Journal of Constructional Steel Research 114 (2015) 129–135

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Tests on plain and steel fiber concrete-filled stainless steel tubular columns

Serkan Tokgoz

Engineering Faculty, Civil Engineering Department, Mersin University, 33340 Mersin, Turkey

ARTICLE INFO

Article history:
Received 16 February 2015
Received in revised form 9 July 2015
Accepted 10 July 2015
Available online xxxx

Keywords:
Stainless steel tube
Steel fiber concrete
Tubular columns
Confinement
Nonlinear material

ABSTRACT

This paper reports the experimental behavior of plain and steel fiber concrete-filled stainless steel tubular columns under biaxial bending and axial compression. In the experimental study, the length-to-diameter ratios of the stainless steel tubes were 12, 15, and 20. The effects of the main test parameters of concrete compressive strength, cross-section, load eccentricity, steel fiber material and slenderness on the structural behavior of plain and steel fiber concrete-filled stainless steel tubular columns were examined. The ultimate strength capacities, load–deflection relations, and load–axial strain behavior were observed in the tests. The plain and steel fiber concrete-filled tube columns have been analyzed with a theoretical method based on the nonlinear behavior of the materials. The experimental and theoretical biaxial load–deflection diagrams have been obtained and compared in the study. The experimental results have exposed significant knowledge to describe the behavior of plain and steel fiber concrete-filled stainless steel tubular columns.

1. Introduction

Stainless steel tubular columns have been increasingly used in modern structures owing to their superior corrosion resistance, ease of construction and esthetic appearance. Concrete-filled stainless steel tube (CFSST) columns are composed by steel tubes and concrete in-filled material. The stainless steel tube offers lateral confinement to the concrete and in-filled concrete provides resistance to the composite section. CFSST columns exhibit significant structural advantages, such as effective stiffness, high strength capacity, ductility, and confinement [1–9]. This type of members can be filled with both plain and steel fiber concrete materials. It is known that the inclusion of steel fibers improves ductility and deformability of high strength concrete and it eliminates crack propagation. Thus, steel fiber concrete is an effective in-filled material for high strength stainless steel tubes in order to show better structural performance [10–12].

In recent years, some analytical and experimental research studies have been carried out to describe the behavior of CFSST columns. Rasmussen [1] studied the determination of the behavior of stainless steel tubular members and connections. Uy [2] researched local buckling effect on the strength of concrete-filled steel box columns. Mursi and Uy [3] presented experimental and theoretical studies to describe the behavior of concrete-filled high strength steel columns incorporating buckling effect. Ellobody and Young [4,5] and Young and Ellobody [6] conducted theoretical and experimental research works to describe the structural behavior of concrete-filled high strength stainless steel tube columns. Liu [7] investigated the analytical and experimental behaviors of high-strength concrete-filled steel tubular columns. Uy [8] investigated stability and ductility characteristics of CFSST columns. Lam and Gardner [9] presented behavior and design of axially loaded concrete-filled stainless steel circular and square hollow sections. Ellobody and Ghazy [10] and Ellobody [11,12] studied eccentrically loaded plain and fiber reinforced concrete-filled stainless steel circular tubular columns. Young [13] described experimental and numerical investigation of cold-formed high strength stainless steel tubular structures. Dabaon et al. [14] conducted an experimental study on concrete-filled normal strength stainless steel stiffened tubular stub columns. The results were compared with the European [15] and ASCE [16] specifications. Uy et al. [17] reported test results of short and slender CFSST columns to examine their behavior under axial force and bending moment. Tao et al. [18] developed a three-dimensional nonlinear finite element analysis method to describe the behavior of stainless steel columns. Lee et al. [19] conducted experimental tests to determine the capacity of circular concrete-filled tube columns using high strength steel or concrete. Liang [20,21], Liang et al. [22] and Patel et al. [23] proposed numerical models to describe the behavior of biaxially loaded high strength concrete-filled steel tubular beam–columns. It is noted in the previous studies that very limited experimental investigations were conducted to examine the behavior of steel fiber CFSST columns under combined axial load and biaxial bending [11,12].

The main purpose of this study is to examine the structural behavior and strength capacity of stainless steel tube columns in-filled with both plain and steel fiber concrete. A total of 15 CFSST columns were constructed and tested under combined axial compression and biaxial bending. Column strengths, load–deflection behavior, load–axial strain

E-mail address: stokgoz@mersin.edu.tr.

http://dx.doi.org/10.1016/j.jcsr.2015.07.013
0143-974X/

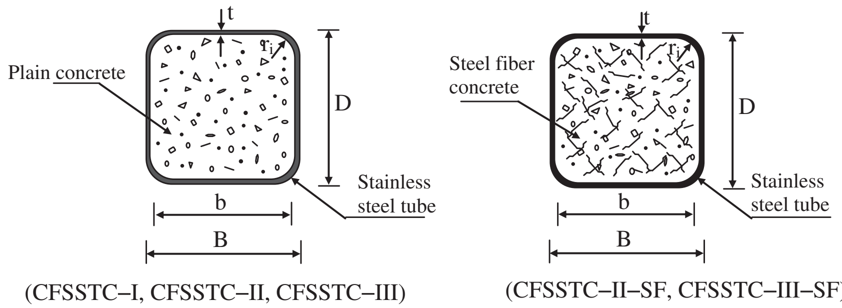

Fig. 1. Cross-sections of plain and steel fiber CFSST columns.

relations and failure modes were observed. The effects of steel fibers on CFSST column behavior have been investigated. In addition, the tested CFSST columns have been analyzed by using a theoretical method and the results have been compared with the experimental results in the study.

