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Research article

Finite element modeling of tapered concrete filled steel tubular columns under axial compression

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ABSTRACT

Concrete filled steel tubular (CFST) column is a kind of composite structure, in which a concrete core is confined within a steel tube. Thanks to the interaction between the steel tube and the concrete core, the compressive load carrying capacity of concrete is increased. This phenomenon is usually referred to as the ``confinement effect''. Correctly modeling the confinement effect, i.e. how the confined concrete behaves under certain types of loadings, is essential in analysis and design of CFST columns. Most of the current works focus on straight columns. In this paper, a novel finite element model is developed in ABAQUS software to analyze the nonlinear behaviors of CFST columns under axial compression, which is suitable for both uniform columns (i.e. the cross-sectional area is constant) and tapered columns (i.e. the cross-sectional is continuously varied with respect to the length of the column). The tapered columns are approximated as columns with piecewise constant cross sections, linearly varying from one end to the other end. Geometrically, as the number of piecewise constant cross sections increases, the model converges to the tapered column. In each segment of constant cross-sections, the material behavior of straight column is assumed. Thus, the current model is an extension to existing models for straight CFST columns. Two types of cross sections are investigated: circular shape and rectangular shape. These two cross sections are also the most popular ones in real life. Pre-processing in ABAQUS, i.e. setup of the model, is conducted via a subroutine written in Python script. The ability of the proposed numerical model in load carrying prediction is demonstrated through comparison with experimental data previously reported in the literatures by other authors.

Key words: CFST structures, tapered column, axial compression, nonlinear finite element model, cross-sections

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INTRODUCTION

Concrete-filled steel tubular columns have drawn intensive attention during the last decades[1,2]. This type of structure is widely applied in bridge construction. In comparison with reinforced concrete (RC columns), the CFST columns have been recognized due to the high ratio of compressive strength over weight without increasing either the complexity or the cost of manufacturing process[3,4]. High resistance of CFST columns to fire[5,6] and seismic loading[7,8] are also experimentally recorded. To foster the design of CFST columns, various finite element models have been proposed, see e.g. references[3,9–13]. Physically, the interaction between the concrete core and the steel skin enables the confinement effect, making the concrete behavior under compression more towards plasticity[3,10,14]. Therefore, development of material models that are able to take the confinement effect into account is essential in numerical analysis. Nevertheless, most of available numerical models are for straight columns with uniform cross-sections. In practice, due to architectural requirements, tapered columns of which cross-sections vary along the longitudinal direction have been increasingly used, see e.g. references[15–17]. A numerical model for tapered CFST columns with square cross-sections was proposed by Lam et al.[18], in which a conservative approach is suggested, that the compression capacity of a tapered CFST is not higher than that of the weakest cross-section. Thus, it is essential to evaluate the weakest cross-section in a given tapered CFST column, though it is a challenging task. Furthermore, only square cross-section was studied in reference[18]. In this paper, a new finite element model is developed based on the Concrete Damaged Plasticity (CDP) model in the software ABAQUS. The tapered CFST column is approximated as a stepped one, with numerous straight cross-sections. The higher number of cross-sections, the better the approximation is. A Python script sub-routine is employed to automatically set up the geometry and material models for concrete core and steel skin, in which the number of cross-sections is defined by users.

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This report is organized as follows. Right after the Introduction, the second section presents the material models of the steel skin and the concrete core. The third section is reserved for finite element model of tapered CFST columns. Results and discussion are provided in the fourth section. Finally, concluding remarks are drawn in the last section.

MATERIAL MODEL FOR CFST COLUMNS

A CFST column consists of a plain concrete core and a steel tube, as schematically depicted in Figure 1. Description of material models for the concrete core and the steel skin is essential to simulate the behavior of the CFST column. Experimentally, in order to determine the axial compression capacity, the column is usually loaded until failure. Therefore, large deformation and material nonlinearity are expected. The top surface of the column is attached with a steel plate, namely the loading plate, while the bottom surface is welded to another steel plate which is fixed to the ground. The compressive load is built up by applying downward (vertical) displacement to the loading plate. In this paper, the material model for straight CFST columns with both circular and rectangular cross sections are adopted from reference [10]. However for brevity, only the calculation of material parameters for circular columns is presented in the following sub-sections. Details about rectangular cross-section can be found in reference [10].

