ISBN: 978-1-948012-01-0

Contents List available at VOLKSON PRESS

Engineering & Technology Innovations (ETI)

DOI : http://doi.org/10.26480/iceti.01.2017.120.122

TEST OF SPECIAL-SHAPED MUTI-CAVITY-BIFURCATED CFST

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ARTICLE DETAILS

Article History:

Received 02 october 2017
Accepted 06 october 2017
Available online 11 october 2017

Keywords:

multi-cavity-bifurcated concrete-filled steel tubular columns; stiffeners; axial compression; compressive bending

ABSTRACT

In order to study the behaviours of special-shaped multi-cavity-bifurcated concrete-filled steel tubular (MCBCFST) columns under axial compression and compressive bending, this work performs testing of two 1:10 scale model specimens of special-shaped MCBCFST columns with some stiffeners. The results show that the stiffeners improve the behaviour of axial compression and compressive bending.

1. INTRODUCTION

The application of concrete-filled steel tubular (CFST) columns in super high-rise buildings has become increasingly popular. With the development of various shapes for architectural purpose, the patterns of cross-section of CFST columns are constantly changing. Accordingly, increasing studies are being performed related to special-shaped cross-sections. Abundant tests and analysis conducted on circular, rectangular and octagonal cross-sections have attained some innovative achievements [1]. Studies have shown that square and rectangular steel tubes provide weaker confined effects to concrete infill compared to circular tubes [2-5]. However, concrete-filled square or rectangular steel tubes have their own advantages including convenient beam-to-column connection, high moment capacities, and aesthetic consideration [6]. As a way to improve the confinement of square or rectangular tubes, some researchers have utilized welded longitudinal stiffeners on the inner or outer wall of square or rectangular steel tubes [7-8] or transverse stiffeners (welded or bolted binding bars at the wall of tube) arranged at an spacing along the longitudinal axis of the steel tubes [9-10]. The main test results revealed that the longitudinal and transverse stiffeners are effective in delaying local buckling and enhancing bearing capacity. Recently, multi-cell mega-CFST column structure is gaining popularity in the super high-rise buildings in China. Axial compressive behaviour of a pentagonal cross-section was tested [11]. The improvements in ultimate strength and ductility of this type of members were remarkable. However, owing to the limitation of loading equipment, the study of mega-column is focused only on a small scale.

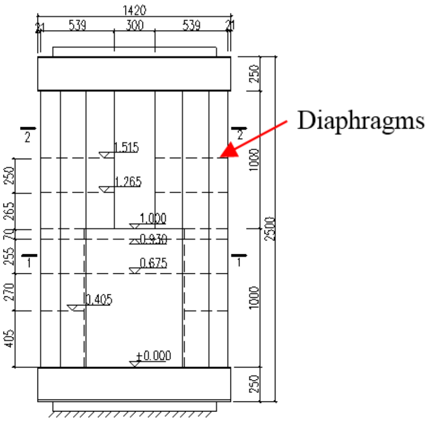
This paper primarily studies the compressive behavior of special-shaped MCBCFST columns under compressive loading, as applicable to the super high-rise China Zun Tower, which is under construction in Beijing, China, as shown in Figure 1. The main parameter of specimens is stiffening arrangements. The parameters are experimentally investigated to estimate their influences on the behaviour of of axial compression and compressive bending.

