Thin-Walled Structures 117 (2017) 224–238

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Full length article

# Experimental research on circular concrete filled stainless steel tubular truss

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A R T I C L E I N F O

*Keywords:*
Concrete-filled stainless steel tubular truss
Ultimate load carrying capacity
Failure modes
Location of concrete-filled
Overall deflection
Flexural rigidity

A B S T R A C T

The flexural behaviour of circular concrete filled stainless steel tubular trusses is presented in this paper. A total of four specimens were tested, including three circular concrete filled stainless steel tubular truss and one hollow circular stainless steel tubular truss. All specimens were tested under static load. The main parameter explored in the test included the location of concrete-filled. (Case 1: Concrete-filled top chord. Case 2: Concrete-filled bottom chord. Case 3: Concrete-filled top and bottom chord. Case 4: Hollow circular stainless steel tubular truss.) This paper presents the failure modes, overall deflections, load-strain curves, load versus displacement curves and load carrying capacity of all the tested specimens. It was found that the typical failure mode includes: the surface plasticity of the top chord, the weld fracture and crack around tubular joints at the bottom chord, and the bent of the top and bottom chords. The flexural rigidity, load carrying capacity and ductility of different types of circular concrete filled stainless steel tubular trusses are different due to the remarkable changes of the location of concrete-filled. It is demonstrated from the comparison that the truss of concrete filled in both top and bottom chord (CC100 × 2.0-BC76 × 2.0-C30A) has the best flexural rigidity and the greatest load carrying capacity per unit truss weight. Whereas, the truss of concrete filled in top chord (CC100 × 2.0-BC76 × 2.0-C30T) has the best ductility.

## 1. Introduction

The use of stainless steel tubular truss girders in exhibition halls, pipeline structures, stadiums and bridges has become increasingly popular all over the world in recent decades; and it is now a highly competitive alternative to traditional tubular trusses. However, the flexural rigidity and load carrying capacity of hollow stainless steel tubular trusses are rather limited as a consequence of the rapid development of the increase of all types of loads and longer-span structures. The stainless steel tubular truss is commonly reinforced by filling the chord members with grout or concrete to increase its flexural rigidity and load carrying capacity. Researchers, all over the world, attach great importance to the issue of steel tubular truss; however, some studies have been mainly focus on steel truss connections and concrete-filled steel tube columns, while the mechanical behaviour of stainless steel tubular truss has not been investigated in detail. Therefore, it is of great significance and prospects to study the mechanical properties of circular concrete filled stainless steel tubular truss under static loading.

In the past decades, a series of tests had been carried out by Chen et al. [1] to investigate the experimental study on concrete-filled multiplanar tubular trusses made of circular hollow section (CHS) members. Feng and Chen [2] presented a numerical investigation on concrete-filled multi-planar circular hollow section (CHS) inverse-triangular tubular truss. Experimental and numerical studies on the behaviour of concrete-filled multiplanar tubular trusses made of circular hollow section (CHS) members described the optimum geometric parameters of the truss in practice. Based on the results of an experimental investigation on a novel hollow connector, referred to as the Howick Rivet Connector (HRC), the bearing strength of the HRC Tee-stubs are proposed by Ahmadi et al. [3]. Zeynalian et al. [4] took eighteen full scale cold-formed steel truss connections tests to investigate the behaviour of cold formed steel truss connections. The study investigated the main factors contributing to the ductile response of the CFS truss connections in order to establish some recommendations for connection designs, the connections respond plastically with a significant drift and without any risk of brittle failure. A new design model of the CFDST short columns was proposed and shown to be a reliable predictor under axial load by Hassanein et al. [5]. Li et al. [6] took twenty four concrete filled GFRP and stainless steel tubular stub columns tests to investigate mechanical and associated properties of concrete (SWSSC) filled glass fiber reinforced polymer (GFRP) and stainless steel (SS) circular tubes exposed to seawater and sea sand. Gao et al. [7] tried to provide an effective method to generate the ground structure in truss topology optimization. Farshchin et al. [8] carried out a new optimal design of circular concrete filled stainless steel tubular

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http://dx.doi.org/10.1016/j.tws.2017.04.026
Received 19 March 2017; Accepted 24 April 2017

**Nomenclature**

| | |
|---|---|
| $d_0$ | chord outer diameter |
| $t_0$ | chord wall thickness |
| $d_1$ | brace outer diameter |
| $t_1$ | brace wall thickness |
| $\beta_1$ | brace diameter-to-chord diameter ratio |
| $\tau_1$ | brace thickness-to-chord thickness ratio |
| w | weld sizes |
| $f_y$ | yield stress |
| $f_{cu}$ | concrete cube strength |
| $F_y$ | yield loads |
| $F_p$ | peak loads |
| $\Delta_y$ | midspan deflection corresponding to the yield load |
| $\Delta_p$ | midspan deflection corresponding to the peak load |
| $\Delta_m$ | midspan deflection |
| $\Delta$ | vertical deflection |
| E | the axial strain |

truss. A system for classification of truss structure types is presented by Zok et al. [9]. A heuristic particle swarm ant colony optimization (HPSACO) is presented for optimum design of trusses by Kaveh et al. [10]. Liu et al. [11] described a study on the effect of concrete filled chord in rectangular hollow section (RHS) and circular hollow section (CHS) steel tube truss. Results of the test found that RHS and CHS trusses have no difference in the load bearing capacity and deformation, while with chord members filled with concrete, the CHS trusses have higher capacity of the overall truss and joints, better deformability than the corresponding RHS trusses. Uy et al. [12] found the behaviour of short and slender concrete-filled stainless steel tubular columns. The results indicated that the performance of the composite columns have the potential to be used extensively as structural members.

