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Performance of T-shaped CFST stub columns with binding bars under axial compression

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ABSTRACT

This paper investigates the axial compressive behaviour of T-shaped concrete-filled steel tube (CFST) stub columns with blinding bars. In this column system, binding bars are applied cross-through the section and produce confinement effects. Eleven specimens with binding bars and five ones without binding bars were tested under axial compressive loading. The experimental results demonstrate that, by setting binding bars, the local buckling failure modes are changed and the occurrence of local buckling is delayed, and the global outward bulge of the steel tube at the concave corners can be effectively restrained. The ultimate strength and ductility of the columns with binding bars can achieve up to 1.53 and 7.5 times higher than those of the columns without binding bars, respectively. Taking into consideration the contribution of binding bars, the confinement effects of steel tube and the other sectional characteristics, a method for predicting the ultimate axial compressive strength of the columns with or without blinding bars is established. The accuracy of the method is validated through comparisons of the experimental results reported in this paper and in other available open literatures.

1. Introduction

In recent years, special-shaped concrete-filled steel tube (CFST) columns, mainly L-shaped, T-shaped and cross-shaped CFST columns, have been increasingly used in engineering structures as single columns or as edge members of shear walls [1], on account of their convenient constructions at beam–column joints, larger moments of inertia of cross-sections and better satisfaction with architectural requirement compared with regular-shaped (such as circular, square or rectangular) CFST sections, as well as superior strength, ductility and seismic behaviour over special-shaped RC columns. Although more and more scholars have engaged in the research and promotion on special-shaped CFST columns, the relevant research publications are still very limited and there are no design specifications currently available in design codes for special-shaped CFST columns. Thus this paper focuses on investigation of the behaviour of T-shaped CFST columns subjected to axial compression.

Previously, Li et al. [2] performed experimental study on the mechanical behaviour of two normal T-shaped CFST columns and four T-shaped CFST columns with binding bars (as shown in Fig. 1(a)). The experimental results of axial loading tests indicated that by setting binding bars, the local buckling of steel tube was postponed and the ductility of the columns could be improved significantly compared with normal T-shaped CFST columns. The bearing capacity of the columns could be enhanced if the spacing of binding bars was decreased. Du et al. [3] and Chen et al. [4] experimentally studied the behaviour of normal T-shaped CFST columns under the axial load, and found that for T-shaped CFST columns, the confinement effects on concrete from steel tube in the concave corner regions were small. Xu et al. [5], Liu et al. [6] and Tu et al. [7] proposed different types of multi-cell composite schemes through welding several rectangle CFST columns to form different T-shaped CFST columns as shown in Fig. 1(b)–(d), respectively. The axial loading tests were undertaken on those columns. It was observed that the column with multi-cell composite schemes exhibited better mechanical performance than the normal T-shaped CFST columns as a result of the increase of the area of steel tube in the cross-section for the confinement effects. It is also noted that the length-width ratio of each leg in the T-shaped section had significant impact on the behaviour of the columns. Zhao et al. [8] and Yang et al. [9,10] experimentally studied the axial load behaviour of T-shaped CFST columns stiffened by battlement-shaped steel bars. The battlement-shaped steel bars were located at the middle positions of the long sides of T-shaped cross-section and at the concave corner positions as shown in Fig. 1(e), and were weld through the height of the columns. The study

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Nomenclature

a_1, a_2, a	lengths of the a_1-side and a_2-side, and a-side, respectively
b_1, b_2	lengths of the b_1-side and b_2-side, respectively
b	total length of b_1-side plus b_2-side
t	thickness of a steel tube
L	initial clear height of a column
a_s	horizontal spacing between the binding bars in each leg
b_s	longitudinal spacing between binding bars
d_s	diameter of a binding bar
n	number of the bars in each leg
A_c	sectional area of core concrete
A_s	sectional area of a steel tube
A_b	sectional area of a binding bar
E_{sb}	elastic modulus of the binding bar
E_{st}	elastic modulus of the steel tube
υ	Poisson's ratio of steel
f_{yb}, ε_{yb} and f_{ub}	yield strength, yield strain and ultimate strength of the binding bar, respectively
f_{yt}, ε_{yt} and f_{ut}	yield strength, yield strain and ultimate strength of the steel tube, respectively
$f_{cu,k}$	characteristic 28-day cubic strength of concrete
f_{ck}	prism strength of concrete, calculated by $f_{ck} = 0.76\, f_{cu,k}$
f'_c	cylinder strength of concrete, calculated by $f'_c = 0.79\, f_{cu,k}$
N_{be}, ε_{be}	experimental load and average longitudinal strain relating to the initiation of local buckling on the a-side steel plate, respectively
N_{ue}, ε_{me}	experimental load and average longitudinal strain at the peak load, respectively
N_{uc}	predicted maximum strength
N_{un}	nominal strength, defined as $N_{un} = f_{yt}A_s + f_{ck}A_c$
ε_{ue}	ultimate average longitudinal strain

