Seismic response analysis of concrete filled steel tubular structures

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Abstract

the concrete filled steel tube structure has a large rigidity, good seismic performance, the weight bearing function and the maintenance function merge into one, give full play to the advantages of concrete and steel, save steel and reduce the cost of a series of outstanding characteristics, so that the researchers at home and abroad pay attention to it, and have obtained a lot of research results. Therefore, the concrete filled steel tubular structure is studied in this paper, and its response under earthquake action is analyzed. In order to explain, seismic response of framed concrete filled steel tubular piers is analyzed by response spectrum method, and some conclusions are drawn.

Keywords

Concrete-filled steel tubular structure; response spectrum method; seismic response.

1. Introduction

Earthquakes are sudden natural disasters, which are often random and have a short process, but they are highly destructive and may be repeated in a short period of time, causing damage to various engineering structures. This not only causes people to suffer major economic losses, but also captures the lives and health of many people. Due to the uncertainty of time and space in the earthquake, in order to reduce earthquake disasters, the prevention-oriented policy should be implemented. The most fundamental preventive measure is to do a good job of seismic fortification and improve the seismic capacity of the engineering structure. It is necessary to have a detailed understanding of the dynamic characteristics of the structural system under earthquake action, which is of great significance for doing a good job in scientific research of seismic engineering, improving the seismic design level and engineering quality of the project.

Concrete-filled steel tube is a structural member formed by filling concrete in steel pipe, and the steel pipe and its core concrete can bear external load together. According to different sections, it can be divided into round steel tube concrete, square, rectangular steel tube concrete and polygonal steel tube concrete. Concrete filled steel tube. Through the interaction between steel pipe and concrete, it makes full use of the advantages of the two materials to make up for the shortcomings of the two materials. At the same time, the outer steel tube can often replace the template, which is convenient for construction, and thus has received more and more attention. China's research on concrete-filled steel tubular structures has become more and more in-depth, especially in recent decades, and remarkable achievements have been made. Component performance and theoretical research are leading in the world.

2. Development process

After the Second World War, Europe urgently needed to rebuild war-damaged houses and bridges. Due to the shortage of steel, a large number of steel-concrete composite structures were used, which saved steel and achieved good economic benefits. After the 1923 and 1968 earthquakes in Japan, it was found that houses constructed with composite structures have good seismic performance, and the combined structure has been rapidly developed in high-rise and super-tall buildings. In 1879, the Severn Railway Bridge in the United Kingdom adopted a concrete-filled steel tube pier, which was filled with concrete to prevent corrosion inside the steel pipe and to withstand pressure.

From 1897, American John Lally filled concrete in circular steel pipes as a load-bearing column for the house and was patented. The application of concrete-filled steel tube in civil engineering has been a hundred years old.

In the Soviet Union, a span-type CFST arch bridge with a span was built in the 1960s. At that time, the United Kingdom, the United States, France and other steel tube concrete beams also carried out a series of theoretical research and experimental work, including design principles, concrete shrinkage and creep, fatigue and construction and manufacturing issues, and achieved a lot of research results.

The development and utilization of concrete-filled steel tubular structure technology in China has been nearly 40 years old. In 1958, the former Institute of Civil and Architectural Research of the Chinese Academy of Sciences first carried out experimental research on the basic properties of concrete-filled steel tube. In the 1970s, the concrete-filled steel tube structure technology was successfully applied in the single-storey factory structure of metallurgy, shipbuilding, electric power and other industries. In 1990, it was successfully applied to the Wangcang Donghe Bridge in Sichuan Province. In the same year, the Ministry of Construction officially promulgated the national recommended technical standard "Design and Construction Regulations for Concrete-filled Steel Tubular Structures". In the year, "Steel Tube Concrete Structure Technology" was included in the key promotion projects for scientific and technological achievements.

In the late 1980s, the application of advanced pumping concrete technology solved the problem of concrete pouring in the steel pipe on site, and the high-strength and high-performance concrete technology also made promising progress, which all injected the development of steel-concrete composite structure. A new vitality.

