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# Experimental behaviour of thin-walled steel tube confined concrete column to RC beam joints under cyclic loading

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ABSTRACT

This paper describes eight tests carried out on thin-walled steel tube confined concrete (TWSTCC) column to reinforced concrete (RC) beam joints subjected to cyclic loading, where the column cross-sectional type and the level of axial load in the column were selected as test parameters. In addition, two concrete filled thin-walled steel tubular column to RC beam joints were also tested for comparison. Each TWSTCC joint specimen consisted of a TWSTCC column and a RC beam pass through the column to represent an interior joint in a building. The experimental results are analysed to evaluate the influences of different testing parameters on the performance of the beam-column joints. It was found that the TWSTCC joints show generally excellent seismic performance and is adoptable in practical engineering, particularly in earthquake zone.



## 1. Introduction

It is well known that concrete filled steel tubular (CFST) column is being used popularly in modern building structures [1]. Some studies have been performed on the behaviour of CFST beam-to-column connections in recent decades, such as a series of experiments on six different connections were conducted by Schneider and Alostaz [2]. Ricles et al. [3] presented test results of ten full-scale moment resisting connections under cyclic loading condition. Five sub-assemblages of cruciform composite joints that simulate the internal region of a semi-continuous frame were tested by Loh et al. [4]. Finite element analysis was carried out by Loh et al. [5] to analyse the behaviour of the composite joints.

In some recently built high rise buildings in China, CFST column to reinforced concrete (RC) beam joints were used, shown as in Fig. 1. However, it was found that the composite joints, sometimes, are difficult to be designed following the well-established knowledge of conventional joints in RC structures.

A type of composite column, shown as in Fig. 2, named as steel tube confined concrete (STCC) column in this paper has been the interests of structural engineers recently [6,7]. Such kind of columns actually were firstly studied by a research group led by Tomii [8–11]. From then on, it has attracted more and more research interest [7,12,13].

Compared with conventional CFST columns, it is evident that only small amount of axial load is transferred through the steel tube for a STCC column, thus the effectiveness of the steel tube in confining the concrete core is maximized, and the possibility of tube buckling can be significantly reduced because the outer steel tube in STCC columns carries very small axial compressive loads. It is thus expected that thinner steel tube (i.e. thin-walled steel tube) can be used in a STCC column than in the conventional CFST. Moreover, the beam-column joint of the STCC column system can be designed following the well-established knowledge of conventional RC beam-column joints.

As mentioned above, some research results on STCC columns have been reported in the literature, which demonstrated the fact that the STCC columns have generally good performance, and have potential of being used in engineering practice [7,12,13]. But there is still no sufficient information on the beam-column joints of the STCC column system, particularly on the seismic design of the composite connections with thin-walled steel tubes used in the STCC columns.

This paper is thus an attempt to study the seismic performance of thin-walled steel tube confined concrete (TWSTCC) column to reinforced concrete beam joints. A series of tests on the composite

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**Nomenclature**

| | |
|---|---|
| $b$ | beam width |
| $D$ | cross-sectional dimension of column |
| $E_c$ | concrete modulus of elasticity |
| $E_s$ | steel modulus of elasticity |
| $f_{cu}$ | concrete cube strength |
| $f_y$ | yield strength of steel |
| $H$ | column height |
| $h$ | beam depth |
| $K$ | relative rigidity |
| $k_M$ | beam-column strength ratio |
| $L$ | beam span |
| $M$ | bending moment |
| $M_{ub}$ | bending moment capacity of RC beam |
| $M_{uc}$ | bending moment capacity of composite column |
| $n$ | axial load level ( $= N_o/N_u$) |
| $N_o$ | axial load applied on composite column |
| $N_u$ | ultimate compression capacity of composite column |
| $P$ | lateral load |
| $P_{ue}$ | ultimate lateral load |
| TWSTCC | thin-walled steel tube confined concrete |
| $t_s$ | wall thickness of steel tube |
| $\Delta$ | lateral deflection |
| $\Delta_y$ | lateral yielding deflection |
| $\varepsilon$ | strain |
| $\mu$ | ductility coefficient |
| $\theta$ | storey drift rotation |
| $\theta_{bc}$ | relative rotation between the beam and column |
| $\xi_{eq}$ | equivalent damping coefficient |

joints subjected to cyclic loading are reported. The influences of different testing parameters on the ultimate strength, rigidity, and the energy dissipation ability, etc., are evaluated.