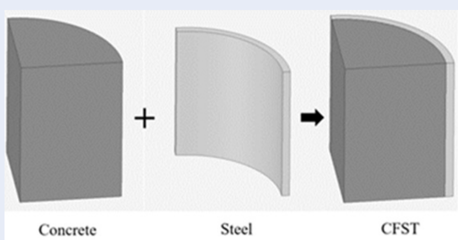

Figure 1: Schematic sketch of a CFST column (one-fourth model)

Material model for the steel tube

In the literatures, various stress-strain relation models have been proposed for the ductile behavior of the steel skin, including elastic-perfectly plastic model [19] and elastic-plastic model with multi-linear hardening [9]. For circular columns, the elastic-plastic model with non-linear hardening proposed by reference [10] is adopted. As illustrated in Figure 2, the stress-strain curve is expressed via four segments: the first one is the linear elastic behavior; the second one is a short period of perfect plasticity when yield stress is reached; the third one is nonlinear hardening until the ultimate tensile strength is achieved; and after that, perfect plasticity is assumed.

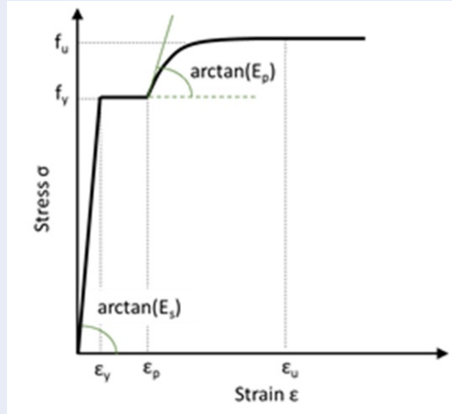

Figure 2: Stress-strain relation for steel [10]

The mathematical description of the steel stress-strain curve is as follows

$$\sigma = \begin{cases} E_s\varepsilon,\ 0 \le \varepsilon \le \varepsilon_y \\ f_y,\ \varepsilon_y \le \varepsilon \le \varepsilon_p \\ f_u - \left(f_u - f_y\right)\left(\dfrac{\varepsilon_u - \varepsilon}{\varepsilon_u - \varepsilon_p}\right)^p,\ \varepsilon_p \le \varepsilon \le \varepsilon_u \\ f_u,\ \varepsilon_u \le \varepsilon \end{cases} \quad (1)$$

where E_s is the elastic modulus of steel; E_p is the plastic modulus; f_y is the yield stress; f_u is the ultimate tensile stress; ε_p is the strain that marks the beginning of hardening; ε_y and ε_u are the strain values corresponding to f_y and f_u, respectively. The strain-hardening exponent p is given by

$$p = E_p.\left(\frac{\varepsilon_u - \varepsilon_p}{f_u - f_y}\right) \quad (2)$$

If measured data are not available, generally the following values can be taken: E_s = 200 GPa, E_p = 0.02 E_s. ε_p, ε_u and f_u can be estimated with respect to f_y, see reference [10].

Material model for concrete core

Concrete is a material that has much better resistance to compression than tension. The compressive strength is roughly 10 times higher than the tensile one. In CFST columns under axial compression, the lateral expansion of the concrete core is restricted by the steel tube, making the concrete core behavior is even more plastic-like (see e.g. references[10,20]). That effect is usually known by "confinement effect". The geometric property of the cross-sections may have influence on the confinement effect. The difference between the behavior of circular CFST columns and rectangular CFST columns was pointed out in reference[10]. In this paper, the empirical calculation[10] is adopted to evaluate the necessary parameters required by the concrete damaged plasticity CDP) model available in ABAQUS. Based on the compressive strength of the concrete, f_c, the elastic modulus of concrete, Ec, is evaluated by

$$E_c = 4700\sqrt{f_c}\,[MPa] \tag{3}$$

The equibiaxial concrete strength, f_{b0}, is calculated from f_c as follows[10,21]

$$\frac{f_{b0}}{f_c} = 1.5\,(f_c)^{-0.075} \tag{4}$$

With f_c and f_{b0} available, the ratio of the second stress invariant on the tensile meridian to that on the compressive meridian, K_c, is estimated by[10]

$$K_c = 5.5 f_{b0}.\,(3f_c + 5f_{b0})^{-1} \tag{5}$$

The dilation angle ψ, which is used by the CDP model to define the plastic flow potential, is calculated with respect to the confinement factor ξ_c [10]

$$\psi = \begin{cases} 56.3\,(1-\xi_c)\,,\ \xi_c \le 0.5 \\ 6.672exp\left(\dfrac{74}{4.64+\xi_c}\right),\ \xi_c > 0.5 \end{cases} \tag{6}$$

Following reference[10], the confinement factor ξ_c is evaluated by

$$\xi_c = \frac{A_s f_y}{A_c f_c} \tag{7}$$

in which A_s and A_c are the cross-sectional area of the steel tube and the concrete core, respectively.

Compressive behavior of concrete

The empirical curve for compressive behavior of concrete, as proposed by reference[10], is expressed in three parts: the ascending branch OA, the plateau OB and the descending branch BC, see Figure 3. It is noticed that curve for confined concrete is different from that of unconfined concrete in two features: the larger strain value at which softening occurs and the larger residual stress.

