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Mechanical Behavior of L-Shaped Concrete Filled Steel Tubular Columns under Axial Compression

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Abstract. L-shaped concrete-filled steel tubular column (CFST) has the advantages such as high bearing capacity, good ductility and high utilization rate of internal space of the building, thus avoiding the occurrence of column shearing in the indoor use space. In engineering application, the axial bearing capacity of CFST is very important for the stability of structure, and is an extremely significant mechanical performance index. Finite element (FE) models are established to calculate the load-deformation curves and the calculated results are verified by the experiments. On this basis of FE models, the parameters of wide-to-limb ratio, steel yield strength, concrete cylinder strength and steel thickness are analyzed. It indicates that the calculation method of axial bearing capacity based on superposition theory is basically suitable for L-shaped concrete filled stub column structure in the ranges of the parameters. Keywords: CFST; L-shaped; column; axial compression; ultimate strength.

1. Introduction

As early as 1879, concrete-filled steel tubular was applied to the piers of severn railway bridge in Britain. In the former Soviet union, the axial and bias properties of concrete-filled steel tubes have also been studied in depth. Moreover, scholars from the United States, Australia, Japan and other countries have studied and applied the main high-strength concrete filled steel tube in engineering. In China, the research on concrete-filled steel tube mainly focuses on the concrete-filled steel tube structure with rectangular section and circular section. It is an internal filled concrete-filled steel tube structure filled with plain concrete. On the basis of previous studies, this paper selects a reasonable constitutive relationship between steel and core concrete, and uses the finite element analysis program Abaqus to establish a three-dimensional nonlinear finite element analysis model of L-shaped concrete-filled steel tubular stub column under axial compression. The load-deformation relationship of the axial compression test members of L-shaped concrete-filled steel tube stub column in this paper's references is checked and calculated. The calculated results are in good agreement with the experimental results. Based on this model, 34 examples of axial compression calculation of L-shaped concrete-filled steel tubes are analyzed, and the calculation results show that the bearing capacity calculation method based on the superposition theory proposed in literature [1] is basically applicable to L-shaped concrete-filled steel tubes. However, in the perspective of safety, it is recommended to multiply the relevant safety factor on the bases of superposition theory. The calculation formula is shown in formula 1.

$$N_u = f_c A_c + f_y A_s \quad (1)$$



2. Finite element calculation

2.1 Establishment of finite element model

Establishing an appropriate 3d nonlinear finite element model is the key to accurately and effectively analyze the mechanical properties of concrete-filled steel tubular composite structures. The stress-strain relation is the physical relation of engineering structural materials and the macroscopic behavior expression of its internal microscopic mechanism. In this paper, the finite element calculation model adopts the constitutive relation model proposed in literature [2], where the L-shaped section correction is equivalent to the rectangular section of equal length and width. The steel pipe adopts the shell element (S4R) with four-node reduction integral format, and the Simpson integral with 9 points in the direction of shell element thickness. Core concrete is a three-dimensional solid element (C3D8R) with an eight-node reduced integral scheme. Figure 1 shows the division of steel tube and core concrete elements in a typical L-shaped concrete-filled steel tube column. This model adopts the interface model proposed in literature [3], which is composed of interface normal contact and tangential bonding slip. Relative sliding occurs between interfaces. Friction penalty formula allowing elastic sliding is adopted in the calculation, in which the interface model coefficient between steel tube and core concrete is set as 0.6.

