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Study on the Influence of Hysteretic Behavior of Concrete Filled Steel Tubular Columns

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Abstract

Compared with the present research progress, this paper composes the research progress of hysteresis performance of steel concrete column, sum up the relevant research status at home and abroad, discusses the influence of axial compression ratio, concrete strength, steel tube strength and other factors on the hysteresis performance of steel concrete column, explores the problems and provides new directions for future research.

Keywords

Steel Pipe Concrete Column; Hysteresis Performance; Influencing Factors.

1. Introduction

China is a vast country, but the population is unevenly distributed and mostly concentrated in the eastern part. Due to its location at the junction of the Asia-Europe plate and the Pacific plate, most of China is in an earthquake-prone region, making it an earthquake-prone country in the world. Earthquakes often cause serious casualties, building collapses, and huge economic and property losses. The damage caused by earthquakes is incalculable both to families and to the country. According to statistics, over the past 10 years, earthquakes of magnitude 5 or higher in China have become significantly more active, with a frequency of more than 20 times per year. The frequency of earthquakes in 2022 exceeded the average of the last decade, and the 2008 Wenchuan earthquake killed nearly 70,000 people and caused a large number of houses to collapse or suffer irreparable damage. Aftershocks from the earthquake exist to this day, affecting people's lives. Therefore, new requirements for the performance of load-bearing elements in buildings are required. The simple increase in the size of members cannot meet the economic efficiency but cause the waste of space and increase the self-weight of the structure. Therefore, the study of new high-strength members is particularly important.

Steel Concrete Composite (SCC) is a composite structural material composed of steel pipe and concrete. It combines the high strength and stiffness of steel pipe with the high toughness and durability of concrete and other advantages in one, widely used. In recent years, along with a large number of engineering constructions, such structures have been widely used in buildings, bridges, high-rise structures, and other projects [1]. Earthquake of earthquake as a very common horizontal dynamic load, its impact on the building structure is particularly important. Therefore, the study of the hysteresis properties of steel pipe concrete plays a crucial role in the seismic resistance of the structure.

This paper compares the progress of research on the effect of fire on the hysteresis performance of steel pipe concrete columns, summarizes the main factors of the effect of fire on the hysteresis performance of such structures, presents future research problems, and looks forward to its wide application in engineering.

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2. Research Status

The hysteresis performance refers to the effect on structural deformation under repeated loading, which can reflect the stiffness degradation and energy consumption of the structure during the stressing process [2]. The study of hysteresis performance of steel pipe concrete columns by fire is one of the hot spots of fire resistance research in recent years. Under the action of fire, the mechanical properties of steel pipe concrete will change, which will have an impact on the bearing capacity and stability of the whole structural system. With the application of steel pipe concrete in engineering practice, scholars at home and abroad have gradually carried out relevant research.

Zhang and Shen [3] carried out a proposed static test study of four 1/2.5 scaled-down two-story single frames and conducted an in-depth study on the performance of structural damage morphology and mechanism, displacement ductility, energy dissipation capacity, etc. from two factors: axial compression ratio and loading direction of L-shaped steel pipe concrete columns.

Wang [4] set up three types of concrete columns from the perspective of whether to set up stiffening ribs or not and explored the damage modes and hysteretic properties of the specimens. The results indicated that stiffening ribs and steel tubes improved the stiffness and load capacity of the structure and had better energy dissipation performance.

Liu [5] et al. investigated the effects of fire time, axial pressure ratio, concrete strength, hollow ratio on the hysteresis performance of each other hollow sandwich steel pipe concrete column, established an ABAQUS finite element model, compared with the test structure, and analyzed the hysteresis curve skeleton.

Ren Pan [6] conducted fire tests on 18 square and circular members according to the ISO-834 heating curve, and carried out hysteresis test studies with concrete strength, axial compression ratio, hollow core ratio, and fire time as parameters to analyze the hysteresis curve, deformation stiffness, and energy dissipation capacity of the members. ABAQUS software was used to simulate the temperature field and mechanical field to compare and study with the test results to further analyze the stressing process and interaction between the internal and external steel pipe concrete.

