Nonlinear Analysis of Edge Joint on T-Shaped Concrete-Filled Steel Tubular Column-H-Shaped Steel Beam Seismic Performance based on ABAQUS

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Abstract

To comprehensively analyze the seismic performance and failure modes of edge joint, which is composed of T-shaped concrete-filled steel tubular column and H-shaped steel beam, the joint was imposed through low frequency cycling loading. Model of edge joint was established by the nonlinear finite element software ABAQUS. The effect of different parameters, such as axial compression ratio and side plate extension length, on the seismic performance were simulated. The results indicates that the buckling of the steel beam occurs at the lateral extension of the side plate due to the strengthening of the side plate; the axial compression ratio has no obvious effect on the ultimate load; the increase of the side plate length can effectively improve the ultimate load.

Index terms— t-shaped concrete-filled steel tubular column; H-shaped steel beam; Seismic performance of joint; finite element analysis.

1 Introduction

he frame structure of concrete-filled steel tubular special-shaped columns and steel beams has attracted increasing applications in high-rise buildings and long span bridges. It not only has high bearing capacity of concrete-filled steel tube (CFST), good deformation capacity and overcomes the disadvantage of special shaped reinforced concrete structure, but also steel tube can be served as form work to pure core concrete, and saves the constructing cost of using formwork, and accelerates the constructing speed [1]. The frame structure composed of concrete-filled steel tubular columns and steel beam has become a kind of seismic structure with many applications. At present, the joints mainly adopt outerdiaphragm, internal-diaphragm, bearing pin and so on rigid connection or hinge connection form [2]. According to the distribution position of the frame column, the composite joints can be divided into the T edge joint, the angular joint and the middle joint. The edge joint is connected by the edge column of frame structure and the beam. The thickness of flange on T shape column is equal tothe thickness of wall. No matter CFST or Reinforced Concrete (RC) is the same, the seismicper formance is different. However, the joint is the key part of the composite structure design, itsrationality is directly related to the safety of the structure and the economy of the project. Many different joint sizes, joint categories and connection types have been used in various engineering for different requirements. Thus, in order to obtain the seismic behaviors of the composite joint, it is necessary to study the influence, with the change of axial compression ratio and side plate extension length.

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In recent years, many scholars have studied the seismic behaviors of different kinds of composite joints on various structure by analytical, experimental and finite element (FE) simulation methods. While, most of them focus on other types of steel tubular special-shaped column-steel beam frame joints. The seismic behavior of joint on T-shaped CFST and H-shaped steel beam is less studied. The domestic scholars have put forward a variety of joint forms on CFST columns and carried out experimental research and theoretical analysis [3][4][5][6][7][8][9]. Zhou Peng et al. [1] studied the failure characteristics and seismic performance of rectangular steel tubular special-shaped column-steel beam frame joints. Foreign scholars such as Ataei et al. [10] In this paper, the joint form of T shaped CFST columns-H steel beam is proposed. The failure mode and seismic performance of T-shaped CFST column-Hshaped steel beam joint is studied, based on the nonlinear finite element software ABAQUS.

3 II. Establishment of Finite element Model

T-shaped CFST column-H-shaped steel beam edge joint is welded by T-shaped CFST column and Hshaped steel beam, and is reinforced by side panels. Fig. 1 shows the specimen size and large sample. The Tshaped CFST column section size, wall thickness of steel tube, column height and steel beam size are 300mm×100mm×200mm×100mm, 5mm, 1800mm, and 250mm×100mm×4mm×4mm, respectively. The properties of steel material are presented in Table 1. The mechanical properties of concrete are shown in Table **??**. The finite element model number and parameters settings are summarized in Table 3.

4 Table 2:

The three-dimensional solid element (C3D8R) with eight-node reduced integral scheme is used to build the above-mentioned joint model, applying nonlinear finite element software ABAQUS. The model mainly includes T-shaped CFST columns, H-shaped steel beams and side plates. The properties of the finite element model are divided into two categories. First, the establishment of concrete properties, including elasticity and concrete damage plasticity, applied to the core concrete. Second, the establishment of steel properties, including elasticity and plasticity, applied to T-shaped steel tube, Hshaped steel beams and side panels. The interaction between the T-shaped steel tube, the Hshaped steel beam and the side plate is the ”Tie” provided in ABAQUS. The interaction between the Tshaped steel tube and the core concrete, between the side plate and the core concrete, selects the ”Surface-to surface contact” provided in ABAQUS, where the ” Surface-to-surface contact ” interaction between the Tshaped steel tube and the core concrete includes ”Normal Behavior”and ”Tangential Behavior”, and the ” Surface-to-surface contact ” interaction between the side plate and the core concrete only includes ”Normal Behavior”.

