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Finite Element Analysis of Low Cyclic Reversed Loading of Interior Joints with Core Steel Tube in Concrete Filled Square Steel Tube

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Abstract. The study explores finite element analysis of lo w cyclic reversed loading of the intern-or joints with co re steel tube in concrete filled square steel tube. The results show that the co re steel tube and the hoop are the supplement to the joint strength, which make the joints have high strength and ductility. According to the hysteretic property analysis, the hysteretic curve of the joint shapes in fusiform, which means that it has good energy dissipation capacity.

Concrete-filled steel tube (CFST) structures have been widely used and developed in high-rise buildings. CFST joints are a key technical problem in the design of CFST structures. Especially, there are still many problems in the joints between CFST columns and reinforced concrete beams. Therefore, the study of such joints is helpful for engineering design and application. In this paper, the work of literature [1] is continued, and the finite element analysis of the improved joints is carried out. The feasibility of the improved joints is analyzed and the superior mechanical performance is confirmed.

Two models of concrete filled steel tubular joints with core steel tube are established. The axial compression ratios of the two models are 0.14 and 0.28. This paper intends to study the seismic behavior of CFST joints with core steel tube, analyze the failure modes, bearing capacity, ductility and energy dissipation capacity of CFST joints with core steel tube under low cyclic loading, verify the feasibility and rationality of the joints, and investigate the influence of different axial compression ratios on the seismic performance of CFST joints with core steel tube under low cyclic loading.

Node Model and Loading System

Taking the mid-joint of frame structure as an example, considering the stress of the structure under horizontal seismic load, the "ten" shaped part between the inflection points of the frame is taken for analysis. According to the 1/3 scale design of the actual structure, two joint models are established. The size and reinforcing bars are shown in Fig.1. The parameters of the model are shown in Table 1.

The model is subjected to low cyclic loading, and the seismic indexes such as failure mode, bearing capacity, ductility and energy dissipation capacity of joints under low cyclic loading are studied. Vertical reciprocating load is applied at the end of the beam. The displacement loading method is adopted. The axial compression ratios of JD-1 and JD-2 are 0.14 and 0.28, respectively. Before loading, the Y-direction displacement of all the joints on the end face of the beam is coupled to a key point. When the displacement is applied, only the displacement is applied in the Y direction of the key point. In the first step, the axial force P is applied to the top of the column in the form of area load, and in the second step, the beam end load R is applied in the form of displacement. For the number of reciprocating loads, according to literature [2], each stage load can be reciprocated once, or it can be reciprocated 2-3 times until failure. The loading sequence is shown in Fig.2

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Table 1 Strengths of materials and other parameters

Specimen number	Square steel tube (B× t)	Core steel tube (D× t× L)	Beam section	Concrete (fc)	Beam bottom reinforcement	Beam upper reinforcement	Joint vertical reinforcement	Joint area stirrups
JD—1T	150*3	89*3.75*700	100*250	15.65	2Φ12	2Φ12	4Φ12	7Φ6
JD—2T	150*3	89*3.75*700	100*250	15.65	2Φ12	2Φ12	4Φ12	7Φ6

