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Experimental Study on the Hysteresis Performance of Stiffened Square CFST

Xinzhi Zheng^{1,2,3,*} Zhixiang Zhou¹ Shuang Zheng⁴ Taotao Wang³

¹Post-doctoral research station of civil engineering, Chongqing Jiaotong University, Chongqing 40074, China;

²Henan engineering laboratory of ecological architecture and environment construction, Henan Polytechnic University, Jiaozuo 454000, China;

³Institute of bridge detection and reinforcement technology, Huanghe Jiaotong University, Jiaozuo 454950, China;

⁴School of civil Engineering, Zhengzhou Institute of Technology, Zhengzhou 450044, China.

*Corresponding author's e-mail: zxz@hpu.edu.cn

Abstract: Stiffened Square Concrete Filled Steel Tubular Columns (SSCFST) were proposed to solve the problem that ordinary square concrete-filled steel tubular columns (SCFST) are prone to appear local buckling and poor hysteresis performance before reaching the limits of carrying capacity in 3 cases such as the thin steel tubular wall, the larger diameter to thickness ratio or width to thickness ratio. In order to investigate its hysteresis behavior, based on introducing its basic concept, the manufacturing method was expounded, and the low cyclic loading tests of 15 SSCFST and 1 SCFST with binding bars were carried out. The author observed experimental phenomena, failure process and failure mode, then analyzed hysteresis loop area and energy dissipation of SSCFST columns under reciprocating loading, and discussed the effect of various factors to its anti-seismic behavior. Compared to SCFST with binding bars, SSCFST has superior anti-seismic performance.

1. Introduction

The constraint of ordinary SCFST columns on the inner filled concrete is mainly focused on the corner region, and the lateral constraint depends on the out-of-plane stiffness of the steel tubular wall (Han and Tao, 2001; Vrcelj and Uy, 2001) [1].

Scholars at home and abroad have conducted a series of studies on the improvement of axial compression behavior of CFST (Liang and Uy, 2000; Uy, 2000; Cai and He, 2006; Cai and He, 2007; Cai and Sun, 2008; Huang and Zhou, 2001; Tao and Han, 2005; Zhou et al., 2008; Susantha et al., 2001) [1-9].

2. Characteristics of SSCFST

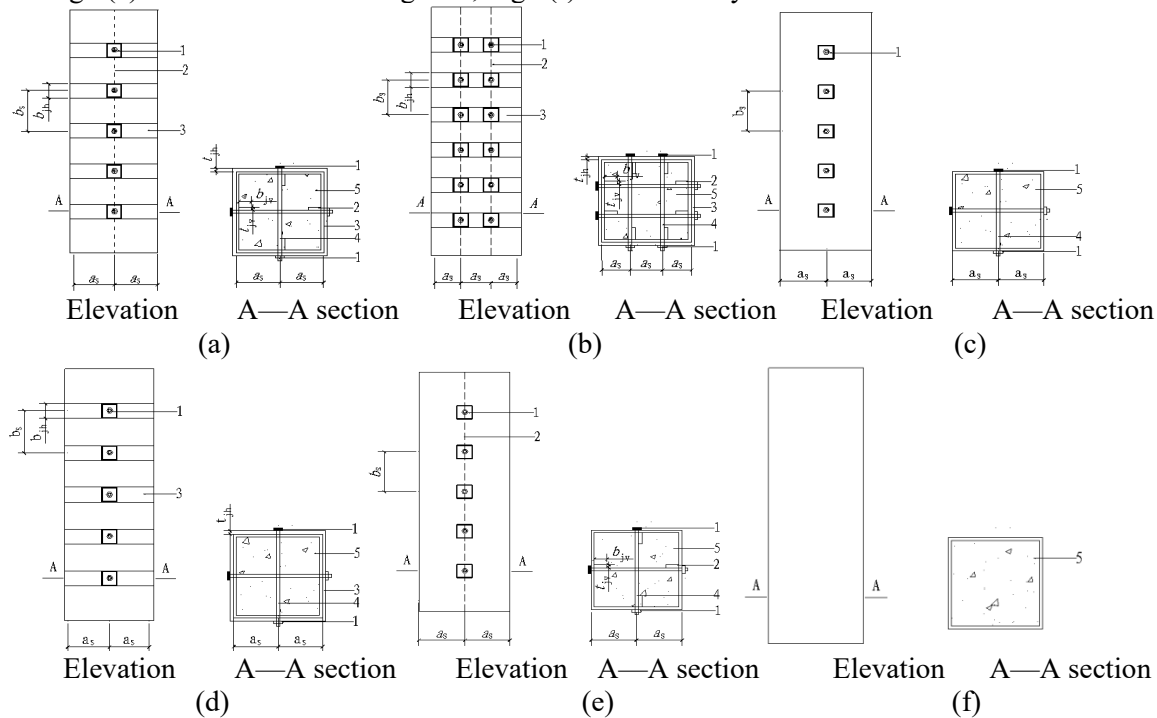
The set of binding bars can greatly improve the mechanical properties of SCFST. Meanwhile, the elastic-plastic buckling phenomena will still appear in the area between the binding bars and as a result the constraints on inner filled concrete are undermined.



