Seismic Retrofit of Steel Frames with Minimal-Disturbance

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Summary

A design and construction scheme termed *Minimal-Disturbance* seismic retrofit pursues "Elegance" with the intention of improving the continuity of business while minimizing obstruction of the visual and physical space of building users. This paper presents the concept and verification tests of a damper device for steel moment-resisting frames, which is designed to meet the requirements of the scheme of *Minimal-Disturbance*.

Keywords: seismic retrofit; minimal-disturbance; steel moment-resisting frames.

1. Introduction

Many techniques and devices have been developed to enhance the seismic performance of existing buildings which present a risk of poor performance in potential seismic events. However, these systems naturally become large in size and often interrupt sight of users. Another distress arises from the use of heavy equipment and hot works (welding/cutting), which forces the occupants to leave the buildings during construction. In such consequences, for relatively small or partial seismic upgrading, rapidly deployable retrofitting devices may be a good option for reducing indirect cost associated with construction.

In steel moment-resisting frames, one of the most vulnerable parts identified in past earthquakes and laboratory testing is the bottom flanges of beams near the beam-column connections partly due to the composite action provided by concrete floor slab. Therefore, reducing the demand of bottom flange directly enhance the deformation capacity of beam-column connections and eventually that of the entire frame. Thus, a supplemental load-resisting device that can reduce inter-story drifts through the stiffness and strength increase as well as reduce the bottom flange tensile strains is proposed.

2. Minimal Disturbance Seismic Retrofitting Technique

2.1 Schematic of developed system

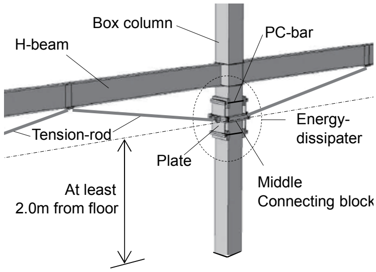

Fig. 1: Schematic of MDAD

A retrofitting technique, named Minimal-Disturbance Arm Damper (MDAD), connects the mid-span of beam and the upper part of column with two identical tension-only rods. At the upper part of column, an energy dissipation part consists of two steel bending plates is attached by pre-stressing force using PC-bars. The mid-part of the steel bending plates are connected each other to realize a stable energy dissipation. The installation to the existing frame does not require welding or heavy construction equipment, and the influence to usage plan is limited as they occupy only the top part of openings.

2.2 Basic behavior

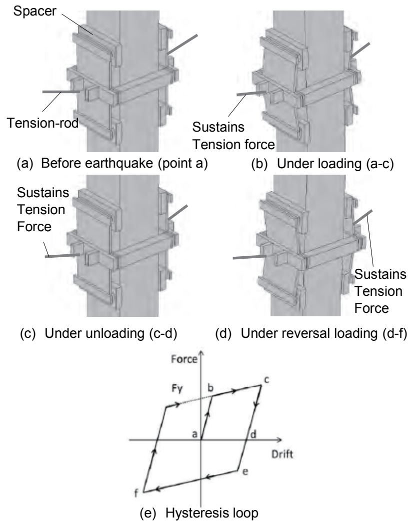

Fig. 2: Basic behavior

Fig. 2 shows the basic behavior of MDAD. When the lateral load is applied to beam-column connection, one side of the beam-column connection opens and the other side closes. Accordingly, the tension-rod in the opening side works in tension and pulls the steel bending plates attached to the column. As the two bending plates are connected at its mid-section, they equally deform and yield as shown in Fig. 2b (path a-c in Fig. 2e). The deformation of the steel plates prevents contraction of the tension-rod in the closing side. When the load is reversed (point d in Fig. 2e), the deformation in both tension-rods are zero and the tension-rod on the closed side starts to sustain tension force, while the tension-rod in opened side loses tension force. This mechanism enables the developed system to dissipate energy with a stable bi-linear.

MDAD adds supplemental stiffness and strength of the existing beam-column connections. Meanwhile, the shear force applied downward at the mid-span of the beam reduces the tensile strain at the bottom flange and prevents early fracture at the beam ends.

3. Proof-of-concept tests

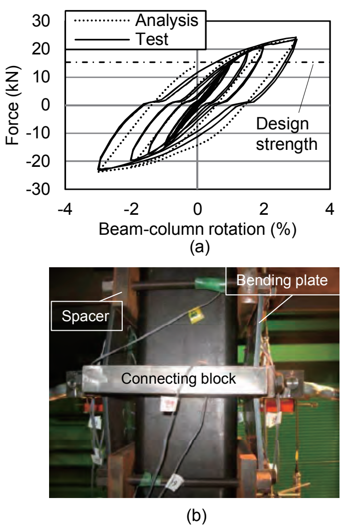

Fig. 3: Baseline specimen

In the proof-of-concept test, the behavior of the developed system was examined in the component level, while all the deformation concentrated to the developed system due to the beam and column were rigid-body. The hysteresis of the baseline specimen in Fig. 3a shows the stable energy dissipating behavior. The initial stiffness and strength matched well between the test and analysis within the discrepancy of 10%. As intended in the design, the two bending plates were deformed in a similar manner with the rigid middle-connection block (Fig. 3b) Thus, the tension rods only sustained tension force thanks to the geometric configuration. The maximum force in the tension rods were sufficiently below their yielding strength. However, slight pinching behavior appeared at 1% due to the vertical slippage of the bending plates against the column surface. When the bending plate slipped, the distance between two ends of tension-rod was shortened and it generated the slip in the relationship between force and beam-column rotation. There are several ways to reduce this phenomenon: apply more pre-stressing force to PC-bar fixing the plates on the column surface, or increase the friction coefficient of the column surface by rusting or manipulate it.

4. Conclusions

A damper device developed under the scheme of *Minimal-Disturbance* was presented. The device adds supplemental stiffness and strength to the steel beam-column connections with structural deficiency and dissipates energy during earthquakes. The geometrical configurations and assemblage of the device is intended for easy installation without usage of welding or heavy constructional equipment, and keeping visibility after installation of the system. The basic behavior of the system was examined in the experimental tests and its high performance was verified.