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Study on mechanical properties of steel pipe constrained reinforced concrete column after fire

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Abstract

Fire has always been an important problem that cannot be ignored in the structural design. The high temperature of the fire affects the mechanical properties of the material and causes serious loss of life and property. As the main vertical load-bearing member of the structure, the concrete column plays an important role in ensuring the bearing capacity and the overall stiffness of the building structure. When the fire occurs, the high temperature will reduce the mechanical properties of the reinforced concrete column, seriously endangering the safety of the structure, so it is very important to study its fire resistance. On the basis of consulting a large number of previous achievements, this paper analyzes the axial pressure performance of steel pipe constraint after the fire, and puts forward some points of its own.

Keywords

Steel pipe constraints on reinforced concrete column; after fire; axial pressure performance.

1. Introduction

Steel pipe constrained reinforced concrete column is a new type of composite structure, which is widely used in high-rise buildings because of its high bearing capacity, excellent ductility performance and construction convenience. Although the mechanical properties of this structure at room temperature have been extensively studied, the changes in its mechanical properties and its influencing factors have not been fully explored after fire. Therefore, the study of the axial pressure mechanical properties of the steel tube is of great significance to evaluate the structural safety after fire and guide the repair work after disaster.

2. Research Background

Concrete filled steel tube dates back to 1879, when concrete was poured into the steel pipe piers of the Seven Railway Bridge to prevent steel pipes from corrosion and bearing pressure. Then the concrete filled steel tube column began to be applied to industrial plants, but the early application generally did not consider the improvement of the constraint effect of steel pipe on concrete on the bearing capacity of components. The study of mechanical properties of constrained concrete columns originates from the study of different stress modes of concrete columns, Gardner and Jacobson (1967) in Canada, Orito et al. (1988) in Japan, Prion and Boehme (1994) in Canada, O'Shea and Bridge (1997) in Australia, Johansson and Gylltoft (2002) in Sweden, Fam et al. (2004) in Canada, CAI Shaohuai and Jiao Zhanuan (1984) in China, Wang Yuyin, Guo Lanhui et al. (2005, 2008) have studied the mechanical properties of CFFcolumns in different stress modes, The stress mode includes: (1) the load acts only on the core concrete; (2) the load acts on the steel pipe and the concrete at the same time, The former is the steel tube restraint concrete column. A lot of research on the mechanical properties of steel tube constrained concrete columns at room temperature. Although domestic research started late compared with foreign countries, it has developed rapidly and been fruitful in recent years. The

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research contents can be divided into square, round and rectangle according to the component section form; there are axial pressure, bending, pure bending, stagnation, pure twisting, shear, etc. However, there are few studies on the mechanical properties of steel pipe constrained concrete columns after fire. The existing studies mainly focus on the mechanical properties of constrained concrete columns after fire, while there are few studies on constrained concrete columns.

3. Research Contents

3.1. Research Progress

Between 1997 and 2001, Sun and Sakino [1,2] conducted the shaft compression test and lag test. The research shows that the improvement of steel content and concrete strength of steel pipe will weaken the constraint of outsourcing steel pipe on concrete. Liu initiator et al. [3] In 2014, the posterior axial pressure mechanical properties of round steel pipe constrained reinforced concrete short column were studied. The results show that the failure mode of specimen is shear failure, but has good ductility. In 2015, Yang Hua et al. [4] performed a foot test on the mechanical properties of round steel pipe constrained reinforced concrete long column after fire. It is found that the whole specimen is bent and deformed, and the local steel pipe bends. In 2017, Song Keyan and Wang Weiyong [5] carried out the axial pressure and bias mechanical properties test of the circular steel pipe under fire, and obtained the temperature field distribution, axial deformation, lateral displacement and failure mode of the specimen under standard heating conditions. The influence of the section size, load eccentricity, steel pipe wall thickness, concrete strength, section steel material strength and load ratio on the specimen temperature field and fire resistance limit is analyzed. In 2020, Sheng Honghe [6] studied the axial pressure mechanical properties of steel pipe constrained steel concrete short column after fire. With the help of finite element analysis software ABAQUS, the temperature field model and axial pressure model of steel pipe constrained steel concrete short column were established. It is found that the steel content and concrete strength are the main factors to improve the residual axial pressure stiffness of the members. In 2021, Yang Dongdong [7] carried out a fire test on two rectangular steel pipe constrained reinforced concrete columns. It is found that the fire resistance of such components decreases with the increase of load ratio or fine-length ratio, and increases with the increase of cross-section size. The aspect ratio has less influence on the fire resistance of reinforced concrete rectangular steel tube constraint column.