SSCFST proposed in this paper contain two enhanced measures that have been set with binding bars and stiffeners.

Fig.1(a)(b)(d)(e) show a typical elevations and cross-sections diagram of stiffened square concrete filled steel tube columns (SSCFST), in which (a) (b) are outer transverse and internal longitudinal type, (d) is outer transverse type, (e) is inner longitudinal type.

Fig.1(c) is SCFST with binding bars, Fig.1(f) is an ordinary SCFST.



1- Anchoring end 2- Longitudinal stiffener 3- Horizontal stiffener 4-Binding bar 5-Concrete

Fig.1 specimens

3. Making of specimens

Table1 Testing parameter of specimens

No.	b (mm)	t (mm)	L (mm)	a_s (mm)	b_s (mm)	d_s (mm)	$b_{jh} * t_{jh}$ (mm)	$b_{jv} * t_{jv}$ (mm)	binding bars	n_0
B2	200	6	600	100	100	10	-	-	ordinary	0.6
B6	200	6	600	100	100	10	40*6	40*6	ordinary	0.4
B7	200	5	600	100	100	10	40*5	40*5	ordinary	0.4
B8	200	4	600	100	100	10	40*4	40*4	ordinary	0.4
B9	200	6	600	100	100	10	40*6	40*6	ordinary	0.6
B10	200	5	600	100	100	10	40*5	40*5	high strength	0.6
B11	200	4	600	100	100	8	40*4	40*4	ordinary	0.6
B12	200	6	600	100	100	10	40*6	40*6	ordinary	0.8
B13	200	5	600	100	100	10	40*5	40*5	high strength	0.8
B14	200	4	600	100	100	8	40*4	40*4	ordinary	0.8
B15	200	6	600	100	85.7	10	40*6	40*6	ordinary	0.6

B16	200	6	600	100	85.7	10	30*8	30*8	ordinary	0.6
B17	200	6	600	100	85.7	10	40*6	40*6	ordinary	0.6
C5	200	6	600	66.7	100	10	40*6	40*6	ordinary	0.4
C6	200	6	600	66.7	85.7	6	20*6	20*6	ordinary	0.6
C7	200	6	600	66.7	100	10	40*6	40*6	ordinary	0.6

In the table1, B , t , L respectively represent the length of sectional side, the thickness of the pipe wall, and the length of the columns; a_s , b_s , d_s respectively represent the horizontal spacing, the vertical spacing and the diameter of binding bar; ih_{jh} , ih_{jv} respectively represent the thickness and the width of the built-in stiffeners; oh_{jh} , oh_{jv} respectively represent the thickness and the width of the external stiffeners; n_0 represents the axial compression ratio.

The local buckling development of each specimen is shown in Table 2.

Table2 Hysteretic testing eigenvalues of specimens

No.	occur of local bucklin g	l bucklin g wave	length of l bucklin g wave	l bucklin g wave	length of l bucklin g wave	l bucklin g wave	length of l bucklin g wave	bucklin g wave form a ring
B2	12r1	12r2	180mm	12r3	190mm	20r1	190mm	20r2
B6	20r1	20r3	50mm	30r1	60mm	30r3	60mm	-
B7	12r3	20r2	60mm	20r3	60mm	30r2	70mm	-
B8	12r3	20r1	65mm	20r2	70mm	30r2	75mm	-
B9	20r1	20r1	55mm	20r2	68mm	40r1	65mm	-
B10	20r1	20r2	70mm	20r3	70mm	40r1	75mm	-
B11	12r2	12r3	68mm	20r1	73mm	20r2	80mm	-
B12	12r3	20r2	65mm	20r2	75mm	30r1	75mm	-
B13	20r1	20r2	75mm	20r3	80mm	20r3	80mm	-
B14	12r2	12r3	72mm	20r1	78mm	20r2	85mm	-
B15	30r2	30r3	45mm	40r1	50mm	-	-	-
B16	30r3	40r1	40mm	-	-	-	-	-
B17	30r2	30r2	50mm	40r1	55mm	-	-	-
C5	30r2	30r3	30mm	30r3	30mm	-	-	-
C6	20r3	30r2	35mm	30r3	35mm	-	-	-
C7	30r3	40r1	30mm	-	-	-	-	-

In the table, the digital in front of "r" is horizontal displacement (mm) under load; the digital in the back of "r" is the cycling number of the amplitude.

