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Hysteresis behavior of concrete filled square steel tube column-to-beam partially restrained composite connections

Su-Hee Park [a], Sung-Mo Choi [a,*], Yo-Suk Kim [a], Young-Wook Park [b], Jin-Ho Kim [c]

[a] Department of Architectural Engineering, University of Seoul, Seoul, Republic of Korea
[b] Hanmi Parsons, Seoul, Republic of Korea
[c] Research Institute of Industrial Science & Technology, Kyungkido, Republic of Korea

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ABSTRACT

This study presents the development of an improved detail for a Concrete Filled Steel Tube (CFT) square column-to-beam partially restrained composite connection (PR-CC) and the evaluation of its hysteresis behavior under cyclic loading. The detail of the connection was designed to prevent brittle failure at the bottom of the connection due to the composite effect and to simplify its fabrication process. The suggested connection is a welded type of bottom beam flange connection and the existing PR-CC is a bolted type with a seat-angle. To evaluate their hysteresis behavior, specimens were fabricated at full scale and tested under cyclic loading. Results revealed that the suggested type fractured at the welding zone without a drop in capacity due to the anchors inside the steel tube, and reached over 0.04 radian of the plastic rotational angle. The stiffness of the suggested type was about 10% greater than the existing type because the bolted connection allowed more deformation than the welded connection. Both connections were classified as Semi-rigid connections by stiffness analysis according to Eurocode3. The suggested type can be classified as a partially restrained connection overall under cyclic loading because it reached more than 0.03 rad of an inelastic rotation angle 80% capacity of the maximum moment capacity. This type was evaluated to exhibit equal or more ductility than the existing type. As a result, it is concluded that the welded bottom beam flange connection type can be used in practice for the CFT column–beam connection instead of the existing bolt connection using a seat-angle.

1. Introduction

Today, because high-rise buildings are becoming taller and larger, structural and economic aspects should be taken into consideration in their design. Structural aspects such as developing high-strength materials and selecting an appropriate structural system are particularly important. As structural members with excellent strength and stiffness, CFT columns have been increasingly used in the construction of high-rise buildings. The purpose of this study is to develop connection details for concrete filled square steel tube column-to-beam partially restrained composite connections. High-rise buildings with an inner core structural system to reduce horizontal strain do not need a full restraint composite connection. Therefore, many studies have been carried out recently on partially restrained composite connections consisting of reinforcing steel at slabs and steel beams. Fig. 1 shows a column-to-beam partially strained composite connection suggested by Leon et al. [1–3]. In this connection, upper slab reinforcing bars are located around the column and the beam is bolted to the column using a web-angle and a seat-angle. The reinforcing bars deliver most of the moment and secure a certain degree of stiffness and ductility. As shown in the figure, because the column is fabricated of wide flange structural steel, it can be bolted easily. However, through-type bolts were used in this study because CFT columns were used instead of W-shaped columns. Through-type bolts create a complication when installing diaphragms and casting concrete in the columns. Consequently, this study suggests a partially restrained composite connection in order to improve workability. This new type of connection detail was designed to resist the moment load at beam ends by means of slab reinforcing bars and lower beam flange welding. In the design of this new connection consideration is made of the excellent welding skills available in Korea and consequently the wide use of field welding.

The basic concept of a partial strength partially restrained composite connection was first introduced by Narnard [4] & Johnson, and Hope-Gill [5]. Since 1987, studies on the partially restrained composite connection have been conducted systematically by Zandonini [6], Leon & Zandonini [1], Leon [2] and Plumier & Doneaux [7]. A series of studies have proved that the partially restrained composite connection provides excellent seismic performance and is appropriate to a system resisting lateral force.

* Corresponding author. Tel.: +82 2 2210 2396; fax: +82 2 2248 0382.
E-mail address: smc@uos.ac.kr (S.-M. Choi).

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However, rupture finally occurred at the connection due to the large asymmetrical tensile force at the lower part of the partially restrained composite connection caused by the composite effect of the concrete slab and steel beam upon positive moment. In other words, it was inferred that the ultimate behavior of a partially restrained composite connection and CFT connection upon positive moment would be determined by the details of the upper part and diaphragm, respectively. The authors of this study have developed a new type of diaphragm and connection details inside steel tube columns. A study has also been conducted on the CFT column-to-beam connection using the new connection type in order to promote the employment of the CFT structure in the field [8–12]. The purpose of this study is to develop new details for the partially restrained composite connection to be employed in CFT structures while considering workability. In this study, three full-sized partially restrained composite connection specimens were fabricated and tests were conducted with the variables of lower connection details in accordance with the ANSI/AISC SSPEC-2002 cyclic loading program [13] in order to evaluate the stiffness, load capacity, ductility and hysteresis behavior of the suggested connection details.