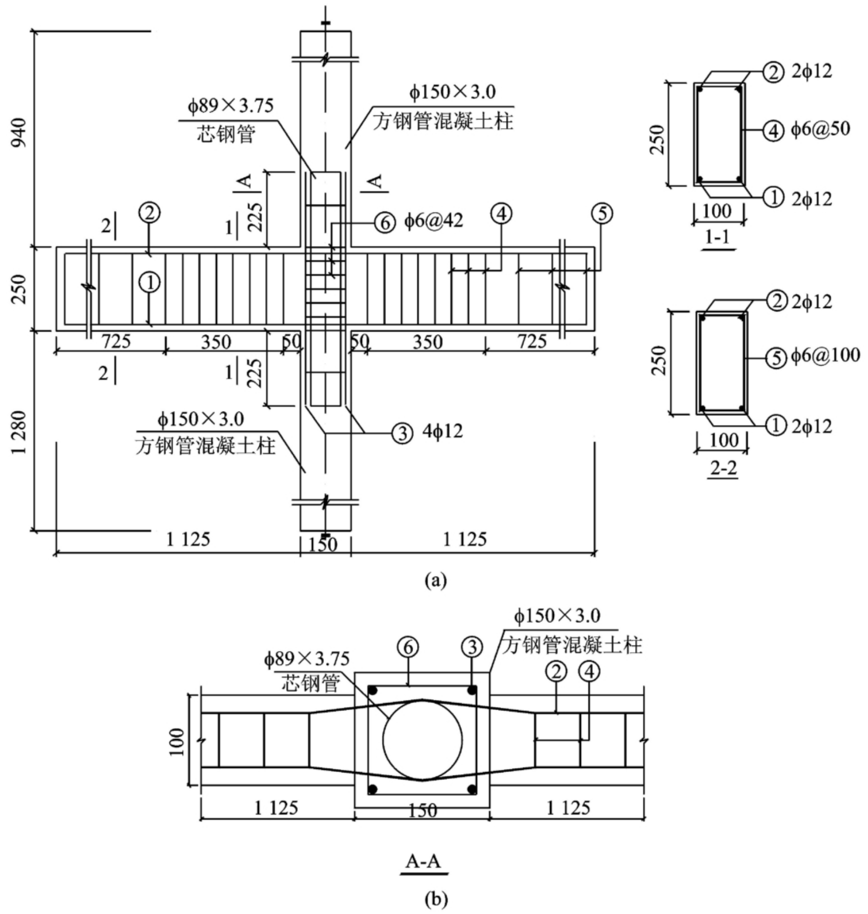


Figure. 1 Section dimension and reinforcement of specimens (mm)

Establishment of Finite Element Model

Selection of Cell Model and Mesh Generation. In this analysis, it is assumed that the bond between steel and concrete is complete. Concrete is simulated by 8-node solid element SO L ID65, steel tube is simulated by 8-node solid element SO LID45, and steel bar is simulated by 6-degree-of-freedom PIPE20. The finite element meshing of model specimens is shown in Fig. 3. The total number of elements in the model is 22,368, including 15,515 SOL ID65 elements for concrete, 5,745 SOL ID 45 elements for steel tube and 1,108 PIPE20 elements for steel bar.

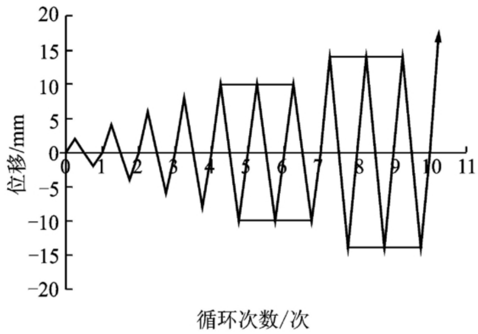


Figure. 2 Cyclic loading

Constitutive Relation of Materials. For concrete materials, the elastic-plastic constitutive model is adopted (Fig.4). The model describes the main characteristics of concrete, including cracking and crushing behavior of concrete. The elastic-plastic constitutive model adopts the will-aim— Wrinkle five-parameter yield criterion, uniform hardening criterion and related flow criterion. According to different stress conditions, different formulas are used to express the constitutive relationship of concrete. There are four different kinds of concrete in this model: frame beam concrete is ordinary concrete, using the constitutive relationship recommended in literature [3]; square steel tube core concrete and core steel tube core concrete, using the constitutive relationship recommended in literature [4]; confined concrete outside the core steel tube in the joint area and in the close-packed hoop, using the constitutive relationship recommended in literature [5-6].