In the past 10 years, the steel-concrete composite structure has achieved rapid development in China and has achieved remarkable achievements. The total height of Shenzhen SEG Plaza Building is 291.6m, which is currently the tallest concrete-filled steel tube concrete building in the world. The main span of Chongqing Wanxian Yangtze River Bridge is 422m, which has become the world's largest span steel tube concrete skeleton arch bridge; the main span of Guangzhou Laksa Bridge 360m, is the world's largest concrete-filled concrete-filled arch bridge. The main span of the Shenzhen Rainbow Bridge, built in March 2000, is 150m. It is the world's first fully-combined structural long-span bridge. It is made of CFST main arch, CFST composite pier, prestressed steel and high-concrete concrete hollow slab composite girder bridge.

3. Characteristics and application of concrete filled steel tube structure

3.1 Characteristics of concrete filled steel tube structure

(1) High bearing capacity

When the concrete-filled steel tubular members are subjected to the axial pressure, the concrete is pressed in three directions, so that the working performance is qualitatively changed, which not only improves the bearing capacity, but also increases the ultimate compressive strain. This is the main reason why the concrete-filled steel tube structure is different from other structures. In 1976, the Harbin Boiler Factory conducted a simple comparative test.

(2) has good plasticity

The damage of concrete has obvious brittle properties. Even reinforced concrete compression members, especially axial compression and small eccentric compression members, are brittle failure. In the concrete-filled steel tubular structure, since the concrete in the steel pipe is in a three-way restraint state, the constrained concrete is different from the ordinary concrete, which not only improves the elastic property of the force stage, but also causes great plastic deformation when broken.

The destruction of its components, without brittle characteristics, is a plastic failure. The interaction between the steel tube and the concrete causes the failure of the concrete inside the steel tube to change from brittle failure to plastic failure, and the ductility of the member is significantly improved.

(3) Superior seismic performance

The performance of concrete filled steel tube is stronger than that of reinforced concrete. Under the bending and bending load cycle, the bending moment hysteresis curve shows that the concrete-filled steel tubular members have particularly good energy absorption characteristics, and the stiffness degradation is rare, and the local stability is not lost. The ductility of the component is obviously improved, the energy consumption is greatly improved, and the seismic performance is superior.

(4) better fire resistance

Because of the mutual contribution, synergistic complementarity and joint work between the steel tube composed of concrete-filled steel tube and its core concrete, the structure has good fire resistance.

(5) Contribute to steel pipe rust prevention

Because the concrete is filled inside the steel pipe, the problem of anti-rust inside the steel pipe is well solved, the corrosion of the steel pipe is slowed down, and the service life of the steel can be effectively extended.

3.2 Application of concrete filled steel tube structure

(1) High-rise buildings

In the construction process of concrete-filled steel tubular columns of high-rise buildings, the construction method of pumping jack-up concrete is very convenient, and the advantages of the concrete-filled steel tube structure itself are very reasonable. Therefore, it is very reasonable to use the concrete-filled steel tube structure in high-rise buildings. Concrete-filled steel tubular structures have been widely used in countries such as the United States, Japan and Australia. China's first high-rise building with steel tube concrete for all columns is Xiamen Jinyuan Building, with 28 floors above ground, with a total height of 96.1m, 2 underground floors and a depth of 9.8m. The main frame root frame columns are all made of concrete-filled steel tubular columns below 20 floors, and the four corner columns are made of concrete-filled steel tubular columns and directly to the roof. They were all completed in 1995.

(2) Single and multi-layer industrial plant columns

Compared with reinforced concrete columns and ordinary steel columns, concrete-filled steel tubular columns have many advantages and are therefore widely used as factory columns. For example, the Hudong heavy-duty diesel engine assembly test workshop built in September 1999 used a pumped jack-up concrete-filled steel column. The assembly unit of the assembly unit of Dalian Marine Diesel Engine Factory completed in 1999 is a low-speed and high-power marine diesel engine assembly and debugging workshop. It is a large-scale single-story industrial plant with concrete-filled steel tubular columns. The two large industrial plants of the Harbin-built Machinery Plant's large container workshop and automobile modification workshop completed in 2000 have adopted concrete-filled steel tubular columns. In the 2000 Luoyang Chemical Fiber PTA project, the design of the silo support column was made of concrete-filled steel tubular columns.

