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Shear performance of steel fibers reinforced self-confinement and self-compacting concrete-filled steel tube stub columns

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HIGHLIGHTS

- Study on steel fibers reinforced self-confinement self-compacting CFST stub columns.
- Thirty-eight tests under shear load were carried out.
- Self-stress improved the rigidity and shear capacity, but decreased deformability.
- Steel fibers lengthened the elastic stage and improved the shear capacity.
- Predicted formulas for the shear capacity were proposed.

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ABSTRACT

This paper described an experimental work for thirty-eight steel fibers reinforced self-confinement and self-compacting concrete-filled steel tube (FSSCFST) stub columns under shear load. The variables considered in the test were self-stress, thickness of steel tube, concrete strength, axial compression ratio, shear span-to-depth ratio and steel fibers volume percentage. Failure mode, shear capacity, load-deflection curve and load-strain respond were investigated. Experimental results showed that the failure mode of FSSCFST stub columns depended on the shear span-to-depth ratio (m). When $m < 0.5$, the specimens failed in shear; when $m \geq 0.5$, the specimens failed in flexure. Self-stress improved the rigidity and shear capacity, but decreased the deformability of FSSCFST stub columns. Steel fiber improved the shear resistance and ductility of concrete through bridging the plastic cracks near the shear failure plane. This beneficial effect from steel fibers lengthened the stage of elasticity and improved the shear strength of CFST specimens. Finally, formulas were proposed to predict the shear capacity of FSSCFST, and the predictions agreed well with the test results from this study and the literatures.

1. Introduction

In recent decades, concrete filled steel tube (CFST) has been frequently used as the dominant members in a vast variety of engineering structures. That can be attributed to the superior structural properties of CFST (e.g. high bearing capacity, rigidity and ductility, desirable performance under seismic loading or fire conditions), resulting from the composite action of steel tube and concrete [1].

However, the difficulty in casting of concrete may result in the surface defect which is rather unfavorable to the composite action, and consequently a sharp drop of bearing capacity and deformability happens for the CFST members. To deal with this puzzle, self-compacting concrete is adopted because of its high fluidity [2–6]. Due to its rheological properties, self-compacting concrete can flow under its own weight to completely fill the steel tube without vibration. Nevertheless, researches [7,8] demonstrated that shrinkage of self-compacting concrete is higher than traditional vibrated concrete due to the increased cement consumption. Shrinkage not only weakens the composite action between filled concrete and steel tube, but also deteriorates durability of the structure. Researchers adopt a self-confinement concrete with a self-expansion behavior to solve the puzzle. The self-expansion behavior is induced by chemical reaction inside self-confinement concrete as a compensation for the shrinkage, simultaneously producing self-stress [9–11]. The use of self-confinement and self-compacting concrete solves the tamping problem, enhances the interaction between steel tube and concrete core and promotes the load

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Table 1
Details of the specimens.