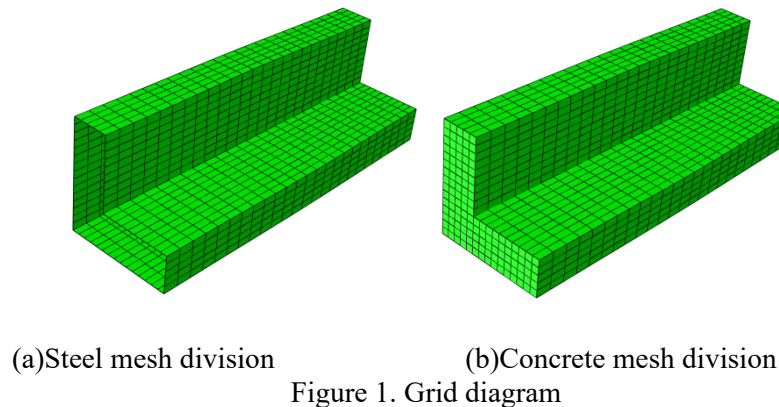


Figure 1. Grid diagram

2.2 Verification of finite element model

In order to verify the reliability and accuracy of finite element calculation results, some axial compression specimens in literature [4] and literature [5] were simulated. The comparison between the finite element calculation curve of mean longitudinal strain relation and the experiment is shown in figure 2 and figure 3. As you can see from figure 2 and figure 3, the variation trend of the finite element calculation curve is similar to the experimental curve. Therefore, the finite element calculation results have certain reliability and accuracy. The calculation results of bearing capacity are summarized in table 1 and table 2.

Table 1. Parameters and Bearing Capacity of Specimens in Literature 4

No.	Specimen number	Specimen length(mm)	$D_0 \times B_0 \times t_0$ (mm)	Stiffener as $\times$ bs $\times$ ds	f_y (MPa)	f_{cu} (MPa)	N_e (kN)	N_{fe} (kN)	N_{fe}/N_e
1	LRA-1	900	300 $\times$ 150 $\times$ 5	45 $\times$ 28 $\times$ 4	320	53.1	4891	4628	0.946
2	LRA-2	900	300 $\times$ 150 $\times$ 5	45 $\times$ 28 $\times$ 4	320	53.1	4875	4628	0.949
3	LRB	900	300 $\times$ 150 $\times$ 6	45 $\times$ 28 $\times$ 4	300	53.1	4852	4905.3	1.011
4	LRC	900	300 $\times$ 100 $\times$ 6	45 $\times$ 28 $\times$ 4	300	53.1	4059	3698.9	0.911

Note: R means specimens with stiffener. N_e means Actual carrying capacity. N_{fe} means bearing capacity of Finite element calculation. Mean of N_{fe}/N_e is equal to 0.954 and the mean square error is equal to 0.0416.