Figure 1. China Zun Tower under construction

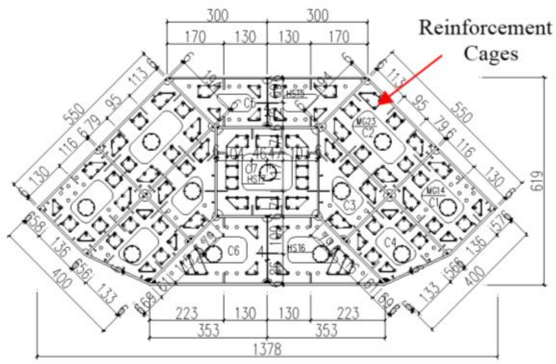
2. Experimental preparation

2.1 specimens

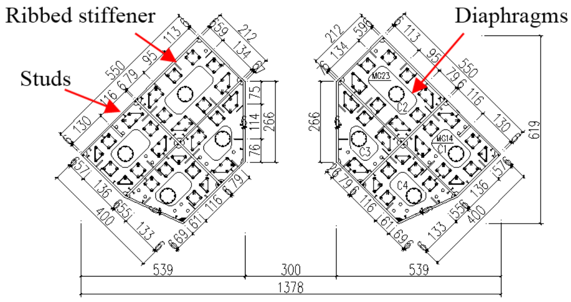
Two specimens of special-shaped MCBCFST columns are considered in this study with a 1/10 scale model. As shown in Figure 2, the two specimens were labeled as the BAC (basic axial compression with longitudinal stiffeners), and the BEC (basic eccentric compression).The components of specimens not only contained longitudinal reinforcement cages, steel plates and ribbed stiffeners but also contained transverse studs and diaphragms. The ribbed stiffeners with the dimensions of L mm×30 mm×3 mm were welded on the internal wall of the steel tubes where the height of ribbed stiffeners L was consistent with the spacing of the diaphragms. The codes of cell were noted by C_x. The cross-sectional shape of each leg of the upper part was hexagonal, and the cross sectional shape of the lower part was octagonal. All two specimens had the same overall dimensions and different stiffeners in the cells. The thickness and length of the cross-section were 619 mm and 1378 mm, respectively. The length, width, and height of chapiter or plinth of each specimen were 1420 mm, 830 mm, and 250 mm, respectively. T3 (Real thickness = 2.75 mm) steel plates were used for the longitudinal ribbed stiffeners and some diaphragms. T4 (Real thickness = 3.75 mm) steel plates were used for the lower part of the specimens. T6 (Real thickness = 5.75 mm) steel plates were used for the longitudinal steel plates of the tubes and some diaphragms.



(a) Elevation of BAC or BEC



(b) BAC or BEC (section 1-1)



(c) BAC or BEC (section 2-2)

Figure 2. Working diagram of specimens (units: mm)

2.2 Properties of material

Mechanical properties of galvanized iron wire and steel plate were tested based on the Chinese code: the Metallic materials-tensile testing-Part 1: Method of test at room temperature (GB/T228.1-2010). The material properties are shown in Table 1. GIW represents circular steel tube and galvanized iron wire. Properties of concrete are shown in Table2.

Types	Thickness or diameter (mm)	Yield strength f_y (MPa)	Ultimate Strength f_u (MPa)	Elastic modulus E_s (GPa)
T3	2.75	321	456	216
T4	3.75	405	527	219
T6	5.75	369	516	205
GIWI	φ2.4	239	356	153
GIWII	φ2.75	269	374	166

Table 1: Material properties of steel.

Designed strength grade	28d cube strength f_{cu} (MPa)	Cube strength at test f_{cu} (MPa)	Elastic modulus E_c (MPa)	Specimens
C50	52.5	53.5	30800	BAC
C50	47.8	46.0	23200	BEC

Table 2: Material properties of concrete.

2.3 Fabricating specimens

Steel members were fabricated, as shown in Figure 3. Due to the complexity in the cross-sectional shapes and the construction of specimens, the fabrication of specimens was conducted by careful plan, coordination and ornization.

(a) Stirrups

(b) Reinforcement cages

(c) Ribbed stiffener

(d) Diaphragms

(e) Assembly

(f) Pouring concrete

Figure 3. Fabricating specimens

3. Results

3.1 Failure modes

As shown in Figure 4(a), the secondary tubes of specimen BAC chiefly damaged at the corner of cavity C2 over the level 1.515m. The severe buckling of specimen BEC happened between level 1.000m and level 1.515m. When the BAC was loading, the damaged phenomenon contain 45°shear slip line, wrinkles of painting coat, cracks of painting coat, buckling and torn weld. Similarly, the BEC undergoes wrinkles of painting coat, cracks of painting coat, buckling of compressive zone, and yield and crack of steel plate at tensile region.

