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Behavior of thin-walled dodecagonal section double skin concrete-filled steel tubular beam-columns

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ABSTRACT

The behavior of thin-walled dodecagonal section double skin concrete-filled steel tubular beam-columns was investigated in this paper. A series of tests were carried out on specimens having the length of 2000 mm. Both outer and inner tubes of test specimens were cold-formed steel dodecagonal hollow sections (DHS). The diameters of outer and inner steel tubes of test specimens were 400 mm and 240 mm, respectively. Each test specimen was tested to failure, and the behavior under loading was recorded. Finite element model was developed using ABAQUS and verified against the test results. Parametric study was conducted using the verified finite element model. The suitability of current design methods was evaluated.

1. Introduction

The use of concrete-filled steel tubes (CFST) is growing because of their superior performance. A creative innovation of composite construction is known as concrete-filled double skin steel tubes (CFDST) which were introduced and have been studied by many researchers [1]. CFDSTs are composite members which consist of an inner and outer steel skin with the annulus between the skins filled with concrete [2]. CFDSTs also hold the characteristics of concrete-filled steel tubes (CFST), and have less self-weight. This kind of composite columns have been recognized to have a series of advantages, such as high strength and bending stiffness, good seismic and fire performance [3]. The outer and inner steel tubes can either have the same or different cross-sections of CFDSTs, the cross sections of CFDSTs previously studied are shown in Fig. 1.

In recent years, many studies have been carried out on concrete filled double skin tubular (CFDST) columns. Han et al. [4–6] conducted a series of tests on CFDST stub columns and beam-columns with the sections of Fig. 1(a), (d) and (e), and corresponding analytical models are derived to predict the load capacity. Zhao et al. [7–9] studied the behavior of CFDST stub columns subjected to axial compression with the sections of Fig. 1(b) and (c). Lin and Tsai [10] tested specimens subjected to combined axial and flexural loading with the section of Fig. 1(a). Tan and Zhang [11] investigated the behavior of CFDSTs subjected to axial compression with the section of Fig. 1(a).

In retrospection of the former studies on circular or rectangular/square section CFDSTs, investigation were also carried out on CFDSTs having other cross sections. Yuan and Yang [12] investigated the CFDST stub columns with octagonal section. Chen et al. [13,14] reported the tests of dodecagonal section CFDSTs subjected to axial compression and bending, respectively. The dodecagonal section double skin concrete-filled steel tube is expected to have better local buckling resistance compared with rectangular/square section CFDSTs. It is also expected to have the advantages of easy fabrication and connecting to brace compared with circular section CFDSTs.

This paper is devoted to investigate the behavior of thin-walled dodecagonal section concrete-filled double skin steel tubular beam-columns. Special attention was placed on the measured deformation and strength in order to discuss the behavior of dodecagonal section CFDSTs subjected to combined axial compression and flexural loading. Finite element analysis was conducted to further investigate the failure mode and the ultimate bearing capacity of tested specimens. Parametric study was carried out using the verified finite element model. The suitability of current design methods was evaluated.

2. Experimental investigation

2.1. Test specimens

The test specimens were fabricated by cold-formed a flat steel plate into a dodecagonal shape, and then the ends of the steel tubes were cut to specified length of 2000 mm. The outside

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Nomenclature

D_o	diameter of the outer steel tube;
D_i	outside diameter of inner tube;
E	elastic modulus of steel;
E_c	elastic modulus of concrete;
f_{cu}	compressive strength of concrete;
f_y	yield stress of steel;
f_u	ultimate tensile strength of steel;
L	length of member;
$N_{u\text{-}A}$	ultimate bearing capacity calculated by proposed method based on AISC Standard;
$N_{u\text{-}H}$	ultimate bearing capacity calculated by Han's method;
$N_{u\text{-}F}$	ultimate bearing capacity calculated by finite element analysis;
N_{ue}	ultimate bearing capacity obtained from test results;
M	required flexural strength;
M_i	ultimate bending moment of the inner steel tube;
M_n	nominal flexure strength;
M_o	combination ultimate bending moment of outer tube and the sandwiched concrete;
P	required compression strength;
P_i	compression strength of the inner steel tube;
M_n	nominal compression strength;
M_o	combination compression strength of outer tube and the sandwiched concrete;
t_i	thickness of inner steel tube;
t_o	thickness of outer steel tube;