The settings of the finite element models are depended on two loading steps. In the first step, the side plate of the column top is coupled to the reference point XRP-2 and an axial concentrating force is applied at the reference point XRP-2. The axial pressure is designed to be 1882.78kN, and the vertical load of the column is loaded at the axial compression ratio of 0.2, 0.4 and 0.6, respectively. Afterwards, the beam end section is coupled with the reference point XRP-3, and apply a vertical periodic displacement on the reference point XRP-3. In the finite element model, all degrees of freedom in the bottom hinge are restrained. The displacement of the node in the horizontal direction is restricted at the loading end of the column, and the displacement of the node X direction is restricted at loading end of the beam, shown as Fig. **??**.

5 III. Finite Element Calculating Results

a) Stress nephogram analysis Fig. **??** shows the Mises stress distribution of four locations, including the T-shaped steel tube, the core concrete, the H-shaped steel beam and the side plate. From the figure, the stress of the steel tube is relatively larger on the upper and lower sides of the middle plate of the steel tube, and the stress of the nodal domain becomes smaller, and buckling of the T-shaped column occurs on the upside of side plate and the underside of the side plate. This is because the side plane assumes a lot of stress, to achieve a very good control. In the corner of the core concrete, the stress is relatively larger, because the constraint of the square steel tube is weak in the corner of the core concrete; the stress at the upper and lower flanges of the steel beam joint domain is larger. Since the reinforcing plate constraints, buckling of steel beams occurs in the side plate portion epitaxial portion; the stress of the side plate is large, it plays a very good restraint to the core area of the steel tube, thus reducing the stress of the steel tube in the core area.

The meshing size has a great influence on the accuracy and computational efficiency of the finite element analysis software ABAQUS. If the size of the finite element model grid is too large, the calculating result of the finite element model may be deviate and even erroneous. If grid is too small, it will take long time to calculate the result. In order to ensure the accuracy of calculation and save the computational resources, the mesh size of the nodal domain is smaller than that of other parts in the process of finite element meshing. The grid diagram is shown as Fig. **??**. **??**, the hysteresis curves of the different axial compression ratios are universally similar. Before the yield, the curve reflecting the relationship between displacement and load is linear. The specimen is in the elastic stage. With the increase of the displacement load, the steel beam gradually column is much larger than the stiffness of the beam, and the low frequency cycling loading is applied to the end of beam. The increase of the axial load ratio has no obvious effect on the ultimate load. The increase of the lateral extension of the side plate can effectively improve the ultimate load. The hysteresis curves of per models do not shrink, which are full of spindle, and showing good seismic performance of the composite joint. The deformation process of structural members under the action of low frequency cycling loading is also the process of absorbing energy. The energy dissipation capacity of structural members determines the seismic capacity of the structure. The energy dissipation capacity of the join model is mainly evaluated by the equivalent viscous damping coefficient ??19].Usually, the average of the reinforced concrete joint is 0.1, and the common steel concrete joint is about 0.3 ??20]. Table 4 shows the equivalent viscous damping coefficient corresponding to the hysteresis curve of each finite element model. As shown in the table 4, the equivalent viscous damping coefficient corresponding to each hysteresis curve is close to 0.2, it is larger than the equivalent viscous damping coefficient of the reinforced concrete beam which is 0.1. It indicates that the T shaped CFST column-H-shaped steel beam has good energy dissipation capacity and seismic capacity.

6 Conclusion

In this paper, the seismic performance of the joint is evaluated, based on the establishment of rationalized T-shaped CFST column-H-shaped steel beam edge joint finite element model. The conclusions are summarized as follows:

1. The buckling of the T column occurs on the upper and lower sides of the side plate, and the buckling of the steel beam occurs at the side plate extension, due to the restraint of the side plate. 2. The increase of the axial load ratio has no obvious effect on the ultimate load, and the increase of the length of the side plate can effectively improve the ultimate load of the beam end, as the stiffness of the column is much larger than the stiffness of the beam, and the low cyclic loading is applied to the beam end. 3. The equivalent viscous damping coefficient corresponding to each hysteresis curve is close to 0.2, which indicates that the T-shaped concretefilled steel tubular column-H-shaped steel beam node has good energy dissipation capacity.