Specimen ID	L (mm)	L/D	t (mm)	D/t	m	n	v (%)	Self-stress (MPa)	f_{cu} (MPa)	f_y (MPa)
E-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	0	45.1	329.7
B-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	4.90	53.9	329.7
B-3.5-0.6%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0.6	4.48	68.1	329.7
B-3.5-1.2%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	1.2	4.10	54.4	329.7
E-2.5-0%-0.3-0.2	300	1.82	2.5	66	0.3	0.2	0	0	45.1	305.3
B-2.5-0%-0.3-0.2	300	1.82	2.5	66	0.3	0.2	0	4.10	53.9	305.3
B-2.5-0.6%-0.3-0.2	300	1.82	2.5	66	0.3	0.2	0.6	3.71	68.1	305.3
B-2.5-1.2%-0.3-0.2	300	1.82	2.5	66	0.3	0.2	1.2	3.19	54.4	305.3
E-4.25-0%-0.3-0.2	300	1.82	4.25	38.8	0.3	0.2	0	0	45.1	327.5
B-4.25-0%-0.3-0.2	300	1.82	4.25	38.8	0.3	0.2	0	5.32	53.9	327.5
B-4.25-0.6%-0.3-0.2	300	1.82	4.25	38.8	0.3	0.2	0.6	5.03	68.1	327.5
B-4.25-1.2%-0.3-0.2	300	1.82	4.25	38.8	0.3	0.2	1.2	4.78	54.4	327.5
D-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	0	44.8	329.7
A-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	4.93	45.3	329.7
A-3.5-0.6%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0.6	4.69	53.3	329.7
A-3.5-1.2%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	1.2	4.32	51.6	329.7
F-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	0	41.8	329.7
C-3.5-0%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0	5.55	61.3	329.7
C-3.5-0.6%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	0.6	4.81	69.2	329.7
C-3.5-1.2%-0.3-0.2	300	1.82	3.5	47.1	0.3	0.2	1.2	4.40	51.3	329.7
E-3.5-0%-0.2-0.2	300	1.82	3.5	47.1	0.2	0.2	0	0	45.1	329.7
B-3.5-0%-0.2-0.2	300	1.82	3.5	47.1	0.2	0.2	0	4.90	53.9	329.7
B-3.5-0.6%-0.2-0.2	300	1.82	3.5	47.1	0.2	0.2	0.6	4.48	68.1	329.7
B-3.5-1.2%-0.2-0.2	300	1.82	3.5	47.1	0.2	0.2	1.2	4.10	54.4	329.7
E-3.5-0%-0.5-0.2	350	2.12	3.5	47.1	0.5	0.2	0	0	45.1	329.7
B-3.5-0%-0.5-0.2	350	2.12	3.5	47.1	0.5	0.2	0	4.90	53.9	329.7
B-3.5-0.6%-0.5-0.2	350	2.12	3.5	47.1	0.5	0.2	0.6	4.48	68.1	329.7
B-3.5-1.2%-0.5-0.2	350	2.12	3.5	47.1	0.5	0.2	1.2	4.10	54.4	329.7
E-3.5-0%-0.75-0.2	500	3.03	3.5	47.1	0.75	0.2	0	0	45.1	329.7
B-3.5-0%-0.75-0.2	500	3.03	3.5	47.1	0.75	0.2	0	4.90	53.9	329.7
B-3.5-0.6%-0.75-0.2	500	3.03	3.5	47.1	0.75	0.2	0.6	4.48	68.1	329.7
B-3.5-1.2%-0.75-0.2	500	3.03	3.5	47.1	0.75	0.2	1.2	4.10	54.4	329.7
E-3.5-0%-0.3-0.4	300	1.82	3.5	47.1	0.3	0.4	0	0	45.1	329.7
B-3.5-0%-0.3-0.4	300	1.82	3.5	47.1	0.3	0.4	0	4.90	53.9	329.7
B-3.5-1.2%-0.3-0.4	300	1.82	3.5	47.1	0.3	0.4	1.2	4.10	54.4	329.7
E-3.5-0%-0.3-0	300	1.82	3.5	47.1	0.3	0	0	0	45.1	329.7
B-3.5-0%-0.3-0	300	1.82	3.5	47.1	0.3	0	0	4.90	53.9	329.7
B-3.5-1.2%-0.3-0	300	1.82	3.5	47.1	0.3	0	1.2	4.10	54.4	329.7

Table 2
Chemical composition of sulfoaluminate-type expansive cement and Portland cement.

composition	CaO (%)	Al_2O_3 (%)	SiO_2 (%)	MgO (%)	Fe_2O_3 (%)	CO_2 (%)	SO_3 (%)	Ig.loss (%)
Sulfoaluminate-type expansive cement	39.0	20.0	5.0	3.0	1.5	1.0	20.0	9.0
Portland cement	62.6	4.6	20.6	2.6	3.2	–	3.0	2.0

Table 3
Concrete mixes.

Concrete ID	Content (kg/mm^3)					Super-plasticizer (%)	v (%)	f_{cu} (MPa)	D (mm)	T_{500} (s)
	Cement	Water	Sand	Gravel	Fly ash					
A-0%	750	247.5	634.1	729	0	0.80	0	45.3	650	1
A-0.6%	750	247.5	634.1	729	0	1.08	0.6	53.3	630	1
A-1.2%	750	247.5	634.1	729	0	1.48	1.2	51.6	610	2
B-0%	750	210.0	675.8	756	0	1.20	0	53.9	655	1
B-0.6%	750	210.0	675.8	756	0	1.89	0.6	68.1	620	2
B-1.2%	750	210.0	675.8	756	0	2.45	1.2	54.4	580	3
C-0%	750	172.5	806.0	814	0	2.50	0	61.3	645	2
C-0.6%	750	172.5	806.0	814	0	3.62	0.6	69.2	620	3
C-1.2%	750	172.5	806.0	814	0	4.75	1.2	51.3	600	5
D	358.0	200	738.0	810	218.4	0.41	0	44.8	670	1
E	496.4	190	740.9	756	177.8	1.10	0	45.1	660	1
F	698.0	180	747.6	810	0	1.52	0	41.8	650	2