Advanced Materials Research *Online: 2010-12-06*
ISSN: 1662-8985, Vols. 163-167, pp 2199-2202
doi:10.4028/www.scientific.net/AMR.163-167.2199

Finite Element Analysis of Middle Long Columns of High-Strength Concrete filled Square Steel Tube with Inner CFRP Circular Tube Under Axial Load

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Keywords: ABAQUS Finite Element; With CFRP Circular Tube; High-Strength Concrete; Axial Compression; Ultimate Bearing Capacity

Abstract. With the development of computer science, the finite element method has been used widely. The paper used the ABAQUS finite element analysis software to carry out the finite element analysis on the middle long columns of high-strength concrete filled square steel tube with inner CFRP circular tube under compressive load. The results of finite element analysis were obtained, which agreed well with theoretical data. This conclusion proved the correctness and feasibility of finite element model.

Introduction

Square steel tube concrete structure has many advantages such as high bearing capacity, simple node structure, good stability, so more and more it is applied in engineering[1-4]. With the continuous development of concrete technology, high-strength concrete is also widely used in constructional engineering and can bring considerable economic benefits. However, the higher strength of the concrete, the worse ductility and the more obvious frangibility destruction. As a result, for the purpose of improving the traits of frangibility destruction of high-strength concrete, it is essential to put it into the constraint of steel tube. However, the constraint of square steel tube for high-strength concrete is worse than that of circular steel tube and square steel tube can easily produce stress concentration in the corner. These shortcomings have limited the application and development of high-strength concrete filled square steel tube[5-8]. For this reason, the CFRP circular steel tube is installed in the high-strength concrete filled square steel tube to form a new type combination construction ,which can solve the problem of the dependence of high-strength concrete for thick wall steel tube or high-strength steel tube and lighten the self weight of component and contemporarily solve the problem of the shortage of CFRP plasticity. Using the ABAQUS finite element software, the author conducts entire process simulation analysis about middle-long columns of concrete filled square steel tube with inner CFRP circular tube under axial load and initially investigates the effect factors of axle load performance and working mechanism.

Creation of finite element model

Unit Selection. Considering components of finite element simulation will produce a large strain in loading, the grid will produce a big stretch, steel tube and concrete need contact analysis and the results of finite element simulation and experimental research are expected to be as close as possible, this article selects three-dimensional solid element (C3D8R) of eight nodes reduced integration scheme for all concrete, steel and load board, which can be used to simulate the larger grid buckling, large-strain analysis and contact analysis simultaneously. CFRP employs composite material shell unit of four node reduced integration scheme (S4R).

Interface treatment. Figure 1 shows the mould composition of middle-long columns concrete filled square steel tube with inner CFRP circular tube under axial load and the contact connection between each material. Core concrete and carbon fiber contact surfaces, concrete and carbon fiber contact surfaces all employ binding constraints for the purpose of the displacement coordination;

steel and concrete uses hard contact in radial direction and sliding friction contact in tangential. Considering the research experience of past researchers [9] on steel tube concrete, this article employs 0.6 as the friction coefficient.

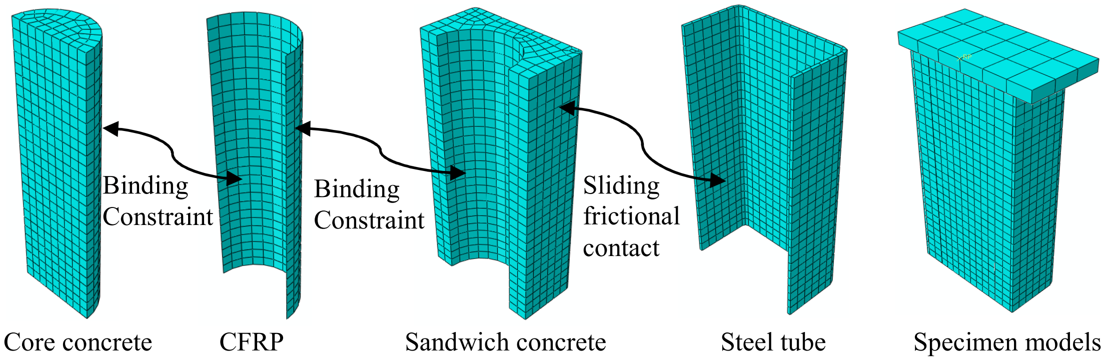

Fig.1: Finite element model of specimen

Boundary conditions and mode of loading. The creation of finite element model employs 1 / 4 model to model building on account of its boundary conditions and symmetry of loading patterns. Finite element model is shown in Figure 2 (a). This paper considers initial defects for the axle load of middle-long columns and the initial imperfections of steel concrete column belong to small eccentricity. Therefore, this paper supposes that component has initial deflection of a thousandth of a bar length (initial eccentricity taken $e_0 = L/1000$) and calculating method is in accordance with the bending component .Loading path is exerting eccentric line loads on the cover board , the fixed line load X, Z direction of displacement, shown in Figure 2 (b) below. Loading program applies load displacement.

