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CFDST stub columns having outer circular and inner square sections under compression

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ABSTRACT

Concrete filled double skin steel tubular (CFDST) members, having a hollow section consisting of two concentric steel tubes and filled concrete between the two walls of the tubes, are lighter than the ordinary concrete filled steel tubular (CFT) members, which have solid cross-sections. Therefore, the CFDST members can work effectively as seismic resistant structures such as bridges high piers during earthquake.
The present study aims to investigate experimentally centric loading characteristics of the CFDST stub column consisting of an outer circular steel tube and an inner square steel tube with in-filled concrete between the double walls, which are abbreviated as CS-CFDST. The two selected testing parameters are the outer tube's diameter-to-thickness ratio and inner width to outer diameter ratio. From the results, observed failure modes were divided into two groups: local buckling associated with shear failure of in-filled concrete and local buckling of the double tubes. These failure modes were affected by inner width to outer diameter ratio. Axial load capacities were also determined by the above described failure modes. Additionally, elasto-plastic biaxial stress behavior of both tubes under plane stress condition is also mentioned. Methods to predict the axial load capacities of CS-CFDST stub columns are also provided.

1. Introduction

A concrete filled double skin tubular (CFDST) member consists of double concentric steel tubes and in-filled concrete sandwiched between their walls as shown in Fig. 1. CFDST members, which have hollow cross-sections, are lighter than ordinary concrete filled steel tubular (CFT) members [1,2], which have solid cross-sections. If CFDST members are applied to bridge high piers, they work effectively as the seismic resistant structures due to the hollow cross section of inner tube.

Tracing the history of past studies on CFDST members, experimental and analytical studies on double circular steel tubes with polymer concrete for marine structural member [3,4] can be found first. Secondly, double concentric circular tubes stub columns [5,6,7], CFDST stub columns having inner rectangular columns inside outer circular columns [8], stub columns having inner circular columns inside rectangular outer columns [9] and double concentric rectangular (square) steel tubes [10] under compression can be found. Then, Tao [11] and Han [12,13] carried out test on beam-columns made out of CFDST members. Next, partially loading and pure torsion tests on CFDST members have been carried out by Yang [14] and Huang [15]. Last, CFDST stub columns with external stainless steel [16,17] can be found.

Under the above described background, the author has carried out five systematic studies on CFDST members consisting of double circular steel tubes having filled concrete between their walls, which were abbreviated as CC-CFDST, with large outer tube's diameter-to-thickness ratio (D_o/t_o) that ranged from 69 to 160 as follows. First, centric compressive loading test on CC-CFDST was carried out and design equations have been proposed [18]. Second, symmetric four-point loading test on CC-CFDST beams under pure bending moment was performed [19]. Thirdly, symmetric three-point loading test under bending and shear was carried out [20]. Then, a comparison of mechanical behavior of the test results of pure bending and centric compressive tests of CC-CFDST members was discussed [21]. From the above series of experimental results, it was concluded that the mechanical behavior of CC-CFDST members was significantly affected by inner-to-outer diameter ratio (D_i/D_o). This is mainly due to the reduction of confined stress on the in-filled concrete between the double tubes. In addition, asymmetric four-point loading test on CC-CFDST deep beam with large diameter-to-thickness ratio was performed by the author [22]. As the double circular tubes presented no ovalization during the loading tests [22], the results showed that shear strength of CC-CFDST could be predicted through the same method as that for RC deep beams.

The present study aims to investigate experimentally the axial loading characteristics of twelve specimens of the CFDST stub columns consisting of an outer circular steel (CHS) section and an inner square hollow steel (SHS) section and filled concrete sandwiched between the two walls, which are abbreviated as CS-CFDST. Two testing parameters were selected, namely, the outer tube's diameter-to-thickness ratio (D_o/t_o) ranging from 69 to 160 and inner width to outer diameter

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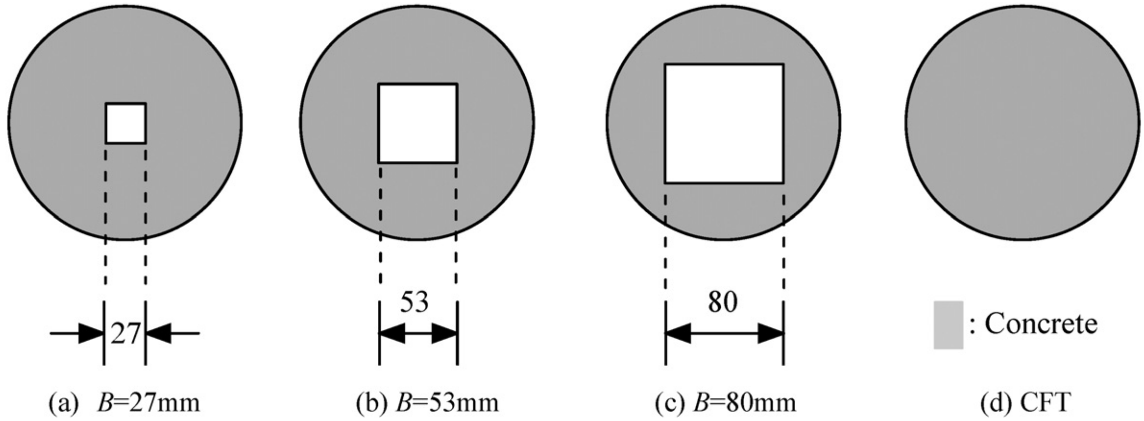