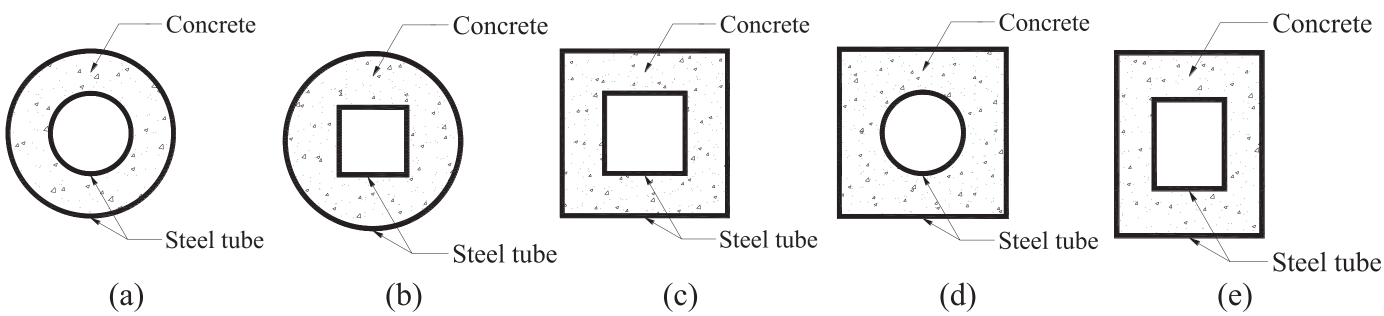

Fig. 1. Concrete-filled double-skin steel tubes previously studied.

Table 1
Geometric size of the test specimens.

Specimen	Geometric size				
	L/mm	D_o/mm	t_o/mm	D_i/mm	t_i/mm
DCS400-3-240-0	2001	399.5	2.99	240.2	2.99
DCS400-3-240-15A	2000	401.2	3.00	240.3	2.99
DCS400-3-240-15	1998	400.5	3.01	239.9	3.02
DCS400-3-240-45	2002	400.6	3.01	239.8	3.03
DCS400-4-240-0	1999	399.8	4.00	240.1	3.00
DCS400-4-240-15	2000	400.0	4.01	240.3	3.00
DCS400-4-240-45	2001	400.2	4.00	240.0	3.01

surface of inner steel tubes and insides surface of the outer steel tubes were brushed to remove any rust and loose debris present. Both the outer and inner steel tubes were placed centric. The self-compacting concrete was cured without any vibration. During curing, a very small amount of longitudinal shrinkage occurred at the top of the column. High strength cement was used to fill this longitudinal gap before the welding of the top steel end plate. Two 20 mm thick steel plates were welded to both ends of the specimens to ensure full contact between specimens and end bearing. There are seven dodecagonal section CFDST specimens designed in this test. The measured geometric size of the test specimens is shown in Table 1, and the geometric size labels are defined in Fig. 2.

The test specimens were labeled so that the type of the specimen, outer diameter of outer steel tube, nominal thickness of outer steel tube, outer diameter of inner steel tube and eccentric distance could be identified from the label. It should be noted that all inner steel tubes have the nominal thickness of 3 mm. For example, the label "DCS400-4-240-15A" defines the specimen as follows:

- The three letters indicate that the type of the specimen, where the prefix letter "DCS" refers to dodecagonal section double skin concrete-filled steel tubes.
- The following three digits "400" indicate the outer diameter of the outer steel tube in mm.
- The following digit "4" is the nominal thickness of the outer steel tube in mm.
- The following three digits "240" indicate the outer diameter of the inner steel tube in mm.
- The following digit "15" is the eccentric distance in mm.
- The last character "A" refers to the repeated test specimen.

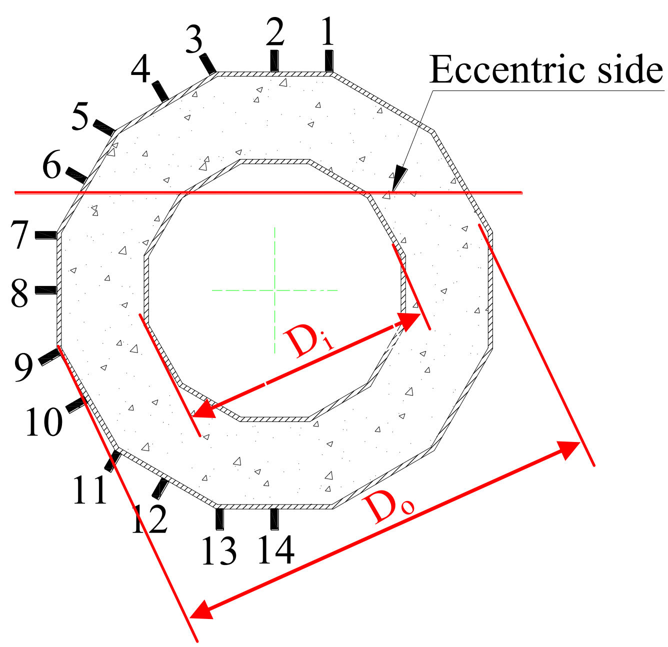

Fig. 2. Size sketch diagram of test specimen and arrangement of strain gauges.