Research on the Behavior of Spatial Steel Truss Confined Concrete under Axial Compression

Qingsuan Shi¹,², Yunxiao Chen¹*

¹ School of Civil Engineering, Xi'an University of Architecture and Technology, Xi'an 710055, Shaanxi, China;
² Key Laboratory of Structural Engineering and Earthquake Resistance of Ministry of Education, Xi'an University of Architecture and Technology, Xi'an 710055, Shaanxi, China
*Corresponding author’s e-mail: cyxsean@163.com

ABSTRACT: In order to study the axial compression performance of spatial steel truss confined concrete composite columns, the finite element software ABAQUS was used to establish the spatial steel truss confined concrete composite column models. The stress and strain states of the steel truss and core concrete in the composite column are analysed. Then, the influence of parameters such as angle steel size, the spacing and arrangement of steel plate, and strength of the concrete on the axial compression mechanical performance and restraining effect of the spatial steel truss confined concrete are discussed. The research results show that the spatial steel truss can exert a good restraining effect on the core concrete. At the same time, the spacing of steel plate is the key factor that affects the restraining effect of the spatial steel truss on the core concrete.

1. Introduction

The steel-concrete composite structure has been researched and developed for decades. At present, domestic and foreign scholars have conducted a lot of experimental and theoretical studies on steel-concrete composite columns with different combinations[1]. The restraining effect on the core concrete is better than that of the solid web type. It has the advantages of good axial load capacity and high material utilization rate. Lu Huawei [2] et al. carried out the axial compression test study of angle steel confined concrete short columns; Chen Zongping [3] et al. Axial compression test research was carried out on the middle and long columns; Kim [4] et al. carried out the eccentric compression test and theoretical research on the steel truss concrete composite columns. In view of the shortcomings of the existing square cross-section confined concrete columns, the spatial steel truss constrains the structure of the concrete composite column is improved and proposed. The steel truss welded by angle steel and plaque is used as a built-in component to replace the new steel-concrete composite column formed by longitudinal reinforcement.

2. Establishment of finite element model of concrete composite column confined by spatial steel truss

2.1. Material constitutive model

The steel adopts a bilinear stress-strain relationship model that does not consider the strengthening effect of steel. Because the thickness of the angle steel of the limbs is relatively thin, the lateral extrusion of the spatial steel truss results in a large deformation of the angle steel. Even if the steel has
a secondary strengthening effect, the strength can't be further developed, and the angle steel even shows local compression and buckling. The Poisson's ratio is 0.3. The stress-strain relationship of the confined concrete can be calculated according to the constitutive model of the axial compression of the spatial steel truss confined concrete established in Reference [5-7]. The Poisson's ratio is 0.2.

2.2. ABAQUS finite element model

The angle steel, the steel plate and the concrete all adopt C3D8R solid element. Research results [8] show that under axial load, when sufficient reinforcement measures are placed between the steel plate and the concrete, the effect of bonding and slippage between the contact surfaces of steel and concrete is not considered, so the effect of bond slip between the two can be ignored. Therefore, the normal direction of the contact surface between the spatial steel truss and the concrete is set to the "hard contact" correlation property, the tangential direction is set to "penalty function", and the friction coefficient is taken to be 0.5.

All displacements and rotation angles in the x, y, and z directions of the bottom surface of the column are fully confined to become fixed ends, and the displacement in the z direction is relaxed on the top surface of the column to apply the displacement load in the z direction. After many trial calculations, the unit size of the concrete is 30mm, and the unit size of the spatial steel truss is 15mm. The spatial steel truss confined concrete composite column mesh is shown in the figure.

3. Stress state analysis of each component of composite column

3.1. Steel truss

Taking the STCC-A1 specimen as an example. It can be seen from Figure 4 that when the axial load reaches the ultimate bearing capacity of the specimen The whole specimen has entered the plastic stage, and the angle steel of the limbs at the mid-section of the specimen has reached the yielding state, and the steel plate at the mid-section of the column has also begun to yield. It can be seen from the Figure 5 that the angle steel of the limbs not only fully yielded, but also suffered serious bending deformation. The steel plates gradually developed from the original only the middle part of the column to the upper and lower sides.
3.2. Core concrete
As shown in Figure 6, it shows the distribution of the stress cloud diagram of the cross section of the core-confined concrete cross-section view at the mid-section of the specimen. It can be clearly seen that in the entire square section, the area with the highest stress is concentrated in the four corners near the angle steel Part, followed by the central part, and the area where the 4 edges are close to the steel plate has the least stress, indicating that the spatial steel truss has the strongest restraint effect on the concrete at the 4 corners, and then gradually decreases along the diagonal direction, 4 edges The central region close to the patch panel has the weakest restraining effect.