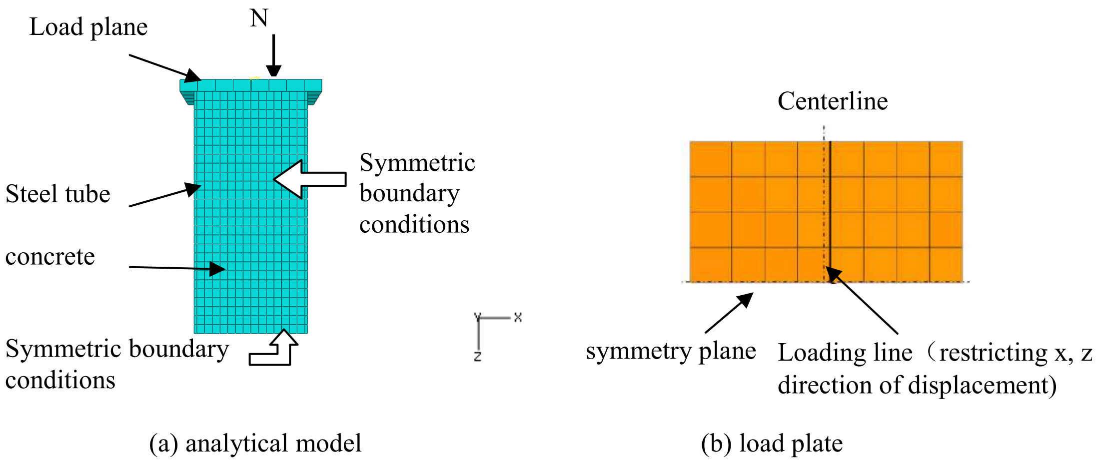

Fig.2:Axial compression model of middle-long columns considering initial defects

The simulation results of numerical analysis

Load - the average longitudinal strain curve. Calculated results and measured results are compared to verify the correctness of ABAQUS finite element analysis. Figure 3 shows the contrast curve about finite element method and the experimental part of the axial compression load in long columns N~ε longitudinal average strain relations. The detailed parameters of the sample are shown in Table 1 which shows that curves of finite element analysis and experimental curves are in good agreement.