The part OA is mathematically given by reference[10]

$$\frac{\sigma}{f_c} = \frac{\bar{A}.\bar{X} + \bar{B}.\bar{X}^2}{1-\left(\bar{A}-2\right).\bar{X} + \left(\bar{B}+1\right).\bar{X}^2} \tag{8}$$

where

$$\bar{A} = \frac{E_c\varepsilon_{c0}}{f_c},\ \bar{B} = \frac{\left(\bar{A}-1\right)^2}{0.55},\ \bar{X} = \frac{\varepsilon}{\varepsilon_{c0}} \tag{9}$$

The strain value at point A and point B, i.e. ε_{c0} and ε_{cc}, respectively, are calculated as

$$\varepsilon_{c0} = 0.00076 + \sqrt{(0.626f_c - 4.33)\,.10^7} \tag{10}$$

$$\varepsilon_{cc} = \varepsilon_{c0}.exp\,(k) \tag{11}$$

$$k = (2.9224 - 0.00367f_c)\left(\frac{f_B}{f_c}\right)^{0.3124+0.002f_c} \tag{12}$$

In Equation (12), f_B is the confining stress providing to the concrete by the confinement effect, and should be evaluated differently for circular cross section and rectangular cross section, see reference[10] for details.

The descending branch BC is written in term of an exponential, as suggested in reference[20]

$$\sigma = f_r + (f_c - f_r)\,exp\left(-\left(\frac{\varepsilon-\varepsilon_{cc}}{\alpha}\right)^{\beta}\right) \tag{13}$$

in which f_r is the residual stress; α and β are two parameters that control the shape of the softening curve. All the three values are referred to reference[10].

Tensile behavior of concrete

Tensile behavior of concrete is not important of CFST columns being subject to axial compressive loads. However, it is needed to define the tensile behavior in the CDP model. Therefore, a simple brittle behavior can be used, in which the stress-strain relation is assumed to be linear until the tensile strength f_t, is reached. Fracture energy G_F can be evaluated by reference[22]

$$G_F = \left(0.0469d_{max}^2 - 0.5d_{max} + 26\right) f_t^{0.7}\,[N/mm] \tag{14}$$

where d_{max} is the maximum coarse aggregate size (in millimeters). Generally, d_{max} = 20 mm can be taken. When the tensile strength of concrete is not available, it can be estimated roughly as one-tenth of the compressive one.

METHODOLOGY: THE PROPOSED FINITE ELEMENT MODEL FOR TAPERED CFST COLUMNS

The finite element model is developed in the software ABAQUS. 3D solid elements C3D8R (8 nodes with reduced integration) are used for the concrete core, and the shell elements S4R (4 nodes with reduced integration) for the steel tube. Hourglass control is active. Interaction between the concrete core and the steel

