics from seismological models (Liu and Pezeshk, 1999).

In this context, the present study provides an analytical approach to account of soil layers stochasticity on the spatial variation of seismic ground motions. The calculation method starts by computing the cross spectral density of the total ground surface displacement (PSD) due to incident random waves impinging the bedrock layer. Then, the free field response spectrum is obtained from the power spectral density function. Numerical examples are conducted in order to illustrate the efficiency of this approach. In this way, two types of soil deposits (soft and firm) extending laterally

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are selected. For reasons of simplicity, it is assumed that stochasticity in soil characteristics is due to the variability in the depth of the layers (Zerva and Harrada, 1997).

CONVERTING POWER SPECTRAL DENSITY FUNCTION TO RESPONSE SPECTRA

For stationary Gaussian random process, there is a relationship between the pseudo-velocity response spectra $S_v(\omega_0,\xi)$ and the PSDF (Sharma *et al.*, 1996; Liu and Pezeshk, 1998; Afra and Pecker, 2002):

$$S_V(\omega_0,\xi) = \omega_d \sigma_q \sqrt{g + \frac{\gamma}{g} + 2\gamma} \tag{1}$$

in which σ_q is the standard deviation of the output process of frequency ω_0(rad/sec) and damping ξ to the input process of PSD $S_{uu}(\omega)$:

$$\sigma^2{}_q(\omega_0,\xi) = \frac{1}{2\pi}\int_0^{\omega_{max}} H^2(\omega) S_{uu}(\chi,\omega)\,d\omega \tag{2}$$

where $H(\omega)$ is the harmonic transfer function of a single degree of freedom oscillator with frequency ω_0 and damping ξ, and $S_{uu}(\chi,\omega)$ is the cross spectral density of the total ground surface displacement which accounts of soil layers stochasticity and is written as (Zerva and Harada, 1997):

$$S_{uu}(\chi,\omega) = [(\omega_0^4 + (2\beta + 4\xi_0^2 - 2)\omega_0^2\omega^2 + (\beta-1)^2\omega^4) \times |H(\omega)|^2 + 4\beta^2\omega_0^4\omega^2 R_{\omega\omega}(\chi) \times |H(\omega)|^4] S_{u_bu_b}(\chi,\omega) \tag{3}$$

where $S_{ubub}(\chi,\omega)$ is the cross spectral density function of the incident motion, and $R_{\omega\omega}(\chi)$ is the correlation function of the pulsation $\omega(x)$ representing its fluctuations in the ground layer around its mean value and it is specific to each soil profile (Harada and Shinozuka, 1987). In equation (1), $g = 2\ln(2 f_q T_q)$, $\omega_d = \omega_0\sqrt{1-\xi^2}$ and γ is the Euler's constant equal to 0.577216. T_q is the duration of the stationary output process and

$$f_q = \frac{1}{2\pi}\left(\sqrt{\frac{m_2}{m_0}}\right) \tag{4}$$

NUMERICAL RESULTS

The pseudo-velocity response spectrum derived from equation (1) is depicted in figure 1 for each type of soil, for coefficients of variation (Cv) of the fundamental pulsation (ω_0) ranging from 0 to 20%. This figure shows that the pseudo spectrums increase as the coefficient of variation increase for both the two types of soil, which indicate that as the heterogeneity of the medium increases, the peak values of response spectra are more important. This result means that this heterogeneity could affect seismic response of structures since the response spectra can be applied as input motions at the supports of structures or buried lifelines in their seismic resistant analysis and design.

Then, resulting response spectra for various separation distances are depicted in figures 2. This figure shows that the amplitudes of pseudo response spectrum attenuate when the separation distance increase (200, 300, 400 m) for both soft and firm soil. This spatial variation of seismic ground motions may induce significant additional forces in the multiplysupported structures than those obtained if it is assumed that the motions at all supports are identical.

CONCLUSİONS

We have investigate in this paper the effect of soil stochasticity on the surface seismic ground motion in terms of pseudo spectra, and the contribution of this stochasticity in spatial variation of ground response. We conclude that the soil stochasticity has great importance on response of structures since the investigated response spectra can be used as input.

