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Behaviour of multi-cell composite T-shaped concrete-filled steel tubular columns under axial compression

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ABSTRACT

To improve the behaviour of conventional T-shaped concrete-filled steel tubular (CFST) columns, multi-cell composite T-shaped concrete-filled steel tubular (MT-CFST) columns are proposed in this paper. Experimental study of 25MT-CFST columns, including 13 short specimens with various cross sections and material properties and 12 slender specimens with different slenderness ratios, subjected to axial loads was conducted. The failure modes, axial load–strain curves for short specimens and axial load–lateral deflection curves for slender specimens were investigated. The test results were compared with design approaches for conventional CFST columns presented in Eurocode 4, AISC specification, Australian standard AS51006, Chinese code CECS159, and Hong Kong steel code, and it was found that all the design codes underestimate the bearing capacity of both short and slender MT-CFST columns to some extent.

1. Introduction

Concrete-filled steel tubular (CFST) columns could make full use of the properties of steel and concrete. As a kind of composite structure with higher bearing capacities and better seismic performance, they are used in more and more applications in residential buildings with good economic benefits. The first experimental research on circular CFST columns was published by Kloppel and Goder [1] in German. Since then, experimental studies that mainly focused on the structural behaviour of CFST columns with a variety of cross-sectional shapes have been reported. To investigate the influence of the cross-sectional shape and the thickness of steel tube on the failure load of the short CFST columns, Schneider [2] performed a comprehensive experimental and analytical study on the behaviour of composite columns under axial compression. Han [3] tested 24 specimens with constraining factors from 0.5 to 1.3 and width ratios of rectangular tube (h/b) from 1.0 to 1.75. It was found that the constraining factor and width ratio had significant effects on both the failure load and ductility of the composite column. A series of research in [4–5] discusses the influence of different concrete strengths and cross-sectional geometries on the behaviour of CFST columns filled with high strength concrete.

An extensive experimental test that investigated the performance of short and slender concrete-filled stainless steel tubular columns under different loading methods was carried out by Uy et al. [6]. Mursi and Uy [7] experimentally studied slender square CFST columns using high strength structural steel and normal strength concrete. Based on the experimental data, a numerical model was proposed to study the behaviour of slender concrete filled high strength steel tubular columns with consideration of material and geometric nonlinearities. An et al. [8] studied the behaviour of slender circular CFST columns under axial compression and developed a finite element analysis method considering the initial out-of-straightness imperfection. Hernandez-Figueirido et al. [9] investigated the effect of slenderness on square and rectangular CFST columns subjected to axial load and a non-constant bending moment distribution through experiments with large number of specimens. Eighteen specimens were tested by Han et al. [10] to investigate the effect of cross-sectional shape, initial deflection, and slenderness ratio on the behaviour of the curved composite members under axial compression. In addition, numerical analysis of slender elliptical CFST columns subjected to axial load was published in [11].

Although significant progress has been made, engineering practices at present show that the problem of pillars protruding from walls remains to be solved despite the fact that the section size of a CFST column has been greatly reduced compared to that of a reinforced concrete column. To solve this problem, the concept of T-shaped cross-sectional CFST columns located at the edges of a structure has been proposed in [12]. However, for a T-shaped cross-sectional column, the separation between the steel tube and concrete at inner corners could prevent two materials from fully functioning and the large width-to-thickness ratio of the steel plate could result in premature local buckling. Du et al. [13] developed a method of welding two rectangular tubes together to form a T-shaped column for preventing inner corners' separation. Nevertheless, the premature local buckling still existed in the

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composite column. Yang et al. [14] conducted an experimental study of welding battlement-shaped bar stiffeners and tensile bar stiffeners on tube surfaces to improve the axial compressive behaviour of T-shaped CFST columns. But it was expensive to weld bar stiffeners on the steel plates and fold the steel plates into a T-shaped cross-sectional hollow tube. Instead of two rectangular steel tubes or stiffeners, this paper proposes the multi-cell composite T-shaped concrete-filled steel tubular (MT-CFST) column for targeting these two problems.

The main objective of the present paper is to understand the behaviour of MT-CFST column subjected to axial load. The experimental campaign is focused on two aspects: (1) short columns with various cross-sectional geometries and material properties; (2) slender columns considering different slenderness ratios. In addition, comparisons between experimental results and available design codes are discussed in this paper to validate the feasibility of the design codes.

2. Experimental investigation

2.1. General

A MT-CFST column is formed by first welding three rectangular tubes together. After that, a 10 mm thick steel cover-plate used as a base for pouring the concrete is welded on the bottom of the tubes (Fig. 1(a)). Then the concrete is vertically poured into the steel tube (Fig. 1(b)) and vibrated simultaneously by a poker vibrator. After two weeks curing, a high-strength epoxy is adopted to fill the space generated by the shrinkage of the concrete and then another 10-mm-thick steel cover-plate is welded on top of the specimen.

