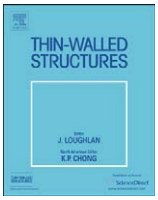
Thin-Walled Structures 47 (2009) 1272–1280

Contents lists available at ScienceDirect

Thin-Walled Structures

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



Concrete-filled aluminum circular hollow section column tests

Feng Zhou, Ben Young *

Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China

ARTICLE INFO

Article history:
Received 4 March 2009
Received in revised form
31 March 2009
Accepted 31 March 2009
Available online 8 May 2009

Keywords:
Aluminum tubes
Circular hollow sections
Composite columns
Concrete
Experimental investigation
Tubular structures

ABSTRACT

An experimental investigation of concrete-filled aluminum circular hollow section (CHS) stub columns is presented in this paper. A series of tests was conducted to investigate the effects of the geometric dimension of the aluminum CHS and concrete strength on the behavior and strength of concrete-filled aluminum CHS stub columns. The structural performance of the concrete-filled aluminum CHS stub columns was investigated using different concrete cylinder strengths of 40, 70 and 100 MPa. The CHS tubes were fabricated by extrusion using 6061-T6 heat-treated aluminum alloy having nominal 0.2% proof stress of 240 MPa. The diameter-to-thickness ratio of the CHS tubes ranged from 9.7 to 59.7. The column lengths were chosen so that the length-to-diameter ratio generally remained at a constant value of 3 to prevent overall column buckling. The concrete-filled aluminum CHS specimens were subjected to uniform axial compression. The column strengths, load-axial shortening relationship, load-axial strain relationship and failure modes of columns were presented. The test strengths were compared with the design strengths calculated using the American specifications and Australian/New Zealand standards for aluminum and concrete structures. It is shown that the design strengths are generally conservative for concrete-filled aluminum CHS stub columns.

1. Introduction

It is well known that concrete-filled steel composite columns have the advantages of high-bearing capacity and ductility, easy construction and cost saving [1–4]. Similarly, aluminum tube columns filled with concrete can effectively take advantages of these two materials to provide both high strength and high stiffness. Furthermore, the aluminum tubes surrounding the concrete core eliminate permanent formwork; hence, construction time can be reduced. However, little research has been carried out on concrete-filled aluminum tube composite columns. Hence, there is a need to investigate the structural performance of concrete-filled aluminum tube columns.

Experimental investigation of concrete-filled aluminum square and rectangular hollow sections (SHS and RHS) composite columns was reported by Zhou and Young [5]. A series of tests was conducted to investigate the effects of the section size of the aluminum tubes, plate thickness and concrete strength on the behavior and strength of concrete-filled aluminum tube columns, using square and rectangular hollow sections. The structural performance of the concrete-filled aluminum tube columns was investigated using different concrete cylinder strengths. The tubes were fabricated by extrusion using 6061-T6 heat-treated aluminum alloy. The overall depth-to-thickness ratio of the tube sections ranged from 8.2 to 63.8. It was shown that the stiffness of the composite columns improves compared with the aluminum SHS and RHS tube columns without concrete infill. Local buckling of the aluminum SHS and RHS tubes was found for specimens with slender sections. Generally, the composite columns failed by the aluminum tubes splitting near the corner of the SHS and RHS sections. Therefore, the design strengths predicted using the American and Australian/New Zealand (AS/NZS) specifications are generally unconservative for most of the concrete-filled aluminum SHS and RHS tube columns.

Circular hollow section (CHS) tube provides much better confining effect to concrete core, especially, when the diameter-to-thickness (D/t) ratio is small compared with SHS and RHS tubes [6]. Furthermore, splitting of aluminum CHS tube is not likely to occur.

The purpose of this paper is to investigate the structural behavior and strength of concrete-filled aluminum CHS stub columns by testing. A series of tests was performed on aluminum CHS tubes with concrete infill of different strengths. The stub composite columns were subjected to uniform axial compression. The dimensions of the aluminum tube cross-sections were chosen, so that they include both compact and relatively slender sections. The test strengths were compared with the design strengths calculated using the general design guidelines specified in the American specifications [7,8] and Australian/New Zealand standards [9,10], for aluminum and concrete structures.

---

* Corresponding author. Tel.: +852 2859 2674; fax: +852 2559 5337.
E-mail address: young@hku.hk (B. Young).

