Journal of Constructional Steel Research 105 (2015) 28–38

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Seismic performance evaluation of weak axis column-tree moment connections with reduced beam section

Keunyeong Oh, Kangmin Lee *, Liuyi Chen, Sung-Bin Hong, Yang Yang

Department of Architectural Engineering, Chungnam National University, Daejeon 305-764, Republic of Korea

ARTICLE INFO

Article history:
Received 16 April 2014
Accepted 2 October 2014
Available online 19 November 2014

Keywords:
Moment resisting frame
Weak axis steel moment connection
Reduced beam section (RBS)
Seismic evaluation
Cyclic testing

ABSTRACT

The purpose of this study was to evaluate the seismic behavior of weak axis column-tree connections used in steel moment resisting frames. Column-tree connections are composed of a shop-welded and field-bolted steel structure. Column-tree connections are well known to provide high quality and economy with shop-welding and field-bolting. In addition, column-tree connections are easier to assemble than field-welded connections. For these reason, column-tree connections are frequently used in steel moment resisting frames in Korea and Japan. Unlike the US and Europe, where strong axis connections are used, weak axis column-tree connections with a beam connection to the column web are often used for convenience in Korea. In this study, a basic weak axis column-tree connection that has been used in Korea was tested to evaluate its seismic performance. Also, two weak axis column-tree connections with a reduced beam section and a tapered beam section at the stub beam were fabricated and tested. The two specimens with the reduced beam section and tapered beam section successfully developed ductile behavior without brittle fracture until 5% story drift ratio. Therefore, the two specimens met the qualification criteria demanded by the AISC Seismic Provisions for use in SMFs. Although a basic weak axis column-tree connection specimen successfully reached 5% story drift ratio, brittle fracturing was detected at the backing bars near the beam-to-column connection. When compared with the energy dissipation capacity at the stub beam for each specimen, the specimen with the reduced beam section showed stable and ductile behavior.

1. Introduction

The column-tree connection is one type of beam-to-column connection frequently used in a moment resisting frame in Korea and Japan. In column-tree connections with moment resisting frames, short stub beams are welded in the shop, and then the middle portion of the beams are bolted to the column trees in the field. Thus, the column-tree connection is a field-bolted–shop-welded structural system [1,2]. Unlike in the United State and Europe, weak axis column-tree connections with a stub beam connection to the column web have frequently been fabricated for convenience in Korea. However, there have been no studies for developing ductility of weak axis column-tree connection [3].

An important seismic design key is the location of plastic hinges, referred to as a 'fuse' element. The plastic hinge can be located at the column, beam, or panel zone in a moment resisting frame. If each specimen follows the strong beam–weak column concept, risk factors are introduced in the overall structural system because a soft-story develops at the column. Also, steel moment resisting frames that include plastic hinges in the beam can be more stable than moment resisting frames that have column plastic hinges. In the strong column–weak beam moment resisting frames, the moment capacity of the beams in the joint was less than the moment capacity of the columns. Under combinations of gravity and lateral loads, a plastic hinge was expected to form in the beam. Therefore, in previous studies, the moment resisting frame system was designed for ductility by locating the fuse element at the beam, and consequently the reduced beam section (RBS) proposed by the Federal Emergency Management Agency (FEMA) has been known for exhibiting satisfactory levels of ductility [4–7].

Of the variety of prequalified beam-to-column connections proposed by FEMA, the reduced beam section (RBS) connection was cut off from the beam flange at a distance away from the column face, thus reducing the moment passed on to the column face. The beam-to-column connection exhibited ductile behavior without brittle fracture due to the formation of a plastic hinge in the beam section. FEMA suggested the detailed reduced beam section form shown in Fig. 1, and RBS dimensions a, b, and c be defined as

$$0.5b_{bf} \le a \le 0.75b_{bf}, \quad (1)$$

$$0.65d \le b \le 0.85d, \quad (2)$$

$$0.1b_{bf} \le c \le 0.25b_{bf}. \quad (3)$$

* Corresponding author. Tel.: +82 42 821 5625; fax: +82 42 823 9467.
E-mail address: leekm@cnu.ac.kr (K. Lee).

http://dx.doi.org/10.1016/j.jcsr.2014.10.005
0143-974X/

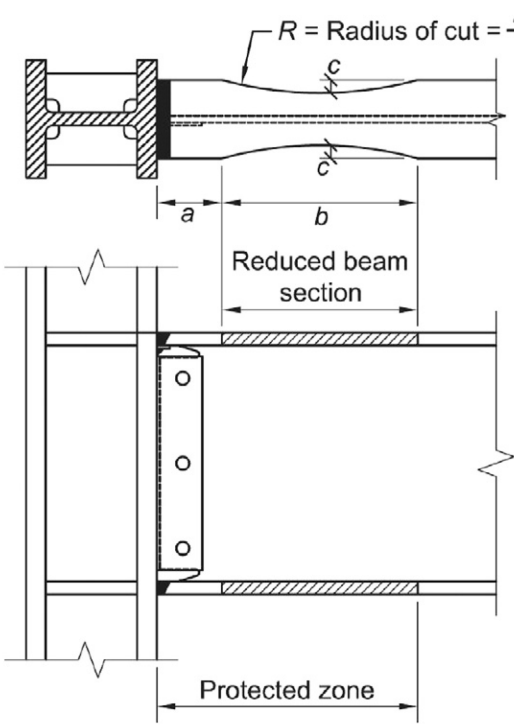

Fig. 1. Reduced beam section connection.

