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Improved SSI analysis based on uhs time history selection

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Abstract

he importance of SSI is observed when a high-rise building rests on soft subsoil where there is a need to estimate deformations caused by application of high loads from previous earthquake time histories. In simulation of SSI problems, it is of great importance to select the most reliable time histories which would reliably adhere effects in the simulation problems. Within this paper a ten-story frame structure was analyzed considering the soil-structure interaction. The site-specific uniform hazard spectrum is used as the target spectrum in selecting and scaling of earthquake records as an input in nonlinear dynamic analysis.

Key words: Soil structure interaction, uniform hazard spectrum, infinite elements

The importance of SSI is observed when a high-rise building rests on soft subsoil where there is a need to estimate deformations caused by application of high loads from previous earthquake time histories. In simulation of SSI problems, it is of great importance to select the most reliable time histories which would reliably adhere effects in the simulation problems. Within this paper a ten-story frame structure was analyzed considering the soil-structure interaction. The site-specific uniform hazard spectrum is used as the target spectrum in selecting and scaling of earthquake records as an input in nonlinear dynamic analysis. For analysis of the selected structure, several earthquake time histories are used and obtained results were compared and discussed. Calculation analysis of the frame structure considering spectral analysis and time histories of three different earthquakes reveal several conclusions. Firstly, the spectral analysis considers various frequency content although analysis is limited to linear analysis. On the other hand, the selected earthquakes are in time domain and can be used in non-linear analysis. The results obtained from the analysis show that correct selection of earthquake time histories has important influence on the results and have to be considered in simulation of soil structure interaction problems.

The model itself is a combination of 2 seismotectonic models: (M1) grid source model and (M2) area source model. Logic tree apparatus was chosen as a tool to capture the epistemic uncertainty associated with the seismotectonic sources and its parameters as well as the ground-motion prediction models used. The applied logic tree scheme accounts the variability of: (1) Two seismotectonic models; (2) Different max. estimations; (3) Different M0 thresholds; and (4) Four attenuation models. According the results of the study which was part of regional BSHAP effort (Salic et al., 2017), the following GMPEs were used for hazard estimation: BSSA14 (Boore et al., 2014), CY14 (Chiou and Youngs, 2014), Aetal14 (Akkar et al., 2014) and Betal14 (Bindi et al., 2014). For the investigated site, UHS (Uniform Hazard Spectrum) was defined for 2 referents return periods TDLR and TNCR, as defined by EC8.

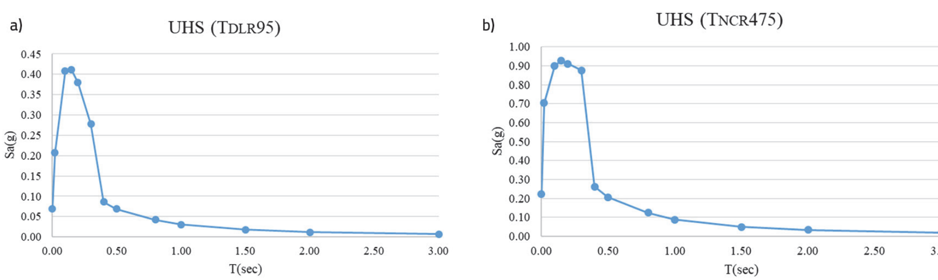

Figure 1. UHS for the investigated site, Soil type A (vs30=800m/s): a) PDLR=10% in 10 years; b) PNCR=10% in 50 years

In accordance with the spectra, earthquake time histories have been selected. The selected earthquakes are of different magnitudes and frequencies in order to trigger different deformations in the frame structure. The structure that is considered is reinforced concrete frame with ten stories and the dimensions as shown in Fig.4. The frame structure consists of three 4.0m spans and a floor height of 3.0m designed according to EC8 and EC2 and is assumed to have been built on four types of foundation such as rigid foundation, hard soil, medium soil and soft soil. Ten same viscous dampers (VD) with damping coefficient of 3.00×106 Ns/m are set up in each story in the middle span.