This paper studies the failure mode and seismic performance of T-shaped concrete-filled steel tubular columns-H-shaped steel beam node, application the finite element numerical simulation. In the future research, it is also necessary to combine finite element simulation with experimental research, and make a more thorough analysis of the node. [1] [2]

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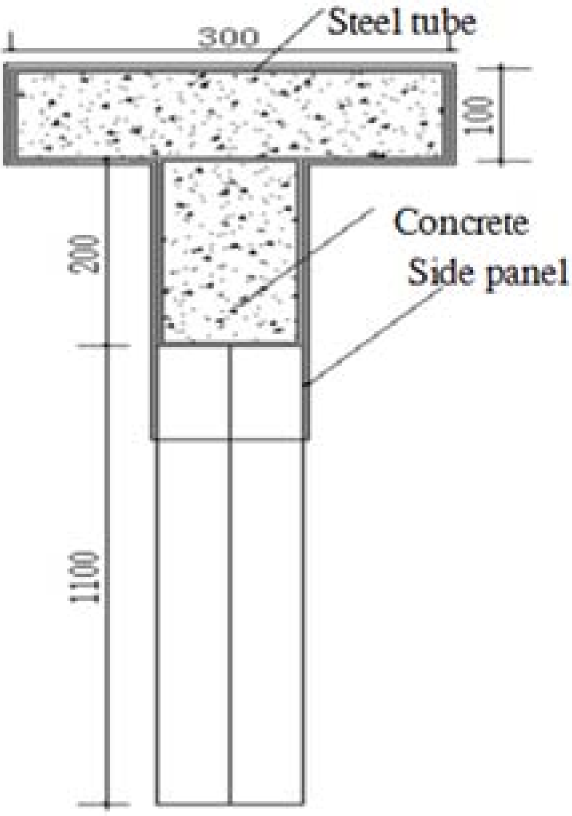

Figure 1: Fig. 1 :

[1]Nonlinear Analysis of Edge Joint on T-Shaped Concrete-Filled Steel Tubular Column-H-Shaped Steel BeamSeismic Performance based on ABAQUS

[2]E © 2019 Global Journals Nonlinear Analysis of Edge Joint on T-Shaped Concrete-Filled Steel Tubular Column-H-Shaped Steel Beam Seismic Performance based on ABAQUS

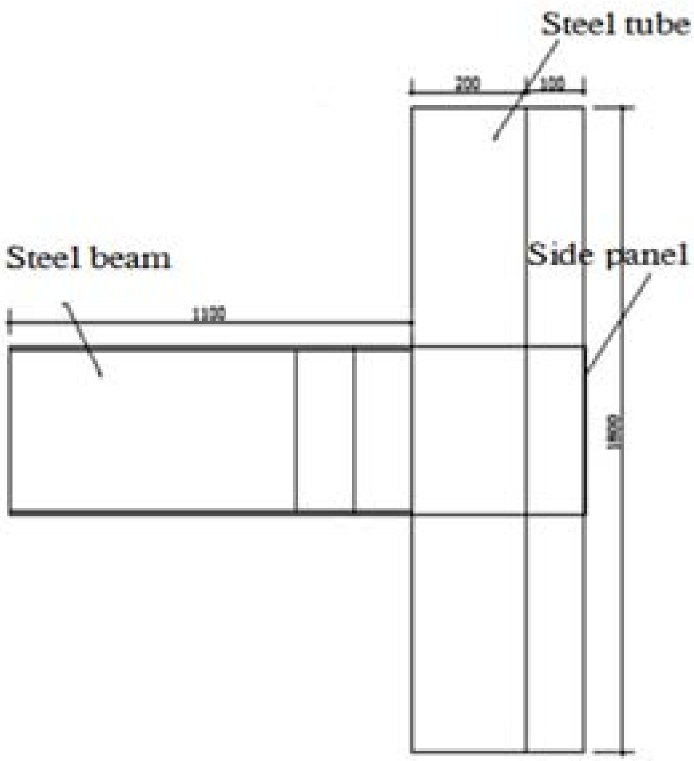

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Figure 2: Fig. 2 : 3 :

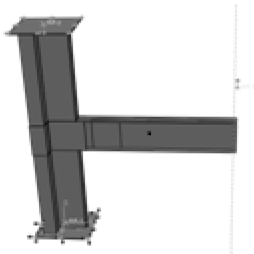

Figure 3:

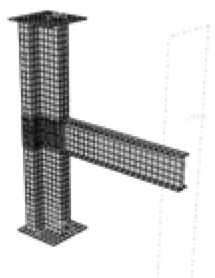

Figure 4:

