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Minimal-Disturbance Arm Damper Retrofitting: Evaluation of Retrofit Effect Using Multi-Span Steel Frame Specimens

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Concrete floor slab contributes to the beam stiffness under positive bending moment in steel moment resisting frames. The composite action shifts up the section neutral axis increasing the risk of fracture at the beam end bottom flanges. A retrofit technique, named minimal disturbance arm damper (MDAD), is proposed as solution to restrain the local deformation at beam ends and reduce the frame responses with moderate increase in stiffness, strength and damping. MDAD retrofits steel frames rapidly thanks to only bolt connections and preserves the open space of the frames. In this presentation, the effectiveness of MDAD to improve the seismic performances of a steel frame was experimentally and numerically examined through the application on two half-scaled multi-span specimens. The test and numerical results both showed significant benefits of MDAD in reducing the positive bending moment at beam ends, delaying the fractures at the bottom flange of beam ends and providing alternative load–carrying paths after fracture to prevent strength reduction. The deformation capacity of a steel moment resisting frame is often determined by the fracture at the bottom flange of beam end, since the composite section effect between steel beam and concrete floor slab leads to a large demand at the beam ends under positive bending. The existing retrofitting techniques can be classified in two types. The first category aims to enhance the strength and ductility of the vulnerable parts; such as braces or haunches added to beam ends. The second category aims to reduce and redistribute stress concentrated at the vulnerable part to a less critical area. One representative example is reduced-beam-section (RBS) connections. The consequences of retrofitting critical part should be carefully evaluated. Retrofit with the first category technique may result in the needs of further strengthening other originally non-critical parts and foundation. With such background, a new retrofit strategy of minimal-disturbance seismic retrofit and the associated example technique has been developed by Kurata et al [1]. A technique named minimal disturbance arm damper (MDAD) protects the beam ends from fracture with the moderate increase of the stiffness and strength of the entire frame, while reducing the installation time by using light-weight steel members with only bolt connections. Lavan et al [2] proposed a design procedure of MDAD that explicitly considers the unique feature of MDAD in directly reducing beam-end local deformation. As a nature of retrofitting, the performance of retrofit cannot be evaluated solely by the testing of retrofit techniques and devices. Many studies about retrofit techniques were conducted to understand the behaviour of a single beam-column steel connection or a single span moment resisting steel frame [3]. If the attachment of retrofit elements alters force distribution and yielding orders, such simple testing is not enough to capture entirely the effect of a retrofit system on a structure. The use of a multi-span specimen that enables to observe the influence of the retrofitting on force-resisting mechanism is more suitable. In case of MDAD, the previous researches [1, 2] evaluated the devise behavior through component-level tests and the retrofit impact to steel moment-resisting frames in numerical simulations. However, the numerical simulation holds many assumptions and the effect of MDAD retrofit on existing frame has not been closely examined yet. In this context, the writers conducted quasi-static testing of multi-span steel frames, with and without MDAD, aiming to evaluate globally and locally the influence of MDAD attachment in delaying fracture of steel frames. The attentions are also paid on moment distribution within the frames, yielding and fracture delay at the beam ends and the post-fracture behavior of the frames.

Conclusion

The effectiveness of MDAD on increasing the seismic capacity of steel frames was examined on a multi-span steel frame subjected to a quasi-static cyclic loading. The test results of the bare frame were compared with the results of the retrofitted frame. In terms of positive bending moment reduction at beam ends, the delay of the fractures and the post fracture behavior. The main findings are summarized as follows:

1) The results showed MDAD reduced the positive bending moment by 18.3% at elastic range of steel frame, which was close to the designed value.

2) The first yielding and the bottom flange fracture of beam end delayed from 0.75% to 1.0% and from 2.0% to 3.0%, respectively. Based on the observation during the loading, the local buckling was not obvious at the bottom flanges of retrofitted beam ends. Thus, MDAD mitigated that damage and promoted the stable behavior of steel frame.

3) The MDADs yielded earlier than the beam ends under positive bending and provided the stable hysteretic behavior.

4) There was no reduction of the capacity of the steel frame even after the fracture occurred. MDAD was able to sustain the tension force at bottom flange of beam end after fracture. This contributed to the stable behavior of the steel frame.

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