## 2. Experimental method

### 2.1. General information of specimens

Eight TWSTCC columns to RC beam joints were designed in the test program. Thin-walled steel tubes were used in the composite joints, where the diameter or width ($D$)-to- steel wall thickness ($t_s$) ratio was 108.7. Each specimen consisted of a TWSTCC column and a RC beam pass through the column to represent an interior joint in a building. In the test program, four specimens were designed with circular columns, and the others were designed with square columns. In each cross-section series, a reference joint with conventional CFST column was also included. The following designation system is used in this paper:

(1) The symbols of STCCJ and CFST are used to indicate joints with TWSTCC column and CFST column, respectively. For clarity, joints with TWSTCC columns or CFST columns are nominated as TWSTCC joints or CFST joints hereinafter.
(2) The following letter of C or S is used to indicate circular or square column used, respectively.
(3) Numbers 0, 3 and 6 in the designation indicates an axial load level of 0.05, 0.3 and 0.6 in the column, respectively.

Table 1 gives the details of each specimen, where $h$ and $b$ are the overall depth and overall width of the RC beam cross-section, respectively. The column height $H$ and the beam length $L$ are 1155 and 1500 mm, respectively, which were determined based on assuming points of inflection at mid-span and mid-height of the prototype beams and columns. The joint sizes were designed to be approximately one-third scale compared with the prototype subassembly, which followed the strong-column weak-beam design philosophy.

More details of the composite joints and the testing arrangements are given in Fig. 3. For joints with circular columns, the RC beams were longitudinally reinforced with four 10 mm plain steel bars, while the hoop reinforcement consisted of 6 mm plain steel hoops with a centre-to-centre spacing of 90 mm. For those with square columns, the beam longitudinal reinforcement was four 12 mm deformed steel bars with 6 mm plain steel hoops spaced at 80 mm centres. The clear cover to the longitudinal reinforcement

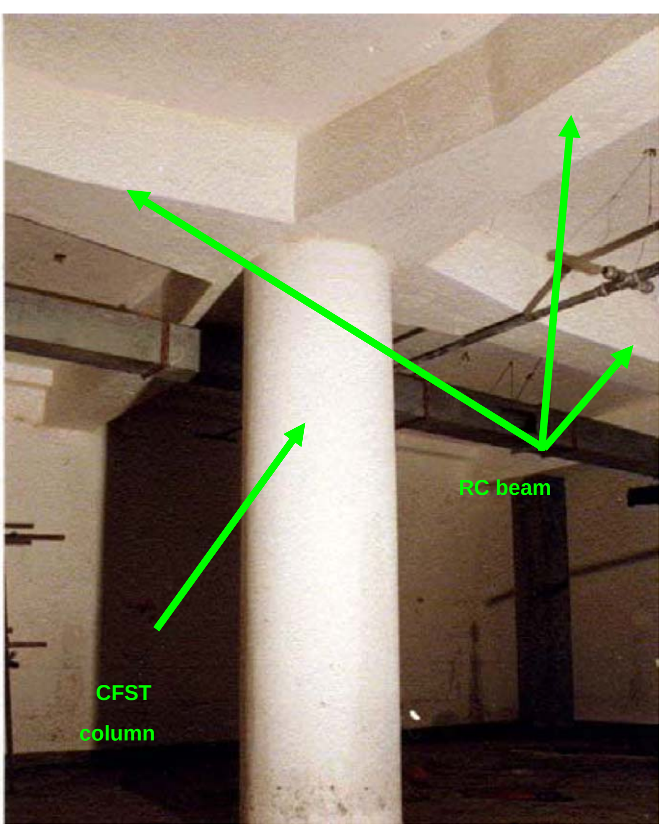


**Fig. 1.** Typical CFST column to RC beam joint.

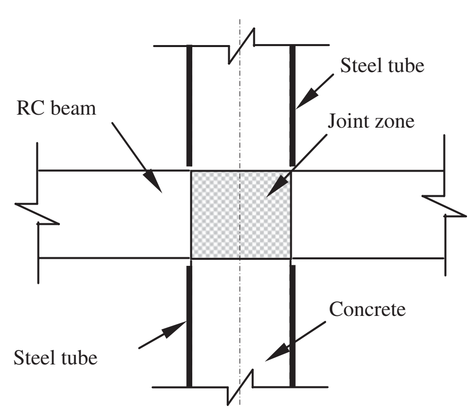


**Fig. 2.** A schematic view of STCC column.