Journal of Constructional Steel Research 147 (2018) 236–246

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Experimental investigation of bolted link-to-column connections in eccentrically braced frames

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ARTICLE INFO

Article history:
Received 1 December 2017
Received in revised form 18 March 2018
Accepted 10 April 2018
Available online xxxx

Keywords:
Long link
Experimental test
Bolted connections
Cyclic loading
Eccentrically braced frame

ABSTRACT

Link-to-column connections in eccentrically braced frames should transfer the large shear and moment induced in a fully plastic and strain-hardened link. Previous studies have shown that most link-to-column connections fail before achieving the required plastic link-rotation capacity. In this paper, experimental tests were carried out on long link-to-column connections. The purpose of this investigation was to evaluate whether bolted angle connections can be suitable for connecting long links to columns. The T-stub connection, as well as the top and seat angle connection with a web angle, was selected. The test parameters included the strength of the connection which was changed by altering the connection details. The test results indicated that the proposed connections can successfully achieve the desired rotations without any strength loss. Based on the results, it is recommended that the bolted connections whose strength is about the same as that of the link are used to connect long links to columns.
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1. Introduction

Eccentrically braced frames (EBFs) have the same advantage as that of concentrically braced frames (CBFs), that is, desirable stiffness, as well as the high energy absorption and ductility of moment-resisting frames. In this system, the axial force of one brace is transferred to another brace or a column by shear and bending in a beam segment called the link beam. The link beam acts as a fuse and dissipates seismic energy by plastic deformations and prevents other members from entering the plastic zone. The critical factor for controlling the link behavior is its length. Links are classified by their length into three groups. If the link length is shorter than the ratio of 1.6 M_p/V_p (in which M_p is the plastic moment capacity of the link section and V_p is the plastic shear capacity), the link is a short one. Shear yielding will dominate the inelastic behavior. If the link length is greater than 2.6 M_p/V_p, the link is long and flexural yielding governs it. A flexure-yielding link develops very large moment and less substantial shear. For link lengths between these two limits, a combination of shear and flexural yielding will occur.

Links can also be divided into two groups according to their location in a frame, as shown in Fig. 1. In the first form, the link element is placed between the diagonal brace and column (Fig. 1[a]), while, in the second form, the link is placed between the two braces (Fig. 1[b]). Due to the fracture of the link beam-to-column connection (Fig. 1[c]), EBFs with the link beam attached to the column have a more elastic rotation capacity than the other one [1,2].

If the links are long, they can have large plastic rotations, and the link-to-column connections should transfer the large shear and moment developed in a fully plastic and strain-hardened link. The integrity of the link-to-column connection is necessary for ductile performance and the frame's safety. In previous research on long link-to-column connections, brittle failure happened in welded connections before they reached the plastic rotation capacity. And since AISC/ANSI 341-16 [4] does not provide any proved connection for long link-to-column connections (AISC/ANSI 341-16), this research was done to study them.

On the other hand, the behavior of EBFs depends directly on the link beam behavior. The latter, in turn, depends on the behavior of the link-to-column connection's performance. Consequently, the strength and stiffness of link-to-column connections significantly affect the behavior of an EBF. Therefore, an experimental test program was conducted to investigate the behavior of bolted connections for connecting long links to columns. For this purpose, the T-stub connection was considered as a high-strength connection and the top and seat angle with a web angle connection was used as a connection with a lower strength and stiffness. In total, three specimens were tested and evaluated.

2. Literature review

EBFs were invented in the 1980s. Since then, many studies have been conducted to investigate their behavior. In this section, investigations into

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https://doi.org/10.1016/j.jcsr.2018.04.009
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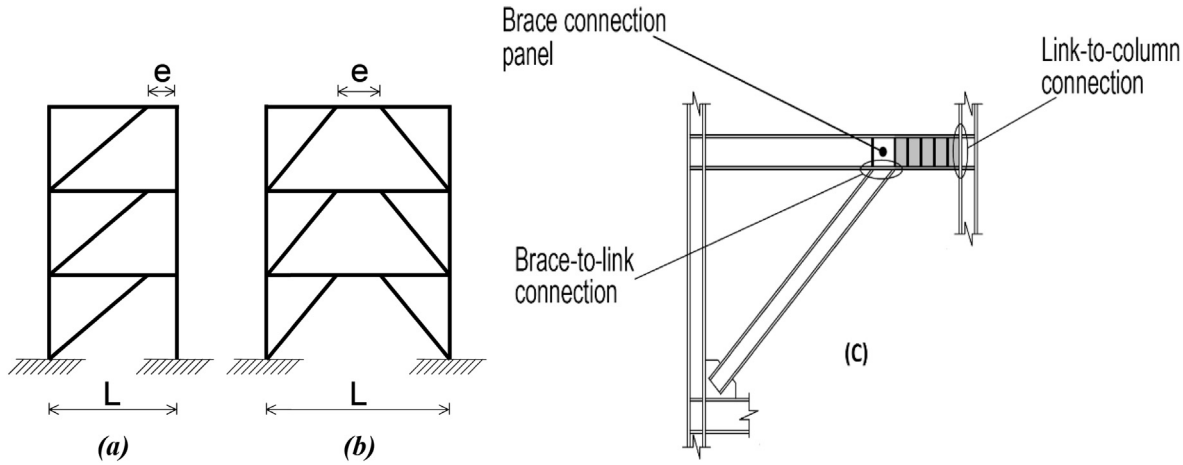

Fig. 1. Link beam location in frame: a) link connected to column, b) k-type EBF, in which the link beam is located between two braces, c) different connections in an EBF when the link is connected to the column [3].

link-to-column connections in EBFs will be briefly reviewed. The studies conducted on T-stubs, as well as on top and seat bolted angle connections, will also be reviewed.