(3) Various bracket columns

In various platforms or structures, the lower struts are often axial compression members and tend to have large loads, so it is reasonable to use concrete-filled steel tubular columns to withstand large gravitational loads. For example, the heater platform column of the Heilongjiang Xinhua Power Plant, which was completed and put into operation in the year, is a concrete-filled steel tubular column for the ore storage silo support column of the Dexing Copper Mine in Jiangxi.

(4) Spatial structure

Built in 1998, Japan's Kitakyushu multi-purpose racing track, with a building area of 94,835 square meters, 8 floors above ground, 1 underground, and a concrete-filled steel tube column and steel structure beam on the ground floor, giving full play to the rigidity and strength of concrete-filled steel tube concrete. It has good resistance to deformation and good fire resistance, and has achieved good construction and economic effects.

4. Study on seismic response characteristics of frame-type CFST bridge piers

4.1 Analysis of seismic internal force response method for framed piers

In order to analyze the seismic response characteristics of framed piers, the response spectrum method is used to calculate the seismic response of framed piers with different parameters. The distribution of internal forces under the seismic action of framed piers and the influence of related parameters on the internal forces of the columns are analyzed.

4.1.1 Distribution characteristics of frame pier shear force

The shear force distribution of the frame pier is basically linear along the pier height, and the pier top shear force and the pier bottom shear force are not much different. The pier top shear force reflects the horizontal seismic force generated by the pier top mass under the action of the earthquake. In addition to the horizontal force generated by the mass of the pier, the shear force also has the horizontal force generated by the piercing mass under the action of earthquake. Since the self-weight of the framed pier body is relatively small, the difference between the pier top shear force and the pier bottom shear force is not very large.

4.1.2 Distribution characteristics of frame pier pier bending moment

According to the calculation of single pier model, if the top of the pier has only concentrated mass, the bending moment of the pier is linearly distributed from the top of the pier to the bottom of the pier, showing a gradual increase trend. The bending moment at the top of the pier is zero and the bending moment at the bottom of the pier is the largest. However, the bending moment distribution of the framed pier column is zigzag. If a column between two beams is regarded as a segment, the bending moment of each column segment is larger at the end near the beam. The middle of the segment is reduced, and the bending moment of the upper column section of the upper and middle sections of the pier has a reverse bend point. However, in general, from the top of the pier to the bottom of the pier, the maximum bending moment of each column segment gradually increases.

4.1.3 Axial force distribution characteristics of frame piers

Although the constant load axial force is not considered in the calculation, and the vertical ground motion is not input, the axial force of the frame type pier foundation column is the smallest, but the axial force of the column at the top of the pier is the smallest but not zero. The axial force of the column at the bottom of the pier is the largest, and the column axial force is the largest. From the top of the pier to the bottom of the pier is not a linear distribution, but a step-like increase. Because the frame type pier is bent, one side column is pressed and one side column is pulled, and the axial forces of the two side columns form a force couple to resist external bending moment. Therefore, where there is a bending moment, there must be axial force (including the position of the pier top), and the larger the bending moment, the greater the corresponding axial force. Because the framed pier is closer to the bottom, the bending moment is larger, so the axial force in the bottom column of the pier is also the largest.

In fact, when the hollow thin-walled piers currently used are bent, one side of the thin wall is pressed, and one side of the thin wall is pulled, but the bending moment and the pressure caused by the bending moment are equal in one section, when the hollow thin-walled pier is used as When a component is viewed, the resultant force of the axial force is zero. Each column of the frame type pier is an independent member. When the frame type pier is bent as a whole, the change of the axial force of each column caused by the bending moment can be reflected in the calculation result. The thin wall of the thin-walled pier is usually a thin-walled rectangle. When the thin wall is subjected to a large pressure, in order to enhance its nonlinear deformation ability and ensure that the core concrete is not crushed, it is necessary to configure complicated stirrups, even if these measures are taken. The compressive properties of thin walls are also not guaranteed. The existing research shows that the concrete-filled steel tube structure has good pressure-bearing capacity, and when the axial pressure is relatively large, it also has good ductility. Based on the force characteristics of the center pillar of the frame pier and the mechanical behavior of the circular steel tubular concrete members, this paper adopts the circular steel tube concrete member as the frame type high pier column to form the frame type CFST high pier and give full play to the CFST concrete members. The material properties solve the shortcomings of traditional concrete thin-walled hollow piers.

