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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
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"Evaluation of Experimental Full-Scale Steel Building Collapse Caused by Two-Directional Column Deteriorations"

Chapter 1　INTRODUCTION & OBJECTIVES

In September 2007, a full-scale four-story steel building was tested to collapse at the E-Defense shaking table facility, using gradually increasing strong ground motions. As a result of recently adopted improvements, there is a small likelihood of connection fractures. The building thus showed soft story mechanism due to column deteriorations in the first story. All previous experimental and analytical studies indicated the local buckling of columns governed the building collapse. However, most of them did not substantially report the physical aspect of local buckling as well as the two-directional correlative column deteriorations.

The major objectives of the study are to

(1) Characterize the cyclic change of displacement direction and its effect on damage.
(2) Clarify different deteriorating sequence of all 6 first-story columns under different varying axial load conditions, and identify the progress of soft-story mechanism.
(3) Characterize the two-directional column behavior under biaxial bending moment and varying axial load, two-directional deterioration due to local buckling, and consequent building collapse, via analyses utilizing the fiber hinge elements.
(4) Further interpret the building response in terms of instantaneous input energy.

Chapter 2　BUILDING RESPONSES AT VARIOUS EXCITATION LEVELS

Inelastic response spectra predicted the input motion to be more damaging in the Y direction than in the X direction, consistent with the experimental building response. The identified change of building dynamic properties at various excitation levels also showed the dominant frame yielding in the Y direction. Local plastifications of frame components, as well as the concentration of the drift in the first story involving significant inelastic deformation of panel zones and columns, are clarified in this chapter. Furthermore, the cyclic change of displacement direction and two-directional soft-story progress is summarized and visualized via floor absolute displacement.

Chapter 3　BUILDING COLLAPSE CAUSED BY COLUMN DETERIORATIONS

Experimental results show totally different deteriorating patterns of biaxial bending moments amongst all six columns because their axial force magnitudes and variations differ considerably due to the column locations. The column deteriorating and damaging sequence is clarified and detailed from these perspectives, in relation with the global response of base shear and story drift displacement during collapse excitation level. This chapter also interprets the building responses in terms of energy input and dissipation. Although the total input energies were almost equal, the maximum instantaneous input energy was more dominant in the Y than in the X directions, input quickly to the frame deteriorated due to column local buckling, consequently causing the rapid translational response and collapse of the first story mainly in the Y direction.

Chapter 4　COLUMN ANALYSES SIMULATING TWO-DIRECTIONAL DETERIORATIONS

This chapter explains the simplified methodology for simulating two-directional column deteriorations by utilizing the fiber hinge element, which is able to clarify the physics of accumulated column damage by characterizing the complex three-axial deformation of local buckling behavior, based on the approximate uniaxial fiber stress-strain hysteretic relation. The empirical calibration for fiber properties (considering cantilever column test results, existing prediction rule for local buckling, and FEM verifications) is presented. This chapter also demonstrates cyclic analyses applying some proposed biaxial loading patterns together with constant axial load. Some other complex loading schemes such as compressive and tensile axial load applied alternately, with additional high frequency axial load caused by vertical accelerations, as well as the cyclic shifting of the bending moment's principal directions are also presented in this chapter.

Chapter 5　BUILDING ANALYSES INVOLVING TWO-DIRECTIONAL COLUMN DETERIORATIONS

The nonlinear dynamic 3D analyses using the fiber hinge elements closely simulated the building responses throughout small to large excitations. The agreement with experimental records was achieved on variety of quantities such as story drift ratios, accelerations, base shear, and energy dissipation. The model was able to simulate the accumulated deteriorations in accordance with the cyclic change of displacement direction causing the earlier column damage in the X direction and later reducing the resistant capacity in the Y direction. The progress of column deteriorations was visualized and detailed via the stress-strain hysteretic relations of column end fibers. The eventual soft story collapse mechanism induced by the weakening of the first-story column ends was also closely simulated.

Chapter 6　CHARACTERIZATIONS FOR CYCLIC DETERIORATIONS OF COLUMNS & SOFT STORY

Some aspects are characterized such as moment-deformation hysteresis shape or two-directional correlative deteriorations. Simulation results indicated that the fiber stress-strain responses under the variation of axial force condition can automatically generate the column moment response, in compatibility with the skeleton and Bauschinger approach. On the other hand, the soft story behavior governed by first-story columns involving two-directional deterioration can be approximated and closely simulated by the simplified analytical column model considering average constant axial load (i.e. building weight divided by number of columns).

Chapter 7　CONCLUSION　(summarizes and concludes the study)