0263-8231/$ - see front matter
doi:10.1016/j.tws.2009.03.014

Nomenclature

The following symbols are used in this paper:

A_a	full cross-section area of aluminum CHS tube
A_c	area of concrete
D	outer diameter of CHS
E_0	initial Young's modulus
F_L	limit state stress of aluminum tube
f_c	measured concrete cylinder strength
k_c	coefficient for compression members
L	length of column specimen
P	design strength
P_{AA-1}	nominal axial strength calculated using the American specifications according to design approach 1
P_{AA-2}	nominal axial strength calculated using the American specifications according to design approach 2
$P_{AS/NZS-1}$	nominal axial strength calculated using the Australian/New Zealand standards according to design approach 1
$P_{AS/NZS-2}$	nominal axial strength calculated using the Australian/New Zealand standards according to design approach 2
P_{-3}	nominal axial strength calculated according to design approach 3
P_{Exp}	test ultimate load (test strength)
t	thickness of aluminum CHS tube
ε_f	elongation (tensile strain) after fracture based on gauge length of 50 mm
$\sigma_{0.2}$	static 0.2% proof stress
σ_u	static ultimate stress
Δ	axial shortening of specimens

2. Experimental investigation

2.1. Test specimens

A series of tests was conducted to study the structural performance of concrete-filled aluminum circular hollow section stub columns. The CHS tubes were fabricated by extrusion using 6061-T6 heat-treated aluminum alloy, hence the residual stresses of the tubes are very small and can be ignored. The test program consisted of ten test series of CHS tubes (CHS1–CHS10). The nominal section sizes ($D \times t$) of series CHS1, CHS2, CHS3, CHS4, CHS5, CHS6, CHS7, CHS8, CHS9 and CHS10 are 38×4, 50×3, 60×2.5, 76×2, 100×2, 120×2.5, 150×2.5, 150×5, 160×4 and $180 \times 3.5\,\text{mm}^2$, respectively, where D is the diameter and t is the thickness of the sections, as shown in Fig. 1. The measured diameter-to-thickness ratio of the CHS tubes ranged from 9.7 to 59.7. The column lengths (L) were chosen so that the length-to-diameter ratio (L/D) for the concrete-filled aluminum CHS stub columns generally remained at a constant value of 3 to prevent overall column buckling. The column specimens were tested using nominal concrete cylinder strengths of 40, 70 and 100 MPa. The aluminum CHS stub columns without concrete infill were also tested for reference purposes. The measured dimensions of the concrete-filled aluminum CHS stub column test specimens are shown in Table 1.

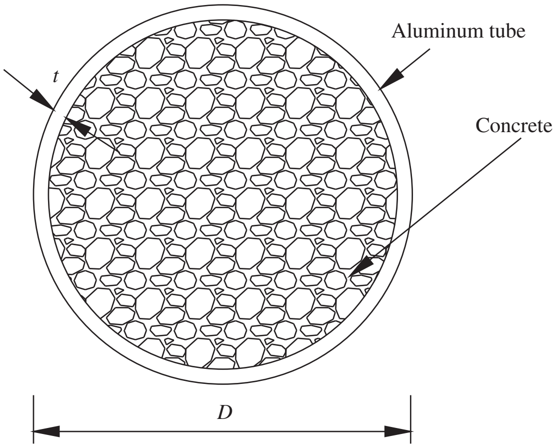


Fig. 1. Definition of symbols for concrete-filled aluminum circular hollow section (CHS) specimens.

2.2. Specimen labeling

In Table 1, the column test specimens are labelled such that the shape of the aluminum tube and nominal concrete cylinder strength could be identified from the label. For example, the label "CHS6C70-R" defines the following specimen:

- The first four letters indicate the shape of aluminum tube and the test series, where CHS is the circular hollow section. This specimen label defines the specimen belonged to test series CHS6, with the nominal dimensions of the CHS of $120 \times 2.5\,\text{mm}^2$.
- The following notation "C70" indicates the nominal concrete cylinder strength in MPa, where "C70" indicates 70 MPa.
- If a test was repeated, then "-R" indicates the repeated test.

2.3. Material properties of aluminum tubes

The material properties of the aluminum tube specimens were determined by tensile coupon tests as well as stub column tests. The tensile coupons were taken from the curved faces of the CHS tubes in the longitudinal direction. The coupon specimens of 6 mm wide with a gauge length of 25 mm were extracted from the CHS tubes. Circular holes with a diameter of 8.5 mm were drilled near both ends of the curved coupons, and the coupons were tested between two pins in a MTS displacement-controlled testing machine. This avoids the bending stress that could be introduced from the singly-symmetric-shaped coupons during the tests. Two strain gauges and a calibrated extensometer of 25 mm gauge length were used to measure the longitudinal strain. A data acquisition system was used to record the load and strain at regular intervals during tests. The static load was obtained by pausing the applied straining for 1.5 min near the 0.2% tensile proof stress and near the ultimate tensile strength. This allowed stress relaxation associated with plastic straining to take place. The material properties obtained from the tensile coupon tests are summarized in Table 2, which includes the static 0.2% tensile proof stress ($\sigma_{0.2}$), static tensile strength (σ_u), initial Young's modulus (E_o) and elongation after fracture (ε_f) based on a gauge length of 50 mm. The typical stress–strain curves obtained from the tensile coupon tests for compact section of CHS2 and relatively slender section of CHS9 are shown in Figs 2(a) and (b), respectively.

The stub column tests of the aluminum CHS tubes were conducted to determine the material properties of the complete