Fig. 1. Cross-section of CFDST ($D_o = 160$ mm).

ratio (B/D_o) ranging from 0.0 to 0.5. The adopted test specimens had combinations of various D_o/t_o and B/D_o. The methods to predict axial loading capacities of CS-CFDST stub columns composed of an inner square hollow section and an outer circular section with large diameter-to-thickness ratio and in-filled concrete are also discussed. In addition, a comparison of axial loading capacity of CC-CFDST [18] is also provided. Part of this study has been already reported in Japan [23].

2. Experimental setup

2.1. Test specimens

Table 1 summarizes the characteristics of the test specimens. Outer tube's diameter (D_o) and specimen's height (H) are 160 mm and 450 mm, respectively and are common to all specimens. As outer and inner tubes' thicknesses, t_i and t_o, three different values, namely, 1.0 mm, 1.6 mm and 2.3 mm were assumed. Therefore, diameter-to-thickness ratios of outer tube (D_o/t_o) and inner width to outer diameter ratios (B/D_o) ranged from 69.6 to 160 and 0.0(CFT) to 0.50, respectively. The detailed cross sections of the specimens are illustrated in Fig. 1.

After bending a thin plate into a cylindrical shape, the edges of the outer circular tube were welded together so as to form a pipe. Biaxial stresses of the inner tube remained in compression due to the surrounding filled concrete. Therefore, due to the surrounding filled concrete, no cracks appeared in the lateral direction at the four corners of the square pipe.

Table 1
List of the specimens.

		Steel tube						
		Thickness	Outer tube's diameter	Inner tube's width	Ratios		Yielding point	Concrete strength
No.	Tag	t (mm)	D_o (mm)	B (mm)	D_o/t	B/D_o	f_y (MPa)	f_c' (MPa)
1	CS10-00	1.0		0.0	160.0	0.00	201	36.5
2	CS10-27	1.0		27.0	160.0	0.17	199	32.3
3	CS10-53	1.0		53.0	160.0	0.33	199	32.3
4	CS10-80	1.0		80.0	160.0	0.50	199	32.3
5	CS16-00	1.6		0.0	100.0	0.00	245	36.5
6	CS16-27	1.6	16.0	27.0	100.0	0.17	278	32.3
7	CS16-53	1.6		53.0	100.0	0.33	278	32.3
8	CS16-80	1.6		80.0	100.0	0.50	278	32.3
9	CS23-00	2.3		0.0	69.6	0.00	253	36.5
10	CS23-27	2.3		27.0	69.6	0.17	345	32.3
11	CS23-53	2.3		53.0	69.6	0.33	345	32.3
12	CS23-80	2.3		80.0	69.6	0.50	345	32.3

Fig. 2 shows the test apparatus. Centric load was applied to the specimens by the 2MN universal tester at Kobe City College of Technology (KCCT). The experimental test was terminated when failure of the specimens was observed.

2.2. Test measurements

Fig. 3 illustrates the arrangement of the biaxial strain gages. Two biaxial strain gages were attached on both inner and outer tubes' external side to obtain their stress conditions. Three displacement transducers were placed at the upper part of the specimens to measure the axial deformations of the specimens as shown in Fig. 3.

3. Results and discussion

3.1. Failure modes

The observed failure modes are shown in Fig. 4. The obtained failure modes were divided into two groups. One was the outer tube local buckling mode associated with shear failure of in-filled concrete, which is identical to the results obtained for an ordinary CFT stub columns under compression. The other was local buckling mode of

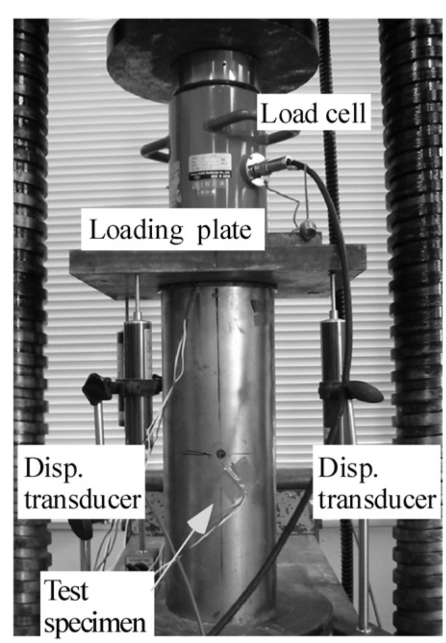

Fig. 2. Test setup.