INVESTIGATION OF SOIL PARAMETERS RANDOMNESS EFFECTS ON EARTHQUAKE DESIGN FORCES

Amina SADOUKI¹, Leila BOUARICHA², Fatima Zahra HADJ HENN³, Zamila HARICHANE⁴

ABSTRACT

The present study is dedicated to investigate the effects of uncertain material parameters of soil such as shear modulus and mass density, which are modeled as spatial random fields, on the earthquake force obtained by site specific response analysis. A comparison has been carried out between the Algerian regulatory design force and the computed one.

Keywords: Seismic code; earthquake force; soil stochasticity; structure; Boumerdes earthquake.

INTRODUCTION

In recent years, civil engineering and geotechnical practice has seen an increasing emphasis on quantifying uncertainty in ground motions due to the soil properties in surface layers, close to structures (DeGroot and Baecher, 1993; Manolis, 2002). Among the practical reasons to incorporate the material uncertainties in numerical simulations is because modern building codes are increasingly being based on reliability methods (Baecher and Christian, 2003). Uncertainties associated with soil properties attributed to the natural variability of soil deposits are known as random type. Mathematical descriptions of uncertainties are usually done within the framework of harmonic waves modeling in random media. On other hand, the many methods for determining seismic forces in structures fall into two distinct categories: (i) equivalent-static force analysis and (ii) dynamic analysis (Dowrick, 2009). Among the dynamic analysis, the response spectrum method is favored by earthquake engineers because it offers a simplified method for finding the design forces for the members of structures for earthquake forces, and is also useful in the approximate evaluation of the reliability and safety of structures under earthquake excitations (Datta, 2010).

In this context, we investigate in this study the effects of uncertain material parameters of soil such as shear modulus and mass density, which are modeled as spatial random fields, on the earthquake force (or base shear) obtained by site specific response analysis. A comparison has been carried out between the Algerian regulatory design force and the computed one.

¹ PhD Student, Geomaterials Laboratory, University of Chlef, Algeria, amina_sadouki@yahoo.fr
² Master Student, University of Chlef, Algeria, lila_happy17@hotmail.fr
³ Master Student, University of Chlef, Algeria, hadj-henni02@hotmail.fr
⁴ Professor, Geomaterials Laboratory, University of Chlef, Algeria, z.harichane@yahoo.fr
OBTENING EARTHQUAKE FORCE

The inherent soil variability is introduced as stochastic variations in the elastic properties: mass density and shear modulus of one-layer soil profile subjected to vertical SH shear wave:

\[
\rho_1(z, p) = \rho_{01}(1 + \varepsilon_1(z, p)) \quad (1-a)
\]
\[
\mu_1(z, p) = \mu_{01}(1 + \varepsilon_2(z, p)) \quad (1-b)
\]

where \(\rho_{01}\) and \(\mu_{01}\) are the mean values of \(\rho_1(z, p)\) and \(\mu_1(z, p)\) and consequently \(\langle \rho_1(z, p) \rangle = \rho_{01}; \langle \mu_1(z, p) \rangle = \mu_{01}; \langle \varepsilon_1(z, p) \rangle = \varepsilon_1(z, p) = 0\). The angular brackets \(\langle \rangle\) denote statistical averages of the ensemble with probability density \(P\). The subjacent half space is assumed to be homogeneous (Sadouki et al., 2012). The analytical method used is that of Karal and Keller (Karal and Keller, 1964):

The amplification function which is the ratio between the displacement amplitude at the free surface and the displacement amplitude at the interface between the soil-layer and the base rock takes the expression:

\[
T_{l,h}(\omega) = \frac{1}{f_j(h)} \quad (2)
\]

with \(f_j(h) = \sum_{k=1}^{4} \frac{F_k(s_k)}{D(s_k)} \exp(s_k h)\), where \(s_k (k=1,2,3,4)\) are the poles of the polynomial \(D(s)\).

When the amplification function is obtained, we convolute the response of this soil profile to an accelerometer excitation at its base. This one corresponds to the base rock accelerations recorded at Keddara’s station during the May 21, 2003 earthquake which shook the Algiers-Boumerdes area in Algeria. An effective earthquake force is written in terms of the mass of the structure (\(m\)) and the spectral acceleration (\(S_a\)) as (Dowrick, 2009):

\[
V = mS_a \quad (3)
\]

NUMERICAL RESULTS

To investigate the soil stochasticity on the earthquake force, a structure with total mass of 554 tones is selected (Bouaricha and Hadj-Henni, 2013). The seismic force is obtained by spectral dynamic analysis.

Firstly, we have computed seismic force at the base of the selected structure for three different one-layer sites (rock, firm, and soft) according to the Algerian Aseismic Regulatory code (RPA99/2003) (Figure 1). Then, we have studied soil stochasticity effects on the seismic force for several fluctuations sizes of the mass density and shear modulus for firm soil layer. Effects of soil stochasticity on the amplification function and earthquake force are presented on figures 2 and 3.
From figure 2, it is clear that as fluctuation sizes increase as the fundamental frequency is shifted to left. The corresponding amplitude decreases with a widening of the frequency contents and a significant attenuation of the amplification function for the highest frequencies. The stochastic variations effects on the frequency spectra (figure 2) are translated on the earthquake force. In fact, figure 3 shows that as fluctuation size increases, an important attenuation in the trend of earthquake force amplitude occurs. This is can be interpreted by the multiples reflections and refractions of incident motion due to the randomness of the media.
Investigation of soil parameters randomness effects on earthquake design forces

Compared to the design earthquake force of RPA99 (figure 1), the attenuation of the “stochastic” earthquake force amplitude in figure 3 translates the filtering effects occurred on frequency spectra.

CONCLUSIONS

We have investigated in this paper the effect of soil stochasticity on the earthquake force by mean of site specific response analysis. The earthquake force is computed for different fluctuation sizes of soil randomness of one-layer soil profile. Obtained results showed that the inherent soil variability (random heterogeneity) induces uncertainty in the computed response (earthquake shear base force) as random fluctuations around the “average response”. The carried analysis highlights the importance of the taking into account of the randomness of soil parameters on response of structures in any dynamic analysis.

REFERENCES