Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 12, No. 2, 2024

A Review of the Properties of Different Concrete-Filled Steel Tube Columns

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Abstract: This paper mainly analyzes different types of concrete-filled steel tube columns to compare different parameters such as loading angle, eccentricity, different steel pipe thickness, different strength grades of concrete, different cross-sectional shapes, etc., and elaborates the changes of mechanical properties of the specimens under the influence of different parameters. The formulas of axial compression and flexural bearing capacity of different concrete-filled steel tube columns and the bearing capacity of concrete-filled steel filled steel tubes after fire were proposed, and the interaction of various materials in the components was studied in depth. The proposed studies are summarized.

Keywords: Concrete-filled Steel Tubes; Heteromorphic Column.

1. Introduction:

The column is the core load-bearing component of the building, and the performance of the column determines the performance of the building to a certain extent, and now with the improvement of people's living standards, more and more buildings choose special-shaped columns with higher space utilization rate as the main load-bearing components, and the special-shaped columns have the advantages of flexible layout and high space utilization, and can be arranged along the wall, while the bearing capacity of ordinary reinforced concrete special-shaped columns is limited and the seismic performance and deformation capacity are poor, in order to improve this kind of problem, Therefore, the special-shaped column is combined with the steel pipe to form the concrete-filled steel tube special-shaped column, and after the continuous research of scholars at home and abroad, the performance and application of the concrete-filled steel tube special-shaped column have achieved initial results. The steel and concrete synergy ability in the concrete-filled steel tube special-shaped column is stronger, can give full play to the performance of steel and concrete, and has high bearing capacity, good deformation capacity, good ductility, and is widely used in high-rise buildings, bridges and other buildings that require high performance of load-bearing components. Due to the addition of more steel in the concrete-filled steel tubular column, the ductility and seismic capacity of the component are greatly improved, and the restraint of the steel pipe to the concrete can improve the bearing capacity and stability of the component, and has a good effect on improving the mechanical properties of the reinforced column, and the steel pipe is more convenient than the ordinary reinforced concrete in the construction process simultaneously, so that the construction process can be simplified and the project progress can be accelerated. Therefore, accelerating the research on concrete-filled steel tubular special-shaped columns has a positive effect on its application and promotion in reality.

2. Concrete-filled Steel Tubular at Room Temperature

(1)Zheng Yongqian et al. [1] carried out eccentric compression tests on 7 multi-chamber and 1 unribbed T-shaped concrete-filled steel tube columns, and carried out tests by controlling variables such as different loading angles and eccentricities, and compared the results and phenomena of different tests and analyzed. The results show that the multi-chamber concrete-filled steel tube specimens begin to appear drum bent when the load drops below 90%, and the deflection is larger when the drum is bent, while the ribless specimens begin to appear drum bent and the deflection is smaller when the load drops below 95%, which shows that the multi-chamber specimens have better ductility than the non-ribbed specimens, which can effectively alleviate the surface drum bending of the specimens, and the damage of the ribless specimens is more serious. Through the load deflection curve, it can be seen that the bearing capacity of the multi-chamber specimen is about 10% higher than that of the non-ribbed specimen, and the initial stiffness is relatively similar, and the bearing capacity of the specimen under different loading angles is also quite different under the same eccentricity. The increase of eccentricity will lead to a significant decrease in the peak load, and at the same time, the stiffness of the specimen will also decrease and the deflection will increase. The comparative test shows that the T-shaped multi-chamber concrete-filled steel tube special-shaped column has better performance than the non-ribbed concrete-filled steel tube column, so the applicable flexural bearing capacity formula is introduced for the new concrete-filled steel tube column[2]:

$$M_u = k_a \gamma_m W_0 f_{se}$$

$$k_a = 1.14 - 0.0019\theta' \begin{cases} 0 \le \theta < 45^\circ & \theta' = 67.5 - \theta \\ 45^\circ \le \theta < 112.5^\circ & \theta' = \theta \\ 112.5^\circ \le \theta < 180^\circ & \theta' = 225 - \theta \end{cases}$$

$$\gamma_m = 1.84 - 0.051 / [tf_y / (Df_c^{'})]$$

Thereinto: W_0 is the flexural modulus of the combined cross-section.