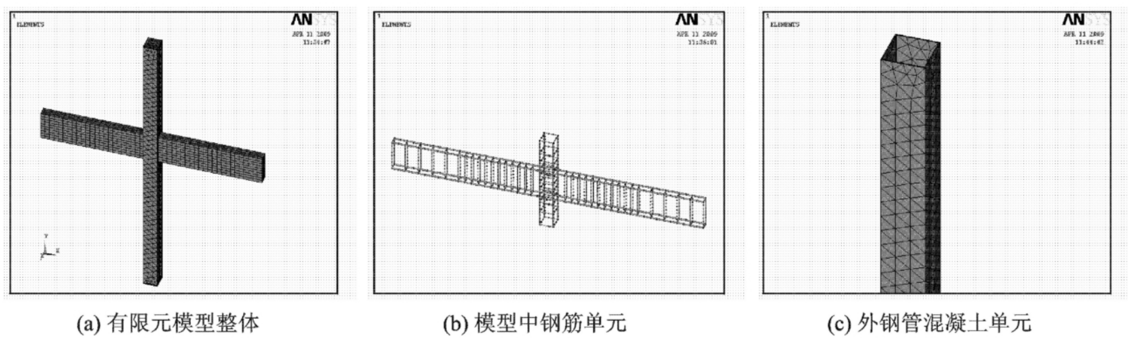


Figure. 3 Meshes of constituent parts of the joints

Results and Analysis

Hysteretic Curve Analysis. Hysteretic behavior is an important parameter for elastic-plastic seismic response analysis of concrete filled steel tubular structures. Under low cycle reciprocating load, in the process of unloading, reverse loading and unloading, the circular curve formed by the relationship curve between reciprocating load and structural deformation is called hysteretic loop. A series of hysteretic loops formed after multiple loading and unloading constitute the hysteretic curve of the structure.

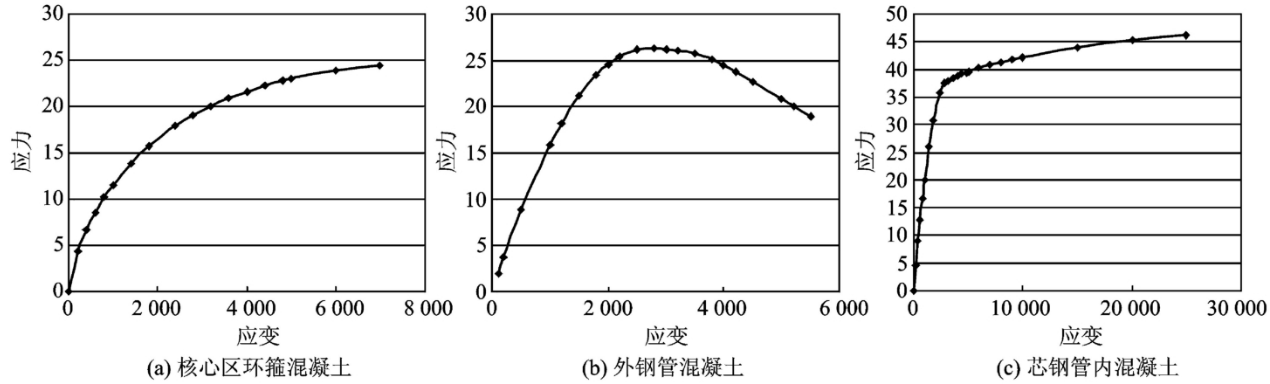
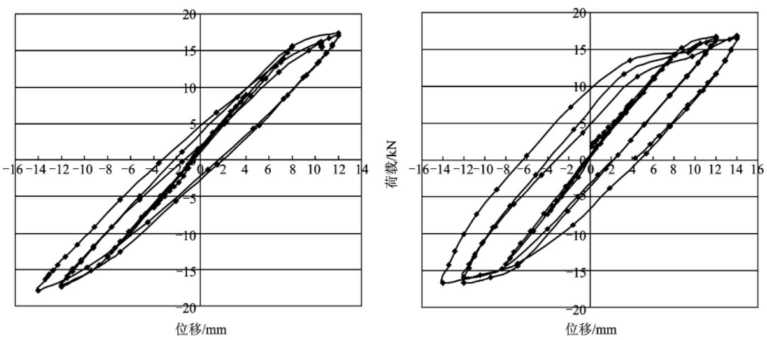


Figure. 4 Constitutive relations of the concrete

Fig.5 is the hysteretic curve of the joints under low cyclic reciprocating loads with different axial compression ratios analyzed by AN SYS. It can be seen from the figure that the joints are in the elastic stage at the beginning of loading, the load-displacement changes linearly, and the hysteretic loop is not obvious. With the increase of cyclic times of reciprocating loads, residual deformation still exists after each unloading, and increases with the increase of cyclic times, the hysteretic loops become more and more full, and the joints are in the non-linear stage. In each loading process, the slope of the curve decreases with the increase of the load. At the same time, the slope of the curve decreases gradually compared with the previous loading, which indicates that the stiffness of the joint is gradually degraded under the reciprocating load.