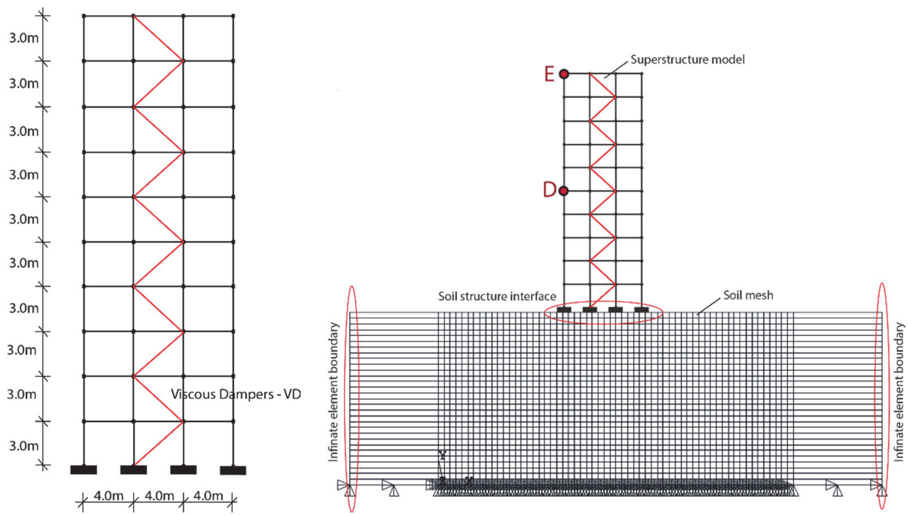

Figure 2. Frame structure including viscous dampers with and without soil model

In the simulation of boundary conditions, infinite elements have been used for absorption of waves propagating in the soil domain. The main advantage of the proposed infinite elements is that the number of nodes on the infinite element allows coupling with finite elements with eight nodes which are used for displacement-sensitive problems. In order to simulate a real situation, total added mass of each floor is 44t (440 kN), specified through MASS21 element. Furthermore, viscous dampers applied in the system are modelled by the spring damper COMBIN14 element, based on Kelvin Voigt model defined by two nodes, a spring constant and damping coefficient. The damping portion of the element contributes only damping coefficients to the structural damping matrix. In order to get a better insight of the structural response by considering different effects. the acceleration comparisons have been done (Fig. 3-6).

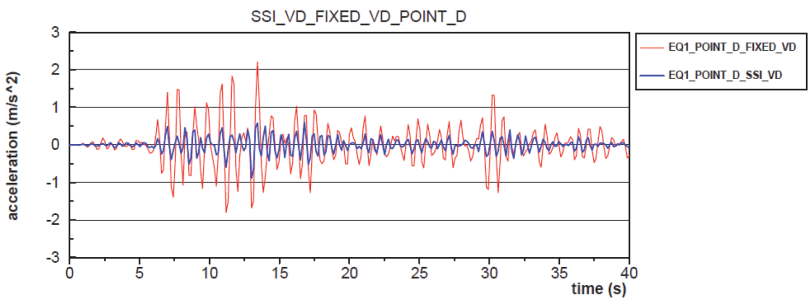

Figure 3. Comparisons of accelerations at middle of the structure - Point D with EQ1

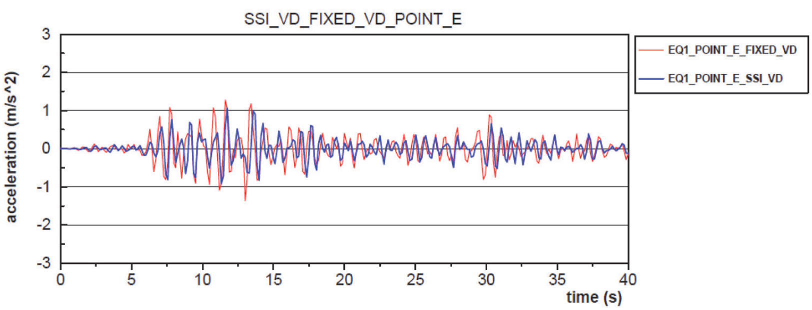

Figure 4. Comparisons of accelerations at top of the structure - Point E with EQ1

As can be seen from figures above there are differences in the acceleration time histories when the structure is founded on fixed base and on soil ground. When fixed base frame structure is simulated the maximum value of acceleration is 1.50 m/s^2. It is clearly seen that the inclusion of soil medium in the analysis decreases the maximum acceleration value to 0.9 m/s^2. On the other hand, the differences in the values of accelerations are more obvious in the middle part of the structure.