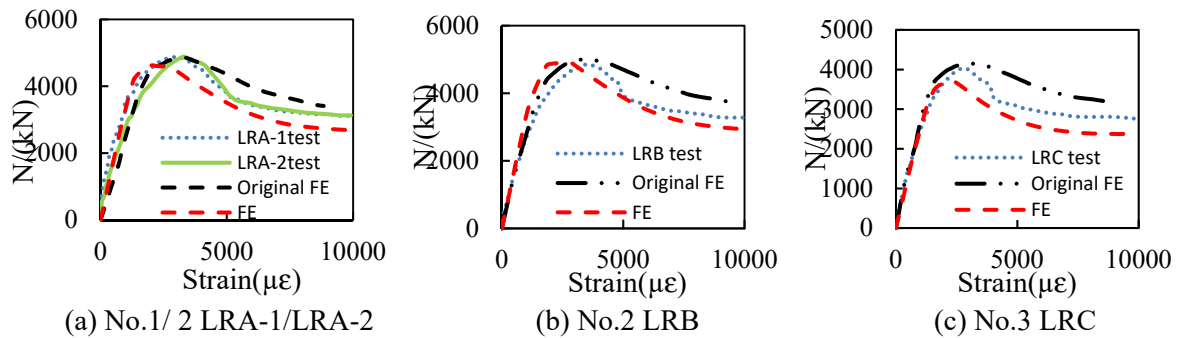
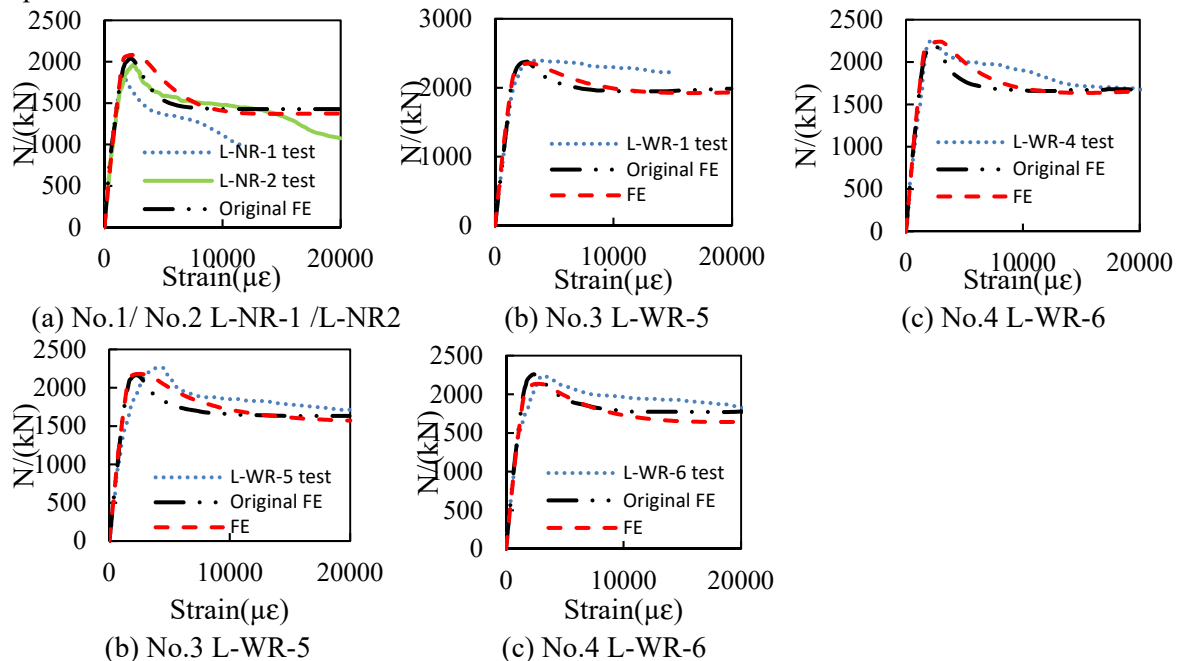
Figure 2. N - ϵ curves simulated in literature 4

Table 2. Parameters and Bearing Capacity of Specimens in Literature [5]

No.	Specimen number	Specimen length(mm)	$D_0 \times B_0 \times t_0$ (mm)	Stiffener	f_y (MPa)	f_{cu} (MPa)	N_e (kN)	N_{FE} (kN)	N_{FE}/N_e
				$a_s \times b_s \times d_s$					
1	L-NR-1	600	200×100×4.3	-	328.2	43.0	1901.2	1889.3	0.994
2	L-NR-2	600	200×100×4.3	-	328.2	43.0	1961.9	1959.8	0.999
3	L-WR-1	600	200×100×4.3	92×600×4.3	328.2	43.0	2410.8	2351.1	0.975
4	L-NR-4	600	200×100×4.3	92×600×4.3	328.2	43.0	2273.6	2241.1	0.986
5	L-NR-5	600	200×100×4.3	46×600×4.3	328.2	43.0	2278.5	2256.9	0.991
6	L-NR-6	600	200×100×4.3	46×600×4.3	328.2	43.0	2254.0	2244.2	0.996

Note: R means specimens with stiffener. N_e means Actual carrying capacity. N_{FE} means bearing capacity of Finite element calculation. Mean of N_{FE}/N_e is equal to 0.990 and the mean square error is equal to 0.009.

