Journal of Constructional Steel Research 67 (2011) 1821–1834

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Cyclic behavior of partially-restrained steel frame with RC infill walls

Guohua Sun [a,b,*], Ruoquan He [a,b], Gu Qiang [a], Youzhen Fang [a]

[a] College of Architecture and Civil Engineering, Beijing University of Technology, Beijing 100124, China
[b] Department of Civil Engineering, University of Science & Technology of Suzhou, Binhe Road1701, Suzhou 215011, China

ARTICLE INFO

Article history:
Received 16 June 2010
Accepted 1 June 2011
Available online 13 July 2011

Keywords:
Partially-restrained connection
Steel frame
Concealed vertical slits
Infill wall
Cyclic test

ABSTRACT

In order to investigate the behavior of partially-restrained steel frame with RC infill wall (PSRCW), two specimens with one-third scale, one-bay, and two-story were performed under reversed cyclic lateral load, where one specimen was with concealed vertical slits in the infill walls and another specimen with solid infill walls. Test results showed that both specimens obtained enough lateral stiffness for controlling drift and yielded enough strength appropriate for resisting lateral load. PSRCW with solid infill walls exhibited moderate ductility capacity and energy dissipation due to the degradation of post-peak strength. PSRCW with concealed vertical slits exhibited much larger ductility, deformability, and energy dissipation capacity than the other one. Once concealed vertical slits were crushed, infill walls behaved as a series of flexural columns provided fairly ductile response and stable cyclic performance. PSRCW with concealed vertical slits can improve post-peak strength degradation considerably. In addition, damaged PSRCW structure subjected to earthquake is easy to be repaired, through knocking off the heavy crushed infill walls and recasting concrete infill walls. This is another advantage of this composite structure.

1. Introduction

In the steel-concrete composite structural system, partially-restrained steel frame with RC infill wall (PSRCW) became a primary lateral-load resisting systems in multistory building [1]. PSRCW consists of bare steel moment-resisting frame, RC infill wall, partially-restrained connections, and shear connectors. The composite action between steel frame and infill walls is achieved by shear connectors. In the PSRCW system, the infill wall serves as the main lateral-resisting element providing high lateral stiffness and strength, while the surrounding steel frame resists the gravity and most of the overturning moment due to the seismic loading. In addition, the employment of partially-restrained connections can provide sufficient rotation ability. However, the degradation of post-peak strength is serious disadvantage of PSRCW with solid infill wall. Concealed vertical slits that are placed in solid infill walls are used to resolve this issue. Before concealed vertical slits are crushed, infill walls behave as a general shear panel, which provides enough stiffness for controlling drift. After concealed vertical slits are crushed, infill walls behave as a series of flexural columns, which can supply a fairly ductile response.

By far, the behavior of infilled steel frames under lateral loads has been investigated by a number of researchers. Liauw and Kwan [2,3] divided infilled steel frames into two categories: (1) those with connectors along the interfaces between the frames and the infill walls were called integral infilled frames; and (2) those without were called non-integral infilled frames. Holmes [4] and Smith [5] conducted experimental and analytical investigations on the lateral stiffness, strength, and failure mode of steel frames with RC infill walls. Mallick and Severn [6] performed half-cyclic dynamic load tests on small scale, two-story infilled steel frames. Test results showed that the application of the shear connectors in the corner of infill walls prevented the rotation of the infilled walls, and increased the stiffness of the structure. But, it did not increase the lateral strength. Furthermore, integral infilled frames exhibited shear failure of infill walls, and non-integral infilled frames exhibited diagonal compression failure of RC infill walls. Liauw and Lee [7], Liauw [8], and Liauw and Kwan [9] conducted a series of static, dynamic, and cyclic tests on both integral and non-integral steel frames with RC infill walls. Test results showed that the strength, stiffness, and energy dissipation of infilled frames increased through placing shear connectors along the entire interface between steel frame and infill walls. Wood [10] and Liauw and Kwan [2,3] developed plastic analysis methods to predict the ultimate strength of infilled frames based on experimental investigations. In Japan, Makino [11,12] conducted a series of tests on one-third scale full-restrained steel frames with RC infill walls. The orientation and section of steel column were studied. A few headed studs were employed with the objective of preventing out-of-plane failure of infill walls. Test results showed that the infilled frames with columns

* Corresponding author at: Department of Civil Engineering, University of Science & Technology of Suzhou, Binhe Road1701, Suzhou 215011, China.
Tel./fax: +86 512 68093334.
E-mail address: Sungh-529@163.com (G. Sun).

0143-974X/$ – see front matter
doi:10.1016/j.jcsr.2011.06.002

bent about their strong axis exhibited favorite deformation capacity. The deterioration of lateral strength of infilled frames with thin walled wide flange section was faster than that of the strength of infilled frames with stocky rolled wide flange section.

In recent years, Tong et al. [1] carried out experimental investigation on a one-bay, two-story PSRCW structure at one-third scale. Test results showed that infill walls tended to develop a pattern of closely-spaced diagonal cracks, prior to any significant yield in the steel frame. This system possessed three main load transferred paths, including shear stud–infill interaction, steel frame–infill strut interaction, and the steel frame. The reinforcing cages around the headed studs avoided the brittle failure modes of the concrete. However, low-cycle fatigue of headed studs became the main failure mode. He also pointed out how to improve the post-peak strength degradation was another important issue. Three one-third scale, one-bay, and two-story specimens with different types of connections, including rigid connection, PR connection (top and seat angles with double-web angles), and flush end plate connection (weak axis of column), were conducted under reversed cyclic lateral load [13–15]. Test results revealed that the specimen with rigid connections without enough rotating capacity led to shear slip failure mode along the top interface of base reinforcing cage, the specimen with semi-rigid connections exhibited shear slip failure along the top interface of the second story due to low-cycle fatigue fracture of shear connectors, and the specimen with flush end plate connections produced diagonal crush of infill walls.

