Seismic Performance Analysis of Steel Reinforced Concrete Columns and Steel Beam Joints

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Abstract: This article is based on The finite element model of five steel-reinforced concrete column and steel beam joint specimens was established on the platform. The comparison results of hysteresis curve, skeleton curve and steel stress distribution state were analyzed, and the ductility of the beam-column joints, concrete strength grade and beam-column joints were analyzed. The three dimensions of bearing capacity are discussed in depth for the seismic performance of steel-reinforced concrete columns and steel beam joints.

1. Introduction

The steel-concrete structure of steel and concrete has the advantages of performance, and it has good ductility, rigidity and energy consumption under the conditions of earthquake occurrence. It has wide application value in high-rise buildings in China. Generally, in the structural system of the building, the shear failure of the frame joint will seriously affect the stability of the overall structure. Therefore, it is necessary to carry out simulation analysis on the force of the joint to optimize the seismic performance of the beam-column joint.

2. Finite Element Model Establishment

2.1. Beam and column node construction scheme

In this paper, five steel-reinforced concrete columns and steel beam joint specimens are selected as research objects, and the test piece numbers are respectively $SSRCJ1-SSRCJ5$, where the test piece $SSRCJ1$ For ordinary steel reinforced concrete beam-column joints, test pieces $SSRCJ2$ Expanded cross-shaped steel setting in the column, test piece $SSRCJ3$ Beam and column $45°$ Skewed, the rest of the test piece columns are diagonally placed in the form of cross-shaped steel, the beams and columns are orthogonal, and ordinary hot rolling is used in the beams. I Font steel. In terms of specimen size, the column cross-section dimensions of all specimen nodes are $250mm \times 250mm$ Except for the test piece $SSRCJ1$ Beam section size is $200mm \times 300mm$ In addition, the beam dimensions of the remaining four specimens are $220mm \times 300mm$; its built-in steel is adopted $Q235$ Steel welded; beam and column longitudinal reinforcement $HRB400$ Grade hot rolled ribbed bar, the diameter of the bar is $20mm$;use $HPB300$ Grade hot rolled round steel bar as a stirrup, the diameter of the stirrup is $6mm$ The distance between the encrypted area and the non-encrypted area is $40mm$, $60mm$, the core area of the node is $100mm$; concrete strength rating is set $C50$, the thickness of the protective layer is set to $20mm$, the axial compression ratio is 0.4.

2.2. Constitutive relationship model of steel reinforced concrete

Based on the damage plastic constitutive model, the mechanical properties of the specimen under low confining pressure are simulated. The effective stress and hardening variables are used to establish the constitutive model:

$$\sigma = (1-d)D_0^{e1} : (\varepsilon - \varepsilon^{p1}) = D^{e1} : (\varepsilon - \varepsilon^{p1}) \quad (1)$$

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Among them D_0^{e1} The initial elastic stiffness of the test piece material; D^{e1} The stiffness of the test piece material after low confining pressure damage; d For the stiffness damage variable, the range of values is $0 \le d \le 1$ .When analyzing the equivalent plastic strain of steel-reinforced beam-column joints under uniaxial tension and compression, the hardening constant must be completed first. ε_t^{01} versus ε_e^{01} The setting of the stress-strain curve under two damage states is carried out to establish a concrete damage plasticity model; in the case of uniaxial tension, the test piece gradually transitions from the linear elastic phase to the yield stress, and then reaches the softening phase. At the same time of decline, there is a certain correlation between the subsequent stress and the cracking strain; under the uniaxial compression state, the test piece gradually reaches the initial yield stress from the linear elastic phase, and then transitions to the strengthening phase and the softening phase, in the process. The hardening data [1] is determined mainly by inelastic strain. It can be concluded that the stress-strain relationship of steel reinforced concrete materials under tension and compression is:

$$\sigma_t = (1-d_t)E_0(\varepsilon_t - \varepsilon_t^{p1}) \quad (2)$$

$$\sigma_e = (1-d_e)E_0(\varepsilon_e - \varepsilon_e^{p1}) \quad (3)$$

2.3. Finite element modeling of beam-column joints

Based on $Abaqus$ The platform completes the numerical analysis and the establishment of the calculation model, and divides the steel, concrete and steel into $S4R$, $C3D8R$, $T3D2$ Three units for processing, using $Spring2$ The spring unit simulates the connection of steel and concrete, based on Tie The constraint simulates the connection between the two to complete the establishment of the finite element model of the node test piece. In the specific analysis process, the following two analysis steps should be set: one is to constrain the x-direction, y-direction and z-direction displacement at the bottom of the column, and to constrain the x-direction and y-direction displacement of the beam to avoid the inclination of the member and the stress at the beam end; The second is to apply y-direction displacement to the top of the column, adjust the boundary conditions of the beam end, constrain the x-direction and z-direction displacement, and release the y-direction displacement.

3. Finite Element Modeling Analysis and Experimental Results Comparison

3.1. Hysteresis curve comparison

Based on $Abaqus$ The low-cycle repeated load test of the platform simulation specimens is compared with the experimentally obtained curves. By observing the difference between the two curves, it can be found that the simulation results are in the cycle number, maximum load, ultimate load, ultimate displacement and other indicators. The above is ideal, but the finite element model can not effectively control the cracking load, and can only directly carry out the displacement cycle, so it can not reflect the stiffness attenuation and cumulative damage in the later part of the specimen. The main reasons for this problem are the following three points: First, in the model establishment process, only the method of embedding concrete is used to fix the steel and steel members, but the slippage of the steel in the concrete is not taken into consideration. The stiffness has a certain influence; the second is that the boundary conditions are not clearly set, there are looseness in the loading process, horizontal displacement occurs, etc., which affects the symmetry of the hysteresis curve; the third is the parameter value problem, the temperature is not Factors such as eccentricity are included in the consideration of the value of the descending segment of the model, and still need to be optimized [2].

