Journal of Constructional Steel Research 129 (2017) 119–128

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Experimental Study on Torsion Behavior of Concrete Filled Steel Tube Columns subjected to Eccentric Compression

Yu-Hang Wang *, Yi-Fan Guo, Jie-Peng Liu, Xu-Hong Zhou

School of Civil Engineering, Chongqing University, Chongqing 400000, China

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 4 November 2016
Accepted 5 November 2016
Available online xxxx

Keywords:
Concrete filled steel tube column
Pure torsion
Eccentric compression load
Torsion

ABSTRACT

Under gravity and the horizontal earthquake load, the eccentric compression and torsion combined action will be produced in the piers of curved girder bridges and the main arch of arch bridge. In order to study the torsion behavior of concrete filled steel tube columns subjected to eccentric compression, tests were carried out on eight specimens of concrete filled steel tube column subjected to static pure torsion, cyclic pure torsion and eccentric compression-torsion cyclic load. The results of tests have indicated that, the hysteresis curve of concrete filled steel tube column subjected to torsion cyclic load was plump; no pinch phenomenon can be found; the damage and degradation degree of the strength and stiffness of specimens is lower; and high energy dissipation capacity can be achieved. The stiffness degradation of the specimens with square section subjected to eccentric compression-torsion cyclic load is more obvious. The eccentric compression has led to weaken of the energy dissipation capacity of the square section concrete filled steel tube column. Under the ultimate state, the wave angle of steel tube was affected by the eccentric compression.

1. Introduction

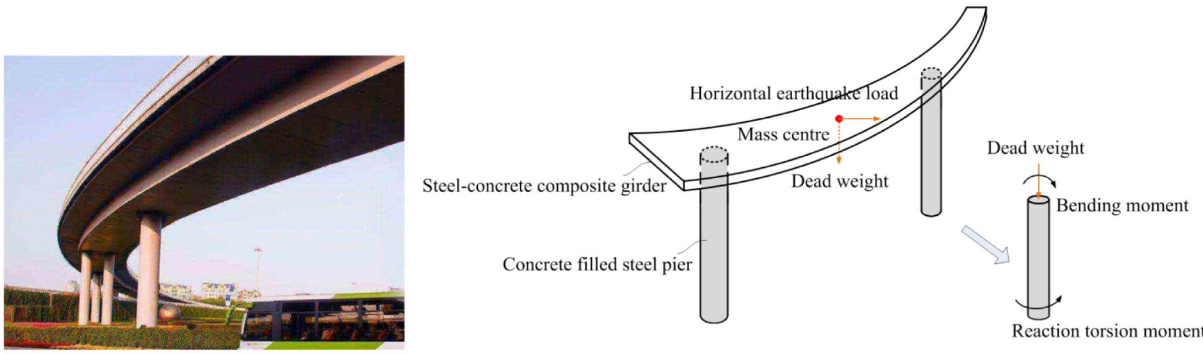
At present, the concrete filled steel tube structure has been widely applied in bridge engineering. In curved girder bridge and other space girder bridge, the gravity of the bridge generates eccentric compression on the pier studs of bridges. As the Fig. 1(a) shows, under horizontal earthquake load, the piers are subjected to the combined effect of eccentric compression and torsion. In the arch beam bridge, as the Fig. 1(b) shows [1], under the gravity and the earthquake action, the main arch is also subjected to the eccentric compression and torsion combined action. In order to improve the design theory of the concrete filled steel tube structure in curved girder bridges, arch bridges and other girder bridges, firstly, the behavior of concrete filled steel tube structures subjected to the eccentric compression and torsion combined action needs to be further studied.

In 1991, Kitada and Nakai have carried out tests on torsion behavior of short square action concrete filled steel columns and contrasted the steel tube columns with short plain concrete columns [2] under pure torsion. Beck and Kiyomiya have carried out tests on concrete filled steel columns specimens with circular sections under pure static torsion. It was found that the concrete filled steel columns had high torsional strength and good ductility. In their tests, superposition method and finite element method were applied to theoretically analyze of the concrete filled steel tube columns mechanical property [3]. Lee has proposed the analysis model of concrete filled steel columns subjected to pure torsion and provided the simplified equations for calculating the torsional capacity of concrete filled steel columns considering axial pressure at ultimate state [4]. In the early 1990s, Han et al. have completed monotonic loading tests on a series of concrete filled steel tube column specimens [5–11], and proposed the equations for calculating the torsion capacity. Nie et al. have carried out tests on a series of concrete filled steel column specimens subjected to pure torsion, axial compression-torsion, bending-torsion [12–16]. In their test, the welded steel tubes are used in the concrete filled steel column specimens. When the torsion angle increases, the vertical crack appear on the steel tube and the specimens could not approach the ultimate state.