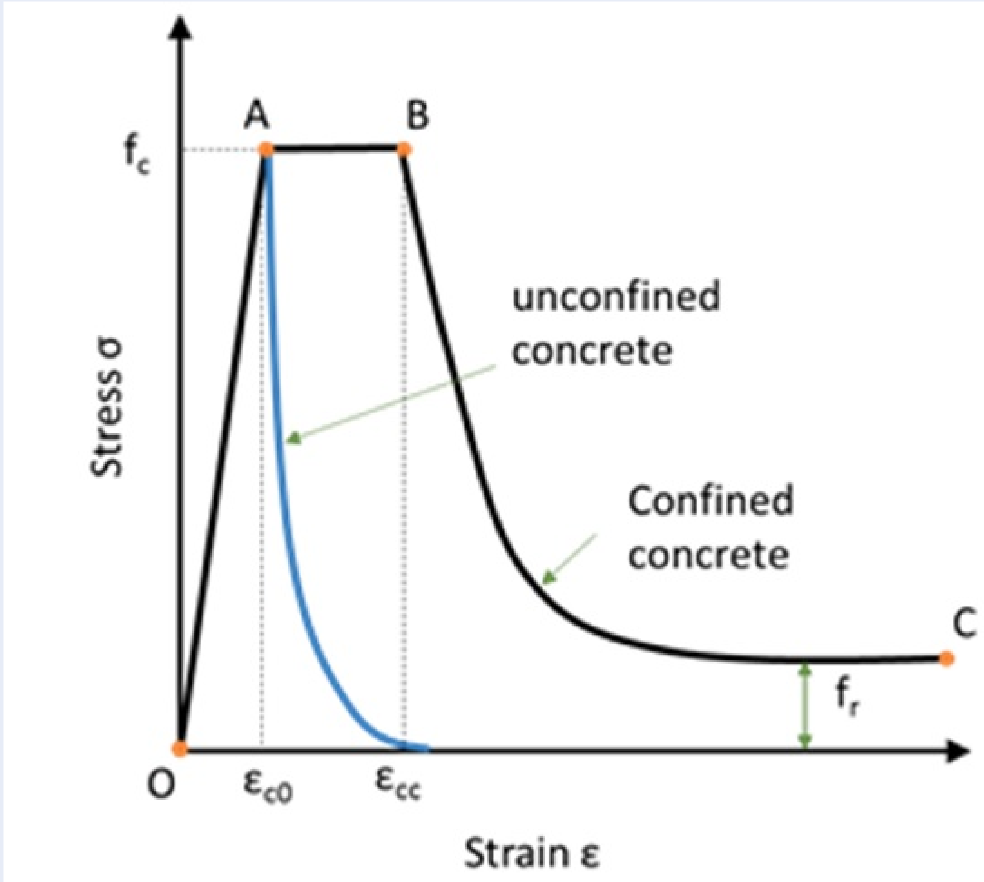

Figure 3: Stress-strain curves for compression behavior of concrete [10]

tube is defined by surface-to-surface contact, with a friction coefficient of 0.6. By using surface-to-surface contact, there is no sharing nodes at the interface between concrete core and steel tube. Therefore, the difference in the number of degrees of freedom between C3D8R element (concrete core) and S4R element (steel tube) does not raise any issue. The top surface of the column is in contact with the loading plate, which is modeled by discrete rigid elements and is allowed to move only in vertical direction. The bottom surface of the column is fixed to the ground.

Reference [18] argued that the compressive load capacity of a tapered column would be equivalent to that of a straight column with cross section equal to the "weakest section" of the tapered column. Nevertheless, it is challenging to determine the "weakest section". Therefore, a different strategy is employed in the current work. The tapered column is now approximated as n straight layers, in which the cross section of each straight layer varies along the longitudinal of the column, see Figure 4. Geometrically, a piecewise straight column will converge to a tapered column with large value of n. Furthermore, the changing of confinement effect due to the changing of cross sectional area is captured. A Python script subroutine is developed to automatically define the n layers with arbitrary n.

RESULTS AND DISCUSSION

The proposed model is applied to predict load capacity of CFST columns under axial compression. Two types of cross-sections are considered: circular and square sections. For each type of cross-sections, the numerical model is compared with experimental data available in the literatures for one straight column and two tapered columns. The material parameters (i.e. yield stress of steel f_y and compression strength of concrete f_c) for each specimen is as follows.

Circular cross section:

- 3HN (Straight specimen) [10]: fy = 287.4 MPa, fc = 28.7 MPa. Size: overall diameter D = 150 mm

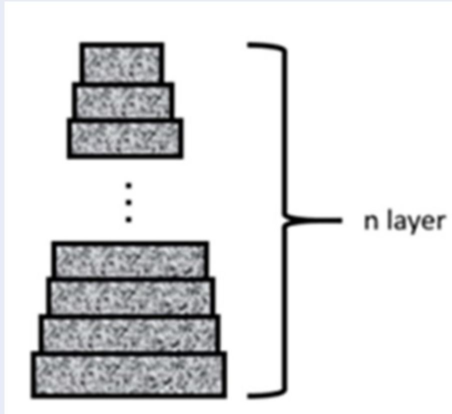

Figure 4: The tapered column is approximated by n layers of straight cross-sections

at both top and bottom surfaces, steel tube thickness t = 3.2 mm, and length of column L = 450 mm.

- TC-2 (Tapered specimen) [15]: fy = 410.1 MPa, fc = 69.6 MPa. Size: overall diameter D = 158 mm at top surface and D = 200 mm at bottom surface, steel tube thickness t = 3.75 mm, and length of column L = 601.36 mm.
- TC-3 (Tapered specimen) [15]: fy = 410.1 MPa, fc = 69.6 MPa. Size: overall diameter D = 116 mm at top surface and D = 200 mm at bottom surface, steel tube thickness t = 3.75 mm, and length of column L = 300.31 mm.

- Square cross section (a special case of rectangular cross section):
- 3MN (Straight specimen) [10]: fy = 287.4 MPa, fc = 28.7 MPa. Size: overall width B = 150 mm at both top and bottom sections, steel tube thickness t = 3.2 mm, and length of column L = 450 mm.
- TS-1 (Tapered specimen) [15]: fy = 410.1 MPa, fc = 69.6 MPa. Size: overall width B = 158 mm at top section and B = 200 mm at bottom section, steel tube thickness t = 3.75 mm, and length of column L = 601.36 mm.
- TS-2 (Tapered specimen) [15]: fy = 410.1 MPa, fc = 69.6 MPa. Size: overall width B = 116 mm at top surface and D = 200 mm at bottom surface, steel tube thickness t = 3.75 mm, and length of column L = 300.31 mm.