(a) BAC

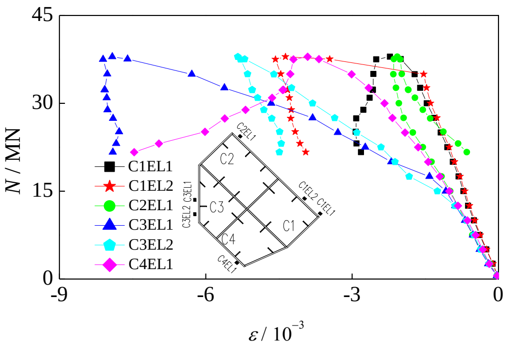
(b) BEC

Figure 4. Failure modes

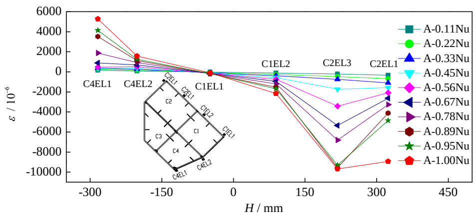
Cite the article: G. Yang, W.L. Cao , H.Y. Dong (2017). Test Of Special-Shaped Muti-Cavity-Bifurcated Cfst , *Topics in Civil, Environmental & Building Engineering* , 1(2) :120-122.

3.2 Strains analysis

The strains of two specimens are presented in Figure 5. In Figure 5(a), the strains become gradually bigger and bigger in the ascending stage. Comparatively speaking, the growth speed of C3EL1 and C3EL2. After the peak load, multiple strains decrease quickly but C4EL1 enlarges smoothly. In Figure 5(b), the change of strains is nearly linear along the height of cross section when the loading locates before 0.56Nu, which reflects the rationality of plane cross-section assumption in the range of steel yield strain 1800 microstrain.



(a) BAC

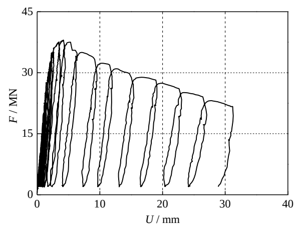


(b) BEC

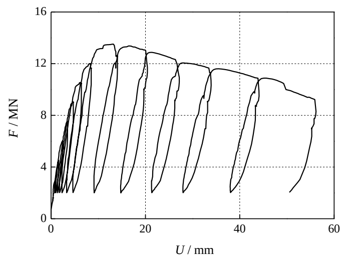
Figure 5. Strains at level 1.132m

3.3 Curves of loading-displacement

As shown in Figure 6, the curves of loading-displacement of two specimen is presented. When the vertical reloading is smaller, the curves show the elastic states of specimens. The relation of loading and displacement is linear line. It is obvious that the stiffness of unloading and loading are consistent. With the development of loading, the linear relation disappear between loading and displacement, which shows the specimen undergoing the state of elastoplasticity or plasticity. After peak load, the bearing capacity and stiffness are little by little degeneration. Two specimens give the good behaviour of axial compression, compressive bending, and ductility by the stiffeners.



(a) BAC



(b) BEC

Figure 6. Curves of loading-displacement

4 Conclusions

(1) The stiffeners in multi-cavity-bifurcated concrete-filled steel tubular column take part in the functions of enhancing bearing capacity and improving ductility.

(2) The plane cross-section assumption is reasonable to the compression and bending of multi-cavity-bifurcated concrete-filled steel tubular column.

Acknowledgements

This work reported in this paper is part of the Project 51578020 supported by the National Natural Science Foundation of China.

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