(2) Chang Xinyu et al. [3] welded 6 L-shaped steel tube high-strength concrete columns and 2 L-shaped ordinary steel tube concrete columns for axial compression tests, and the tests were carried out by controlling variables such as different steel pipe thicknesses and grouting strengths. The test results show that the synergy between the outer steel pipe and the inner concrete is good, and all the specimens are in

the elastic stage before the load reaches 90%, and there is almost no obvious change. When the specimen with a thickness of 4mm steel pipe begins to show slight drum curvature on the surface, and with the increase of the load, the degree of drum curvature becomes larger and larger, and when the peak load is exceeded, the bearing capacity decreases rapidly, and the drum curvature extends to other faces, in which the specimen with the drum bending position far away from the end plate forms a plastic hinge and has obvious bending in the drum bending area, while the specimen near the end plate at the drum bending position does not bend the phenomenon. When the load exceeds the peak load, the load decreases slowly, and the specimen without high-strength grouting material and the low-strength grouting material first appears drumming, as the load continues to decrease, the drum bending range increases, and the load of the specimen without high-strength grouting material decreases to 89%, and the load of the specimen without high-strength grouting material decreases to 89%, and the load enters the fluctuation stage and finally enters the descending section, and the high-strength grouting material specimen is finally destroyed due to excessive deformation. The drum bending phenomenon of the remaining two high-strength grouting specimens with high strength is not obvious. The test shows that the thickness of the steel pipe can effectively inhibit the drum curvature of the specimen and increase the ductility of the specimen, and the expansion of the grouting material of different strength in the steel pipe is different, which affects the ability to work with the steel pipe, so the failure mode of the specimen is different, and it can be seen from the load displacement curve that the higher the strength of the grouting material, the greater the ultimate bearing capacity, and the greater the thickness of the steel pipe, the greater the ultimate bearing capacity. Finally, the formula of the axial compressive stability bearing capacity of concrete-filled steel tubular proposed in the specification AISC360 [4] is the closest to the actual situation, and the axial compressive bearing capacity of such components is obtained by using this formula, and the formula is as follows:

$$\frac{N_0}{N_{cr}} \le 2.25, N_u = N_0(0.658^{\frac{N_0}{N_{cr}}})$$

$$\frac{N_0}{N_{cr}} > 2.25, N_u = 0.877N_{cr}$$

$$N_0 = A_s f + 0.85A_c f_c'$$

$$N_{cr} = \pi^2(E_s I_s + C_1 E_c I_c)/(0.7L)^2$$

$$C_1 = 0.25 + 3\frac{A_s}{A_s + A_c} \le 0.7$$

(3) Du Guofeng et al. [9] designed and fabricated 12 L-shaped concrete-filled steel tube columns with built-in steel frames and 3 L-shaped concrete-filled steel tube columns without internal steel frame structures for axial compression tests, and analyzed their effects on the mechanical properties of the specimens by controlling the internal bone matching ratio. The test results show that there is no obvious change in the initial loading stage of the specimen without steel bone, and after more than 60%, the sunny angle surface of the specimen begins to appear local drum curling, which is separated from the internal concrete, when the load is close to the peak load, the drum curvature appears in the part close to the end, and the rest of the drum curvature gradually becomes more, and the drum curvature phenomenon occurs on different surfaces. When the load drops to 90%, the middle part of the column begins to appear outward, and then the different surfaces also begin to bulge, the weld of the specimen drum part is cracked, and the failure form of the specimen is convex bending. There is no obvious change before the load reaches 80%, the compressive deformation of the specimen is linear, the lateral deformation is small, the local drum bending phenomenon occurs on the sunny angle surface after the load exceeds 80%, and the strain growth of the steel pipe and steel bone is nonlinear. When the load reaches the peak load, the strain of the steel bone and the steel pipe increases rapidly, the drum curvature range of each surface increases, and when the load drops to about 90%, a large range of local convex drum appears in the middle of about 10 cm from the top, and the weld crack at the column angle is damaged, and the failure form is similar to that of the specimen without steel bone. Through the test, it can be concluded that the external steel pipe of this kind of specimen can work well with the internal steel composite structure, and the addition of steel structure can effectively improve the bearing capacity and ductility of the specimen. Through the analysis, the formula of axial compressive bearing capacity of L-shaped concrete-filled steel tube columns with built-in steel bones is proposed:

