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Flexural behavior of high strength concrete filled high strength square steel tube

Guochang Li [a], Di Liu [a], Zhijian Yang [a,*], Chunyu Zhang [b]

[a] School of Civil Engineering, Shenyang Jianzhu University, Shenyang 110168, China
[b] Department of Civil and Environmental Engineering and Construction, University of Nevada Las Vegas, 89119, USA

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ABSTRACT

To study the mechanical behavior of high-strength concrete filled high-strength square steel tube (HCFHST) under pure bending load, six specimens with different steel ratio were tested. The corresponding nonlinear finite-element models were established to analyze the mechanical properties. The load-displacement curves obtained from the numerical analyses are consistent with the experimental results. In addition, the influences of different materials are analyzed in this paper. The moment-curvature relationship can be divided into three stages: elastic stage, yield stage and hardening stage. And the ultimate bearing capacity increased with the steel ratio, steel yield strength and concrete compressive strength. Moreover, the ultimate bearing capacity of the experiment and finite-element analysis (FEA) model is compared with the requirements of codes: AISC-LRFD (1999), AIJ (1997), EC4 (1994) and GB50936-2014 (2014). The test and FEA result were the most compatible to the calculated result of EC4 (1994). And find the results in this paper is the most compatible to the code EC4 (1994).

1. Introduction

Compared with traditional reinforced concrete structure, concrete filled steel tube (CFST) has a higher bearing capacity, ductility and fire resistant capacity. Besides, it's also an economic structure type and can be constructed easily. Because of these characteristics, it has been widely used in practical engineering such as high-rise buildings and long-span bridges. The modern building has a higher demand for the construction height and span length. Therefore, the structure design becomes more ponderous. High-strength concrete filled high-strength square steel tube (HCFHST), which takes the advantage of both high-strength concrete and high-strength square steel tube can raise the ultimate bearing capacity and decrease the weight of the structure.

Varma et al. [1,2] presented an experiment of monotonic and cyclic load on CFST column. The results showed that ACI code can predict bearing capacity of high strength CFST beam-column accurately. Liu et al. [3] conducted an experiment on 22 high strength rectangular CFST columns, which showed that ultimate bearing capacity decreased with the rise of depth-width ratio. Liu et al. [4] reported the test results of 12 high strength rectangular CFST beams, the result illustrated that the formula of EC4, ACI and AIJ codes to calculate bearing capacity for high strength CFST need to be modified. Liu et al. [5] designed an experiment on 26 CFST specimens under axial compression load, the results showed that the code EC4 overestimated the ultimate bearing capacity of the specimens. Young et al. [6] presented an experimental investigation of concrete filled cold-formed high-strength stainless steel tube columns, and proposed design recommendations for design. Mursi et al. [7,8] reported the test and analysis results of high strength steel columns subjected to bi-axial bending. Choi et al. [9] proposed a simplified strength formula to establish the P–M interaction curve of CFST with concrete strength up to 100 MPa. The results indicated that the simplified formula could greatly improve the accuracy of the results and reduce the effort of calculation. Chung et al. [10] compared some existing material models of the steel and concrete, and proposed a non-linear fiber element method. Jung et al. [11] did a test study on 4 high strength CFST columns. The results showed that ultimate strength of steel and concrete can influence the axial bearing capacity and ductility of specimens. Chung et al. [13] investigated 6 HCFHST beam specimens. The calculated results of numerical method were consistent with the test results. Guler et al. [14] studied the influence of steel tube thickness and bond strength on bearing capacity and ductility of square and circular high strength CFST columns. Li et al. [15] studied the mechanical behavior of HCFHST column under axial load by finite-element analysis (FEA), the results shows that the FEA result of bearing capacity are consistent with different codes. Patel et al. [16] presented a new efficient numerical model to predict the cyclic performance of high strength rectangular CFST slender beam-columns. Kim et al. [17] presented an experiment on 2 CFST columns and 4 concrete encased steel columns with high strength steel and high strength concrete.