Figure 3. N - ϵ curves simulated in literature 4

3.parameter analysis

In multi-storey and high-rise commercial and residential buildings, the width of L-shaped concrete-filled steel tubular column is taken as the thickness of the wall, generally 200mm. In this paper, a total of 34 specimens were designed in an equal proportion of 1:1. The section details of the specimens are shown in Figure 4. The limb width B of the specimen was set at 200mm, the section

aspect ratio D/B was set at 2, 2.5 and 3, the steel tube thickness was set at 20mm, 25mm and 30mm, the steel yield strength f_y was set at 200MPa, 400mpa, 600mpa and 800mpa, and the axial compressive strength f_c' of the concrete cylinder was set at 20mpa, 40mpa, 60mpa, 80mpa and 110mpa, respectively. The calculation results of axial compression bearing capacity are shown in table 3. Figure 5 is a typical axial compressive stress-strain curve of l-shaped concrete-filled steel tube. As shown in figure 5, the axial load of CFST column comes from the superposition of the axial force provided by steel tube and inner concrete. What's more, the restraint effect of steel tube on core concrete is the key factor to improve the axial bearing capacity of concrete-filled steel tube. Compared with rectangular concrete-filled steel tubes of equal length and width, the restraint effect of steel tubes on core concrete in L-shaped concrete-filled steel tubes is obviously weaker than that of rectangular concrete-filled steel tubes, which is caused by the fact that steel tubes at the middle and negative corners of L-shaped concrete-filled steel tubes are subject to compression and bending deformation earlier than those at the positive corners, failing to form a better hoop effect. The axial bearing capacity of CFST short columns calculated according to formula 1 is slightly higher than that calculated by finite element simulation. Therefore, in the perspective of safety, the calculation of axial bearing capacity of L-shaped concrete-filled steel tube is suggested to be based on the superposition theory which were multiplied by the relevant safety factor in practical engineering application. That is, the modified superposition theory calculation method. The calculation formula is shown in formula (2). ϕ is the safety coefficient.

$$N_\mu = \phi(f_c A_c + f_y A_s) \quad (2)$$

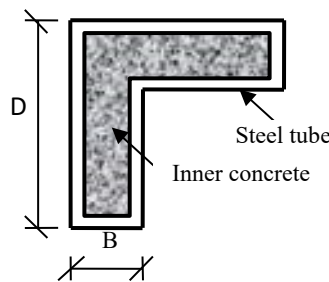


Figure 4. Section of L-Shaped CFST

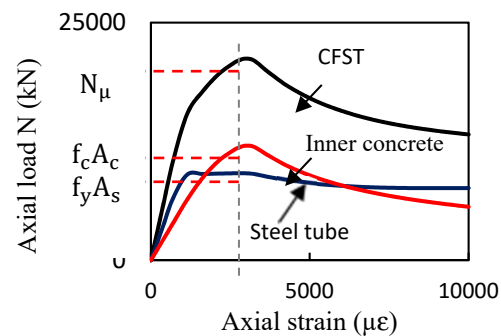


Figure 5. N-ε curves for a typical L-Shaped CFST

Table 3. Axial compression capacity calculation results

NO.	D/B	f_y	f_c'	t(mm)	N_s (kN)	N_c (kN)	N_u (kN)	N_e (kN)	N_{se} (kN)	N_{ce} (kN)	N_u/N_e
L1	2.5	200	20	25	9500	2250	11750	11585.7	8982.61	2556.91	1.014181
L2	2.5	200	50	25	9500	5625	15125	14921.9	9059.46	5699.51	1.013611
L3	2.5	200	80	25	9500	9000	18500	18245.7	9113.17	8830.56	1.013938
L4	2.5	200	110	25	9500	12375	21875	21495.8	9161.3	12050.1	1.017641
L5	2.5	400	20	25	19000	2250	21250	20941	17595.5	3166.39	1.014756
L6	2.5	400	50	25	19000	5625	24625	24171.7	17839.6	6096.16	1.018753
L7	2.5	400	80	25	19000	9000	28000	27448.1	17869.4	9264.19	1.020107
L8	2.5	400	110	25	19000	12375	31375	30599	18120.2	12385	1.02536
L9	2.5	600	20	25	28500	2250	30750	30778.2	26681	3733.73	0.999084
L10	2.5	600	50	25	28500	5625	34125	33472.6	26205.2	6813.83	1.019491
L11	2.5	600	80	25	28500	9000	37500	36668.7	26436.6	9829.28	1.022671
L12	2.5	600	110	25	28500	12375	40875	39938.2	26706.4	12804	1.023456
L13	2.5	800	20	25	38000	2250	40250	40469.9	35668.3	4263.53	0.994566
L14	2.5	800	50	25	38000	5625	43625	42778.5	34569.1	7654.81	1.019788
L15	2.5	800	80	25	38000	9000	47000	45964.9	34585.9	10778.7	1.022519
L16	2.5	800	110	25	38000	12375	50375	49110.2	34736.8	13827.8	1.025754
L17	2	200	20	20	6080	1792	7872	7797.7	5745.34	2033.02	1.009528

