# Seismic Behavior of Composite Concrete Filled Steel Tube Column-Wide Flange Beam Moment Connections

J. M. Ricles, M.ASCE[1]; S. W. Peng[2]; and L. W. Lu, M.ASCE[3]

**Abstract:** The results of an experimental research study involving the testing of ten full-scale moment resisting connections under simulated seismic loading conditions are presented. Each test specimen modeled the interior joint of a moment resisting frame consisting of square concrete filled steel tube columns and wide flange steel girders, where energy dissipation was designed to occur either primarily in the beams or in the connection panel zone during a severe earthquake. The results of the study indicate that moment resisting connection details can be economically designed that enable more than 0.045 rad of inelastic story drift to develop under cyclic loading. These details include split-tee connections without a shear tab, weak panel zone connections, and extended tee connections. Panel zone shear yielding and local buckling are shown to be a ductile mode of response, with minimal strength deterioration occurring in the connection. The use of interior diaphragms in the column is shown to locally stiffen the joint, but also lead to strain concentrations and fracture of the beam flanges at their weld access holes. Furthermore, strain concentrations develop at connection details that lack a gradual transition in geometry and result in a reduction in connection ductility.

**DOI:** 10.1061/(ASCE)0733-9445(2004)130:2(223)

**CE Database subject headings:** Composite structures; Tubes; Beams; Connections; Seismic design; Concrete.

## Introduction

Steel–concrete composite materials have been widely used in framing systems for high-rise buildings over the past several decades. A common form of composite construction consists of a steel frame with composite columns. This system has the attributes of a lightweight, ductile steel frame with the added stiffness of steel–concrete composite columns to control story drift. One particular type of composite column is a concrete filled tube (CFT). This type of composite column has the benefit of the tube serving as a convenient formwork for placing the concrete and providing confinement for the cured concrete. By confining the concrete in a CFT, an increase in the concrete's compressive strength may be realized in addition to preventing the concrete from spalling while subjected to overload. Furthermore, the concrete inside the tube acts to restrain local buckling from occurring in the wall of the steel tube.

Extensive research has been done in Japan to study the behavior of moment connections between a CFT column and wide flange (WF) beams under seismic loading conditions. Seismic resistant design recommendations appear in the Architectural Institute of Japan (AIJ) provisions (1987). Research by Kato (1982), Matsui (1985), and Yokoyama et al. (1991) on welded beam-to-column CFT connections having interior and exterior diaphragms, respectively, have shown that these elements develop a complex stress state and are susceptible to fracture or local buckling. Cyclic tests on CFT moment connections were conducted by Kanatani et al. (1987), as well as Morino et al. (1996), in which shear yielding of the steel tube within the connection's panel zone occurred. Their test results demonstrated that a ductile hysteretic behavior in the specimens can be achieved, as long as shear buckling and fracture of the steel tube within the panel zone is inhibited.

Some of the above studies lead to the recommendations in the AIJ provisions for the panel zone seismic strength $V_t$ of a welded beam-to-column CFT with interior diaphragms:

$$V_t = 2.5A_c F_c \frac{b}{d} + 1.2A_{\mathrm{web}} \frac{\sigma_y}{\sqrt{3}} \quad (1)$$

The first term in Eq. (1) is associated with the concrete contribution and the second is the steel tube contribution to the panel zone shear strength. In Eq. (1) $A_c$, $A_{\mathrm{web}}$, $F_c$, $\sigma_y$, $b$, and $d$=cross-sectional area of the concrete, the area of the web of the steel tube, the concrete shear resistance (in kgf/cm$^2$), the yield stress of the steel tube, depth of the steel tube, and depth of the beam, respectively. The concrete resistance $F_c$ is equal to

$$F_c = \min(0.12f'_c; 18 + 0.036f'_c) \quad (2)$$

where $f'_c$=concrete cylinder strength (in kgf/cm$^2$).

As an alternative to exterior and interior diaphragm connection details in a WF beam-to-CFT column connection, the studies by Kanatani et al. (1987) included tests on specimens with bolted connection details. The tests lead to the following design recommendation for panel zone shear capacity for split-tee connection details:

[1]Professor, Dept. of Civil and Environmental Engineering, ATLSS Center Faculty Associate, Lehigh Univ., 117 ATLSS Dr., Bethlehem, PA 18015. E-mail: jmr5@lehigh.edu

[2]Former Graduate Research Assistant, ATLSS Center, Lehigh Univ., 117 ATLSS Drive, Bethlehem, PA 18015.

[3]Professor, Dept. of Civil and Environmental Engineering, ATLSS Center Faculty Associate, Lehigh Univ., 117 ATLSS Dr., Bethlehem, PA 18015.

Note. Associate Editor: Sherif El-Tawil. Discussion open until July 1, 2004. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on September 11, 2002; approved on January 27, 2003. This paper is part of the ***Journal of Structural Engineering***, Vol. 130, No. 2, February 1, 2004. ©ASCE, ISSN 0733-9445/2004/2-223–232/$18.00.



J. Struct. Eng. 2004.130:223-232.