* Corresponding author.
E-mail address: faemail@163.com (Z. Yang).

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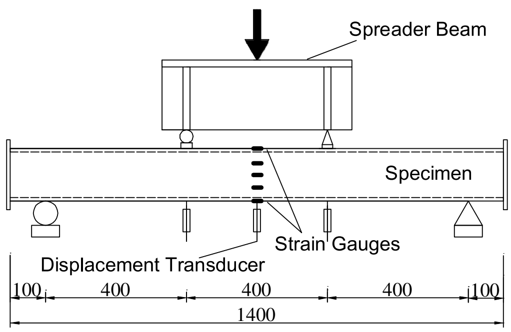
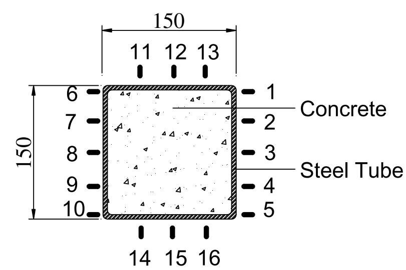
0143-974X/

(a) Test specimen in place



(b) Diagrammatic view



(c) Strain gauges location

Fig. 1. Test setup.

Table 1
Details of the specimens.

No.	Specimens	$B \times t \times L_0$ (mm × mm × mm)	α	ξ	f_y (MPa)	f_u (MPa)	f_{cu} (MPa)
1	SCW1-1	150 × 4 × 1200	0.116	0.699	434.56	546.2	98
2	SCW1-2	150 × 4 × 1200	0.116	0.692	430.00	547	98
3	SCW2-1	150 × 5 × 1200	0.148	0.863	420.00	516	98
4	SCW2-2	150 × 5 × 1200	0.148	0.855	416.30	513.7	98
5	SCW3-1	150 × 6 × 1200	0.181	1.084	430.00	545	98
6	SCW3-2	150 × 6 × 1200	0.181	1.101	436.90	550.4	98

Note: B is the width of the steel tube. t is the tube wall thickness. L_0 is the calculated length. α is the steel ratio ($\alpha = A_s / A_c$, where A_s, A_c are the cross-section area of steel tube and concrete), ξ is the confinement factor ($\xi = A_s f_y / A_c f_{ck}$), f_y is steel yield strength, f_u is the steel ultimate strength and f_{cu} is the 28-day concrete cube strength.

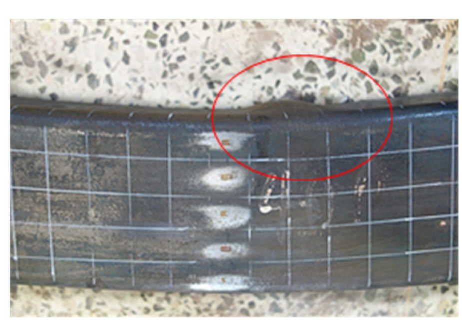
CFST member has no advantages to bear bending load alone, therefore it is not suited to be flexural member. In practice project, CFST columns generally subjected to axial and bending load. Pure bending is the special case of beam-column without axial load, but the flexural behavior of CFST is not independent of the behavior under axial load and axial load–moment interaction. As a result, it is necessary to study the flexural behavior of HCFHST, which is beneficial to know the behavior of HCFHST under eccentric load. Most of the former researches focus on analyzing the HCFHST under the axial loading. However, there are few studies about the HCFHST member under the bending moment. This paper presents a test result of 6 HCFHST beams under pure bending. Besides, the corresponding FEA models were established to predict and compare with the analysis results.

2. Experimental investigation

2.1. Test design

The test specimens were full-scale models of prototype HCFHST beams under two symmetric load, as shown in Fig. 1(b). Six specimens are in

(a) Over all failure mode



(b) Local buckling

Fig. 2. Failure mode of specimens.