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Dynamic Analysis of a Full-Scale Four-Story Steel Building Experimented to Collapse Using Strong Ground Motions

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SUMMARY

A full-scale 4-story steel building was experimented to collapse on the E-Defense shake-table in Japan in September 2007. The paper deals with the numerical three-dimensional modeling of the building specimen involving both structural and non-structural components, addressing the local buckling behavior of columns. Fiber method approach which can simulate local buckling at the component end joints is adopted in the study. According to this approach, the hinge zone is modeled as a group of 'fiber elements' distributed over the member section. Rotation characteristic of the fiber hinge model is defined by assigning the finite length of buckling zone. The finite length takes effect locally to compute fiber strain and bending stiffness of the hinge. However, it is noteworthy that the existence of fiber hinge element contributes certain additional flexibility to the member due to finite length of the fiber element. Hence, the flexibility should be eliminated by stiffening the associated column portion. A case study on analyzing behavior of a simple cantilever column is carried out, showing the efficiency of the approach. Dynamic collapse analyses on the 4-story steel building are carried out, using the same input motions as those recorded on the shake-table facility. In general, global response of the analytical model is satisfactory with good accuracy of story shear and inter-story drift ratio under each case of excitation level. Since non-structural components are taken into account in this study, the analytical model is capable of capturing the difference between the acceleration-based story shear force (obtained from inertial force) and frame-based story shear force (obtained from column restoring forces), demonstrating the contribution of non-structural components in global lateral stiffness of the building. Under the collapse excitation level, plastic hinges are localized to all columns of the first story, at both top and bottom ends. The analytical model was successful in performing the column deterioration due to local buckling behavior leading to weak story collapse mechanism of the building. Further hypothetical analyses for examining collapse probability of the building specimen under any orientation of the original ground motion are also conducted, showing that the building likely collapses in all cases, with the same collapse manner as that recorded in the experiment in spite of different biaxial bending effects among cases.