New Exploratory Research (Project No.: 2019H-04)

Project name: A novel substructure-based online test platform for collapse simulation of steel building structures

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Name of DPRI collaborative researcher: Yoshiki Ikeda

Research period: 01 04 2019 ~ 31 03 2020

Research location: Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, 6110011, Japan

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Number of participants in the collaborative research: 4 (DPRI: 3 non-DPRI: 1)

- Number of graduate students: 2 (Masters: 1 Doctoral students: 1) (Included number)
- Participation role of graduate students [Numerical Modelling, Investigation, Test Preparation, Lab Assistance]

Anticipated impact for research and education

Earthquake events have the potential to exact a heavy toll to the communities and countries by destroying access to basic services, energy, housing, transportation and more. To eliminate these social and economic risks, understanding the collapse mechanism and capacity margins of structures is essential. This will enable engineers to develop more efficient design or retrofitting methods that explicitly enhancing the progressive collapse resistance of structures. The present research not only provides the research community with an effective and modern experimental platform to address these challenges, but also can be used to train undergraduate and postgraduate students to latest earthquake engineering technologies building awareness and advanced skills; while untimely can modernize the field.

Research report

(1) Purpose

Under extreme earthquakes the safety margins of structures can be exhausted quickly and disproportionately. The sudden failure of an individual structural component and its interaction with the adjacent elements can trigger significant structural instabilities in both local and global level thus leading the structure to unexpected partial or total collapse. This research aims to investigate the collapse mechanisms of steel moment-resisting frames (SMRFs) by developing a computational platform with fully-controlled loading conditions to mimic the real interaction of isolated test components with the rest structure being able to evaluate and quantify their actual ductility margins and earthquake resistance.

(2) Summary of research progress

A hybrid test method that utilizes the nonlinear static (pushover) analysis to examine the force-deformation response of building structures until collapse is developed. The ultimate performance of the columns at the base of a SMRF designed according to Japanese codes is evaluated experimentally considering force redistribution at the column top due to frame-type failures at panel zones (shear yielding, buckling) and beams (flexural yielding, local buckling). The test method combines static sub-structuring techniques and finite element analysis methods. The behavior of the SMRF is simulated by the finite element analysis program ABAQUS, while the first story column is physically tested interactively. Three actuators are used to simulate the physical continuity between the analytical and experimental substructures by controlling the axial load, the drift angle, and the bending moment distribution along the column length.

(3) Summary of research findings

A square tubular steel column was tested as a part of a five-storey five-bay SMRF. The frame was deformed to a roof drift equal to 12% using pushover analysis that incorporates a novel mixed force/displacement controlling algorithm. The measured storey drift for the tested column was almost 30.0%. The test system ensured realistic loading and boundary conditions to the column sub-structure, which was tested in full interaction with the SMRF until global frame collapse. The frame deformed in a collapse mechanism that involved the first two storeys.

(4) Publications of research findings

Skalomenos KA, Kurata M, Y Ikeda, Hybrid collapse test of steel columns with nonlinear frame substructuring and force redistribution: In Proceedings of XI EURODYN International Conference on Structural Dynamics, 22-24 June 2020, Athens, Greece

A journal paper is in preparation and will be submitted this year.