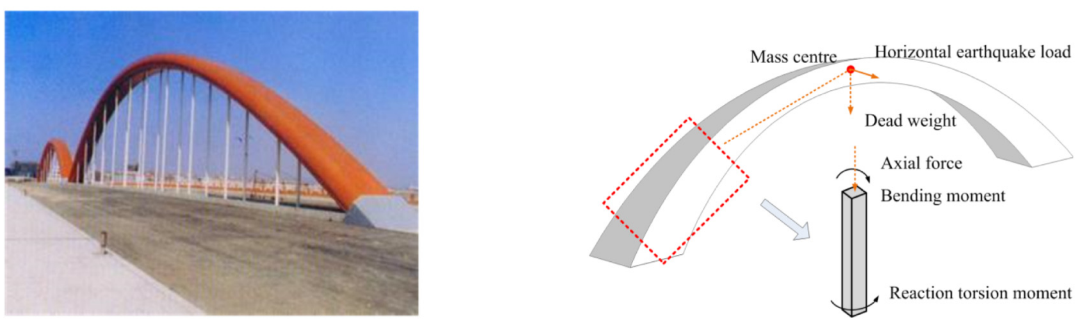
In order to make up the shortcomings in the research of the seismic behavior of concrete filled steel columns subjected to the complex loading in the literatures available, the quasi-static load of pure torsion, cyclic pure torsion and eccentric compression-cyclic torsion load have been applied on the specimens of square and circular section concrete filled steel tube columns with various length. Moreover, through the research of the concrete filled steel tube column subjected to the pure torsion and eccentric compression-torsion combined action, the hysteresis relationship between the torsion moment and the angle, the damage mode, the failure mechanism have been found. Furthermore, the torsion angle, the distribution and development of the tube strain have been preliminarily analyzed based on the test results.

* Corresponding author.
E-mail address: wangyuhang@cqu.edu.cn (Y.-H. Wang).

http://dx.doi.org/10.1016/j.jcsr.2016.11.011
0143-974X/



(a) Curved steel-concrete composite bridge



(b) Concrete filled steel tube arch bridge

Fig. 1. Concrete filled steel tubes subjected to torsion in bridge structures.

2. Test program

2.1. Test specimens

8 specimens of concrete filled steel tube column with square section and circular section are designed. The size of square section is 200 × 200 mm, and the diameter of circular section is 200 mm. The heights of these two kinds of specimens are 975 mm and 475 mm respectively. The steel tubes in the tests are hot-rolling seamless ones. Different loading modes are used in the tests to study the seismic behavior of concrete filled steel tube columns subjected to various mechanical state. The detailed parameters of specimens and loading modes are shown in Table 1, in which the size of the section refers to the actual measured size after the production of steel tube.

When the concrete are poured into steel tubes, concrete cubic blocks with the length 150 mm are produced for material strength test. Concrete cubic blocks and the concrete in specimens are maintained under the same condition [17]. The concrete compressive strength results are shown in Table 2. Based on the methods in literature [18], the yielding strength and the ultimate strength of the steel tubes are tested and the results are shown in Table 3.

2.2. Test setup and loading system

In order to apply the quasi-static cyclic load of compression and torsion on concrete filled steel tube columns, a special loading set-up is designed, as shown in Fig. 2. Two end plates are set with each specimen. The top and the bottom of the specimens are connected to the roof plates and the base plates with fillet weld. High strength bolts are used to connect the roof plates and the rigid girders, the base plates and the steel bases. Pre-tensile force produced in high strength bolts is able to guarantee that no relative slip occurs to the end plates of the specimens, the rigid girders and the steel bases when applying cyclic

Table 1
Parameters of specimens.

Specimen no.	Section size (mm)	Height of the specimen (mm)	Loading mode
R-T1	200.1 × 200.4 × 6.1	975	Pure static torsion
R-T2	200.3 × 200.0 × 6.0	975	Cyclic torsion
R-T3	200.0 × 200.0 × 5.8	475	Cyclic torsion
R-CBT	200.3 × 200.0 × 6.0	975	Eccentric compression-cyclic torsion
C-T1	200.0 × 6.0	975	Pure static torsion
C-T2	200.0 × 6.2	975	Cyclic torsion
C-T3	200.0 × 6.2	475	Cyclic torsion
C-CBT	200.0 × 6.2	975	Eccentric compression-cyclic torsion