The peak load results of circular columns are reported in Table 1, and those of square columns are presented in Table 2, showing good agreement between numerical prediction and experimental data.

The distribution of total displacement (the whole column) and von Mises stress (steel tube) of TC2 specimen near the peak load are depicted in Figure 5 and Figure 6, respectively. Largest displacement is observed at the top section. Nearly two-third of the steel tube has almost reach the ultimate tensile strength. Near the end of the load-displacement curve, the column tends to be swollen near top section (see Figure 7). This observation is in agreement with that from experiment [15] that outward buckling occurs near the top section where the concrete is crushed.

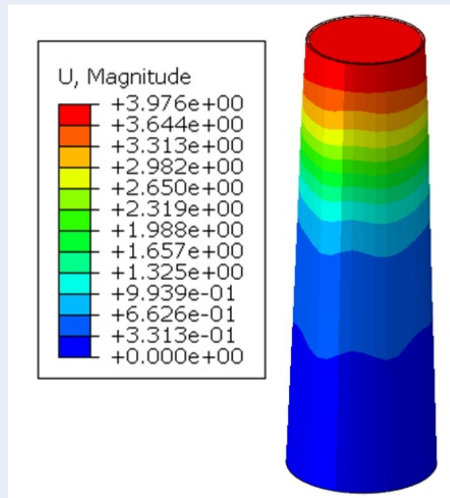

Figure 5: Distribution of total displacement of TC2 specimen near the peak load

For TS1 sample, the observation in Figures 8, 9 and 10 is similar, except that the local buckling is much clearer.

The graphs of axial load versus nominal axial strain (the ratio between vertical displacement and initial length) of specimen TC2 and TS1 are depicted in Figure 11 and Figure 12, respectively. For the square column TS1, the prediction by current FE model is better than that by reference [18].

CONCLUSION

A novel finite element model for tapered CFST columns under axial compression is proposed and verified by comparison with experimental data. The proposed model can be considered as a straightforward extension from the existing model [10] for straight CFST columns. Results evidently show that the model is applicable for both circular and square cross-sections. For square columns, prediction of compression capacity can be achieved with better accuracy

Table 1: Comparison of peak loads in circular CFST columns between numerical model and experimental data.

Name	Peak load (model)	Peak load (experiment)	Ratio
3HN	1021 kN	1067 kN	0.957
TC-2	2352 kN	2515 kN	0.935
TC-3	1604 kN	1759 kN	0.912

Table 2: Comparison of peak loads in square CFST columns between numerical model and experimental data.

Name	Peak load (model)	Peak load (experiment)	Ratio
3MN	1135 kN	1130 kN	1.004
TS-1	3041 kN	2842 kN	1.070
TS-2	2087 kN	1976 kN	1.056

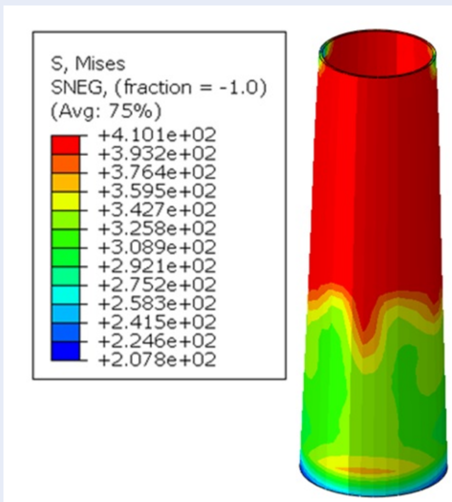

Figure 6: Distribution of von Mises stress on the steel tube of TC2 specimen near the peak load

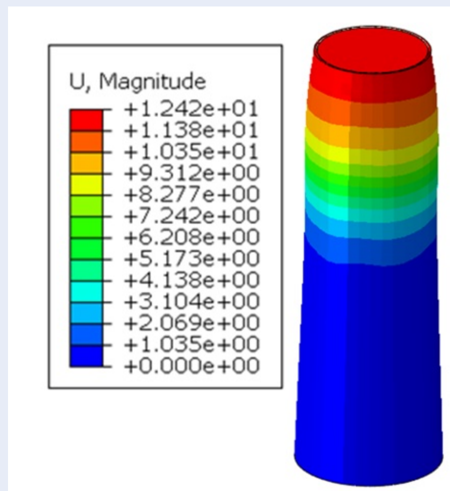

Figure 7: Distribution of displacement of TC2 specimen near the end of load-displacement curve

than the model previously reported in reference [18] (Circular columns were not studied in reference [18]).

