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Hysteretic behavior of square CFT columns with binding bars

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ABSTRACT

This paper presents the hysteretic behavior of square concrete-filled steel tubular (CFT) stub columns with binding bars. A total of ten square CFT stub columns including eight specimens with binding bars and two specimens without binding bars were tested under constant axial load and cyclic lateral loads. The effects of the axial load level and the spacing of binding bars on the hysteretic behavior were investigated carefully. Experimental results demonstrate that the specimens with binding bars show higher lateral bearing capacity, higher stiffness, higher ultimate deformation capacity and better energy-dissipation capacity compared with those without binding bars. In addition, the initial local buckling for specimens with binding bars is significantly delayed by the binding bars. Furthermore, the lateral bearing capacity, the ultimate deformation capacity, the energy-dissipation capacity and the stiffness of the specimens with binding bars are significantly improved with the spacing of binding bars decreasing. The ultimate deformation capacity decreases with an increase in axial load levels while the energy-dissipation capacity increases with an increase in axial load levels. Finally, the fiber element analysis for all specimens is carried out. The calculated envelope curves and the calculated hysteretic curves of the specimens by the fiber element analysis are in good agreement with the experimental results.

1. Introduction

Concrete-filled steel tubular (CFT) columns are being extensively used in buildings and bridges due to high strength, high stiffness, good ductility, large energy absorption and convenience for construction. The static behavior of CFT columns has been investigated experimentally and analytically for decades [1–14]. In recent years, the seismic behavior of square CFT columns has been concerned due to their good performances in earthquake. A large number of experimental studies on the hysteretic behavior of square CFT columns have been conducted [15–29]. Also, several analytical models for predicting the hysteretic behavior of CFT columns have been proposed [30–35]. According to the studies above, square or rectangular CFT columns show better static and hysteretic behavior compared with reinforced concrete columns. Additionally, remarkable confinement effects can be expected in circular CFT columns while square or rectangular CFT columns show only a small increase in axial strength due to triaxial effects. Furthermore, it is indicated that the ductility of square or rectangular CFT columns is obviously inferior to that of circular CFT columns.

To improve the behavior of rectangular, L-shaped, T-shaped CFT columns, a simple and efficient stiffening scheme has been proposed for these columns [36–41]. This scheme involves level orthotropic binding bars arranged at specified spacing along the longitudinal axis of the steel tube. As innovative structural members, CFT columns with binding bars have been applied in tall buildings in China such as Guangzhou New China Mansion and Guangzhou Mingsheng Plaza. A number of experimental investigations into square, rectangular and L-shaped CFT columns with binding bars subjected to axial or eccentric loads have been conducted (Cai et al. [36–37]; Zuo et al. [39–40]). Additionally, some analytic studies on CFT columns with binding bars have been carried out. Cai and Long [38] studied theoretically the local buckling of steel plate in CFT columns with binding bars. Long and Cai [41] proposed a stress-strain relationship model of concrete for rectangular CFT columns with binding bars. These studies show the merits of CFT columns with binding bars: (1) the local buckling modes of the CFT stub columns are changed and the local buckling can be considerably delayed by setting binding bars; (2) the lateral deformation of concrete core are constrained by the binding bars, namely, the concrete core can be more efficiently confined by the binding bars; and (3) the CFT columns with binding bars show higher bearing capacity and better ductility than those without binding bars subjected to axial or eccentric loads. Previous researches focus on static performances of CFT columns with binding bars. However, the hysteretic behavior of CFT columns with binding bars is still open so far.

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Nomenclature

A_c	cross-sectional area of concrete core
A_s	cross-sectional area of steel tube
B	width of square steel tube
t	tube wall thickness
L	length of steel tube
a_s	horizontal spacing between binding bar
b_s	longitudinal spacing between binding bar
d_s	diameter of binding bar
f_c	cylinder strength of concrete
f_{ay}	yield strength of steel tube
f_y	yield strength of binding bar
P	applied axial load in CFT columns
P_u	nominal axial bearing capacity of CFT columns, defined as $P_u = f_{ay} A_s + f_c A_c$
n	axial load level, defined as $n = P/P_u$
H_y	the lateral yield load
θ	the story drift ratio
θ_y	the story drift ratio corresponding to H_y
H_b	the lateral load with respect to occurrence of local buckling
θ_b	the story drift ratio corresponding to H_b
H_s	the lateral load with respect to the rupture of binding bars
θ_s	the story drift ratio corresponding to H_s
H_m	the peak lateral load
θ_m	the story drift ratio corresponding to H_u
H_u	the lateral load corresponding to θ_u
θ_u	the ultimate story drift ratio

To investigate the seismic behavior of square CFT columns with binding bars, a total of 10 specimens, 8 with binding bars and 2 without, were tested under constant axial load and cyclic lateral loads. The parameters in this study include the axial load level (n), the horizontal spacing of binding bars (a_s) and the longitudinal spacing of binding bars (b_s).

