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# The effect of stiffeners on the strain patterns of the welded connection zone

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ABSTRACT

The behavior of the welded I-beams to box-columns connections is investigated both experimentally and numerically to identify the effects of stiffeners and column flange thickness on the energy dissipation characteristic of the connection. Numerical test specimens were developed and analyzed by the finite element method and the results were compared with full-scale experiments. The effects of various stiffeners such as, column stiffeners, side-stiffeners, and top-flange, and bottom-flange stiffeners were investigated. The contribution of each stiffener in controlling the location of the plastic deformation and the energy dissipation in the connection zone were examined.



## 1. Introduction

The use of I-beam to box-column connection (IB–BC) in the steel moment resisting frame structures (Fig. 1) is increasing because of the inherent strength properties, when subjected to multi-directional loading [1]. The parameters affecting the performance of the connection are: type and size of the stiffeners, column size, beam size, the column versus beam stiffness, the slenderness of the beam and column elements, and the welding material residual stresses. Any or combinations of these parameters can significantly alter the behavior and performance of the connection [2].

White and Fang [3] and Chen and Lin [4] studied the effects of both internal and external stiffeners on the behavior of IB–BC connections. They concluded that the connections with triangular stiffeners have the lowest rigidity while those with side-stiffeners present significantly higher moment-rotation capacity. Shanmugam et al. [2] studied 15 different IB–BC connections with various stiffeners and monitored the stress distribution at the web of the box-column and the flange of I-beam. Among the connections tested, the connections with side-stiffeners exhibited higher ductility. Ghobadi et al. [5] investigated the performance of the retrofitted connections with side-stiffeners. The results showed an improvement in the ductility of the connection while eliminating the crack propagation at the connection zone. Design guidelines were proposed based on full-scale experiments and finite element analyses. The results indicated that connections with sufficient stiffeners satisfy the basic seismic design criteria and provide sufficient strength, stiffness, and rotation capacity [6,7].

The benefits of using side-stiffeners were also studied by Shin et al. [8] and Kang et al. [9] on concrete filled tabular (CFT) columns connected to I-beams. Most tests conducted on the CFT connection with side-stiffeners showed stable hysteresis and adequate ductility.

The objective of this study is to build on previous studies and to investigate the stress and strain distribution and load transfer mechanism in the stiffeners of the IB–BC connections under cyclic loading by varying critical connection variables in order to optimize the connection details and control its cyclic performance. Thus, a nonlinear 3D finite element model was used to model and to simulate the performance of the connection. This study particularly focuses on: (1) the connections with and without column stiffeners; (2) variation of column flange thickness; (3) variation of top-flange stiffener; and (4) variation of side-stiffener.

## 2. Experimental testing

Following the AISC Seismic Provision [10] and the FEMA design capacity procedure [11], Ghobadi et al. [12] performed five full-scale tests on the improved and retrofitted IB–BC connection specimens to investigate the effect of the weld size on the connection. These connections were fabricated in pairs in order to verify the cyclic response of the specimens.

Among the five moment resisting connections tested by Ghobadi et al. [12], only one failed prematurely due to early fracture of

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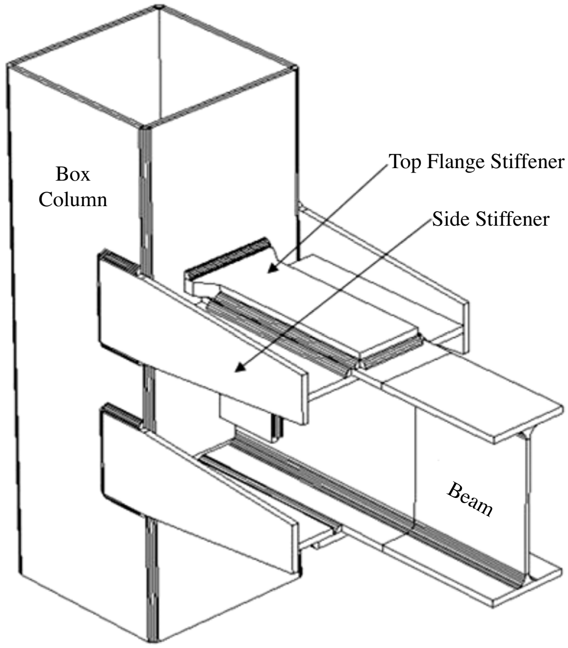


**Fig. 1.** A Typical I-beam to box-column connection.

the single fillet weld of the top flange. Two of the specimens failed due to lateral torsional buckling and fracture in the beam flange. The other two specimens sustained the cyclic loads for the story drift in excess of more than 5% before the failure occurred.

In this study, the experimental results of RC3 and RC4 introduced by Ghobadi et al. [12], and RC7 by Ghobadi et al. [5] were used for the finite element verification. Fig. 2 illustrates the details of the RC3. which is stiffened and retrofitted with the side-stiffeners. The RC4 connection is fabricated with 8 mm (5/16 in.) double fillet weld. The details of this connection are presented in Fig. 3.