3.2. Experimental Research

Yanrui [8] conducted 6 groups of 18 square steel pipes. The main parameters are fire time and section size, the fire time is 0min, 45min and 90min respectively, the side length of test section is 200mm and 250mm respectively, and the height is 600mm and 750mm respectively. The test was carried out in the Structure and Seismic Test Center of Civil Engineering, Harbin Institute of Technology, using a 500-ton press for loading. When loading, the load of the specimen is measured by a 500-ton force sensor, and the displacement of the specimen is measured by four LVDT displacement sensors.

The test shows that the high temperature will make the material degradation, resulting in the reduction of the residual bearing capacity of the test, so the mechanical performance of the short concrete column of the steel pipe behind the fire is the longer the fire time, the lower the residual bearing capacity. Under the condition of the same fire time, due to the larger heat capacity of the large section specimen, the lower the historical highest temperature of the specimen points, the larger the section area of the steel pipe constrained concrete short column behind the fire, and the higher the ratio of the residual bearing capacity to the untreated fire bearing capacity. The axial pressure bearing capacity of the side length 200mm and 250mm

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was reduced by 18% and 7% at 45min, and the axial pressure bearing capacity by 47% and 33% at 90min, respectively.

With the increase of fire time, the residual stiffness of the steel pipe after fire decreases. At the same time, the smaller the section, the lower the residual stiffness of the specimen. The axial pressure stiffness of 200mm and 250mm short columns decreased by 39% and 24% at 45min, and by 56% and 48% at 90min.

Wang Xishan [9] divided the test into two parts: short column axial pressure test and medium and long column axial pressure test. In the process of test loading, the shape and deformation trend of the specimen were observed and recorded. It was concluded that the square steel pipe is prone to shear failure and waist drum failure during the loading process. The ultimate bearing capacity of the short column member increases with the increase of concrete strength and the decrease of heating time. The steel content of steel pipe of axial pressure short column was increased from 3.21% to 6.21%, and the ultimate bearing capacity of test pieces in 0min, 45min and 90min was increased by 2.45%, 5.16% and 4.08% respectively. The increase of steel content of steel pipe has little effect on improving the remaining bearing capacity of short column after fire, but it can improve the ductility of specimens after fire.

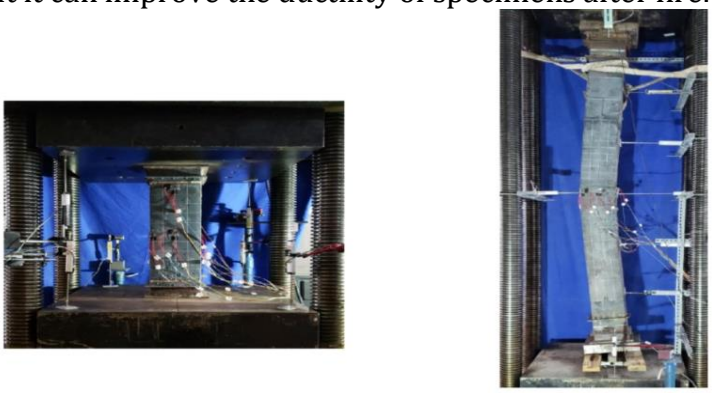

Fig. 1

In the specimen temperature field test, ISO 834 standard heating curve is used to control the furnace temperature, which matches the furnace temperature curve and ISO 834 standard curve well in the heating stage, and it takes a long time for the furnace temperature to drop from 200℃ to room temperature during the natural cooling process.The external heat is transferred along the radial section of the specimen to the center of the section, and the temperature change of the internal measuring point of the section lags behind the average temperature in the furnace respectively, and the farther the shortest distance of the measuring point from the outer steel pipe, the more significant the lag phenomenon is, the lower the historical highest temperature, the slower the cooling trend of the temperature curve. At the same time, high temperature will weaken the difference degree of different positions of steel pipe on concrete in the short column of square steel pipe. Compared with the normal temperature specimen, the concrete inside the short column specimen after fire is more uniform and constrained by the steel pipe.

Liu initiated [10] a total of 5 pieces of ISO 834 standard foot components under the action of fire, 4 of which are round steel pipe constraint reinforced concrete column, to investigate the impact of load ratio and component mode on its mechanical properties under fire, the other one is round concrete filled steel tube column contrast parts. The main overall instability failure of the test steel pipe constraint is accompanied by the local buckling of the steel pipe. With the increase of the fire time, the crisp and peeling phenomenon of the internal concrete is more and more serious, but the outsourced steel pipe effectively restricts the shedding of the concrete, so that the large area of the concrete does not occur.