Also, Chen et al. proposed that if the loss cross-section is of the reduced beam section (RBS) type, the plastic deformations concentrate on a limited area; thus, only a limited energy dissipation capacity is expected, and its deformation characteristics are classified as brittle [8]. However, if a plastic hinge was exhibited over the whole loss cross-section, the moment resisting frame would have a greater capacity for plastic deformation and dissipate more energy than the reduced beam section (RBS) type. This is achieved by tapering the beam flange near the connection according to the moment gradient so as to produce an enlarged area of plastic hinge. On the basis of this concept, a new type of beam-to-column connection can create a finite area of plastic zone by means of the concept of constant stress.

Therefore the main purpose of this study is to evaluate the seismic performance of weak axis column-tree connection details with reduced beam section (RBS) proposed by FEMA and tapered beam section proposed by Chen et al. The seismic performance of weak axis column-tree connection details commonly used in Korea was also investigated for comparison purpose. For this purpose, the cyclic testing of three full-scale weak axis column-tree connection specimens was conducted to verify the validity of comparing the new concepts with a common Korean weak axis column-tree connection details.

2. Test program

Three full-scale test specimens of weak axis column-tree connections, designed and detailed according to the AISC Seismic Provisions (AISC 2010) [9], were fabricated and tested. Quasi-static cyclic loading was applied to the specimens to evaluate the hysteretic behavior of weak axis column-tree connections.

2.1. Test specimens

The basic specimen was fabricated according to the construction practice in Korea, in which the backing bars and weld taps are not eliminated. Although these factors cause brittle fracture at the beam-to-

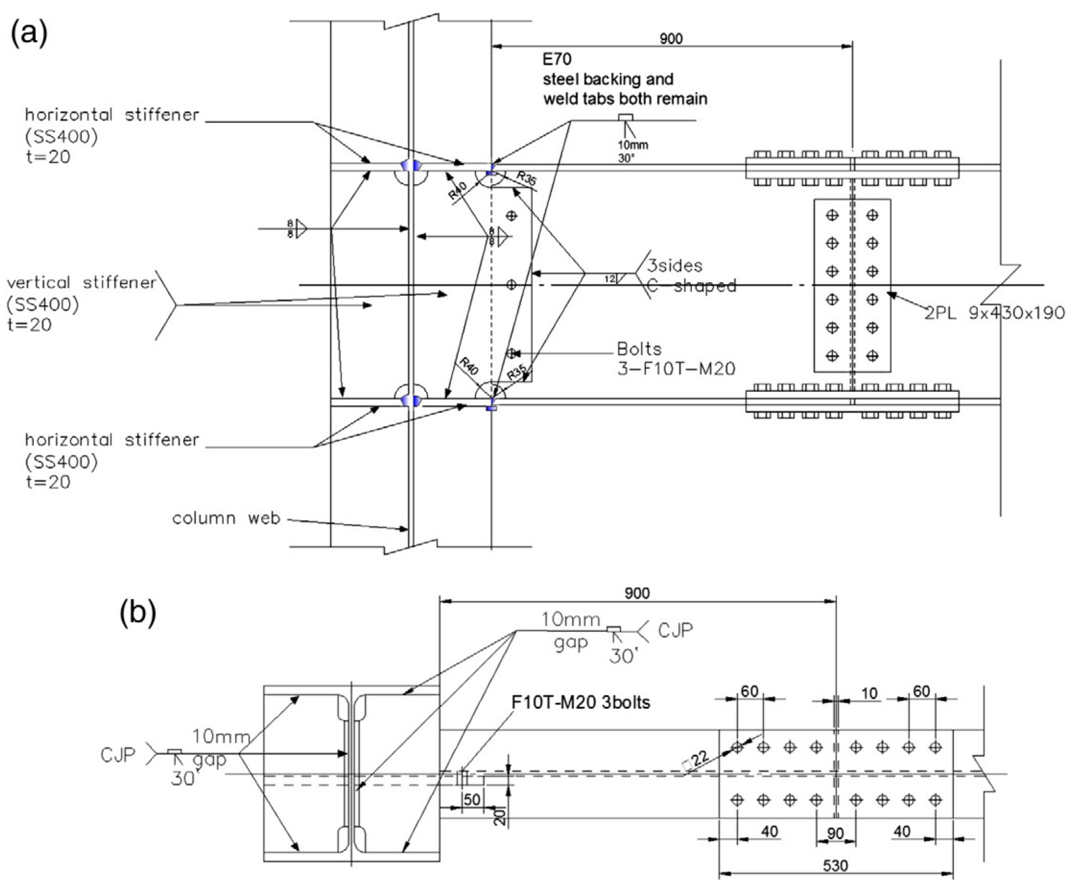

Fig. 2. Details of the ‘CT-BASE’ specimen: (a) side view; (b) top view.