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SEISMIC BEHAVIOR OF HIGH-RISE STEEL BUILDINGS ON PILE GROUPS ACCOUNTING FOR SOIL-STRUCTURE INTERACTION EFFECTS ON SOFT SOIL

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The problem of soil-structure interaction (SSI) in the seismic analysis and design of structures has become increasingly important as it may be inevitable to build structures at locations without favourable geotechnical conditions in seismically active regions (Bagheri et al., 2018; Tabatabaiefar and Fatahi, 2014). In this research, the main objectives of the numerical parametric study are acquiring better understanding of key parameters (soil type and ground motion characteristics) which influence SSI under seismic loads and capturing the effects of SSPSI in the seismic design procedure of regular high-rise moment resisting building frames to ensure design safety and reliability.

The numerical analysis is carried out to investigate various factors affecting the seismic response including configurations and length of the piles and characteristics of the ground motions. The structural and soil elements are modelled as an inelastic and an elastoplastic continuum material. Figure 1 shows a three-dimensional (3D) view of the building. The height of the structure was chosen 15-story with the height of each level 3 m.

Each model is subjected to four ground motion records selected from the PEER Strong Motion Database (Pacific Earthquake Engineering Research (PEER) Centre, 2012). The ground motions were selected to cover a range of intensities, durations, and frequency contents, in order to enable a comprehensive evaluation of SSI on softened ground. The PGA, PGV, and PGD values in Table 1 are the maximum absolute values of acceleration, velocity, and displacement for each ground motion. Two near-field earthquakes including Kobe (1995) and Northridge (1994) and two far-field earthquakes comprising El Centro (1940) and Hachinohe (1968) are selected and utilized in time-history analysis.

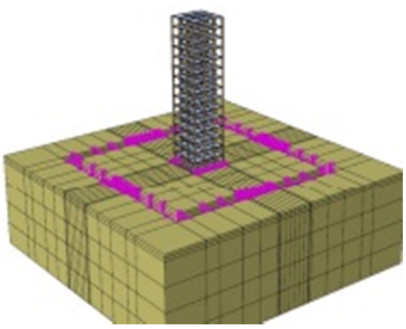

Figure 1. 3D view of steel moment resisting frame on soft soil.

Table 1. Earthquake data for the parametric analysis (PEER, 2012).

Earthquake Motion Parameters	Northridge Earthquake (USA)	Kobe (Japan)	El Centro (USA)	Hachinohe (Japan)
Date of occurrence	1994	1995	1940	1968
Magnitude of earthquake, M_w	6.7	6.8	6.9	7.5
Maximum horizontal acceleration (g)	0.843	0.834	0.349	0.231
PGV/PGA (sec)	0.157	0.112	0.102	0.146
Arias intensity (m/sec)	5.004	8.389	1.758	0.899
Type	Near field	Near field	Far field	Far field
Hypocentral distance (km)	9.2	7.4	15.69	14.1

To assess the capability of the developed numerical model in simulating the SSI and SSPSI, the results of the conducted shaking table tests (Hokmabadi et al., 2014; Tabatabaiefar and Fatahi, 2014) are employed to verify and calibrate the developed numerical model in ABAQUS (Figure 2).

It should be noted that when the pile length increased from 10 to 28 m, there was generally a gradual increase in the maximum total shear forces. For example, the base shear forces under the El Centro earthquake for the 28-meter-long pile model was 61% more than that of the 10-meter-long piles. Similarly, base shears under the Northridge earthquake is 24% more, for foundations with 28-meter-long piles, then for foundations with 10-meter-long piles. The values show that the length of piles influences the total shear forces absorbed by the structure during an earthquake as longer piles have a larger contact surface with the surrounding soil and, thus, absorb extra energy.

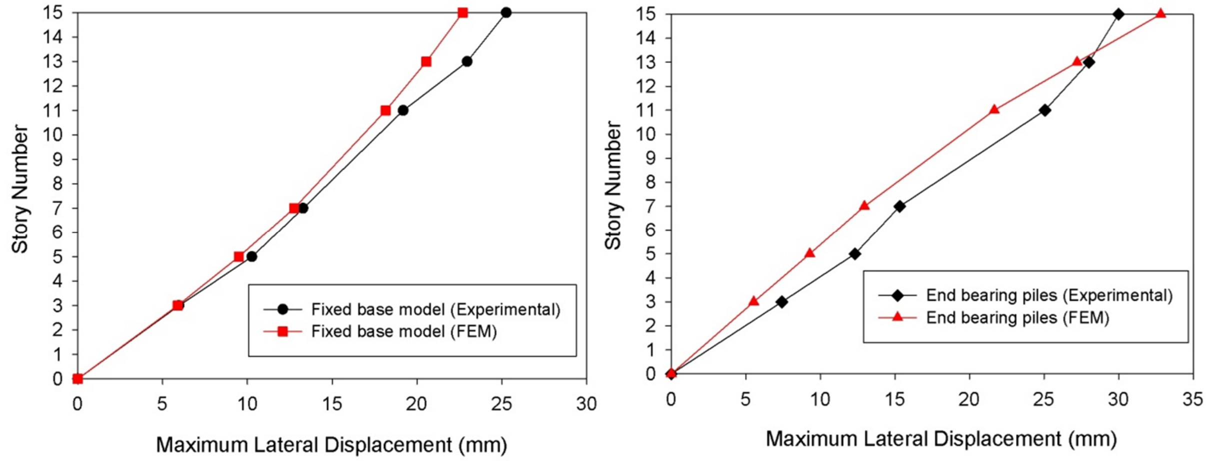

Figure 2. Comparison between maximum lateral displacement of the structure from test and numerical predictions for the fixed base, and pile-raft foundation cases under the influence of Northridge earthquake.

For instance, in the first level of the 15-storey superstructure supported by the pile-raft foundation there was a reduction of 38% for the maximum shear force experienced compared to the fixed-based structure being affected by the 1994 Northridge earthquake, whereas the seventh level experienced virtually no reduction in the generated shear force (less than 10%). In fact, depending on the type of foundation, the soil–structure interaction actually changed the dynamic characteristics (natural frequency and damping) of the system so that the input excitation caused different portions of the structure's higher mode responses to contribute to the fluctuations in the shear force distribution along the superstructure. Therefore, longer piles do not necessarily result in a safer design under strong ground motions when the interaction between soil and structure is considered.

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