$$N_u^c = f_c A_c \left[1 + (1+K)\theta\right](1 + 0.6\zeta)$$

$$\zeta = f_{ys} A_s / (f_{yt} A_t)$$

$$\boldsymbol{\theta} = f_{yt} A_t / (f_c A_c)$$

Thereinto: f_{ys}, f_{yt} The yield strength of steel bones and steel pipes are respectively, A_s, A_t is the area of the steel frame and the steel pipe.

3. Concrete-filled Steel Tubular after Fire

Lv Xuetao et al. [5] designed and fabricated 14 round concrete-filled steel tube stubs equipped with longitudinal stress reinforcements, and carried out the temperature rise test according to the ISO834 curve, 2 were used to measure the temperature field, and the remaining stub columns were cooled to carry out the axial compression test. The effects of different fire time and reinforcement ratio on the mechanical properties of the specimens were analyzed. The test results show that when the specimen is taken out of the furnace after being subjected to high temperature, the oxide layer on the surface becomes crisp or falls off directly, the middle color of the specimen after 30min of fire becomes red, and the two ends of the specimen change little, and the two ends of the specimen after 60min of fire turn red and the middle turns light blue, indicating that the temperature in the middle is higher than that at both ends. During the loading process, with the increase of load, the surface oxide layer first falls off, and then shear slip lines begin to appear when the load exceeds 30%, and most of them are at an angle of 45° to the axis of the specimen. With the continuous increase of the load, the surface steel pipe gradually began to appear drum and has a tendency to increase, the slip line gradually extended to the middle, covering the entire surface when the load reaches 80%, at the same time, the internal concrete began to break, the outer steel pipe appeared more drum bending, the whole specimen appeared obvious deformation, and the test ended when the deformation exceeded 20mm. The compressive failure mode of the specimen under different fire times is basically inhibited by the specimen at room temperature, and the concrete shear failure, while the stiffness of the specimen is lower after fire, and the stiffness of the specimen decreases significantly with the longer the fire time, the increase of reinforcement ratio can effectively improve the stiffness of the specimen, and the steel tube reinforced concrete column has good ductility and bearing capacity, and the fire specimen has little effect on the bearing capacity, but has a great impact on the ductility of the specimen. Based on the ultimate equilibrium theory and the superposition principle, the formula for calculating the axial compressive bearing capacity of reinforced concrete stub columns after fire [6] is proposed:

$$N_{\mathrm{u}} = k_{\mathrm{N}} N_{\mathrm{u},0} + f_{\mathrm{yb,T}} A_{\mathrm{sb}}$$

Thereinto: k_N,:Is the influence coefficient of the bearing capacity of the concrete-filled steel tube stub column after high temperature

$N_{u.0}$,:It is the bearing capacity of concrete-filled steel tubular at room temperature

A_{sb},:Is the area of the reinforcement

$f_{yb,T}$,:Is the yield strength of the steel bar after high temperature,

$T_m \le 330℃$, $\frac{f_{yb,T}}{f_{yb}} = 1$; $330℃ < T_m \le 600℃$, $\frac{f_{yb,T}}{f_y} = 1.1 - 3 \times 10^{-4} T_m$

$$T_{\mathrm{m}} = T_{\max} \cdot \mathrm{e}^{-45.6x/(D\sqrt{t_{\mathrm{k}}})}$$

4. Conclusion and Prospects

With the wide application of concrete-filled steel tubular columns in recent years, there are more and more studies on concrete-filled steel tubular columns. In this paper, the loading angle, eccentricity, internal form, thickness of steel tube and grouting strength of different forms of concrete-filled steel tube columns are studied, and the fire and non-fire specimens and different cross-sectional shapes are compared under axial compression, the research status of CFST columns is introduced, and the suitable bearing capacity formula at room temperature and the bearing capacity formula of CFST columns after fire are summarized and deduced through research. The gradually improved theoretical system will provide a theoretical basis for the development of different CFST columns.

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