PERFORMANCE LEVELS OF ECCENTRIC STRUCTURES DUE TO TORSION AND SOIL-STRUCTURE INTERACTION

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In this paper, effect of torsion on the inelastic responses of structures resting on a nonlinear flexible medium is studied. The focus here is on the plan-wise distribution of inelastic responses between different lateral load bearing lines of a torsional structure under SSI. Nonlinear behavior of structural systems and the underlying soil are both taken into account and the responses are compared with the fixed-base counterparts of the flexible-base buildings. Such a study has been extremely rare within the examined SSI problems in the past. As related to this paper, some of the SSI studies as follows, have explored how the inelastic responses vary for different soil-structure systems.

Nakhaei and Ghannad (2008) studied the effects of SSI on the damage index of equivalent single degree of freedom systems resting on a base having two transitional and one rotational degrees of freedom. It was observed that the seismic damage index of slender systems and the ones having small periods resting on softer underlying soils was considerably larger than the similar systems having fixed bases. Behnamfar and Banizadeh (2016) investigated the effects of nonlinear SSI on the seismic vulnerability of five RC buildings being different in number of stories. The nonlinear dynamic analysis showed that the location of the maximum overall building response moves to the first story when accounting for SSI. Moreover, they found several members with increased seismic damage that was especially true for the beams of shear wall systems. Ghandil and Behnamfar (2017) explored the nonlinear response of moment frames on inelastic soft soils. The soil-structure interaction was modeled using the direct approach. The relative displacements, shear forces and ductility demands of the stories of different buildings were calculated using nonlinear time-history analysis. It was observed that the story drifts and ductility demands were increased considerably in the lower stories

In this study, a multi-story building is considered on soft soil. The 3D structure is eccentric in plan to the extent that the dynamic response can be considered torsionally coupled. The system is excited by the two orthogonal horizontal components of strong seismic ground motion. The structural members can develop yielding and damage, hence behave inelastically. The soil beneath the building foundation may also have a nonlinear response under the combined effects of ground and building motions. The load bearing system consists of special steel frames having 4, 8, and 12 stories. The soil type is D, being a relatively soft soil. Nonlinear modeling of the studied buildings is performed using OpenSees. Use is made of concentrated plastic hinges at the ends of beams and columns. The damping matrix of the structure is assumed to be of the Rayleigh type.

The torsional eccentricity is assumed to originate from live load dislocation in an originally symmetric loading plan. Center of stiffness remains to be concentric at the center of area of the plan during linear response. For minimizing the already numerous cases of analysis, the mass eccentricity is produced by equal movements of the mass center in the x and y horizontal directions as 5 to 30% of the plan dimension. The whole model of the inelastic structure and its foundation is placed over a set of dampers and nonlinear springs representing the underlying soil that yields in compression. 11 earthquakes are selected and scaled for each building using magnitude, distance and soil type criteria. Totally, 660 analysis cases are performed. Both horizontal components of each earthquake are applied concurrently. The story drifts and the plastic hinge rotations are calculated. The maximum of each response parameter is determined under each earthquake for each building. The averaged maximum value is calculated for the set of 11 earthquakes.

The maximum story drift is determined at the most critical edge of the plan. For instance, Figure 1 shows the maximum drift ratios of the 12-story building with flexible base normalized to those of the rigid base building. In all of the cases, the drift response ratio is largest in the first story when the base is flexible. This amplification is larger for taller buildings where it reaches to about 30%.

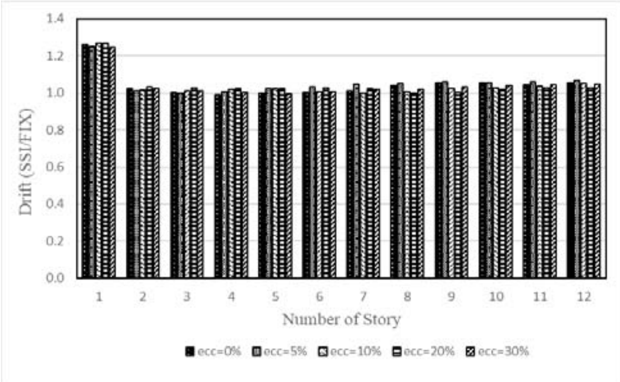

Figure 1. Maximum story drifts of the 12-story building with SSI normalized to those on the fixed base.

The averaged maximum value of plastic hinge rotation summed over instantaneous absolute values of all hinges of each story is determined for each case with SSI and normalized to the corresponding values without SSI. A sample result is shown in Figure 2. It is observed that SSI increases the plastic hinge rotations mostly in upper stories and in taller buildings. The amplification is more than three times in the case of Figure 2. The value of eccentricity has a large effect on SSI amplification. At the same story where SSI has the largest increasing effect, the amplification factor changes from 1.7 at ecc=30% to 3.7 at ecc=10%.

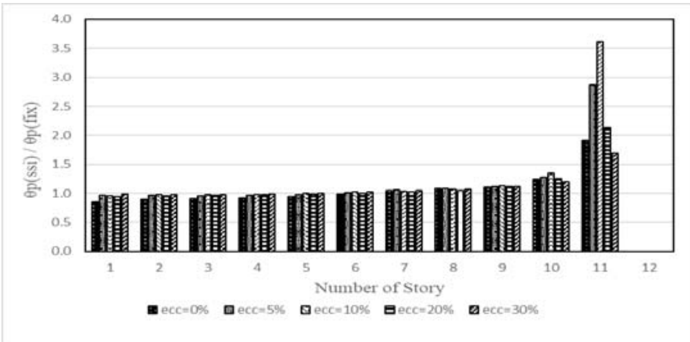

Figure 2. Averaged maxima of total plastic hinge rotation with SSI normalized to those without SSI.

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