4.2 Characteristics of seismic internal forces with frame parameters

Considering that the height of the pier is 50m, the mass of the pier is 800t and the diameter of the column is 1.2m. The diagonal bracing is assumed to be concrete material with a cross section of 0.5m×0.5m square. Change the main parameters of the frame pier to form different calculation models. For each model, the seismic response is calculated by response spectrum method, and the seismic response internal force of the key section of the frame pier is given. When analyzing the influence of the main parameters of the frame pier on the internal force of the seismic response of the column, it should be noted that when the response spectrum method is used, the input response spectrum is the design response spectrum, which is characterized by the decrease of the response spectrum value as the cycle increases. The change of the frame type bridge pier also causes the change of its natural vibration period. As can be seen:

(1) When there is no diagonal bracing, no matter the spacing of the column, as the moment of inertia of the beam increases, the bending moment at the bottom of the column generally decreases. Considering that the stiffness of the beam increases, the structure frequency increases, the period decreases, the response spectrum increases, and the seismic response should also increase, while the bending moment at the bottom of the column does not increase. Therefore, it can be known that when the frame type pier has no diagonal braces, the beam stiffness is increased, and the column bending moment can be reduced. However, after the beam stiffness increases to a certain extent, the column bending moment is no longer reduced.

(2) When there is no diagonal bracing, as the spacing of the column increases, the bending moment of the column at the bottom of the pier increases, and the rigidity of the beam increases, the increase of the bending moment is larger. The main reason for this phenomenon is that the spacing of the column increases. The structural frequency also increases, and the corresponding response spectrum value is also large, so the seismic response of the structure is large, and the bending moment in the column also increases.

(3) After the diagonal bracing is set, the influence of the beam stiffness on the bending moment of the column is obviously reduced. Except for the case where the beam stiffness is particularly small, the bending moment of the column does not change substantially with the beam stiffness. Considering that after the diagonal bracing is set, the natural vibration frequency of the frame pier does not change with the beam stiffness, so it can be known that the bending stiffness of the beam has no influence on the bending moment of the column. In summary, the results of the analysis without the diagonal bracing can be concluded that the bending stiffness of the beam has little effect on the bending moment of the frame pier.

(4) When there is a diagonal bracing, the spacing of the columns has a greater influence on the bending moment of the column. As the spacing of the columns increases, the bending moment of the columns generally decreases. Especially when the spacing between the columns is too small, appropriately increasing the spacing of the columns can not only increase the rigidity of the frame piers, but also reduce the bending moment of the columns. For example, when the column spacing is increased from 2m to 3m, the first-order natural frequency of the frame pier increases from about 0.36Hz to about 0.5Hz. Although the corresponding response spectrum value increases, the bending moment of the column decreases. Nearly 20%.

(5) After the diagonal bracing is set, although the frequency of the frame type pier is improved, the bending moment at the bottom of the column is obviously reduced, and the larger the spacing of the columns is, the more obvious the reduction is. For example, when the column spacing is 5m, the

bending moment of the column with the diagonal bracing is reduced to about 60% without the diagonal bracing.

(6) When there is no diagonal bracing, as the spacing of the columns increases, the axial force of the column is gradually reduced. For the reason, as described above, the axial force of the legs of the two legs forms a force couple, and the frame type caused by the horizontal earthquake is resisted. The bending moment of the pier and the spacing of the columns increase, which is equivalent to the increase of the arm, so the axial force is reduced. However, it should be noted that after the column spacing increases, the frequency of the frame pier increases, the horizontal seismic response increases accordingly, and the bending moment of the pier bottom also increases. Therefore, when the column spacing increases, the axial force does not always decrease. small.

(7) When there is no diagonal bracing, as the stiffness of the beam increases, the axial force of the column generally increases gradually, and the variation is large. For example, when the column spacing is 5 m, the moment of inertia of the beam increases from 0.004 to 0.049, and the axis of the column The force is increased from approximately 3800 kN to 11000 kN. Analysis shows that this is mainly due to the increase in structure frequency.

(8) When there is diagonal bracing, the axial force of the column changes relatively with the rigidity of the beam and the spacing of the column. The axial force of the column changes substantially between 12000k N and 14000k N. As the stiffness of the beam increases, the axial force of the column increases gradually, and the influence of the column spacing on the axial force of the column is small and the variation is irregular.

