Journal of Constructional Steel Research 127 (2016) 231–241

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Experimental study of slender LCFST columns connected by steel linking plates

Minyang Xu [a], Ting Zhou [a,c,*], Zhihua Chen [a,b], Yanbo Li [a], Luke Bisby [d]

[a] Tianjin University, Tianjin, China
[b] Tianjin Key Laboratory of Civil Engineering Structure and New Materials, Tianjin University, Tianjin, China
[c] Tianjin Key Laboratory of Architectural Physics and Environmental Technology, Tianjin University, Tianjin, China
[d] School of Engineering, University of Edinburgh, Edinburgh EH93JN, UK

ARTICLE INFO

Article history:
Received 15 October 2015
Received in revised form 8 August 2016
Accepted 9 August 2016
Available online 15 August 2016

Keywords:
L-shaped composite columns
Experimental investigation
Concrete-filled steel tubes
Steel linking plates
Axial compression
Eccentric compression

ABSTRACT

This paper presents the results of an experimental investigation of L-shaped columns composed of concrete-filled steel tubes (LCFST columns) connected by steel linking plates. As a new kind of composite column, the fundamental structural behavior of LCFST columns connected by steel linking plates is discussed in this paper. Eight large-scale LCFST columns were constructed and loaded under either concentric axial compression or biaxial eccentric compression up to failure. Slenderness ratio, thickness of the steel linking plates and load eccentricities were all studied within the experimental program. The relationships of load versus longitudinal displacement, lateral deflection at mid-height, longitudinal strain at mid-height etc. are presented. It is demonstrated that specimens with larger slenderness ratios or eccentricities have lower ultimate load capacities, as expected. It is also demonstrated that the steel connection plates, also as expected, have a considerable influence on confining lateral deflections of the mono CFST columns and that they significantly contribute to the columns' ultimate carrying capacity. Predictive formulas for calculating the ultimate loads of LCFST columns connected by steel linking plates are proposed based on modifications of the ANSI/AISC 360-05 guidelines.

1. Introduction

In recent years, various types of novel columns for applications in buildings have been widely used and studied all around the world. L-shaped reinforced concrete columns were first studied and the basic structural behavior of this kind of column under concentric or eccentric axial compressive loading was previously investigated by [1–3]. With the advent of high strength concrete and steel, these materials have also been used in L-shaped reinforced concrete columns. Tokgoz et al. [4] experimentally studied the behavior of L-shaped section steel fiber reinforced high strength reinforced concrete and steel-concrete composite columns under eccentric axial compression. Recently, with the increasing usage and popularity of concrete-filled steel tubular columns, owing to their highly efficient load carrying capabilities, inherent deformability and excellent energy dissipation properties, concrete-filled L-shaped (and other novel shaped) steel tube columns have been proposed and studied in considerable detail. For example, Yang et al. [5] studied the compressive behavior of T-shaped concrete-filled steel tubular columns. The seismic behavior of concrete-filled unconventional-shaped steel tube columns was also experimentally investigated by [6], demonstrating that all the specimens exhibited favorable energy dissipation and ductility. Due to the weak bond between the special-shaped steel tubes and concrete in-fill, relative slippage between the two materials was observed to occur at failure.

To improve the properties of concrete-filled novel-shaped steel tube columns, various shapes of columns composed of concrete-filled steel tubes (SCFST columns) linked by shear connections were proposed by Chen et al. [7,8]. Three cross-sectional shapes of L-shape, T-shape, as well as crisscross-shaped columns, when used as corner columns, side columns, and middle columns were previously proposed and experimentally studied. Because of the small width of the concrete filled steel tube mono columns in SCFST columns, SCFST columns can be embedded within the walls of buildings, which in turn enlarges the usable area of the buildings, with obvious benefits for developers. The fundamental structural behavior of SCFST columns connected by 'lacing bars' (i.e. effectively trussed CFST columns) under axial compression was studied by [9].

Based on the research above, SCFST columns connected by steel linking plates were proposed as shown in Fig. 1. Two LCFST columns connected by steel linking plates were tested to investigate the effect of inner concrete on the behavior of the columns by Zhou et al. [10]. The behavior of the columns subjected to constant axial load and cyclically varying flexural load was also investigated by Zhou et al. [11]. Furthermore, related research on the heat transfer properties of this new kind of LCFST column, with a view to better understanding their fire resistance have been carried out using finite element methods [12].The seismic performance of frame structures composed of this novel kind

* Corresponding author at: Tianjin University, Tianjin, China.
E-mail address: tdjgtingzhou@163.com (T. Zhou).

http://dx.doi.org/10.1016/j.jcsr.2016.08.006

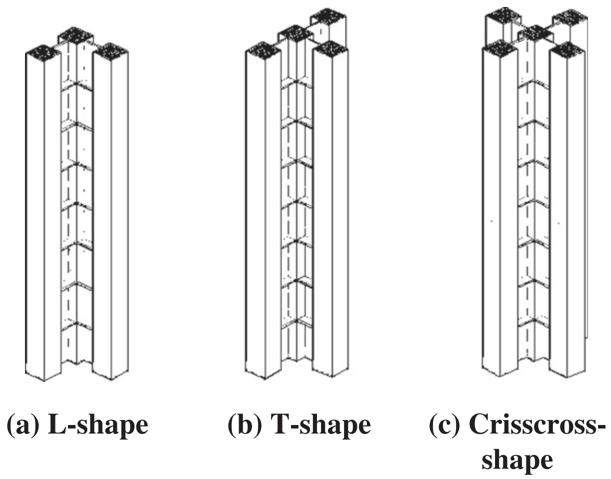

Fig. 1. SCFST columns connected by steel linking plates.