2. Research background and test plan

2.1. Research background

The case study for this research is a high-rise building with 37 stories and 5 underground stories, constructed by the S company in Korea. The typical plan of the building is shown in Fig. 2. The building has 9 bays of 8.4 m span in the long direction and 2 bays of 14.5 m span and a RC core in the short direction. The RC core and exterior CFT frame were used as the lateral load resisting system. Most of the lateral load is resisted by the RC core and only about 10% of the total lateral load is resisted by the exterior CFT frame. The CFT frame connection must resist more than 60% of the beam moment according to the frame analysis of the lateral load. Therefore, a practical PR-CC connection detail must be developed.

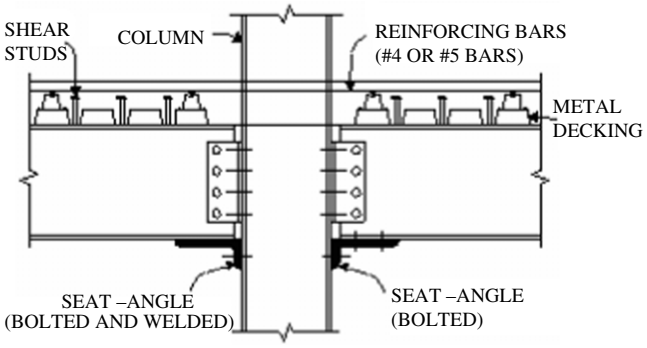
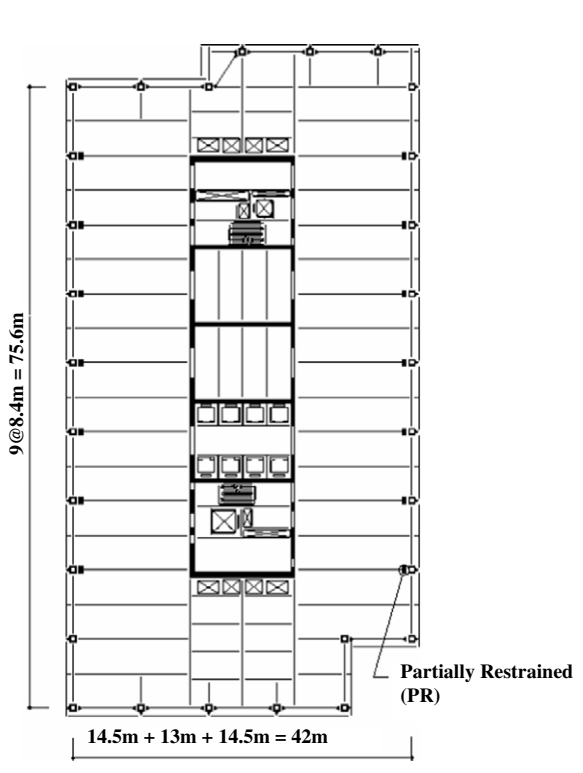


Fig. 1. Existing PR-CC detail.

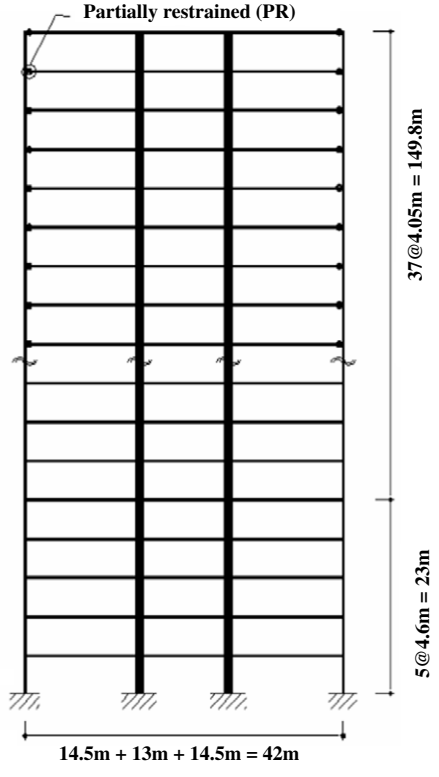
According to research carried out by Leon [1–3], the rotational stiffness and moment capacity of a PR-CC can be obtained sufficiently by the reinforcing bars of the slab and the seat-angle, and the behavior of the PR-CC under the cyclic loading is governed by the performance of the seat-angle. Therefore, the concept of the PR-CC can be used in the exterior CFT frame and the detail of the PR-CC must be modified to apply the CFT column instead of the W-shape column. In other words, a new bottom detail for the PR-CC was developed as an alternative to the existing PR-CC, which carries the possibility of fracture due to the large tension caused by the composite effect of the slab and beam under positive moment.

2.2. Specimen design

Three specimens were designed according to the AISC-LRFD PR-CC's Design Guide 8 [14]. The sections of members in the specimens were determined with the condition that the beam spacing



(a) Plan.



(b) Elevation.

Fig. 2. Typical plan of 37 story building.