2. Experimental program

2.1. Test specimens

A total ten square CFT specimens including 8 with binding bars and 2 without were tested under cyclic lateral loading. The details of the specimens are shown in Fig. 1 and the properties of the specimens are listed in Table 1. Specimens A1–A2 are without binding bars while specimens B1–B4 and C1–C4 are respectively with two binding bars and six binding bars on the cross-sections of specified spacing. The rectangular steel tubes were fabricated by welding together four pieces of steel plates with pre-drilled holes for the binding bars. Each binding bar is fixed to the steel tube through a nut and washer on the two ends and the constructional details of binding bars are displayed in Fig. 2. Furthermore, the holes for the bars are pre-drilled on the tubular wall in the factory. The load pillars and the stiff stub footings of the specimens were well reinforced to prevent from possible failure during testing. The properties of steel tubes and binding bars, as listed in Table 1, were obtained from tensile tests on coupons taken respectively from the same batch of steel tubes and binding bars. In addition, the properties of concrete were determined based on the cylinder test results at the time of testing.

As listed in Table 1, the parameters in this study include the axial load level (n), the horizontal spacing of binding bars (a_s) and the longitudinal spacing of binding bars (b_s).

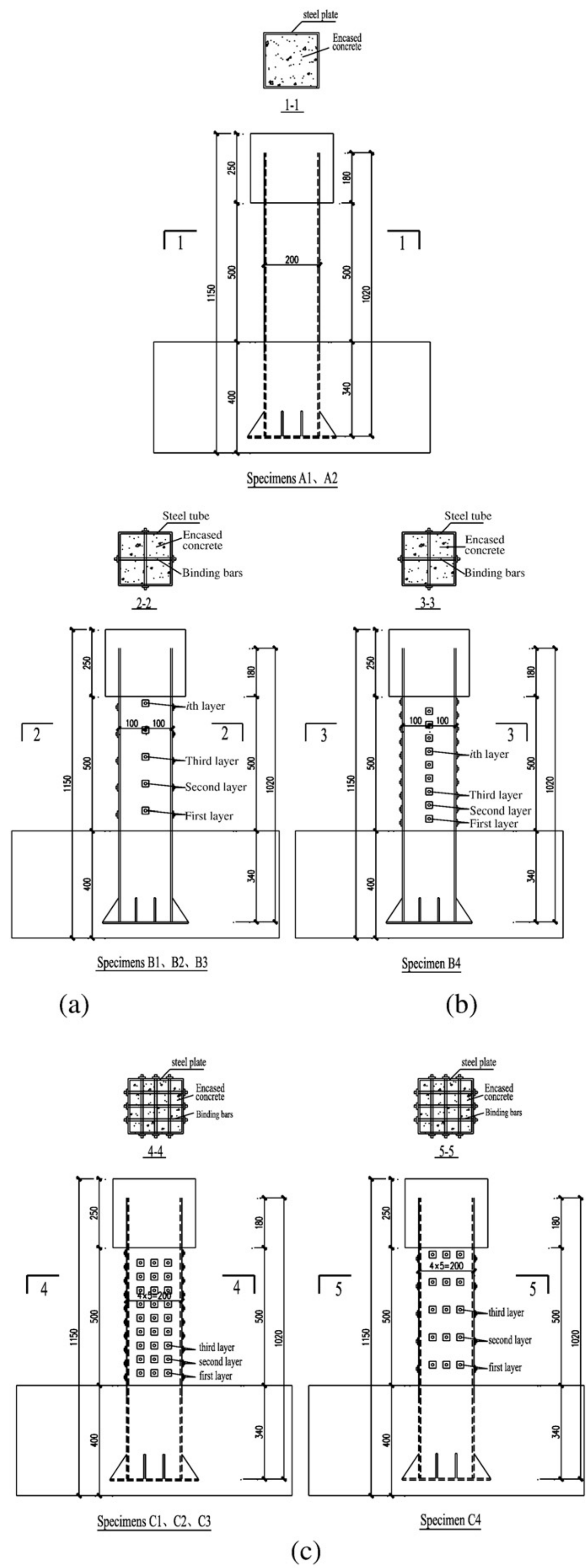

Fig. 1. Test specimens.