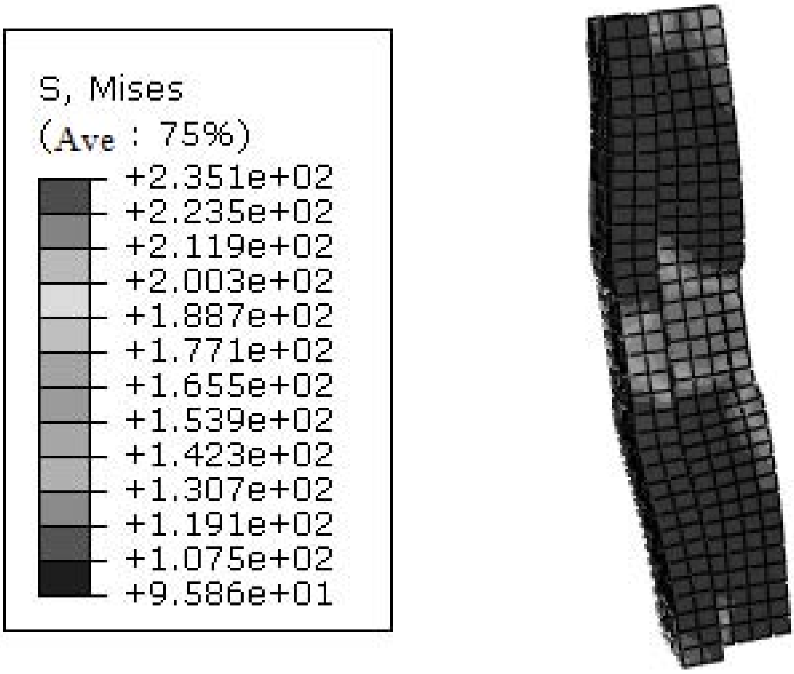

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Figure 5: Fig. 6 Fig. 6 :

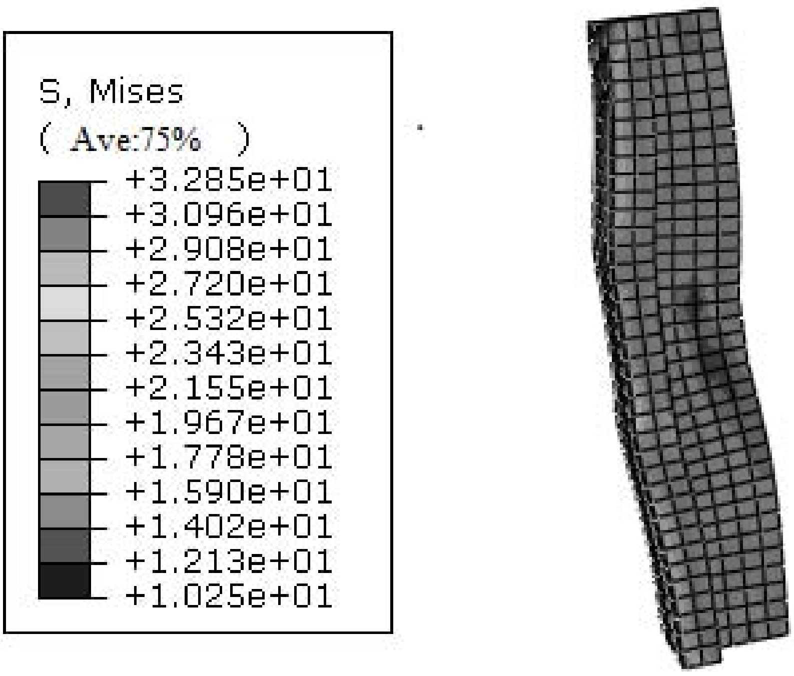

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Figure 6: Fig. 7 : 6 2019 E©

6 CONCLUSION

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Hwang et al. [11] studied the seismic behavior of the joint of U-shaped steel-concrete composite beams and RC columns. XU et al. [12] analyzed the seismic behavior of cross section joints of CFST columns and steel girders under different axial compression ratios. Fukumoto et al.[13] studied the joint specimens of high-strength steel tubular columns and steel beam, and the types of the joints include inner partition joint of square steel tubular columns-steel beam and outer partition joint of concrete circular steel tube-steel beam. Kubota et al.[14] proposed a separate type of outer diaphragm joint with square Steel tubular column and H-shaped steel beam, which is less welding work and easier to

Figure 7: Table 1 : Material properties of steel

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Steel model	Elastic modulus	Yield strength	Ultimate strength
Q235	2.06×10 5 Mpa	235Mpa	370Mpa
Concrete strength grade	Elastic modulus	Axial compressive strength standard value	Axial compressive strength design value
C40	3.25×104Mpa	26.8Mpa	19.1Mpa

Model number	Axial compression ratio	Side plate extension length(mm)	Concrete strength grade	Steel model
A	0.2	258	C40	Q235
B	0.4	258	C40	Q235
C	0.6	258	C40	Q235
D	0.6	308	C40	235
E	0.6	356	C40	Q235

Figure 8: Table 3 :

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Figure 9: Table 4 :

.1 Acknowledgements

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