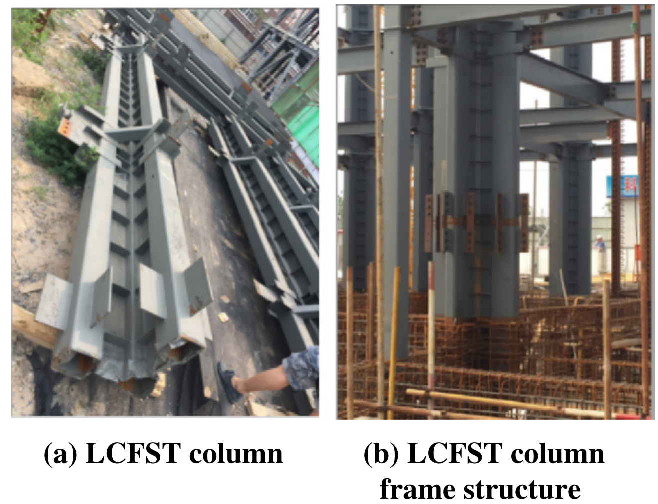

Fig. 2. LCFST columns connected by steel linking plates in Cangzhou China.

of LCFST columns was also recently experimentally studied [13]. Nonetheless, research on this type of LCFST column is limited to date, and a large number of relevant parameters have yet to be investigated.

In the current study, eight large-scale L-shaped specimens were tested under either axial compression or biaxial eccentric compression. Parameters studied include slenderness ratio, thickness of steel linking plates and the eccentricities of applied axial compressive load were selected to analyze their effects on the failure modes and deformation processes of LCFST columns. Specimen layout and experimental setup are described first, followed by discussion of the effects of the three aforementioned parameters on the response of the columns under compressive loading, including load-longitudinal displacement relationships, load-lateral deflection relationships and load-longitudinal strain relationships are presented. LCFST columns connected by steel linking plates are then compared against LCFST columns connected by so-called 'lacing bars' to clearly demonstrate their advantages. Finally, the experimental results are compared with predicted values obtained from proposed formulae based on modification of the ANSI/AISC 360-05 [14] guidelines.

2. Experimental program

2.1. Introduction

Eight large-scale LCFST columns were fabricated and tested. The primary objective of the testing was to study the effects of various parameters including: slenderness ratio, thickness of the steel linking plates and the eccentricities of loading on the failure modes, load carrying capacity and deformation response of the specimens. The test specimens were 2/3 scale LCFST columns; these have already been applied in real projects in residential buildings in Cangzhou, China, as shown in Fig. 2.

2.2. Specimens layout

Vertical stiffeners with a height of 100 mm were welded to the top and bottom of the columns to prevent local failure at the heads of the specimens. Two steel plates with a thickness of 20 mm were also welded to the tops and bottoms of the specimens to apply uniform compressive loads during testing. For the specimens tested under biaxial eccentric compression, the eccentricities were 40 mm or 80 mm from the centroid of the specimens along a symmetry axis, Y′-Y′, as shown in Fig. 3. The details of the columns are shown in Fig. 4. To prevent out-of-plane buckling failure of the steel linking plates, transverse stiffeners were welded to the steel linking plates and steel tubes at a spacing of 200 mm.

All specimens were divided into three groups. The first group, labeled "SR", includes the specimens differing in slenderness ratio, the second group, labeled "T", contains the specimens used to study the effects of thickness of steel linking plates, and the third group, labeled "E", consists of the specimens loaded at different eccentricities. For example, Specimen SR-13.8-1000 had a slenderness ratio λ of 13.8 and a height of 1000 mm; Specimen T-3.75 means the thickness of the steel linking plates is 3.75 mm; and Specimen E-40 means the eccentricity is 40 mm. The test program is summarized in Table 1.

2.3. Material properties

The material properties of the steel were determined using tensile tests on coupons taken from the steel tubes and linking plates. Concrete cube and cylinder tests were used to determine compressive strength and elastic modulus. Mechanical properties of the steel and concrete are shown in Table 2.

2.4. Test setup and instrumentation layout

The tests were performed using a 5000 kN hydraulic compression machine, as shown in Fig. 5. To measure the longitudinal and transverse strains of the specimens, 60 strain gauges were bonded to the top, middle, and bottom of the steel tubes, except the four areas connected to the steel linking plates where strain gauges were bonded onto the mid-height of the areas. Furthermore, another two strain rosettes were bonded to the mid-heights of the steel linking plates to determine the directions of the principal strains as well as longitudinal and transverse strains under different loading conditions. Fig. 6 shows the layout of strain gauges on the specimens. The lateral deflections and longitudinal

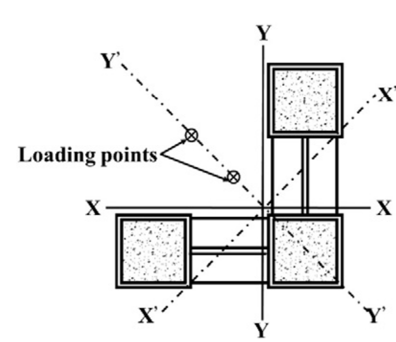

Fig. 3. Arrangement of loading points for specimens under biaxial eccentric loading.