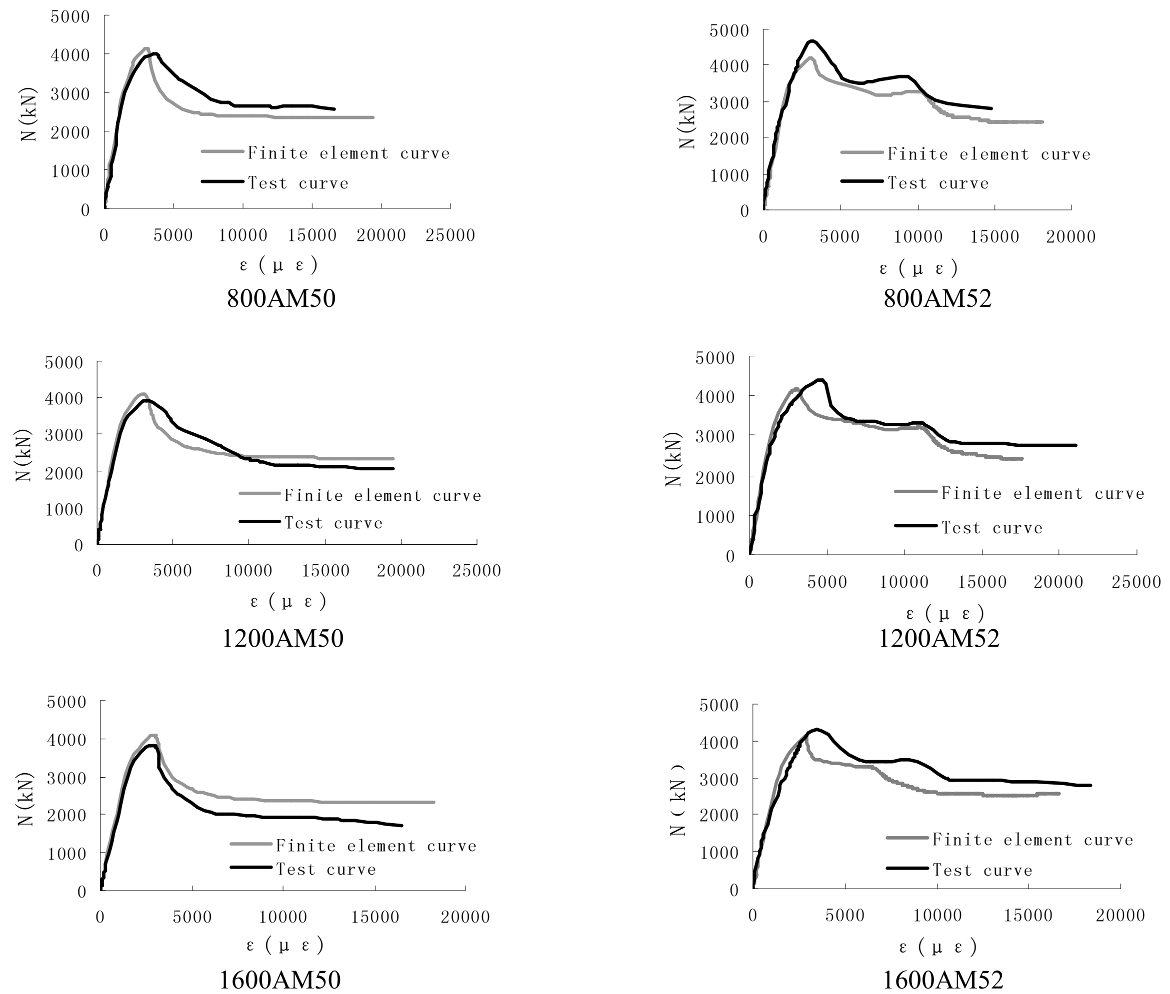

Fig.3: The comparison between the experimental curve of middle-long columns subjected to axial compression and the finite element curve

Table 1 Comparison of Ultimate Bearing Capacity

Specimen No.	B(mm)	t(mm)	f_y (MPa)	α	δ_{cfrp}	f_{ck} (MP)	N_u (kN)	N'_u (kN)	$\frac{N'_u}{N_u}$
800AM41	200	4	313	0.0851	0.167	65	4113	4003	0.973
800AM50	200	5	320	0.108	0	65	4006	4131	1.031
800AM51	200	5	320	0.108	0.167	65	4269	4197	0.983
800AM52	200	5	320	0.108	0.334	65	4660	4204	0.902
800AM61	200	6	335	0.1317	0.167	65	4336	4431	1.022
1200AM50	200	5	320	0.108	0	65	3926	4111	1.047
1200AM51	200	5	320	0.108	0.167	65	4190	4155	0.992
1200AM52	200	5	320	0.108	0.334	65	4474	4175	0.933
1600AM50	200	5	320	0.108	0	65	3813	4087	1.072
1600AM52	200	5	320	0.108	0.334	65	4380	4130	0.943
2000AM50	200	5	320	0.108	0	65	3718	4054	1.090
2000AM52	200	5	320	0.108	0.334	65	4209	4094	0.972
2400AM50	200	5	320	0.108	0	65	3615	4031	1.115
2400AM52	200	5	320	0.108	0.334	65	4070	4054	0.996

Note: The first letter A of specimen No. means axial compression, the second letter M middle-long column; the first Roman numbers 4,5 and 6 behind letters signify that thickness of tube wall are 4mm, 5mm and 6mm respectively; the second Roman numerals 0,2 behind letters mean that the number of carbon fiber layers around CFRP circular tube is 0 and 2 respectively. B is outside length of square specimen section, t as the thickness of steel tube wall, L as the length of the specimen, α as steel radio, δ_{cfrp} as the thickness of carbon fiber cloth, f_y as the yield strength of steel tube, f_{ck} as the axial compressive strength of concrete; N_u and $N_u^{'}$ are ultimate compressive strength obtained from specimen experiments and from the finite element method separately.

The comparison of ultimate bearing capacity. Table 1 shows the detailed information and ultimate bearing capacity of all middle-long column specimens. The analysis shows that the error of calculated values and experimental values about ultimate bearing capacity of all components are less than 10% .The mean and variance of the $N_u^{'}/N_u$ value of concrete filled square steel tube are 1.005 and 0.003 respectively, showing that finite element analysis results agree well with the experimental results. Thus, using ABAQUS finite element method to analyze the mechanical function on middle-long column of high-strength concrete filled square steel tube with internal CFRP circular tube under axial load has reliability.

Conclusions

Using ABAQUS can carry out finite element analysis well on middle-long columns of concrete-filled square steel tube with inner CFRP circular tube under axial load. And the load ~ longitudinal average strain relations of finite element analysis show a good agreement with the experimental results.

The ultimate bearing capacity of all middle-long column specimens obtained by finite element analysis can be a good match with experimental results.

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