2.1. Link-to-column connection in EBFs

Some experimental work has been done to investigate the performance of link-to-column connections. Malley and Popov [5] studied the behavior of welded flange and bolted web connections. It was observed that the large cyclic shear force developed in the links could cause repetitive bolt slippage, which, in turn, caused sudden failure of the connection by a fracture near the link flange groove weld. Engelhard and Popov experimentally studied the behavior of long links attached to columns. The dominating failure mode was the fracture of the flange link at the connection location. The fractures occurred at the rotations that were judged to be inadequate in severe earthquakes [1]. Ghobarah et al. conducted experimental tests on bolted end-plate beam-to-column connections. They concluded that properly designed and detailed extended end-plate connections can provide excellent ductility as moment-resisting components in the seismic design of frames [6].

Okazaki et al. investigated the cyclic behavior of welded link-to-column connections by testing 12 large-scale specimens. Four

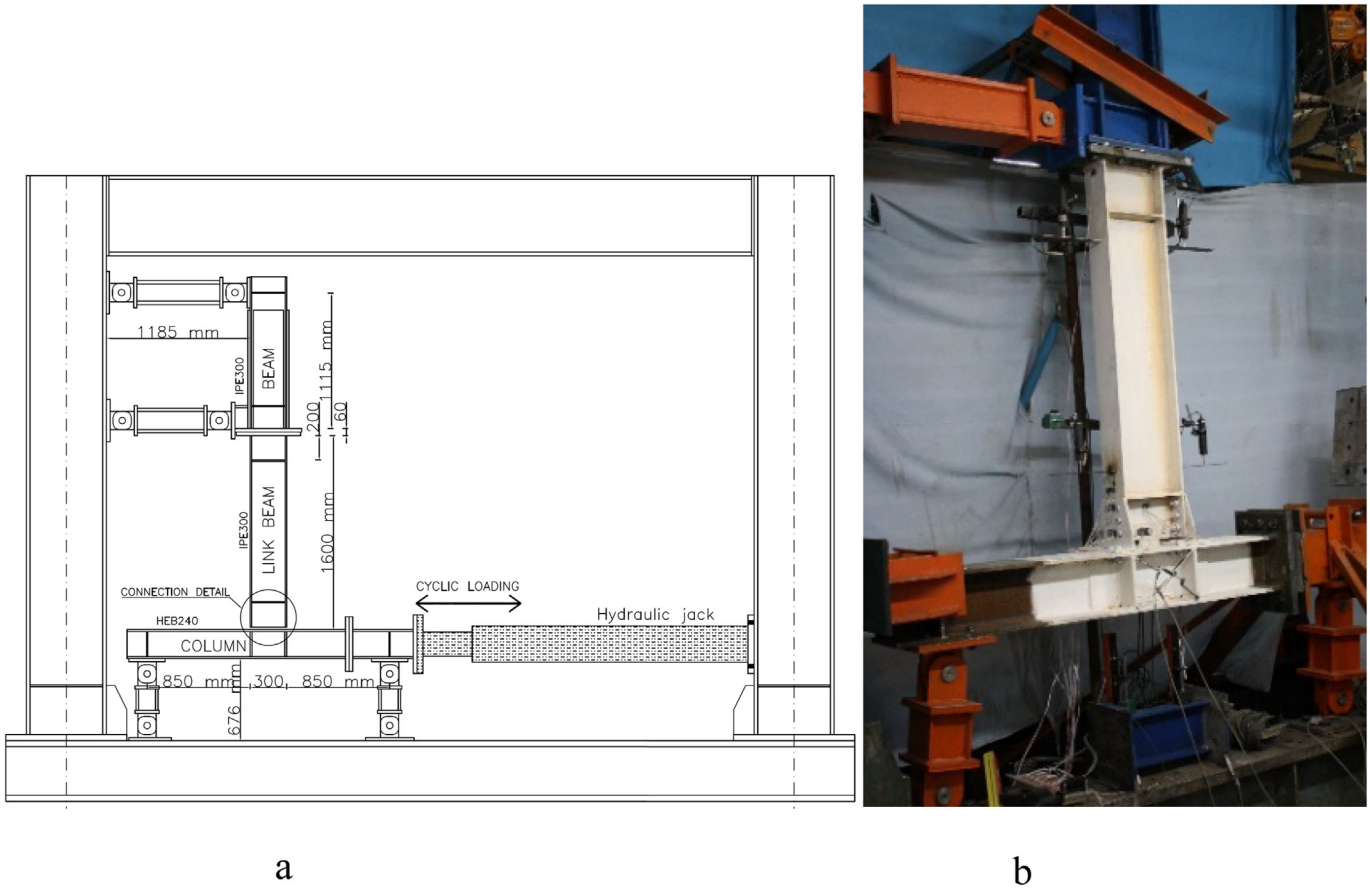

Fig. 2. a) Details of the test setup, b) view of the test setup.

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