(9) Under the same horizontal seismic force, the axial force of the column will be reduced after the framed pier is set up, but the reduction is not large. For example, when the column spacing is 2m and 3m and the beam stiffness is 0.049, the frequency is similar when there is no orbiting, so the horizontal seismic force is basically the same, but the axial force of the column is relatively small when there is diagonal bracing. It is noted that in the case where the majority of the parameters are the same, the axial force of the column with the diagonal braces is greater than the axial force of the column without the diagonal braces, because the frequency is large when the bracing is performed, and the horizontal seismic force is also large. When the diagonal braces are not set, the shearing force of the pier bottom column increases with the increase of the beam stiffness, and also increases with the increase of the column spacing, which reflects that the horizontal seismic force of the frame pier increases with the increase of the frequency. In the case of diagonal bracing, the overall shearing force of the column is small, but when the beam stiffness is extremely small and the column spacing is large, the shearing force in the column is relatively small. By changing the relevant parameters, it is found that the axial stiffness of the beam is too The weak situation is caused by the fact that the axial stiffness of the beam is very small and a part of the horizontal seismic force is transmitted through the diagonal bracing, so the shearing force of the column is small.

5. Conclusion

The distribution of seismic internal forces of single-limb columns of frame-type CFST piers and the influence of changes of relevant parameters on the internal forces of the columns are analyzed by response spectrum method. The variation characteristics of the internal force of the frame pier with the partial parameters are discussed, and the following conclusions are obtained:

(1) The shear force of the framed pier column is linear, the bending moment distribution is sawtooth, and the pier column segment between the two beams at the upper part of the pier has a point where the bending moment is zero, that is, A reverse bend occurred. The axial force of the frame pier is not linearly distributed from the top of the pier to the bottom of the pier, but is a step-like increase and has a large axial force corresponding to the larger axial moment.

(2) When there is no diagonal bracing for the frame type pier, the beam stiffness can be increased, and the bending moment of the column can be reduced. However, after the beam stiffness increases to a certain extent, the bending moment of the column is no longer reduced; The degree of influence

of the bending moment of the column is obviously reduced. Except for the case where the beam stiffness is extremely small, the bending moment of the column does not change substantially with the rigidity of the beam.

(3) When there is no diagonal bracing in the frame type pier, the bending moment of the column increases at the bottom of the pier, the axial force of the column is gradually reduced, and the rigidity of the beam is larger, the increase of the bending moment is larger. The axial force of the column is gradually increased as a whole; after the diagonal bracing is set, the spacing of the column has a greater influence on the bending moment of the column. As the spacing of the columns increases, the bending moment of the columns generally decreases. Especially when the spacing between the columns is too small, appropriately increasing the spacing of the columns can not only increase the rigidity of the frame piers, but also reduce the bending moment of the columns, and the axial force of the columns changes relatively with the rigidity of the beams and the spacing of the columns.

(4) After the diagonal bracing is set, the bending moment and shearing force of the beam are obviously reduced. With or without the diagonal bracing, as the beam stiffness increases, the bending moment and shearing force of the beam increase, and as the column spacing decreases, The bending moment and shearing force of the beam also increase.

(5) The EL CENTRO seismic wave is used to analyze the time-history of the frame pier. The hollow pier is mainly subjected to bending under the earthquake, and the frame pier is subjected to the bending, but the bending moment is relatively small. When there is no diagonal bracing, the frequency of the frame pier is very low and the stiffness is very small. After the diagonal bracing is set, the frequency of the frame pier is close to the frequency of the hollow pier, which reflects that the horizontal stiffness of the hollow pier and the framed pier with diagonal braces are very close. For the seismic response of internal forces and displacements of framed piers with and without diagonal braces, it can be found that when there is no diagonal bracing, the displacement of the pier top is relatively large due to the small stiffness, but the axial force and bending moment of the column are relatively small. After the diagonal bracing is set, the axial force of the column increases a lot due to the increase of the rigidity and the influence of the diagonal braces, and the bending moment and the axial force of the column also increase greatly. The bracing of the frame type pier should not be too strong. The diagonal bracing should be yielded and damaged first in the case of strong earthquakes to reduce the seismic response of the frame pier and the internal force of the column and protect the column.

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