Possible improvement would be focused on material models, which can reflect the material behavior closer to experiments. Various authors [10,11,23] have pointed out that the columns with square cross section (and generally rectangular cross-section) are more sensitive to pre-stressed condition and geometric imperfection than those with circular cross section. It is also noticed that in practice, the columns may in some certain cases be subject to eccentric compression [16,17]. Those topics would be interesting directions for further extension of the current model.

APPENDIX: BRIEF DESCRIPTION OF THE PYTHON SCRIPT UBROUTINE

The subroutine is designed to calculate the stress-strain values for the material models of steel tube and for every cross sections of the concrete core. The steps of calculation has been described in Section 2. Input parameters include the dimensions of the column, the material parameters (e.g. E_s, f_y, f_c) and the number of cross sections along the length of the column. Flowchart of the subroutine is provided in Figure 13.

LIST OF ABBREVIATIONS

CFST column: Concrete-filled steel tubular column
CDP: Concrete damaged plasticity model

CONFLICT OF INTEREST

There is no conflict of interest.

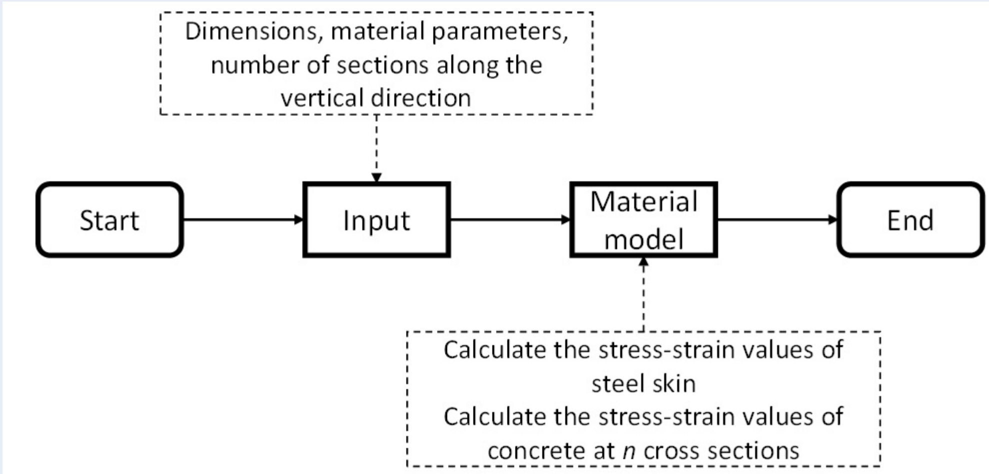

Figure 13: Flowchart of the Python script subroutine

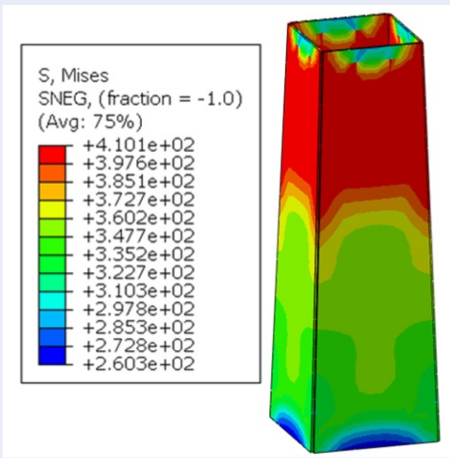

Figure 9: Distribution of von Mises stress on the steel tube of TS1 specimen near the peak load

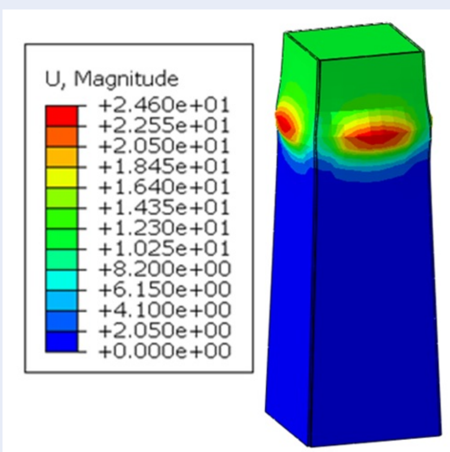

Figure 10: Distribution of displacement of TS1 specimen near the end of load-displacement curve

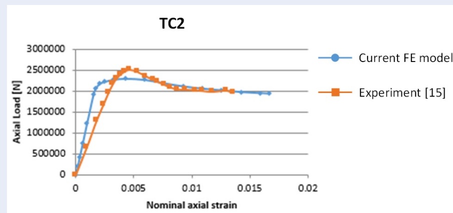

Figure 11: The graphs of axial load versus nominal axial strain (i.e. the ratio between vertical displacement and the initial length for the TC2 specimen