3.2. Skeleton curve comparison

Based on $Abaqus$ The load-displacement skeleton curve of the test piece is generated by the platform, and the calculation result is compared with the test curve. It can be observed that the change trend of the two curves is basically consistent, and the fitting degree of the negative load curve is better, and the test piece is better. $SSRCJ4$ The peak load is different from the experimental value 1.5% Extreme displacement phase difference 12% .This shows that before reaching the peak load, $SSRCJ2-SSRCJ5$ The stiffness and bearing capacity of the specimen are lower than the calculated value; after reaching the peak load, the stiffness decay rate shown by the finite element model is slowed down, the downward trend is more stable, and the extension performance is more advantageous. In general, the test piece is generated by transforming and designing the steel-reinforced concrete beam-column joints. $SSRCJ2-SSRCJ5$ Compared to ordinary test pieces $SSRCJ1$ In terms of the superior ductility and energy consumption, the seismic performance of the beam-column joints is significantly improved.

3.3. Steel stress distribution state

Select test piece $SSRCJ2$ As a research object, different degrees of pressure were applied thereto, and the stress state of the test piece was observed. when $SSRCJ1$ when only the axial pressure is applied, the stress and strain of the test piece are small, and the elastic working state is maintained. When the horizontal load is applied, the compressive stress of the flanges on both sides of the cylindrical steel is asymmetrically distributed, and the core area is y-direction. The stress on the web is increased; in horizontal loads P Value $95.95kN$ When the steel web has local yielding, the maximum stress is $241.04MPa$;in P Value $116.8kN$ When the core zone beam steel web and the flange edge partially yield, the cylindrical steel y mostly yields to the web, and the maximum stress is $252.38MPa$;when P Value $133.61kN$ When the core zone x is bent to the profiled steel flange and the web, the maximum stress is $271.32MPa$ With the continuous increase of the loading displacement, when P Reduced to maximum load capacity 80% At the time, the core zone steel web and the flange will produce most of the yield, and the profile steel will be deformed, and the node reaches the limit state.

3.4. Seismic performance analysis

Generally, the ductility of steel-reinforced concrete beam-column joints is determined by the axial compression ratio, which in turn affects the bearing and deformation of the beam-column joints. Comparing the two specimens with the same construction and different axial compression ratios, it can be found that the axial compression ratio has a great influence on the variation trend of the load-displacement skeleton curve. The larger the axial compression ratio, the smaller the bearing capacity and stiffness of the joint; When the axial pressure ratio exceeds a certain value, the curve will enter the descending phase, and the displacement ductility will decrease accordingly; when the axial pressure ratio is controlled at $0.3-0.6$ In the interval, under the constraint of the flanged cross-shaped steel, the stiffness of the curve in the elastic phase will not be significantly affected, which can ensure the member has good stiffness and deformation ability. Therefore, under the condition that the steel content is consistent, the steel-reinforced beam-column joints should be set by diagonally arranging the cross-shaped steel, which can effectively improve the stiffness and deformation of the joint.

Taking the concrete strength grade as a variable, two test pieces were selected to draw the load-displacement skeleton curve. It can be found that the concrete strength grade is proportional to the shear capacity of the joint. When the enlarged cross-shaped steel is used in the column, the concrete strength grade is on the column. The effect of the skeleton curve is more pronounced. Generally, the higher the concrete strength grade of the test piece, the faster the skeletal curve descends. The reason is that the brittleness of the concrete increases accordingly. When the load reaches a certain value, the concrete part reaches the ultimate tensile strength, which in turn causes cracks. The shear capacity is reduced. Therefore, the emphasis should be placed on the selection of cross-shaped steel with diagonal lines in the column to optimize the seismic performance of the steel-reinforced beam-column joints [3].

Using the loading angle as a variable, select 2 test pieces to draw the load-displacement skeleton curve, from which it can be found that when the loading angle is 0° Increase to 60° When the bearing capacity of the specimen gradually decreases, the ultimate displacement decreases after a period of time; when the loading angle is 0° Increase to 45° When the bearing capacity of the specimen gradually decreases, the ultimate displacement remains unchanged; when the loading angle exceeds 45° When the test piece bearing capacity and deformation capacity are reduced; reach at the loading angle 60° When the specimen stiffness is the minimum. Therefore, when loading in the orthogonal direction, the bearing capacity and deformation resistance of the steel-reinforced concrete beam-column joints are optimal, which can effectively improve the seismic performance of the members. However, in the actual application process, due to the uncontrollability of the seismic direction, it is still necessary. Strengthen the checking of bearing capacity in different directions and optimize the quality assurance of node design.

4. Conclusion

This article uses *Abaqus* The program constructs the structural model of the steel-reinforced concrete column and the steel beam joint. By comparing the numerical analysis results with the experimental results, the force performance and deformation degree of the beam-column joint under the low-cycle repeated loading are obtained, based on the axial compression ratio. The three parameters of concrete strength and loading angle are used to optimize the arrangement of beam-column joints, thus ensuring that the seismic performance of the joints is significantly improved.

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