Although many researchers have investigated the performance of concrete-filled tubular truss and stainless steel tubular stub columns, there are few research projects being carried out on the behaviour of circular concrete filled stainless steel tubular truss. This paper mainly investigates the flexural performance of stainless steel trusses. The test parameter included the location of concrete-filled. The failure modes, overall deflection, load-strain curves, load versus displacement curves and load carrying capacity of all the specimens, are presented in this paper.

## 2. Experimental study

### 2.1. Test specimens

A total of four types of circular concrete filled stainless steel tubular trusses including the truss of concrete filled in top chord (CC100 × 2.0-BC76 × 2.0-C30T), the truss of concrete filled in bottom chord (CC100 × 2.0-BC76 × 2.0-C30B), the truss of concrete filled in both top and bottom chord (CC100 × 2.0-BC76 × 2.0-C30A) and the hollow circular stainless steel tubular truss(CC100 × 2.0-BC76 × 2.0-C0) were designed according to the design guidelines given in the CIDECT code [13]. The label ‘CC100 × 2.0-BC76 × 2.0-C30T’ contents the following meaning:

The first letter ‘C’ denotes circular section.

The second notation ‘C100 × 2.0’ denotes the dimension of chord members are Φ100 × 2.0 in which ‘100’ indicates the outer diameter of stainless steel tube is 100 mm and ‘2.0’ indicates the wall thickness of stainless steel tube is 2.0 mm.

The third part of the label ‘BC76 × 2.0’ denotes the dimension of brace members are Φ76 × 2.0, in which ‘76’ indicates the out diameter of stainless steel tube is 76 mm and ‘2.0’ indicates the wall thickness of stainless steel tube is 2.0 mm.

The last part of the label ‘C30T’ indicates that the specimen was fabricated by filling concrete with nominal cube strength of 30 MPa in the top chord.

In this paper, the main parameter in the test is the location of concrete filled in the CHS stainless steel tubular truss. For convenience, specimens CC100 × 2.0-BC76 × 2.0-C30A, CC100 × 2.0-BC76 × 2.0-C30B, CC100 × 2.0-BC76 × 2.0-C30T, CC100 × 2.0-BC76 × 2.0-C0, are called specimens CA, CB, CT and CH for short, respectively. ‘T’ represents top chord, ‘B’ represents bottom chord, ‘A’ represents top and bottom chord, ‘H’ represents hollow top and bottom chord. All specimens were fabricated by filling the concrete in the chord members to optimize the structural performance of the element. All specimens are trusses with k joint, symmetric geometry, the same loading application and boundary conditions. Hence, the internal forces of brace members along the truss span are also in symmetry. The nominal dimensions of circular hollow section (CHS) members including chord members and brace members of all types of planar tubular trusses are identical, in which the overall length, width and height are 3300 mm, 100 mm and 500 mm, respectively. The effective span between the end supports of the top chord members is 3000 mm. Therefore, the height-to-span ratio and height-to-width ratio are 1:6 and 5:1, respectively. The distance of each two tubular joints is 500 mm along the truss span. The dimension of top and bottom chord members of all specimens are Φ100 × 2.0, in which “100” indicates the outer diameter ($d_0$) is 100 mm and ‘2.0’ indicates the wall thickness ($t_0$) is 2.0 mm. Also, the dimension of brace members of all specimens are Φ76 × 2.0, in which ‘76’ indicates the outer diameter ($d_1$) is 76 mm and ‘2.0’ indicates the wall thickness ($t_1$) is 2.0 mm. The outer diameter-to-chord thickness ($d_0/t_0$) of the corresponding top chord is equal to 50.0, which is identical to that of the bottom chord. The outer diameter to thickness ratio ($d_1/t_1$) of the corresponding brace is equal to 38.0. The corresponding brace diameter-to-chord diameter ratio ($\beta_1 = d_1/d_0$) and brace thickness-to-chord thickness ratio ($\tau_1 = t_1/t_0$) are equal to 0.76 and 1.00, respectively. The flexural behaviour of all specimens are shown in Fig. 1. The dimensions of all types of concrete-filled planar CHS stainless steel tubular structure truss including chord members and brace members are detailed in Fig. 2.

The welds connections of brace and chord members were designed according to the American Welding Society (AWS D1.1/1.1M)

(a) Front view  (b) Side view

**Fig. 1.** All specimens after test.