2. Experimental investigation

2.1. Test specimens

The experimental program included a total of 15 of both plain and steel fiber CFSST column specimens. TIG welded stainless steel tubes were used for constructing the CFSST columns. The column specimens were manufactured in three series (I, II, and III). Three different concrete mixtures were designed to construct the plain and steel fiber CFSST column specimens. In each series, the section sizes of tubes were 60 × 60 × 3 mm, 80 × 80 × 3 mm, and 100 × 100 × 3 mm, the inner radii (r_i) of these tubes were 6.3 mm, 8.7 mm, and 11.1 mm, respectively. All the CFSST columns were 1200 mm in length. The cross-section details of the CFSST column specimens are presented in Fig. 1. The specimens CFSSTC-I, CFSSTC-II, and CFSSTC-III were filled with plain concrete, the specimens CFSSTC-II-SF and CFSSTC-III-SF were constructed with steel fiber concrete including 0.70% volume fraction of steel fibers. The plain and steel fiber CFSST columns included in the series of II and III (e.g., CFSSTC-II and CFSSTC-II-SF) were designed with almost the same concrete mixtures and tested with the same conditions in order to observe the steel fiber effects. The amount of concrete compositions of the test specimens are given in Table 1.

The plain and steel fiber concrete material were prepared using Portland CEM I 42.5 R-type cement content, maximum sizes of 16 mm, well-dried and clean local aggregates, tap water and the end hooked RC 65/35 BN-type steel fibers. The steel fibers had a length of 35 mm, diameter of 0.55 mm, aspect ratio of 64, and density of 7850 kg/m^3. The fibers were distributed randomly into the steel fiber concrete mixtures. Super-plasticizer was added to the mixtures to provide good workability for both plain and steel fiber concrete. The column specimens were compacted by using a vibrating table. Three control concrete cylinder specimens were cast from each concrete batches to obtain the concrete compressive strength. In the study, two bearing plates were welded at the top and bottom ends of each column specimen to ensure the biaxial bending condition.

Table 1
Concrete mix design for CFSST columns.

Specimen no.	Gravel (kg/m^3)	Sand (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	Plasticizer (kg/m^3)	Steel fiber (kg/m^3)
CFSSTC-I	1120	750	400	150	4	–
CFSSTC-II	1160	710	400	135	6	–
CFSSTC-II-SF	1150	700	400	135	6	55
CFSSTC-III	1180	650	400	125	10	–
CFSSTC-III-SF	1170	640	400	125	10	55

The concrete strengths were determined from standard cylinder tests at the time of the CFSST column tests. In the experimental study, the mean concrete compressive strengths of the CFSST column specimens were obtained between 40.14 and 60.51 MPa (Table 2). The typical experimental stress–strain curves of plain and steel fiber concrete are illustrated in Fig. 2. It is seen in the diagrams that, steel fiber concrete exhibited more ductile behavior when compared with plain concrete. This behavior indicates that, steel fiber concrete can be appropriately used as in-filled material for high strength CFSST columns to provide better deformability. The material properties of the stainless steel were determined by tensile coupon test. The yield strength, ultimate strength and modulus of elasticity of stainless steel material were obtained as 650 MPa, 820 MPa and 200 GPa, respectively.

2.2. Test setup and procedure

The CFSST column specimens were tested by using a hydraulic testing steel frame in the Structural Laboratory at Cukurova University in Adana, Turkey. The specimens were loaded vertically with pinned conditions at both ends subject to combined axial load and biaxial bending. In the tests, a 500 kN capacity load cell and four linear variable displacement transducers were used to measure the applied load and corresponding lateral deflections. In addition, strain gauges were used to obtain the axial strain values. The strain gauges were mounted on the mid-height of the most stressed compressive side of the stainless steel tube columns. In the experimental study, a data acquisition system was used to collect the applied load, lateral deflections and axial strain values at each load increments. The typical test arrangement of the column specimens is illustrated in Fig. 3(a, b). In the tests, the biaxial load was applied to the column specimens in small increments of 1 kN/s. All the column specimens were loaded from zero to failure in the study.

The properties of the cross-section dimensions, the diameter-to-plate (D/t) thickness, the length-to-diameter (L/D) ratios, the average concrete compressive strength (f_c), and the eccentricities of applied

Table 2
Properties of CFSST column specimens.

Specimen no.	B × D × t (mm)	D/t	f_c (MPa)	e_x (mm)	e_y (mm)
CFSSTC-I	60 × 60 × 3	20	40.14	30	30
	80 × 80 × 3	26.67	40.14	40	40
	100 × 100 × 3	33.33	40.14	50	50
CFSSTC-II	60 × 60 × 3	20	54.32	35	35
	80 × 80 × 3	26.67	54.32	45	45
	100 × 100 × 3	33.33	54.32	55	55
CFSSTC-II-SF	60 × 60 × 3	20	53.18	35	35
	80 × 80 × 3	26.67	53.18	45	45
	100 × 100 × 3	33.33	53.18	55	55
CFSSTC-III	60 × 60 × 3	20	58.42	45	45
	80 × 80 × 3	26.67	58.42	55	55
	100 × 100 × 3	33.33	58.42	65	65
CFSSTC-III-SF	60 × 60 × 3	20	60.51	45	45
	80 × 80 × 3	26.67	60.51	55	55
	100 × 100 × 3	33.33	60.51	65	65