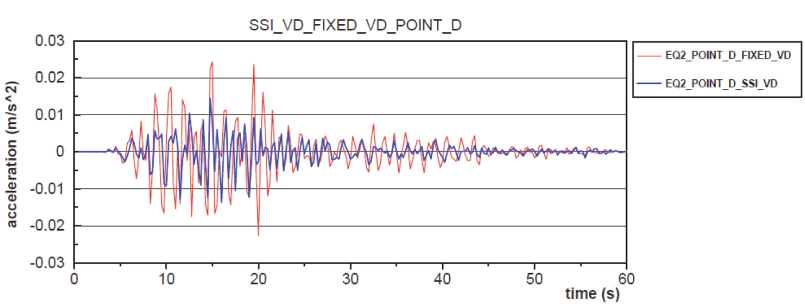

Figure. 5. Comparisons of accelerations at middle of the structure - Point D with EQ 2

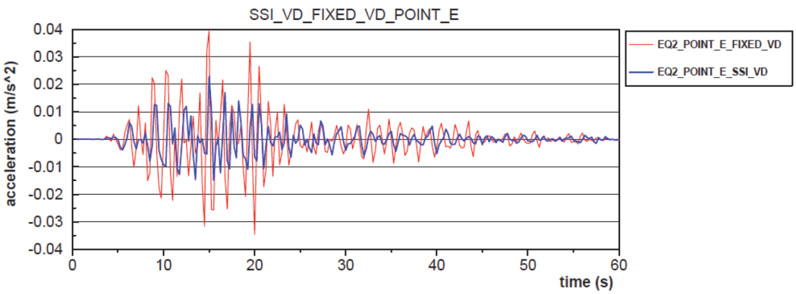

Figure 6. Comparisons of accelerations at top of the structure - Point D with EQ 2

The energy dissipation effect of dampers gets worse as the excitation frequency reduces. Consequently, when the foundation of viscous dampers becoming softer, the energy dissipation system shows less effective behavior. The above statement is confirmed with the hysteretic force-displacement relationship of the VD installed in the bottom storey and presented in Fig.7. It can be seen from the figure that along with the foundation softening, the hysteretic loops become bigger and flatter. This shows the importance of the selection of damping elements in the overall system.

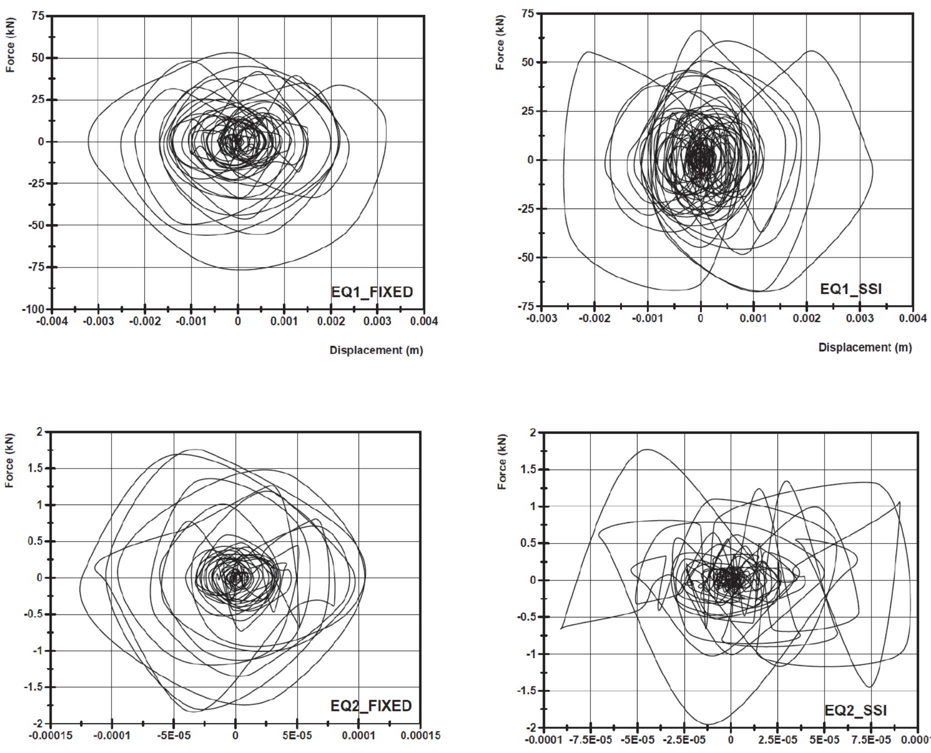

Figure 7. Force-displacement relationship for viscous damper for fixed base and different types of soil

Calculation analysis of the frame structure resting on soil media has shown that the structural response depends greatly on the soil's stiffness characteristics. The soil structure interaction calculations show that it is crucial to know the soil conditions when analyzing and designing structures resting on soil media. On the other hand, the influence of dampers present in the frame structure has advantageous effects when designed carefully. The unbounded soil boundary conditions are considered to be of infinite elements which simulate the boundaries in such a way that no boundaries are reflected back. The results obtained from the analysis show that two earthquakes EQ1 and EQ2, although obtained from the same spectrum, have different effects on the overall structural response.

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