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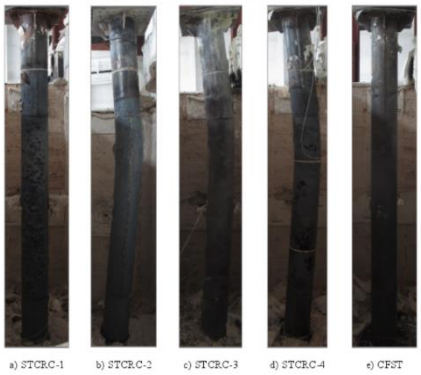

Fig. 2

Eight thermocouples are installed at different heights of the fire test furnace to monitor the temperature in the furnace. The temperature in the fire test furnace is relatively uniform, and all are well consistent with the ISO 834 standard heating curve.

The following table is obtained from the test, where L is the component height (mm) and tR is the measured value of the fire resistance limit. It can be seen from this table that the load ratio has a great influence on the fire resistance limit of steel pipe constrained reinforced concrete members, the greater the load ratio, the lower the fire resistance limit of the members; with the increase of the opening of steel pipe, the fire resistance limit of the members increases slightly, but the impact is small. Under the same conditions, the fire resistance limit of steel pipe restraint reinforced concrete column is much higher than that of concrete filled steel tube column, which proves that better fire resistance can be obtained by embedding some steel in the form of reinforcement.

Table 1

Number	D(mm)	ts(mm)	L(mm)	n	Nf(KN)	Component mode	tR(min)
STCRC-1	300	2.75	3810	0.25	1340	a	≈116.5
STCRC-2	300	2.75	3810	0.33	1800	a	82.5
STCRC-3	300	2.75	3810	0.42	2240	a	50
STCRC-4	300	2.75	3810	0.42	2240	b	53.5
CFST	300	6.00	3810	0.42	2168	-	23

4. Summary and Outlook

Compared with reinforced concrete columns, the former has higher compressive bearing capacity, bending bearing capacity and shear bearing capacity, and better ductility. The constraint effect of the steel pipe constrained concrete column makes the core concrete in the three-way compression state, and the constraint of the outsourced steel pipe can effectively avoid the shedding of the protective layer of the reinforced concrete column, the yield and even pull and the instability of the longitudinal reinforcement, which can greatly improve the bearing capacity and ductility of the components. Based on the above advantages, steel pipe constrained reinforced concrete columns have been applied in super high-rise buildings and large-span sports venues in recent years, and it may be a trend to use steel pipe constrained concrete columns in future buildings. For the future development, the influence of different parameters (such as steel pipe wall thickness, concrete strength, loading method, etc.) on the axial pressure mechanical properties of steel pipe constrained reinforced concrete column after fire can be deeply studied, so as to provide a more accurate theoretical basis for practical engineering application. At the same time, the mechanical performance analysis model of steel pipe

constrained reinforced concrete column after fire is continuously improved and optimized, and the accuracy and reliability of the model are verified through more test data.

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References

[1] Xiao Yan, Guo Yurong, He Wenhui, et al: Study on strengthening the reinforced concrete column with partial reinforced steel casing, Journal of Architecture, Vol. 24 (2003) No.6, p. 79-86.

[2] Zhou Xuhong, Gan Dan, Liu Jiemeng, et al: Experimental study and analysis of reinforced concrete axial pressure short column constrained with square steel pipe, Journal of Architectural Structure, Vol. 32 (2011) No2, p. 68-74.

[3] Liu F, Gardner L, Yang H: Post-fire behaviour of reinforced concrete stub columns confined by circular steel tubes, Journal of Constructional Steel Research, Vol. 102 (2014) No0, p. 82-103.

[4] Yang H, Liu F: Gardner L. Post-fire behaviour of slender reinforced concrete columns confined by circular steel tubes, Thin Walled Structures, Vol. 87 (2015), p. 12-29.

[5] Song Keyan: Study on fire resistance of steel pipe constrained concrete (MS., Chongqing University, China 2018), p. 10-46.

[6] Sheng Honghe: Study on mechanical properties of steel pipe constrained concrete after fire (MS., Harbin Institute of Technology, China 2020), p. 9-32.

[7] Yang D, Liu F, Huang S-S, et al: Structural Fire Safety Design of Square and Rectangular Tubed-Reinforced-Concrete Columns, Structures, Vol.29 (2021), p. 1286-1321.

[8] Yan Rui: Study on the mechanical properties of steel pipe after fire (MS., Harbin Institute of Technology, China 2020), p. 10-46.

[9] Wang Xizhen: Study on mechanical properties of steel pipe after fire (MS., Harbin Institute of Technology, China 2022), p. 9-40.

[10] Liu Faqi: Study on mechanical properties of reinforced concrete columns with circular steel pipe under fire and after fire (Ph.D., Harbin Institute of Technology, China 2016), p. 16-37.