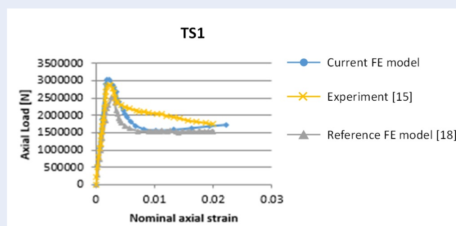

Figure 12: The graphs of axial load versus nominal axial strain (i.e. the ratio between vertical displacement and the initial length for the TS1 specimen

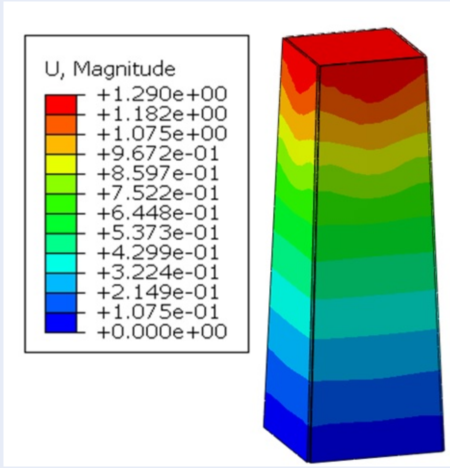

Figure 8: Distribution of total displacement of TS1 specimen near the peak load

AUTHORS' CONTRIBUTION

Minh N. Nguyen contributes in ideas brainstorming, data checking, proofreading and editing of the manuscript.

Thang H. Nguyen contributes in developing the python script code that is used for setup of the proposed model in ABAQUS. He also runs the simulation and get the results.

Tinh. Q. Bui contributes in data checking, proofreading and editing of the manuscript.

REFERENCES

1. Han LH, et al. Development and advanced applications of concrete-filled steel tubular (CFST) structures: Members. Journal of Constructional Steel Research . 2014;100:211–228. Available from: https://doi.org/10.1016/j.jcsr.2014.04.016.
2. Qu X, et al. Axial compressive behavior of concrete-filled steel tubular columns with interfacial damage. Advances in Structural Engineering. 2020;23(6):1–14. Available from: https://doi.org/10.1177/1369433219891639.
3. Han LH, et al. Performance of concrete-filled thin-walled steel tubes under pure torsion. Thin-Walled Structures. 2007;45:24–36. Available from: https://doi.org/10.1016/j.tws.2007.01.008.
4. Yu Q, et al. Experimental behaviour of high performance concrete-filled steel tubular columns. Thin-Walled Structures. 2008;46:362–370. Available from: https://doi.org/10.1016/j.tws.2007.10.001.
5. Song QY. Fire resistance of circular concrete-filled steel tubular (CFST) column protected by intumescent coating. Journal of Constructional Steel Research. 2018;147:154–170. Available from: https://doi.org/10.1016/j.jcsr.2018.03.038.
6. Romero ML, et al. Recent developements and fire design provisions for CFST columns and slim-floor beams. Journal of Construtional Steel Research . 2020;172:106159. Available from: https://doi.org/10.1016/j.jcsr.2020.106159.
7. Liao FY, et al. Seismic behaviour of circular CFST columns and RC shear wall mixed structures: Experiments. Journal of Constructional Steel Research. 2009;65:1582–1596. Available from: https://doi.org/10.1016/j.jcsr.2009.04.023.
8. Phan DH. Numerical analysis of seismic behavior of square concrete-filled steel tubular columns. Journal of Science and Technology in Civil Engineering. 2020;15(2):127–140.
9. Liang QQ, Fragomeni S. Nonlinear analysis of circular concrete-filled steel tubular short columns under axial compression. Journal of Constructional Steel Research . 2009;65:2186–2196. Available from: https://doi.org/10.1016/j.jcsr.2009.06.015.
10. Tao Z. Finite element modelling of concrete-filled steel stub columns under axial compression. Journal of Constructional Steel Research. 2013;89:121–131. Available from: https://doi.org/10.1016/j.jcsr.2013.07.001.
11. Thai HT, et al. Numerical modelling of concrete-filled steel box columns incorporating high strength materials. Journal of Constructional Steel Research. 2014;102:256–265. Available from: https://doi.org/10.1016/j.jcsr.2014.07.014.
12. Pham DD, Nguyen PC. Finite element modelling for axially loaded concrete-filled steel circular tubes. in Ha-Minh C., Dao D., Benboudjema F., Derrible S., Huynh D., Tang A. (eds) CIGOS 2019, Innovation for Sustainable Infrastructures, Lecture Notes in Civil Engineering. 2020;54:75–80. Available from: https://doi.org/10.1007/978-981-15-0802-8_8.
13. Abed F, et al. Experimental and numerical investigations of the compressive behavior of concrete filled steel tubes (CFSTs). Journal of Constructional Steel Research. 2013;80:429–439. Available from: https://doi.org/10.1016/j.jcsr.2012.10.005.
14. Xiong MX, et al. Axial performance of short concrete-filled steel tubes with high- and ultra-high-strength materials. Engineering Structures. 2017;136:495–510. Available from: https://doi.org/10.1016/j.engstruct.2017.01.037.
15. Han LH, et al. Test on inclined, tapered and STS concrete-filled steel tubular (CFST) stub columns. Journal of Constructional Steel Research . 2010;66:1186–1195.
16. Ren QX. Experimental behaviour of tapered CFST columns under combined compression and bending. Journal of Constructional Steel Research . 2017;128:39–52. Available from: https://doi.org/10.1016/j.jcsr.2016.08.005.
17. Li W. Behavior and calculation of tapered CFDST columns under eccentric compression. Journal of Constructional Steel Research. 2013;83:127–136. Available from: https://doi.org/10.1016/j.jcsr.2013.01.010.
18. Lam D. Behaviour of inclined, tapered and STS square CFST stub columns subjected to axial load. Thin-walled Structures. 2012;54:94–105. Available from: https://doi.org/10.1016/j.tws.2012.02.010.
19. Johansson M, Gylltoft K. Mechanical behavior of circular steel - concrete composite stub columns. Journal of Structural Engineering. 2002;128:1073–1081. Available from: https://doi.org/10.1061/(ASCE)0733-9445(2002)128:8(1073).
20. Binici B. An analytical model for stress-strain behavior of confined concrete. Engineering Structures. 2005;27(7):1040–1051. Available from: https://doi.org/10.1016/j.engstruct.2005.03.002.
21. Papanikolaou VK, et al. Confinement-sensitive plasticity constitutive model for concrete in triaxial compression. International Journal of Solids and Structures . 2007;44(21):7021–7048. Available from: https://doi.org/10.1016/j.ijsolstr.2007.03.022.
22. Bazant ZP, Becq-Giraudon E. Statistical prediction of fracture parameters of concrete and implications for choice of testing standard. Cement and Concrete Research. 2002;32(4):529–556. Available from: https://doi.org/10.1016/S0008-8846(01)00723-2.
23. Nguyen TT, et al. Behaviour and design of high strength CFST columns with slender sections. Journal of Constructional Steel Research. 2021;182:106645. Available from: https://doi.org/10.1016/j.jcsr.2021.106645.

