Working Mechanism of OATSCB-CFST Joint

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Abstract—Concrete filled steel tube (CFST) and steel castellated beam are ideal components in the structure. However the research about the connection of them is less at present. In order to analyze the working mechanism of outer annular-stiffener type steel castellated beam-concrete filled steel tube (OATSCB-CFST) joint, load-bearing process of this type of middle column joints under low cycle load are simulated by finite element software. Before simulating, the simulation method is verified by the test data of a middle joint of outer annular-stiffener type steel solid beam-concrete filled steel tube (OATSB-CFST). The results show that: the high stress area of the OATSCB-CFST joint is mainly focused on the position of the castellated beam and the annular-stiffener near the border between them, the position of the tube near annular-stiffener, the position of the annular-stiffener near medial axis of the steel beam, and the position of the core zone concrete. This implies that the annular-stiffener zone should be a key consideration in the design.

Keywords- CFST; Steel Castellated Beam; beam-column joint; force behavior;working mechanism.

I. INTRODUCTION

Concrete filled steel tubular (CFST) is made of steel tube filled with concrete. It has high bearing capacity, plasticity and toughness, and it is easy to be constructed, so it has been widely used in engineering [1]. Steel Castellated Beam (SCB) is made of wide flange steel H-beam or I-beam with castellated holes, which can save steel and is convenient in construction for the pipelines can pass-through the castellated holes and etc. And SCB also has been widely used in civil engineering [2]. Especially due to outer annular-stiffener earthquake, due to the constraints effect of the steel tube, the inner concrete will not be peeled or cracked, which made the superior compressive performance of concrete and good tensile properties of the steel tube played enough. So CFST has excellent seismic performance and is easy to realize the project of "strong column". At the same time, because the castellated holes of SCB exist near to the neutral axis, which reduce the elastic bending modulus of the cross-section a little but reduce the inelastic bending modulus of cross-section larger. When the earthquake happened, SCB is easier to enter into plastic and to form "weak beam" yielding mechanism. In all, CFST and SCB are ideal components in civil engineering. Therefore, it becomes one of the focuses of civil engineers that how to connect them together and how the force behavior of the connected joint is. But little study is done on it. So, in this paper, the force behavior of OATSCB-CFST would be analyzed.

II. FINITE ELEMENT SIMULATION AND ITS VERIFICATION OF OATSCB-CFST JOINT

According to the form of OATSB-CFST joint [3-4], the OATSCB-CFST joint is designed as Fig .1.The loading process of the OATSCB-CFST joint is simulated with ABAQUS which is a kind of finite element software. The loading device schematic diagram is shown as Fig .2. In simulation: the stress-strain curve of SCB and steel tube are used with the elastic-plastic material model; the stress- strain curve of the core concrete is plastic damage model; S4 shell elements are used to simulate Steel tube and SCB; eight-node reduced integration of the three-dimensional solid elements (C3D8R) are used to simulate the core concrete and loading plate. The default hard contact is used to simulate the normal direction of the contact between steel tube and concrete, and the tangential coulomb friction model is used, in which, the friction coefficient is taken as 0.6 from reference[5]. The upper and lower end of the steel column is hinged by only binding the displacement of y-direction. In order to avoid stress concentration, the concentrated force is transformed into surface load. Ant-symmetric low cyclic loading is applied on both ends of beam-end. And we use Newton-Raphson iteration method to solve it. In order to test the validity of the simulation method, the loading process of the OATSB-CFST member in reference [6] is simulated by above method, because no test has been done on OATSCB-CFST joint before. The skeleton curves between simulation and

experiment are shown as Fig .3. It can be seen from Fig .3, the result of simulation and test are similar to each other. So, it has a certain rationality that this kind of finite element simulation method can be used to study force behavior of the OATSCB-CFST.