Most of these experimental studies that have been conducted with either small-scaled specimens or frame sections might not represent real structures. Furthermore, due to the complicated interaction between steel frame and infill walls, several aspects require further investigation, that is, inherent mechanical performance, load transferring mechanism, and post-peak behavior. This study aims at investigating the influence of infill wall on the performance of PSRCW structure under cyclic lateral load. The failure mode, deformability, ductility, energy dissipation capacity, initial stiffness and strength degradation of two specimens were studied and compared.

2. Experimental program

2.1. Test specimens

Two specimens were designed and tested. Both specimens were one-third scale, one-bay, and two-story PSRCW structure with PR steel frame as the boundary element and RC shear walls embedded inside the frame. Test specimens were designated as specimen no. 1 that consisted of infill walls with concealed vertical slits and specimen no. 2 that consisted of infill walls with solid RC walls, respectively. Details of test specimens are shown in Figs. 1 and 2. Steel frames with identical dimension were fabricated, that is, 1900 mm (length) × 2125 mm (height), measured center-to-center of the steel members. The typical infill wall height was 950 mm, the width was 1750 mm, and the thickness was 80 mm.

The columns consisted of H150 × 150 × 6 × 8 welded wide flange steel sections and the beams consisted of H150 × 100 × 6 × 8 welded narrow flange steel sections, which met design concept of "strong column-weak beam". Partially-restrained connection consisted of a top, a seat angle and double web angles. The section of top and seat angles was L125 × 80 × 8, and the section of web angles was L63 × 6. The total plastic moment of the partially-restrained connection considering the effect of axial force from the diagonal compression strut in the infill wall was predicted to be 15.37 kN-m, approximately 51% of the plastic moment of the steel beam. The column web stiffeners were employed to reduce the bucking of the column flange and deformation of column panel zone.

The infill walls were assumed to transfer 100% of the seismic story shear and 20% of the corresponding overturning moment. The dimension of slit walls of specimen no. 1 was 220 mm (width) × 660 mm (height) × 80 mm (thickness), and shear span aspect ratio was 3. The height of concealed vertical slits was 660 mm, the width was 20 mm, and the thickness was 30 mm. Details of concealed vertical slits are shown in Fig. 3. Four 8 mm smooth bars were used as the longitudinal reinforcement in each boundary element (longitudinal reinforcement ratio was equal to 2.09%). The hoops were fabricated using 4 mm

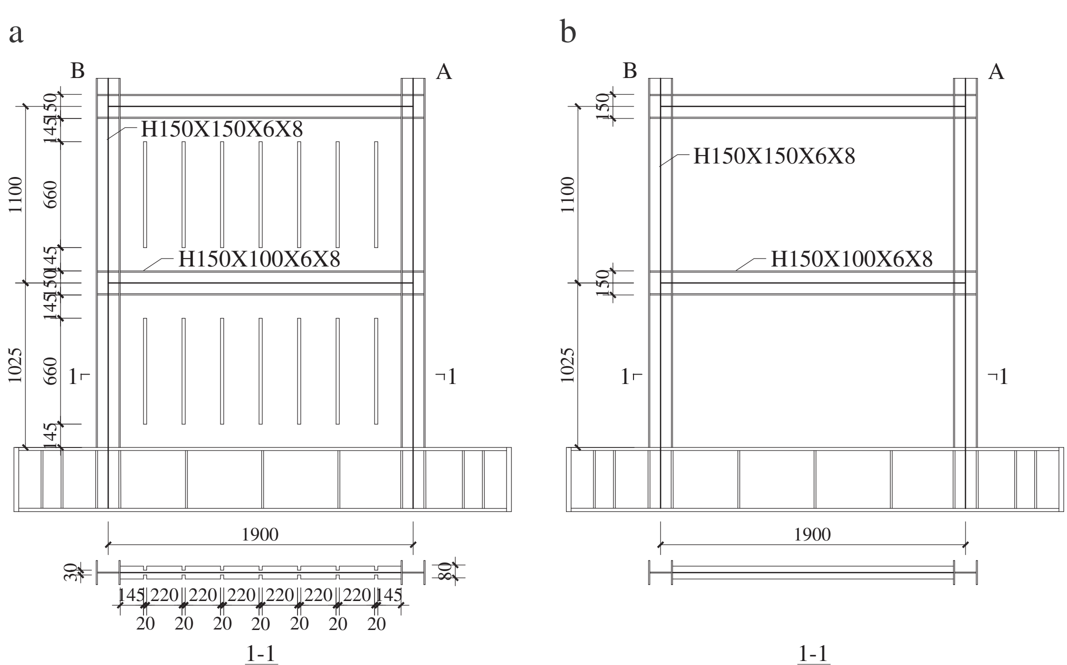

Fig. 1. Dimensions of specimen: (a) specimen no. 1; (b) specimen no. 2 (dimension in mm).