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Seismic Performance Analysis of High-rise Steel-concrete Composite Structures under Earthquake Action Based on Sound-Vibration Method

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ABSTRACT. *In the design of high-rise steel structures in China, structural designers are willing to adopt the steel-concrete hybrid structure system, and the building height is getting higher and higher. The steel-concrete hybrid structure system has the advantages of fast construction speed of steel structure, high stiffness of concrete structure and low cost. It is considered to be a better structural form of high-rise buildings in line with China's national conditions. In earthquakes, the rapid release of energy from the earth's crust causes earthquakes. In the high-rise building system, reinforced concrete structure is the main form of building structure. Therefore, for the theoretical calculation model of this structural system, the relative displacement control between structural layers under the action of frequent earthquakes. And the research needs of structural failure modes under the rare earthquakes are becoming more and more urgent. In this paper, the seismic response analysis model of high-rise mixed structure is established based on the seismic design principle of hybrid structure, and the seismic behavior of high-rise steel-concrete hybrid structure under two-way seismic action is discussed.*

KEYWORDS: *Buildings; Earthquakes; High-rise buildings; Seismic resistance*

1. Introduction

In recent years, in the design of high-rise steel structures in China, structural designers are willing to adopt the steel-concrete hybrid structure system, and the building height is getting higher and higher [1]. The steel-concrete hybrid structure system has the advantages of fast construction speed of steel structure, high stiffness and low cost of concrete structure [2]. It is considered to be a better structural form of high-rise buildings in line with China's national conditions. During the process of earthquake, the crust releases energy rapidly, and produces seismic waves, which induces vibration. Earthquake waves generated during the process of earthquake action will cause ground vibration, and earthquake motions will act on buildings. Once the house can't resist the effect of the earthquake force, it will have different degrees of damage or even collapse directly [3]. The greater the intensity of the earthquake, the greater the seismic force acting on the house, and the more serious the damage. In the earthquake, the key to minimizing losses is to strengthen the seismic performance of the building structure [4]. To minimize its losses in the earthquake, comprehensive and in-depth research on the seismic performance of the combined structure is an urgent need of current engineering.

In the high-rise building system, the reinforced concrete structure is the main form of building structure. In the earthquake, the rapid release of energy from the earth's crust causes ground vibration, and its occurrence is characterized by randomness, suddenness and uncertainty [5]. At present, there is no corresponding specification in China to guide the seismic design of such structures. Therefore, the theoretical calculation model of this structural system controls the relative displacement between structural layers under the action of frequent earthquakes [6]. And the research needs of structural failure modes under the rare earthquakes are becoming more and more urgent. In this development background, the steel-concrete composite structure has been gradually applied, and it has been widely used in high-rise buildings, especially in super-high-rise building structures [7]. The steel structure in the composite structure has the advantages of fast construction speed, low cost and high stiffness. It belongs to an ideal structural form in high-rise buildings which is suitable for China's national conditions [8]. Based on the seismic design principle of hybrid structure, this paper establishes the seismic response analysis model of high-rise hybrid structure, and discusses the seismic performance of High-Rise Steel-Concrete Hybrid Structure under bidirectional seismic action.

2. Problems Existing in Base Isolation System

When the response of the structure under earthquake moves from elastic stage to elastic-plastic stage, it is impossible to calculate the response of the structure at each moment by mode superposition method. In the traditional structural seismic system, building structures often absorb and dissipate seismic energy by increasing structural stiffness and structural deformation. Deformation and damage of some structures and bearing components absorb and consume seismic energy at the same time. Time history analysis method is more advanced than response spectrum method. In practical engineering, time history analysis method is often used to check whether there are weak parts in bearing capacity, stiffness and so on. Under the horizontal seismic load, the steel frame and the concrete core cylinder are horizontally displaced at the elevation of the floor, that is, the two-part structure cooperates with the horizontal load [9]. The structure is regarded as a cantilever rod, and the structural mass is concentrated on each floor, and the vertical load-bearing member that combines the entire structure becomes a vertical rod. The energy dissipation technology is completely different, it is to install energy dissipating devices in some parts of the structure. When an earthquake occurs, a large amount of energy is first absorbed and dissipated by the energy dissipating device to attenuate the seismic response of the building.

