



京都大学防災研究所

Disaster Prevention Research Institute

Kyoto University

New Exploratory Research

2025NE-02

Development and Advancement of Seismic Retrofit Strategies Using Curved members and 3D modeling for Steel structures

March, 2026

Coordinator Kun-Sian Lin

New Exploratory Research (Project No. 2025NE-02)

Project Title : Development and Advancement of Seismic Retrofit Strategies Using Curved members and 3D modeling for Steel structures

Principal Investigator : Kun-Sian Lin

Affiliation : Kyoto University

Name of the DPRI Contact Person : Masahiro Kurata

Research Period / Duration of Stay : April 1, 2025 - March 31, 2026

Research Location / Location of Stay : Kyoto University, DPRI

Number of the Participants in the Project: (DPRI: 2 / non-DPRI: 0)

Anticipated Impact on Research and Education

Advances research on curved members through validated models, experimental verification, and BIM-integrated tools, enhancing seismic retrofit methodologies, promoting practical adoption, improving material efficiency, and strengthening education in computational structural engineering.

Research Report

(1) Purpose

This project aims to develop seismic retrofit techniques for brittle and aging structural components in steel buildings by leveraging the structural advantages of steel curved members. The project further seeks to advance practical design methodologies by integrating curved members into 3D modeling approaches through Building Information Modeling (BIM). By developing simplified and standardized modeling approaches, the research aims to enhance design flexibility, promote wider adoption of curved members, and improve both the competitiveness and seismic resilience of steel structures.

(2) Summary of Research Progress

The research has progressed according to the planned tasks. First, a literature review on curved member applications and seismic retrofitting has been conducted. A dataset of steel curved members has been established by a series of tests, including material properties and the effects of temperature during bending processes.

Second, numerical models have been developed using OpenSees for structural analysis and BIM integration (Grasshopper and Rhinoceros). Estimation equations of curved members have been proposed based on parametric studies that investigate the elastic stiffness, plastic strength, slenderness effects, and section compactness with different boundary conditions.

Third, case studies of a steel frame incorporating curved members have been carried out. These studies include data collection, numerical simulations, and

performance evaluations under seismic loading conditions, focusing on the effectiveness of curved members as a retrofit option.

Fourth, quasi-static experimental program is conducted at the DPRI Structural Laboratory. These tests are designed to validate the proposed retrofit strategies and confirm the reliability of the numerical models.

Finally, design recommendations including a modified connection design method for curved members are prepared to facilitate their practical implementation.

(3) Summary of Research Findings

The findings highlight that bending process and associated temperature conditions affects the material properties and deformation capacity of curved members. The test results showed that for H-shaped steel, temperature and heating time varied depending on how and where it was bent. SN steel showed a small drop (10%) in yield and tensile strength. However, cold-formed BCR steel tubes exhibited significant reductions in yield and tensile strength, along with increased elongation after induction-heating bending. It indicates that hot-bent BCR295 should be treated as having properties similar to lower grade steel.

Estimation equations of curved members for yield strength and buckling behavior with different boundary conditions were developed. The experimental program of a retrofit technique employing curved members at the column base and beam-column joints in a steel frame was conducted and verified to exhibit stable and ductile hysteretic behavior by the effectively redistributed forces of curved members. A general numerical modeling approach was developed to represent the responses of the retrofitted steel frame and validated against the experimental results.

The study developed an integrated parametric analysis framework using Rhinoceros and Grasshopper, coupled with OpenSees, as shown in Figure 1. Through Grasshopper, a visual programming environment, large number of parametric simulations were efficiently conducted by adjusting input parameters such as curvature, dimension, and retrofit configurations.

These findings have contributed to developing a connection design methodology that enhances material efficiency while preventing overly conservative designs.

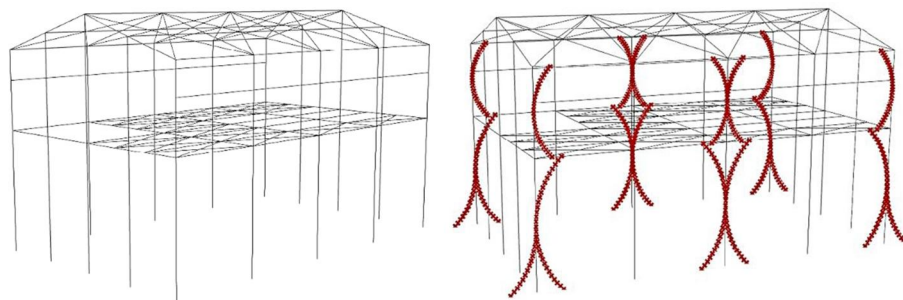


Figure 1. Illustration of numerical models in 3D modeling platform.

(4) Publications of Research Findings

1. Lin, K. S., Kurata, M., and Kawasaki, Y. 2026. "Plastic behavior and design methodology for curved members in seismic applications." Jpn. Archit. Rev. 9(1): e70069. <https://doi.org/10.1002/2475-8876.70069>
2. Lin, K. S., Kurata, M., Kitamura, K., Kitatani, Y. 2026. "Subassembly Tests of Seismic Retrofit Technique Using Curved Members for Steel Frames." J. Structural Eng. (ASCE). (Accepted)