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New Exploratory Research (Project No.: 30H-04)

Project name: Numerical and Experimental Investigation of the Seismic Performance of Steel Braces with Stronger Mid-Length Treated by Induction Hardening
Principal Investigator: Konstantinos Skalomenos
Affiliation: Disaster Prevention Research Institute
Name of DPRI collaborative researcher:
Research period: 1 4, 2018 ~ 31 3, 2019
Research location: Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, 6110011, Kyoto
Number of participants in the collaborative research: 3 (provide numbers for DPRI and non-DPRI staff)

- Number of graduate students: 2 (provide numbers for Masters and Doctoral students)
- Participation role of graduate students [Graduate students worked primarily on the numerical investigation of the new structural member under earthquake load simulations. They prepare also the drawings for the preparation of the test specimens and helped on the experimental research thought the large-scale validation tests as Lab assistants]

Anticipated impact for research and education

The present research adopted a new material technology, the induction heat (IH) treatment technology, as a key technology of Material Science to deal with a fundamental problem of Structural Engineering and Steel Structures, the failure of buckling. New mechanical properties of the treated steel material were identified and tailored in a way to control the overall behavior of the member. Physics-based deformation equations to describe the buckling theory were introduced that can advance both research and education.

Research report

(1) Purpose

In steel structures, steel braces constitute the main seismic-resistant mechanism. However, conventional steel braces experience severe buckling in compression and lose significant strength rapidly. The structures cannot resist lateral loads anymore and often collapse suddenly under strong earthquakes. The present project investigated an alternative brace design to control overall behavior in a way that increases structures ductility. By maintaining the same construction simplicity with the current brace design, a simple post-treatment material method can increase the member's strength predefined critical locations with precisely and automated manufacturing control.

(2) Summary of research progress

Based on the data of coupon tests of IH-treated steel, an accurate finite element model was created. A parametric study was conducted to evaluate the influence of major design parameters, such as the yielding stress ratio of IH-to-conventional steel, design configurations of brace-to-end plate connections and the bending direction with respect to the frame plane. A large-scale experiment was designed and conducted under cyclic loading protocol until collapse to validate the seismic performance of the new member. The test results will be used to generalize the analysis findings and improve the analysis model. The design method of the new member is under development and the final goal is the promotion of the product to actual structures.

(3) Summary of research findings

Based on the test results, the IH steel brace provides with a 2.6 times larger strength in the mid-length which in turn increases the buckling load nearly by 16%. Based on the numerical investigation, the improvement was capped at the values of IH-to-conventional steel yielding ration more than two. An appreciable higher post-yielding stiffness around 6% of the initial stiffness was also achieved which is beneficial to reduce the maximum and residual story shear deformations to avoid a premature soft-story failure mechanism and finally collapse. Under larger deformations, a severe local buckling took place within the conventional steel portions which may lead to an earlier fracture than excepted. The fracture ductility can be further enhanced by carefully designing the brace-to-end plate connections. This is a subject of continuing investigation.

(4) Publications of research findings
A research paper related to IH braces has been submitted in the Journal of Engineering Structures, Elsevier, and is under review. This year a second paper will be prepared.