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Bài nghiên cứu

Mô hình hóa phần tử hữu hạn cho cột ống thép nhồi bê tông tiết diện thay đổi đều khi chịu nén dọc trục

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TÓM TẮT

Cột ống thép nhồi bê tông (CFST) là một loại kết cấu liên hợp, với lõi bê tông được nhồi chặt bên trong ống thép. Nhờ vào tương tác giữa lõi bê tông và ống thép mà khả năng chịu tải nén của bê tông được cải thiện. Hiện tượng này được gọi là ``hiệu ứng kháng nở hông''. Mô hình hóa chính xác hiệu ứng kháng nở hông, tức là ứng xử của bê tông trong điều kiện bị kẹp chặt khi chịu tải, là yếu tố quan trọng khi phân tích và thiết kết cột CFST. Hầu hết các nghiên cứu hiện nay đều tập trung và cột thẳng (tức có tiết diện không đổi). Trong bài báo này, một mô hình phần tử hữu hạn mới được phát triển dựa trên phần mềm ABAQUS để phân tích đáp ứng phi tuyến của cột CFST khi chịu nén đúng tâm, áp dụng cho cả trường hợp tiết diện không đổi và trường hợp tiết diện biến đổi đều. Cột tiết diện biến đổi đều được xấp xỉ bởi nhiều đoạn tiết diện không đổi, trong đó giá trị tiết diện của từng đoạn thay đổi dần từ chân cột đến đỉnh cột. Về hình học, khi số lượng đoạn chia tăng lên, mô hình sẽ hội tụ về trường hợp cột có tiết diện biến đổi đều. Trong từng đoạn chia, tính chất vật liệu của cột thẳng sẽ được áp dụng. Do đó, mô hình hiện tại có thể xem là mở rộng của mô hình cột thẳng hiện có. Hai loại tiết diện được khảo sát trong bài báo là tiết diện tròn và tiết diện chữ nhật. Đây cũng là những trường hợp phổ biến trong thực tế. Quá trình thiết lập mô hình trong ABAQUS được thực hiện qua chương trình con viết bằng Python script. Khả năng của mô hình trong dự đoán giới hạn chịu nén của cột được khảo sát và so sánh với kết quả thực nghiệm đã công bổ bởi các tác giả khác.

Từ khoá: Kết cấu CFST, cột tiết diện thay đổi, nén dọc trục, mô hình phần tử hữu hạn phi tuyến, tiết diện

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