4. Analysis of factors influencing mechanical properties of confined concrete composite columns by spatial steel truss
In order to comprehensively analyze the axial pressure performance of the combined column, from the angle steel size, the spacing of the steel plates, and concrete strength grade. The parameters of the established finite element analysis model are shown in Table 1.

| Specimen number | Angle Steel (mm) | Patchwork (mm) | Patch spacing (mm) | Concrete strength grade |
|-----------------|------------------|----------------|-------------------|------------------------|
|                 | Limb length | thickness | Steel content of section | length | width | thickness |                     |
| STCC-A1         | 70          | 4         | 2.48%               | 260    | 100   | 6         | 100                 | C40                   |
| STCC-A2         | 70          | 6         | 3.63%               | 260    | 100   | 6         | 100                 |                       |
4.1. Angle steel size

The load-displacement curve of STCC-A1-A5 and the stress-strain curve of core-confined concrete are shown in Figure 7 and Figure 8. It can be seen from the figure: under the condition that other influencing factors remain unchanged, as the size of the angle steel increases, the ultimate bearing capacity of the specimen increases, the corresponding peak displacement increases, and the final bearing of the specimen after stopping the loading force also increases accordingly. By comparing the stress-strain curves of the core confined concrete, the change trend of the five specimens is basically the same. After increasing the size of the angle steel, the restraining effect of the spatial steel truss on the core concrete can be improved, although the improvement effect is not significantly, but the restraining effect of increasing the angle steel size on the core concrete can't be ignored.

4.2. Patch spacing

Through ABAQUS finite element modeling and calculation, the load-displacement curve of STCC-A3, A6, A7, A8 specimens and the stress-strain curve of core-confined concrete are shown in Figure 9 and Figure 10. It can be found that when the other influencing factors remain unchanged, as the distance between the patch plates increases, the ultimate bearing capacity of the specimen decreases, and the corresponding peak displacement decreases. At the same time, after the loading stops, the specimen's ultimate bearing capacity is also reduced. As the spacing of the steel plate increases, the restraining effect of the spatial steel truss on the core concrete gradually weakens, and as the restraining effect weakens, the core-confined concrete reaches the peak stress. The stress reduction will continue to increase when the loading continues, especially when the spacing of the steel plate is greater than 150mm, the core confined concrete will drop significantly after reaching the peak stress, and the restraining effect will be significantly weakened.
Therefore, this article suggests that the configuration of the steel plate adopts the ratio of the steel plate spacing to the steel plate width of 1:2, and the steel plate spacing is less than 150mm, the spatial steel truss has the best restraining effect on the core concrete, which can greatly improve the composite column Axial mechanical properties, greatly improve the ductility of composite columns.

4.3. Concrete strength grade

Through ABAQUS finite element modeling and calculation, the load-displacement curve of STCC-A3, A9, A10 specimens and the stress-strain curve of core-confined concrete are shown in the figure 11 and figure 12. It can be found that as the concrete strength level increases, the ultimate bearing capacity of the specimen increases, but the final bearing capacity of the specimen decreases slightly after stopping the load, so the constraints generated when the concrete strength is low The effect is more obvious. The three specimens show the same change trend, and after reaching the peak stress, the curve advances to the descending section and enters the gentle section; the concrete strength is lower At the time, the resulting restraining effect is more significant, the curve has a shorter falling section, will enter the platform section earlier, and is more gentle; and when the concrete strength is higher, the curve will have a more obvious falling section, its falling section Longer; finally, when the curves enter the gentle section, the mechanical properties of concrete with different strengths tend to stabilize.

5. Conclusion

(1) The spatial steel truss can effectively restrain the core concrete, which greatly improves its mechanical properties;

(2) When the size of the angle steel is increased, the ultimate bearing capacity of the test piece is improved, but the constraint effect of the angle steel on the core concrete cannot be ignored;

(3) The spacing of the steel plate reflects the volume steel ratio of the test piece. The smaller the spacing of the steel plate, the better the restraint effect of the spatial steel truss on the concrete, and
the stress-strain curve will enter the gentle horizontal section earlier.

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