L18	2	200	50	20	6080	4480	10560	10452.7	5796.98	5479.57	1.010265
L19	2	200	110	20	6080	9856	15936	15686	5858.11	9730.51	1.015938
L20	2	400	20	20	12160	1792	13952	13801.5	11231.8	2435.93	1.010905
L21	2	400	50	20	12160	4480	16640	16398.8	11405.4	4864.09	1.014708
L22	2	400	110	20	12160	9856	22016	21544.1	11599.7	9902.54	1.021904
L23	2	800	20	20	24320	1792	26112	26337.7	22559.9	3303.76	0.991431
L24	2	800	50	20	24320	4480	28800	28360.4	22057.2	5983.12	1.0155
L25	2	800	110	20	24320	9856	34176	33362.1	22161.4	10891.3	1.024396
L26	3	200	20	30	13680	13680	16312	16010.2	12938.9	3013.61	1.01885
L27	3	200	50	30	13680	13680	20260	19867.1	13029.4	6685.5	1.019776
L28	3	200	110	30	13680	13680	28156	27435.9	13134.7	14062.5	1.026247
L29	3	400	20	30	27360	27360	29992	29610.1	26213.9	3741.55	1.012898
L30	3	400	50	30	27360	27360	33940	33172.7	25711.2	7176.76	1.02313
L31	3	400	110	30	27360	27360	41836	40603.7	26057	14476.4	1.030349
L32	3	800	20	30	54720	54720	57352	57220.4	52316.7	5019.96	1.0023
L33	3	800	50	30	54720	54720	61300	59826	50208.4	8961.23	1.024638
L34	3	800	110	30	54720	54720	69196	67017.6	50307.5	16227.2	1.032505

Note: N_c is axial bearing capacity of core concrete, N_s is axial bearing capacity of steel tube, N_u is axial bearing capacity of steel tube concrete, N_{se} is axial bearing capacity of steel tube calculated by finite element method, N_{sc} is axial bearing capacity of core concrete calculated by finite element method, N_e is axial bearing capacity of concrete tube calculated by finite element method.

4. Conclusion

CFST has become an important development direction of structural engineering discipline and achieving good economic benefits and architectural effects. So far, the calculation method of axial bearing capacity of concrete filled steel tube column is not perfect. According to the calculation results in this paper, the calculation result of axial bearing capacity of L-shaped concrete-filled steel tube column based on the superposition theory is slightly larger. If a reasonable and economical safety factor can be determined on the basis of superposition theory, it will provide a good design basis for future engineering designers.

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References

- [1] Rong, B., Chen, Z., Zhou, T. (2009) Research on axial compression strength of L-shaped short columns composed of concrete-filled square steel tubes. *J. Industrial construction.*, 39: 104-107.
- [2] Tao, Z., Wang, Z., Yu, Q. (2013) Finite element modelling of concrete-filled steel stub columns under axial compression., 89: 121-131.
- [3] Liu, W. (2005) Study on mechanical behaviors of concrete-filled steel tube under local compression. D. Fuzhou: Doctoral dissertation of Fuzhou University. (in Chinese)
- [4] Lin, Z. (2008) Study on some key problems of mechanical properties of l-shaped concrete-filled steel tubular members. D. Shanghai: Doctoral dissertation of Tongji University. (in Chinese)
- [5] Zhu, Y. (2017) Study on axial pressure behavior of l-ribbed concrete-filled steel tubular short column. D. Nanchang: Master's thesis of East China Jiaotong University. (in Chinese)