In addition, it can be seen from Fig.5 that the two groups of hysteretic curves are shuttle-shaped and full, which shows that the joints have good plastic deformation capacity, good seismic performance and energy dissipation performance. Comparing the two groups of hysteretic curves, the curves with large axial compression ratio are fuller and the bearing capacity is larger. There are few models, so it can only be explained that in a certain range, the increase of axial compression ratio can improve the energy dissipation capacity of joints.



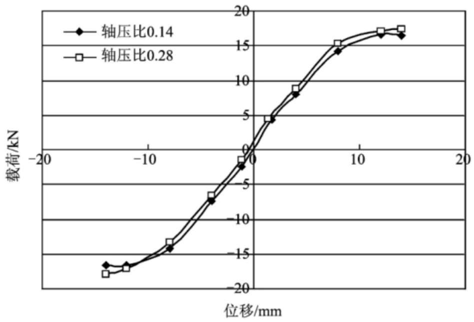


Figure. 5 Loading-displacement hysteretic curve of beams in joints Figure 6 Loading-displacement curve of joints

Skeleton Curve Analysis. Skeleton curve is the curve obtained by connecting the peak points of each load in the same direction on the hysteretic loop curve of components under the action of reciprocating load. Many tests show that for the components with the same parameters, after comparing the skeleton curve of repeated loading test with the load-displacement (P -Δ) curve of monotonic loading, the shape of the curve is similar, and the change rule of each index is the same, but the value is different. The P -Δ of the joints in this paper is almost the same as the elastic stage of the skeleton curve under reciprocating loading, but the ultimate bearing capacity of the joints is reduced due to the reciprocating loading.

Fig.6 is a comparison of skeleton curves of different axial compression ratios under reciprocating loads analyzed by AN SYS. From the skeleton curve, it can be seen that the stiffness of the structure degrades gradually during the whole loading process. It is in the elastic stage before joint yielding. At this stage, the two curves of different axial compression ratios coincide basically, which indicates that in the online elastic stage, the effect of the change of axial compression ratio on the bearing capacity of joints is not obvious. It can be seen from the figure that the slope of the joint skeleton curve with large axial compression ratio decreases slowly after the joint yielding, which indicates that the stiffness degradation of the joint is slower.

Conclusions

Through the finite element analysis of the concrete filled square steel tubular joints with continual beam and discontinue column and core steel tube, the reciprocating loads are applied to the joints, and the different axial pressures are applied to the joints. Two calculation models of the joints are established. The mechanical properties of the joints under reciprocating loads are analyzed. The following conclusions are drawn:

1).Based on the ANSYS finite element analysis results and the observation of the whole process of joint failure, it is concluded that the failure process of the joint is reasonable, which proves the feasibility and rationality of this type of concrete filled square steel tubular column joint under horizontal repeated load.

2).According to the results calculated by ANSYS, the hysteresis curve and skeleton curve are analyzed. Under the action of repeated loads, the hysteretic curves of the two joints calculated models are shuttle-shaped with full curves, there is no obvious pinching phenomenon and it has good energy dissipation performance. The skeleton curves of the joints are inverted Z-shaped. When the joints are in the elastic stage, the slope of the skeleton curves is basically the same. When the joints begin to yield, the stiffness of the joints begins to degenerate and the slope of the skeleton curves becomes smaller.

3).Analysis of two joint models under different axial compression ratio shows that the area surrounded by hysteretic curve envelope of joints increases with the increase of axial compression ratio, and the stress increases under the same displacement load. It shows that in a certain range, increasing the axial compression ratio can improve the energy dissipation capacity and bearing capacity of joints.

References

[1] Y.H. Wang: Experimental Study and Bearing Capacity Calculation of the New Type of Break-Type Joints of Concrete-Filled Steel Tubular Beams and Columns [D], Xi'an: Chang'an University, 2006. (In Chinese)

[2] T.Y. Wang: Structural Testing of Civil Engineering [M], Wuhan: Wuhan University of Technology Press, 2003:7.(In Chinese)

[3] Tianjin University, Tongji University, and Southeast University: *Concrete Structure: The first Volume*[M], Beijing: China Architecture & Building Press, 1998: 21-23.(In Chinese)

[4] L.H. Han: Concrete-Filled Steel Tubular Structure[M], Beijing: Science Press, 2000: 106-ll0.(In Chinese)

[5] Z.H. Guo: Principle of Steel Reinforced Concrete[M], Beijing: Tsinghua University Press, 1999: 174-178.(In Chinese)