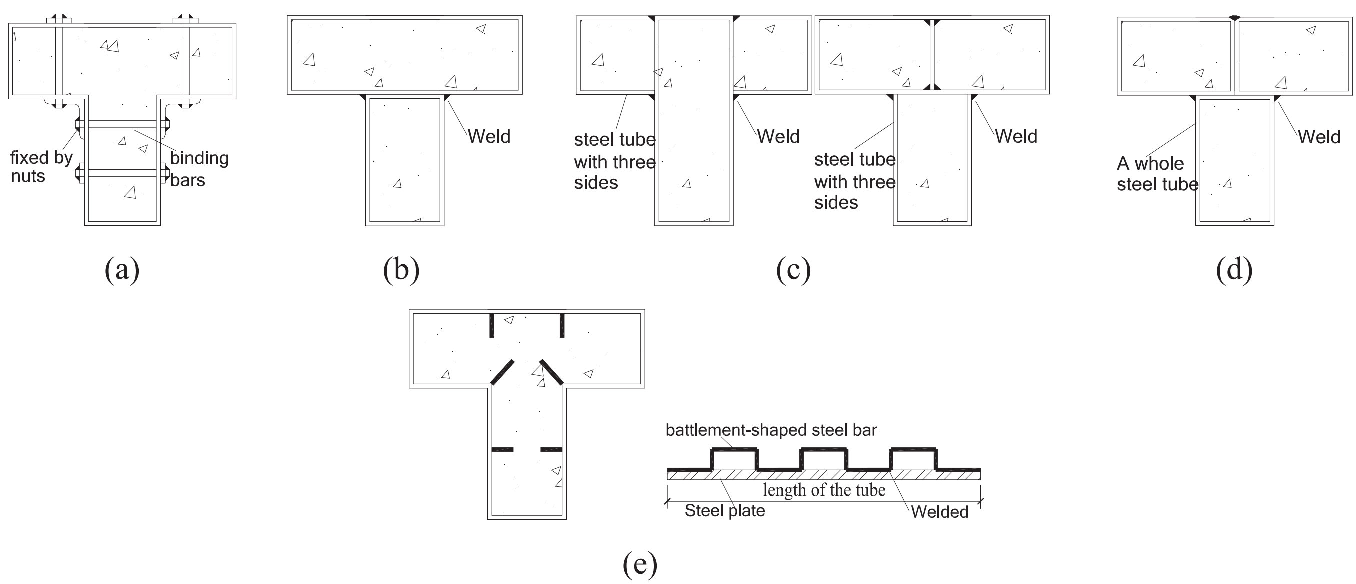

Fig. 1. Stiffened T-shaped CFST columns: (a) stiffened with binding bars [2]; (b) type 1 of multi-cell composite section [5]; (c) type 2 of multi-cell composite section [6]; (d) type 3 of multi-cell composite section [7]; (e) stiffened with battlement-shaped steel bars [8–10].

Table 1
Details of specimens.

No.	$a_1/a_2/b_1/b_2/t/L$ (mm)	$a_s/b_s/d_s/n$ (mm)	$f_{cu,k}$ (MPa)	f_{yt} (MPa)	f_{yb} (MPa)	a/t	a/t limit	
							EC4 [21]	AISC [22]
C1	80/78/78/80/3.75/720	–	45.84	374	–	63	41	40
C2	80/78/78/80/3.75/720	50/50/6.75/1	45.84	374	493	63	41	40
C3	80/78/78/80/5.73/720	–	45.84	347	–	42	43	41
C4	80/78/78/80/5.73/720	50/50/6.75/1	45.84	347	493	42	43	41
C5	80/78/78/80/3.75/720	50/100/6.75/1	45.84	374	493	63	41	40
C6	80/78/78/80/3.75/720	50/50/5/1	45.84	374	489	63	41	40
C7	80/78/78/80/3.75/720	50/50/8.5/1	45.84	374	372	63	41	40
C8	80/78/78/80/7.8/720	–	45.84	285	–	31	47	45
C9	80/78/78/80/7.8/720	50/50/6.75/1	45.84	285	493	31	47	45
C10	80/78/78/80/3.77/720	–	45.84	289	–	63	47	45
C11	80/78/78/80/3.77/720	50/50/6.75/1	45.84	289	493	63	47	45
C12	180/78/78/180/3.75/1320	150/50/6.75/1	45.84	374	493	117	41	40
C13	180/78/78/180/5.73/1320	–	45.84	347	–	76	43	41
C14	180/78/78/180/5.73/1320	50/50/6.75/3	45.84	347	493	76	43	41
C15	180/78/78/180/5.73/1320	75/75/6.75/2	45.84	347	493	76	43	41
C16	180/78/78/180/5.73/1320	150/150/6.75/1	45.84	347	493	76	43	41

Notes: "–" means no binding bars available.