Sun [7] conducted an experimental study of the whole process of fire on a square steel pipe concrete column under constant axial pressure, and considered the effect of warming time on the properties of axial compression stiffness and residual deformation after fire. The experimental study showed that fire reduces the ultimate bearing capacity and flexural stiffness; the longer the fire time, the greater the residual deformation of the post-fire member and the greater the energy dissipation coefficient and equivalent viscous damping coefficient.

Lin [8] conducted a large number of monotonic loading and reciprocal loading test studies on steel pipe concrete members after fire, established a theoretical model for hysteresis performance analysis of steel pipe concrete compression-bending members, and used ABAQUS to establish and verify the accuracy of the model, analyzed the load-displacement curves of axial compression and compression-bending members after fire, and studied the force state of the members in depth.

Bai [9] conducted a study of composite stainless steel tube concrete columns through tests and ABAQUS simulations, the main research parameters were the width-thickness ratio of square steel tube, diameter-thickness ratio of round steel tube, diameter-width ratio of round steel tube and square steel tube, etc. and axial compression ratio, steel tube strength, etc., to further reveal its force process and working mechanism. The results show that the test piece hysteresis performance is good, composite steel pipe components hysteresis performance is better than stainless steel square steel components.

P. Gajalakshmi and H. Jane Helena [10] found that mixing steel fibers into core concrete can improve the ductility and energy dissipation capacity of the members based on experimental studies, and proposed a simplified cumulative damage equation for steel tube concrete columns.

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3. Influencing Factors

At present, a large number of experimental studies and theoretical analyses have been conducted on rectangular steel pipe concrete structures at home and abroad, and the main factors affecting the hysteresis performance are axial pressure ratio, concrete strength, steel pipe strength, and fire time.

The study shows that the axial pressure ratio has a significant effect on the hysteresis performance of steel pipe concrete columns. As the axial pressure ratio increases, the stability of the column will gradually weaken, the inclination of the hysteresis curve will gradually become larger, and the ductility of the column will also gradually decrease. When the axial pressure is relatively large, the hysteresis curve of the column will appear obvious steep section, and the force performance of the column will decline rapidly.

The higher the concrete strength grade, the better the hysteresis performance of the steel pipe concrete column. The higher strength and initial stiffness of high-strength concrete allows it to withstand greater loads and deformations. This results in smoother hysteresis curves, larger peak displacements, and the ability to withstand greater seismic loads for high-strength concrete steel pipe concrete columns. High-strength concrete is more ductile and is able to maintain high seismic performance over a wide range of deformations. This means that high-strength concrete steel pipe concrete columns have better energy dissipation and seismic damping performance when subjected to seismic loads.

The strength grade of steel pipe has some influence on the hysteresis performance of steel pipe concrete. First of all, the higher the strength grade of steel pipe, the higher the load and strain value it is subjected to. At this time, within the steel pipe concrete members, the steel pipe flexural stiffness and strength will be enhanced, thereby improving the stiffness and strength of the entire structural system. These factors will make the steel pipe concrete members in the bearing capacity and deformation of better performance, the hysteresis curve of the toughness and ductility index will be improved. Secondly, the higher strength steel pipe can provide better restraint effect, and its stiffness will make the concrete more restrained, thus increasing the load-bearing capacity and ductility of the steel pipe concrete members and making them have better seismic performance.

4. Conclusion

Steel pipe concrete is a new type of concrete structure, which has better mechanical properties and hysteresis properties that change gradually with time, and has been widely used in engineering. Future research directions can be carried out from the following aspects:

1) Material research: the mechanical properties of steel pipe concrete are related to materials, and the hysteresis performance of steel pipe concrete can be improved in the future by exploring different types, grades, shapes and sizes of steel pipes, as well as different ratios of concrete.

2) Structural research: steel pipe concrete consists of steel pipe and concrete, the future can further study the mechanism of the interaction between steel pipe and concrete, and improve the overall performance of steel pipe concrete structure by optimizing the communication mechanism, designing tight joints, etc.

3) Simulation study: According to the simulation data, the influence of relevant parameters on the hysteresis properties of steel pipe concrete is studied, and the prediction model of hysteresis performance of steel pipe concrete is established, in order to better guide the actual engineering application.

In conclusion, the future research direction of hysteresis performance of steel pipe concrete will be multifaceted and comprehensive, which needs to be explored by using various methods, combining theory, laboratory tests and practical engineering applications.

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