Experiments with 25 specimens under axial compression were carried out. The specimens were divided into two groups based on the influence of different factors. Group I contained 10 short columns that were subjected to axial loads so as to investigate the effect of cross-sectional geometries (wall thickness, c/a and b/a ratio) and material properties (concrete strength). Group II contained 15 columns that were subjected to axial compression so as to study the influence of the slenderness ratio. Details of the specimens are listed in Tables 1 and 2, and the parameters (a, b, c and t) and axis (x–x and y–y) of the composite T-section are defined in Fig. 2. To avoid the effects of overall buckling and end conditions, the physical length (L, not including the cover-plates) of the short specimen was chosen to be 3 times the width of the longest side of the T-section [15].

2.2. Material properties

The material properties of steel and concrete were obtained according to the requirements defined in China National Codes (GB/T 50081-2002 and GB/T 228-2002). Test coupons were fabricated with the steel material used for constructing the steel tubes and were tested in tension. The test results suggest that these steel coupons don't have obvious yielding platform. Fig. 3 shows the

Table 1
Test data of specimens in Group I.

Specimen	$a \times b \times c$ (mm^3)	t (mm)	L (mm)	f_y (MPa)	f_{ck} (MPa)	N_{us} (kN)	SI	DI
1	60 × 100 × 80	2.4	450	326	55.3	1550.5	1.041	4.50
2	60 × 120 × 60	2.4	500	326	55.3	1497.3	1.073	–
3	60 × 100 × 120	2.4	700	326	55.3	1961.0	1.043	3.71
4	60 × 80 × 80	2.4	450	326	55.3	1466.7	1.053	–
5	60 × 120 × 80	2.4	500	326	55.3	1661.3	1.046	4.17
6	60 × 120 × 120	2.4	700	326	55.3	2033.0	1.028	2.43
7	60×80×80	2.0	450	330	55.3	1281.0	1.090	2.03
8	60×80×80	3.4	450	315	55.3	1849.3	1.150	
9	60×100×80	2.4	450	326	38.7	1314.5	1.051	–
10	60×100×80	2.4	450	326	61.0	1628.6	1.036	4.21

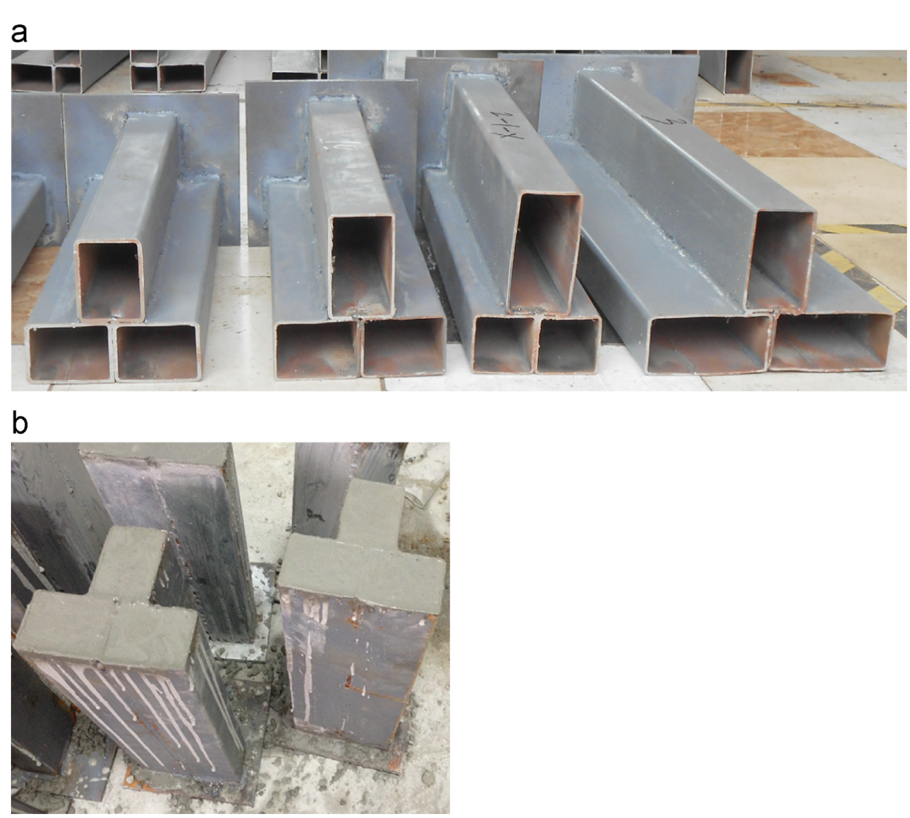

Fig. 1. Multi-cell composite T-shaped concrete-filled steel tubular (MT-CFST) columns.