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Preliminary Experimental Tests of a Seismic Retrofit Technique for Steel Connections Using Curved Members: Design Concepts and Test Results

〇Kunsian LIN, Yutaro KAWASAKI, Kotaro KITAMURA, Masahiro KURATA, Yoshio KITATANI

1. Introduction

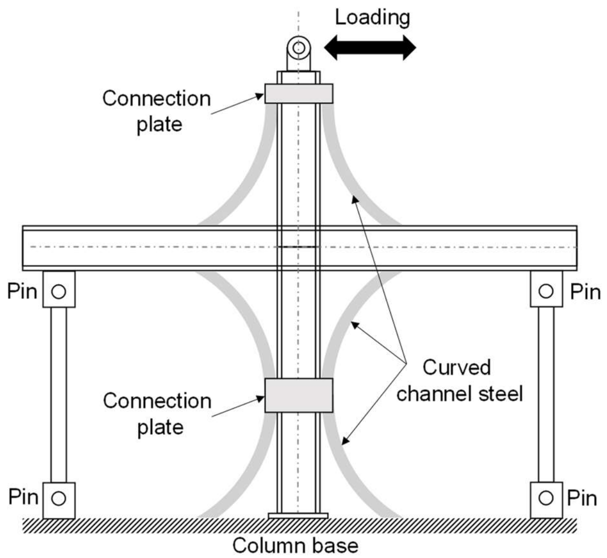
In Japan, a significant number of industrial buildings such as factories with long-span frames were constructed between the late 1960s and early 1990s, prior to the collapse of the bubble economy. These industrial buildings are primarily steel structures approaching the end of their legal lifespan of 34 years. Consequently, extending the service life of not only these aging structures but also damaged structures through retrofit techniques has become increasingly critical.

More recently, a new type of seismic retrofit technique for steel column bases using the benefits of curved members with a novel mechanism was developed [1] compared to conventional retrofit methods and provides an alternative solution to steel structures retrofitting. The intended eccentricity provided by the curved member itself has the feature of lateral stiffness loosely coupled with the yield strength [2] which enables to achieve the seismic design objectives effectively, and controls the component's buckling direction and avoids the sudden loss of strength due to buckling [3]. Also, strength degradation of the retrofit system was well limited and provided a stable behavior with yielding regions evenly distributed at the middle of curved members.

This study aims to propose an extension of the curved member retrofit technique for brittle or older structural components (e.g., connections) in steel industrial buildings that increases repairability and ductility limit with reduced seismic demand.

2. Proposed Retrofit Techniques

Figure 1 shows the proposed seismic retrofit technique for the beam-column connection and column base using 6 curved channel steels. Curved channel steels are leaned against the existing column and connected to each other by high-strength bolts connection with steel plates.



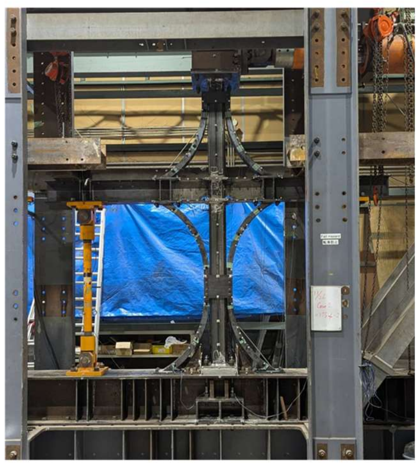


Figure 1 Test setup and photo of the experimental program

The design concept is to benefit from the features of curved members to have moderate-enhanced strength, stiffness, and improved ductility for the structures while design targets are to increase the repairability, and ductility limit, and reduce the seismic demand for non-ductile components in older or damaged structures.

3. Test Plan and overall behavior

A pilot experimental program of a prototype specimen has been conducted at the DPRI structural laboratory to examine the effect of curved members on connections and the failure mechanism of the retrofitted frame, as shown in Figure 1. The lateral cyclic loadings were applied by an actuator through a relatively stiff loading beam connected to the column at the top. A four-pin loading frame system was adopted which contributed no lateral resistance.

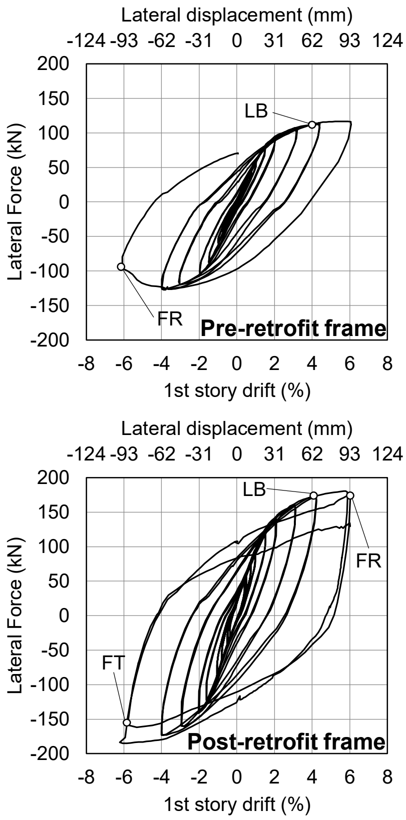


Figure 2 Measured hysteretic responses

Figure 2 shows the measured hysteretic responses of the pre- and post-retrofit frames in the test. After retrofitting, the ultimate strength of pre-retrofit frame increased by 31% and the initial stiffness increased by 43%. The pre-retrofit frame developed the local buckling (LB) in the cycles of 4% story drift and the fracture (FR) initiation in the cycles of -6% story drift on the beam ends. Test results verified that the proposed retrofit method provided very ductile hysteretic responses with no strength degradation up to 6% story drift under cyclic loadings. Beam flange tearing (FT) occurred under the 2nd cycle of -6% story drift, and has however not led to negative post-yield stiffness due to the existence of curved members. For the post-retrofit frame, rotation demands of the column base were reduced by 27%, and beam end moments were also reduced in the elastic region.

4. Conclusions

This study concluded the following key findings: (1) The proposed retrofit method improved the frame's performance, increasing ultimate strength by 31% and initial stiffness by 43%, while demonstrating great ductility with no strength degradation up to 6% story drift. (2) The post-retrofit frame reduced column base rotation demands by 27%, reduced beam end moments, and effectively limited the deformation of connection components.

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