An Experimental Study on the Seismic Response of BIEs using Mechanical Pins

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Introduction

The present paper proposes an improved design of conventional steel braces (CBBs). CBBs are characterized by intense local buckling in the middle, limited post-yielding stiffness, and provide with very large strength and stiffness. In the proposed steel brace design, the brace is installed with intentional eccentricity (*e*) along the member's length. The inherent action moment caused by eccentricity affects its response and the brace displays approximate trilinear behavior under tension offering an increased post-yielding stiffness. Under compression, the brace bends more uniformly and the local bucking delays. The eccentrically applied axial load forces the brace ends to rotate, and therefore restraint-free connections are required. The seismic behavior of the proposed brace, called brace with intentional eccentricity (BIE) (Fig.1), is evaluated in this study where the basic concept and experimental results are introduced.

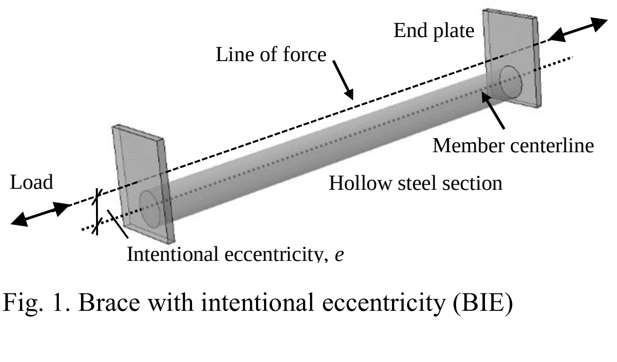

Fig. 1. Brace with intentional eccentricity (BIE)

Concept of BIE

Figure 2 describes a BIE supported by pins at both ends and subjected to an axial force along the longitudinal axis. The deformation of BIE under tension and compression with small and large applied loads is illustrated schematically. The eccentricity helps the brace to bend from small deformations. Under large tensile force two plastic hinges are formed at the brace ends and the eccentricity in the middle becomes almost zero. At that time, the steel brace is subjected to pure tension. Under compression, the brace buckles uniformly having an arc-shaped deformation, while a plastic hinge is created in the mid-length under large compressive loads. Because of this deformation mechanism, the BIE appears different response characteristics compared with the CBB as discussed at a later section.

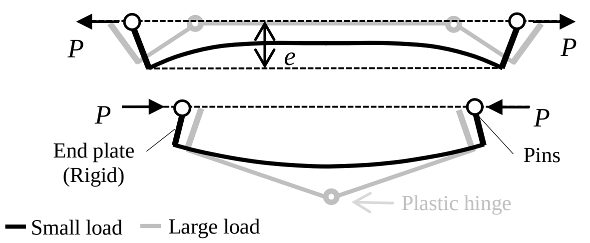

Fig. 2. BIE deformation under tension and compression

Experimental Study

A half-scaled BIE specimen is subjected to a cyclic lateral load protocol with drift angles ranging from 0.10% to 4.0%. A compact circular hollow steel section (HSS) with diameter (D) 114.3 mm, thickness (t) 3.5 mm, and D/t ratio 32.7 is adopted, made of conventional Japanese STK400 steel. The steel tube has a pin-to-pin length of 2131 mm and a slenderness ratio λ = 54.4. The influence of eccentricity is examined by adopting the value of 60 mm, which determines e/D ratio equal to 0.53. The experimental investigation is completed by testing a CBB (0 mm eccentricity) specimen of the same cross-section. By using the CBB's test results comparative remarks are made to evaluate various aspects of the proposed steel brace. The test specimens were designed following the recommendations of AISC (2010).

The deformed shape of BIE, as discussed in Figure 2, requires free rotation at the brace ends. At this first step of BIE development, an ideal choice is the use of mechanical pins which are adopted in this study to connect the BIE specimen into the four-pin loading frame as shown in Figure 3.

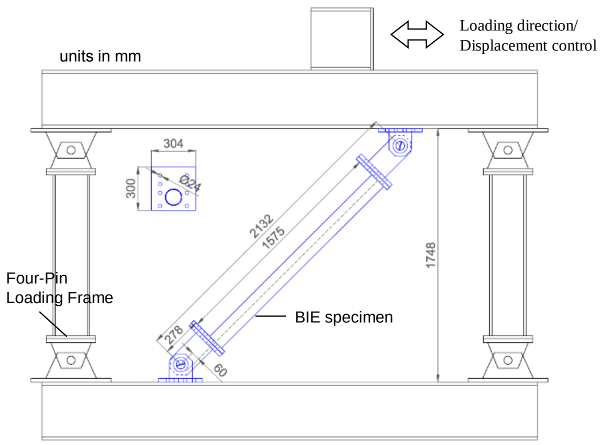

Fig. 3. BIE installed into frame with mechanical pins

Test Results

Hysteresis curves of the lateral load versus lateral drift angle are shown in Figure 4. The elastic stiffness of the BIE is 24.26kN/mm, and that of CBB is 65.54kN/mm. Yielding occurs during the first cycle of the 0.25% tensile drift, which corresponds to a yield strength of 89.9kN for BIE, and 222.6kN for CBB. The post-yielding stiffness for the specimens is 3.93 and 0.60kN/mm, respectively. The specimens reach almost identical maximum lateral force (~300kN). The results clearly indicate that desired values for the initial stiffness can be assigned without changing the maximum tensile strength of the brace.

The test results show that the BIE offers 63% smaller stiffness and begin to dissipate energy at an almost two times smaller force than CBB. Due to the earlier yielding and the gradually reduction of the eccentricity in the middle under tension, BIE provides large post-yielding stiffness near at 16.2% of the initial stiffness. An advanced tri-linear behavior (Fig. 4a) characterizes the tensile response. Under compression, the BIE moves smoothly into the post-buckling behavior, thus avoiding the severe drop of its compressive load. An almost elastoplastic behavior dominates the response up to 1.5% drift.

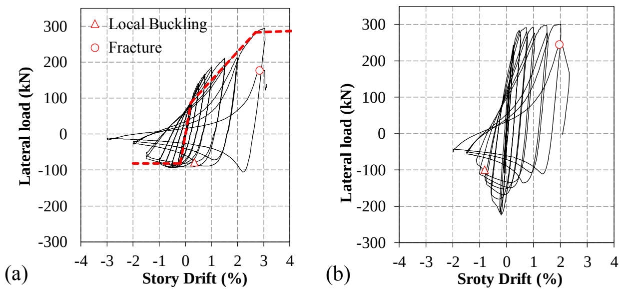

Fig. 4. Hysteresis curves of the: (a) BIE; and (b) CBB

Compared with the CBB, a notable delay of the occurrence of local buckling is observed in BIE. Owing to the more uniformly strain distribution in BIE, local buckling occurs during the 2.0% compression drift instead of 1.0% drift at which local buckling occurs in CBB. Finally, fracture follows the local buckling during the second cycle of the 2% tensile drift for CBB and during the second cycle of the 3% tensile drift for BIE.

Conclusions

The following conclusions are drawn:

(a) The BIE displays tri-linear tensile behavior and provides with large post-yielding stiffness and high ductility. Appreciable delay of local buckling and fracture in the middle is observed compared to CBB.

(b) In BIE concept, stiffness and strength can be assigned independently. The stiffness is a function of eccentricity, while the maximum tensile strength remains a function of the cross-section area.

References

AISC (2010). "Specifications for structural steel buildings." AISC/ANSI Standard 360-10; Chicago.