Table3 Area of hysteresis loops and energy dissipation coefficients of specimens

No.	3mm (1/200)		6mm (1/100)		9mm (1/67)		12mm (1/50)		20mm (1/30)		30mm (1/20)		40mm (1/15)	
	area	co.	area	co.	area	co.	area	co.	area	co.	area	co.	area	co.
B2	1198.915	1.8692	3404.275	1.7193	7016.175	1.9768	10265.590	2.0560	20118.336	3.0827	—	—	—	—
B6	1584.655	1.8645	5334.235	2.1699	8133.611	2.0811	11755.860	2.0896	23419.755	2.4641	40376.120	2.9538	-	-
B7	1365.815	1.8637	3934.395	1.8899	7058.142	2.0776	11060.285	2.2649	20102.240	2.5882	32837.331	2.8359	-	-
B8	1347.735	1.8507	3732.801	2.0382	6373.225	2.0550	10041.051	2.2745	18870.350	2.5899	28319.292	3.0483	-	-
B9	2079.825	1.9427	5592.590	1.8873	9901.080	2.2337	14303.900	2.3489	28412.965	2.8272	41427.475	2.8986	-	-
B10	1819.090	1.9087	4898.120	1.9062	9528.035	2.3144	12825.590	2.1675	25839.190	2.9207	40633.230	3.3631	-	-

B11	2003.050	2.0457	4784.480	1.9107	8537.100	2.1051	12900.810	2.6070	22500.230	3.2242	32294.765	4.3812	-	-
B12	2248.210	1.9884	6066.015	1.9397	12171.420	2.2493	16016.515	2.2269	31342.295	3.0003	47297.050	3.2529	-	-
B13	2076.130	2.0833	5398.580	2.0379	9407.305	2.2490	13930.135	2.2473	31342.295	2.9375	47297.050	3.2529	-	-
B14	2088.500	1.9872	5299.231	1.9172	9686.533	2.0436	14743.571	2.7368	27962.815	3.4804	-	-	-	-
B15	1670.605	1.8921	4407.935	1.8088	7780.195	1.7817	12172.745	2.0233	26035.355	2.6083	43821.775	2.6314	-	-
B16	2081.000	2.0725	5465.795	1.9843	-	-	13587.490	2.2908	25200.715	2.5018	42866.245	3.0079	56529.365	3.0729
B17	1544.445	1.9648	3928.170	1.8962	7093.815	2.1157	9034.830	2.0106	23264.105	2.2285	41974.310	2.6403	-	-
C5	1856.635	2.0408	4806.815	1.9574	9175.505	2.0892	13686.340	2.2731	27076.870	2.6319	45089.540	2.8949	-	-
C6	1845.900	1.9831	4754.440	1.8177	8602.900	1.8510	12474.400	1.8570	26667.250	2.6332	45986.120	4.0837	-	-
C7	2155.220	2.1590	5317.045	1.9411	9649.215	2.0890	13922.820	2.0690	26235.145	2.5885	46630.020	3.0408	80961.56	3.4820

In the table, area represents the area of the hysteresis loops; co. shows energy dissipation coefficients.

4. Conclusion

Based on the hysteresis behavior test of 15 SSCFST and 1 SCFST with binding bars, the failure process and hysteresis loop area of SSCFST under reciprocating load are analyzed.

(1)The local buckling time is significantly delayed, the buckling wave length is obviously reduced, and the buckling modes emerged as a fundamental change. It shows the excellent anti-seismic resistance performance of SSCFST.

(2)The area of hysteresis loops and the energy dissipation coefficients of specimens with the thinner steel tubular wall still have good energy dissipation capacity. It shows SSCFST are considerably better than that of thick wall of SCFT specimen with binding bars specimens.

(3)The energy dissipation capacity of specimens can be improved with smaller ratio of width to thickness of the external stiffening plate or larger ratio of width to thickness of internal stiffening plate.

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