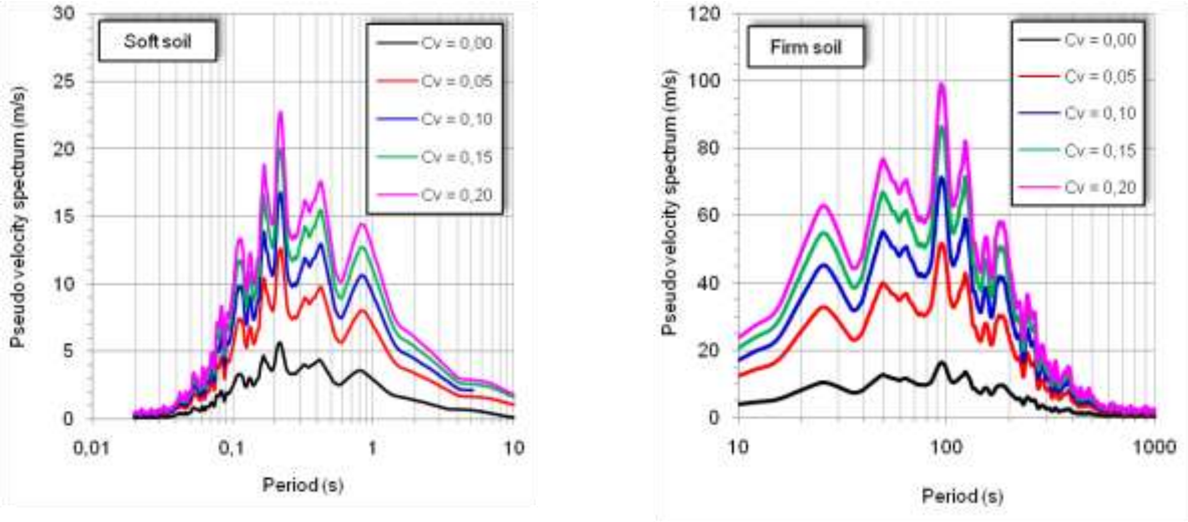

Figure.1 Effects of soil stochasticity on the pseudo velocity spectrum.

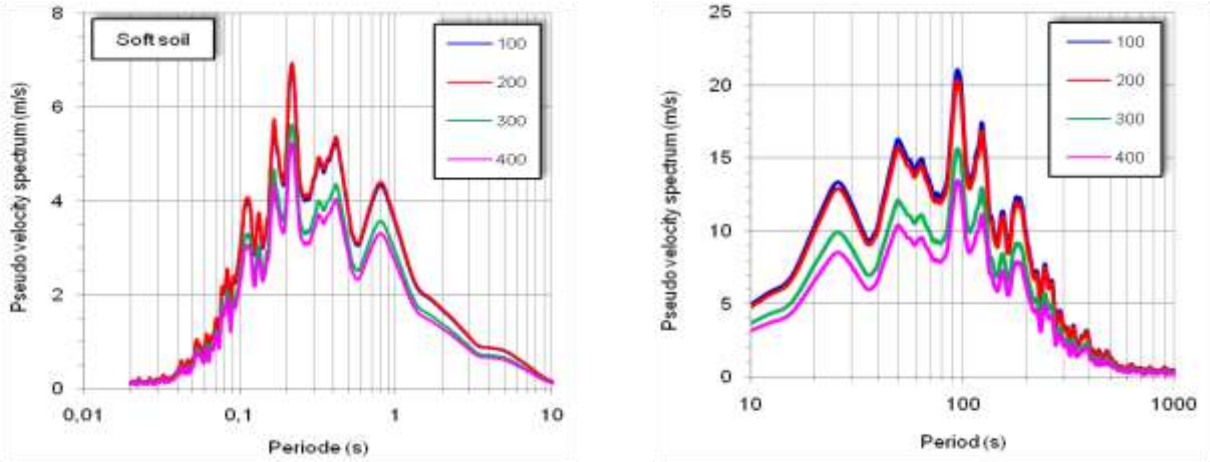

Figure.2 Spatial variation of the pseudo velocity spectrum.

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