The specimen RC7 was designed and tested by Ghobadi et al. [5] with a factor of 1.2 for the calculation of plastic moment capacity of the beam. The RC7 connection contained column stiffeners, top and bottom beam flange stiffeners, and side-stiffeners. The various stiffeners included in this connection provide the capability of removing the stiffeners or altering the stiffener thickness while maintaining the stability and effectiveness of the connection. Ghobadi et al. [5] also investigated the seismic performance and ductility of RC7 when the connection was retrofitted by a side-stiffener. Fig. 4 shows the details of the Connection RC7. The geometric details of the test specimens RC3, RC4, and RC7 are presented in Table 1.

A typical test setup presented by Ghobadi et al. [5] and Ghobadi et al. [12] is shown in Fig. 5 and a typical experimental specimen is presented in Fig. 6. A concentrated load was applied at the tip of the 2520 mm (99.2 in.) column using a 500 kN (112.5 kips) hydraulic jack with the maximum stroke of ±200 mm (±8 in.). Specimens were subjected to the cyclic displacement history in accordance with the FEMA [11] as shown in Fig. 7. The tip displacement corresponding to a story drift ratio of 0.01 rad was 26 mm (1.02 in.). The results of the coupon tensile test of all the components of the connections are shown in Table 2.

## 3. Finite element model analysis

The finite element method was used to model the connection assembly and to investigate the stress and strain distribution patterns in the connection stiffeners. The finite element software ABAQUS 6.8-1 [13] with the capability of performing both geo-

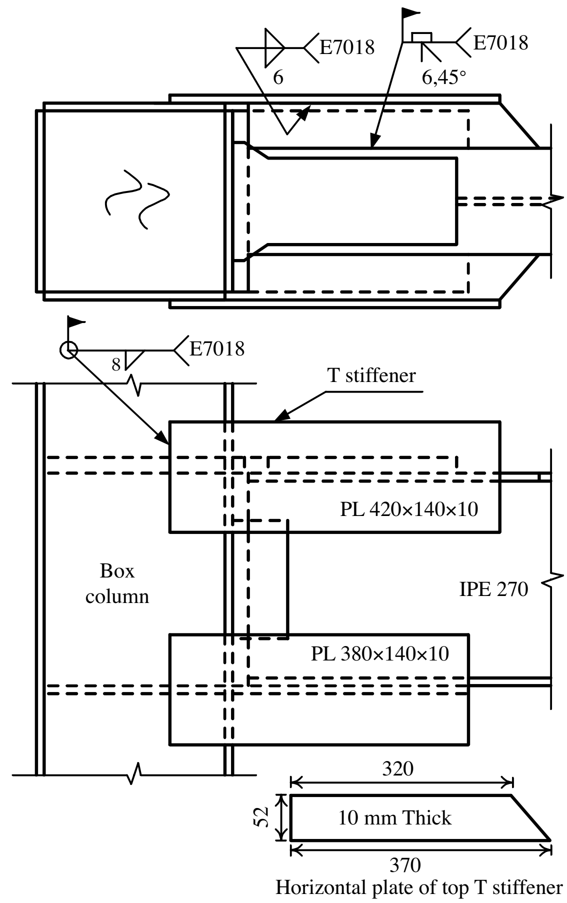


**Fig. 2.** Connection details of specimen RC3, Ghobadi et al. [12].

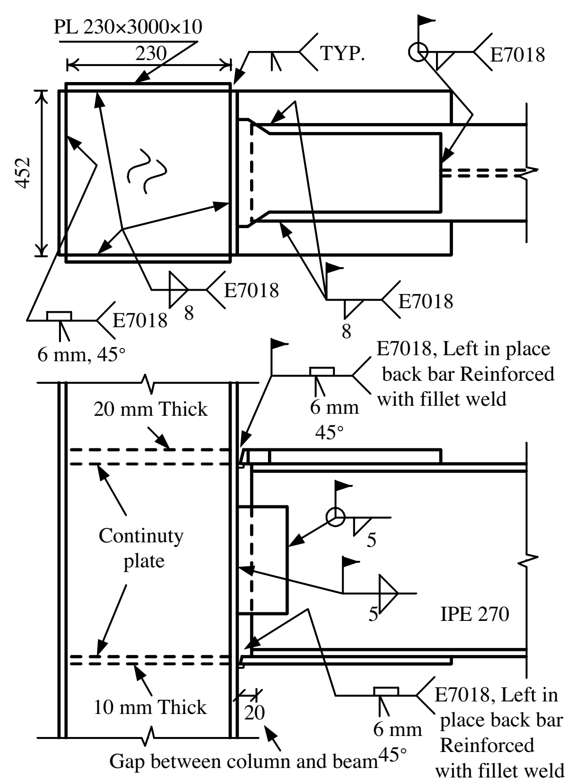


**Fig. 3.** Connection details of specimen RC4, Ghobadi et al. [12].