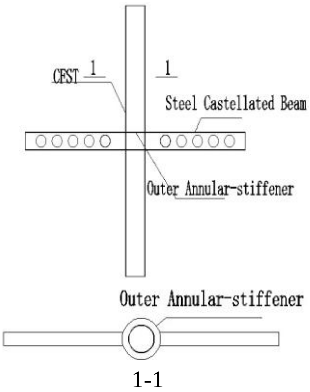


Figure 1. Schematic structure of OATSCB-CFST

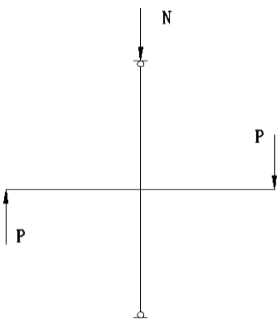


Figure 2. Loading device schematic diagram

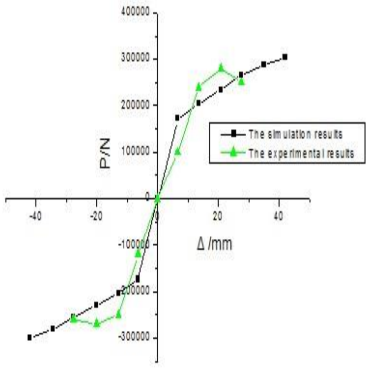


Figure 3. Skeleton curves Comparison

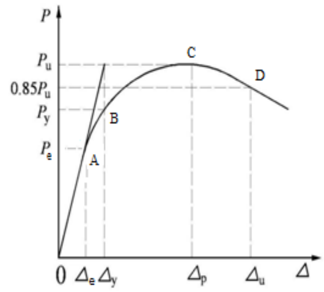


Figure 4. Schematic diagram of the P-Δ skeleton curve

III. WORKING MECHANISM OF OATSCB-CFST

In order to analyze the force behavior of OATSCB-CFST joint, a scaled OATSCB-CFST joint is designed and the corresponding three-dimensional solid finite element model is established. At the same time, a OATSB-CFST with the same size is also designed and the corresponding 3D finite element model is also established. The specific dimensions are as follows: the diameter of CFST is 200 mm, the steel tube wall thickness is 5mm; the height of CFST is 2200 mm; the length of SCB is 1100 mm; the cross-section height of SCB is 150mm; the width of the flange is 100mm; the thickness of web plate is 6mm; the thickness of the flange is 8 mm; the SCB hole is round hole; the circle is on the centerline of SCB, the diameter of the hole is 100 mm; the first hole from the column edge is 200mm; the distance or the holes are 160mm; the outer annular-stiffener width is 50mm and its thickness is 8 mm. In simulation, the axial compression ratio is 0.4 at the head of column.

In order to analyze the working mechanism of OATSCB-CFST joint, we extract its mises stress nephogram in concrete, tube and SCB of points A,B,C,D which are on the envelope curve of the load-displacement hysteresis curve (P-Δ skeleton curve for short). P-Δ skeleton curve is showed as Fig .4, in which, P represents the load applied on the beam end, Δ represents the displacement on the beam end, Pe represents its proportional limit, Py represents its yield load, Pu represents its ultimate load, Δe represents the displacement of its proportional limit, Δy represents the displacement of its yield load, Δp represents the displacement of its ultimate load, Δu represents the displacement of 85% ultimate load. Mises stress nephogram is showed in Fig .5 to Fig .7, in which the unit for stress is Mpa. The mises stress nephograms of concrete are showed in Fig .5, concluding a nephogram of the whole column, nephograms of the sections of the column where the outer annular-stiffeners are, a nephogram of radial section of the column.

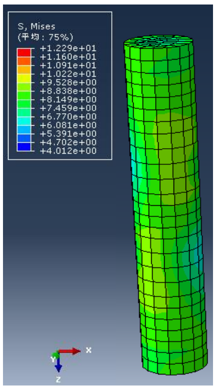
From Fig .5-Fig .7, it can be seen that the high stress area of the OATSCB-CFST joint is mainly focused on the position of the castellated beam and the annular-stiffener near the border between them, the position of the tube near annular-stiffener, the position of the annular-stiffener near medial axis of the steel beam, and the position of the core zone concrete. This implies that the annular-stiffener zone should be a key consideration in the design.

IV. Conclusion

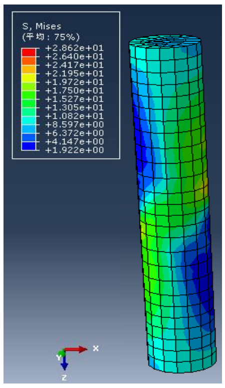
Based on the above analysis, the following conclusions can be obtained:

The high stress area of the OATSCB-CFST joint is mainly focused on the position of SCB and the annular-stiffener near the border between both, the position of the tube near annular-stiffener ,the position of the annular-stiffener near SCB's medial axis, and the position of the core zone concrete.

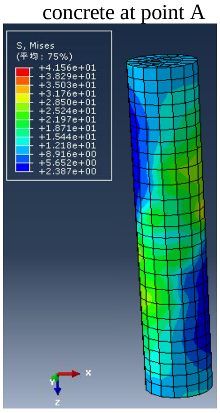
The joint in the position of the border between SCB and outer annular-stiffener lose efficacy firstly. The high stress area is mainly focused on the area near the border between outer annular-stiffener and SCB, and the tube near the outer annular-stiffener.



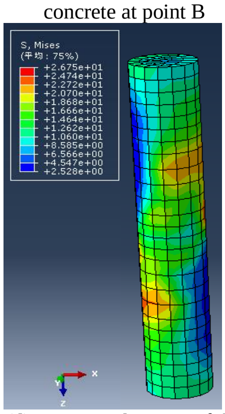
(a) Stress nephogram of the concrete at point A



(b) Stress nephogram of the concrete at point B

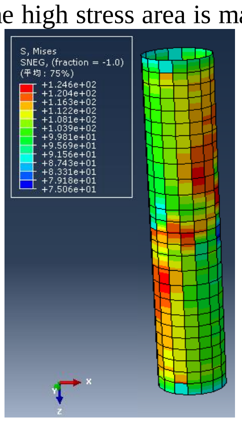


(c) Stress nephogram of the concrete at point C

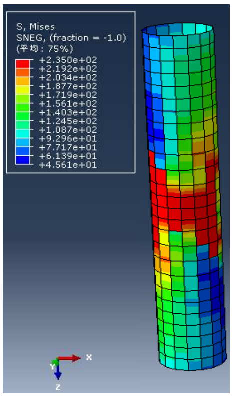


(d) Stress nephogram of the concrete at point D

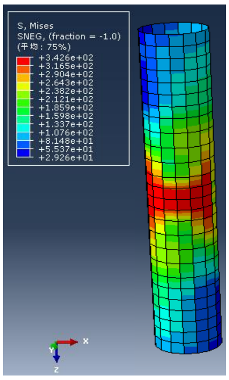
Figure 5. Stress nephogram of the concrete corresponding to the different points of the P-Δ skeleton curve



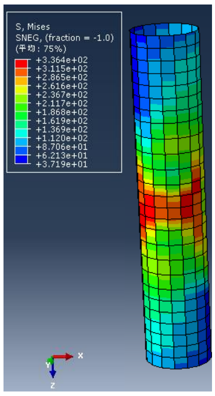
(a) Stress nephogram of the steel tube at point A



(b) Stress nephogram of the steel tube at point B

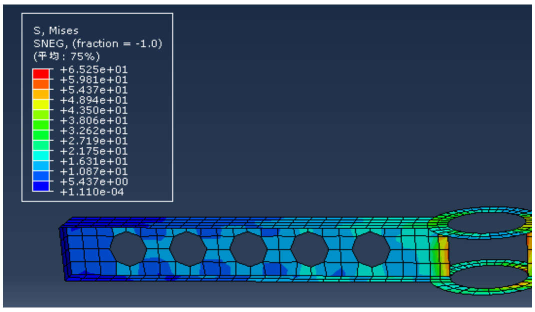


(c) Stress nephogram of the steel tube at point C

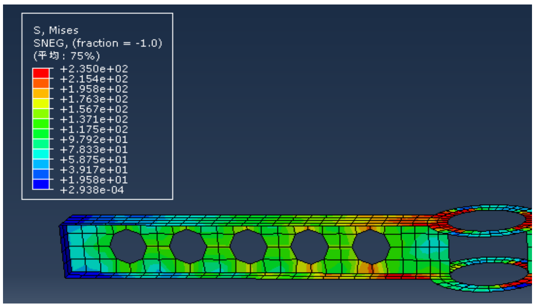


(d) Stress nephogram of the steel tube at point D

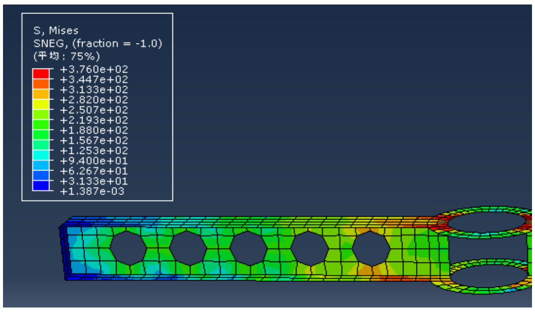
Figure 6. Stress nephogram of the steel tube corresponding to the different points of the P-Δ skeleton curve



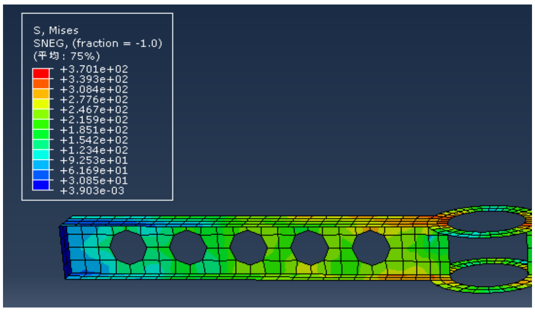
(a) Stress nephogram of the SCB at point A



(b) Stress nephogram of the SCB at point B



(c) Stress nephogram of the SCB at point C



(d) Stress nephogram of the SCB at point D

Figure 7. Stress nephogram of the SCB and the outer annular-stiffener corresponding to the different points of the P-Δ curve

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