The layer model can be used to determine the inter-layer shear force and the lateral displacement of the structure, but the internal force and deformation of each member of the structure cannot be determined. The rod model uses the rod restoring force model to characterize the variation of the rod element with the internal force of the stiffness during the earthquake process. It is convenient to consider the variation of the stiffness of the rod unit along the length in the elastoplastic stage. The single-mass structure generally requires that the stiffness of the superstructure is large relative to the foundation, and the basic isolation structure is mostly applied to the multi-layer structure. In the multi-layer structure, the superstructure can be considered as a mass point. In the early practical engineering, the designer applied the single-mass structure. Concentrated stiffness distribution model and distributed stiffness model. In the lumped stiffness model, the plastic deformation of the member is concentrated at a point at the end of the member to establish the element stiffness matrix, without considering the change of the element stiffness along the length of the member in the elastic-plastic stage. Compared with the layer model, the member model can describe the stress state of the structure more carefully, and can give the internal force and deformation of the member elements of the structure in the course of earthquake. When a base-isolated structure is subjected to earthquake, the isolation layer will deform before the superstructure, and absorb most of the energy through damping and deformation. The superstructure is almost translational. Figure 1 is a single-particle structure.

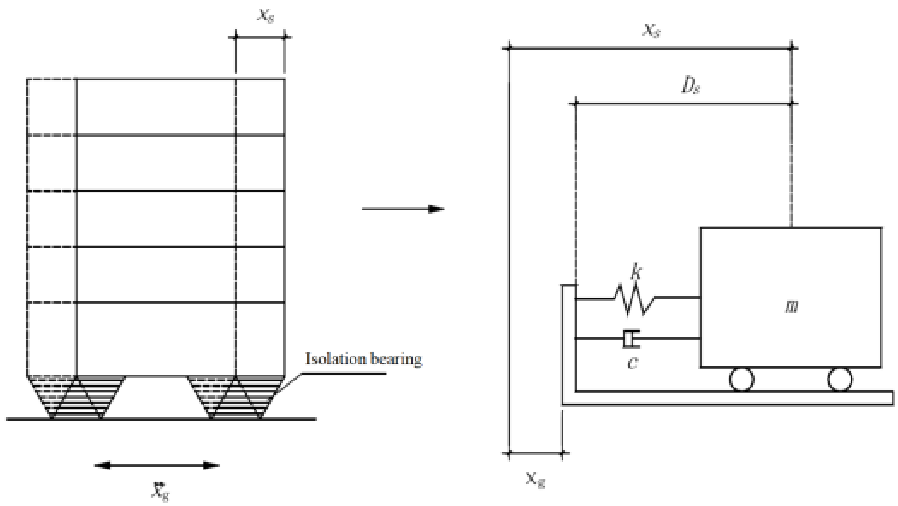

Figure 1 Single mass isolation model

Dynamic characteristics analysis describes the structure by the inherent dynamic properties of frequency, damping, and mode shape. With the development of economy and science and technology, more and more high-rise buildings and super high-rise buildings, the corresponding basic isolation technology is also increasingly used in high-rise and super high-rise buildings. If the structure is only subjected to elastic analysis or elastoplastic maximum response analysis, the holding time can be slightly shorter. For example, the calculation of the energy dissipation process of the structure under earthquake action should be longer. The seismic response of buildings is not only related to the peak acceleration of earthquakes, but also to the duration of earthquakes, site and soil properties, the preeminent period of earthquakes, the location and shape of buildings. The influence of earthquake duration on structural response mainly occurs in the non-linear phase of response. Therefore, the selected duration of strong earthquakes should ensure that the vibration of the structure enters the steady state stage. In order to get the maximum response of the structure in the calculation, according to the basic natural vibration period of the building structure, the predominant period of the actual seismic record is adjusted to make them close.

3. Analysis of Seismic Performance of Structures

The change of the stiffness between stories can reflect whether the structure is vertical or not, and the vertical rule of the structure directly affects the shear bearing capacity and the inter-story deformation of the structure. Deformation of structure is the real response of spatial stiffness and load distribution of structure. It is not only the requirement of the normal use of the structure, but also the requirement of the safety of the structure to control the overall and interlayer deformation of the structure. Because of its limitations, single-particle and double-particle models have been unable to carry out such complex analysis. The greater the thickness of shear wall, the greater the stiffness of the connection between frame beam and shear wall. It is more reasonable and accurate to simplify the seismic response of the superstructure of base isolation structure into multi-particle model analysis. In the absence of external disturbances, it will automatically become static as time goes by. The reason for this phenomenon is that there are factors inside the system that make energy consumption. Damping is the factor that makes the system energy dissipate. Enter the component geometry and material information for the structure. The single-rigid beam-column is obtained by simplifying the analytical model of the semi-rigid frame to form the stiffness of the semi-rigid frame of the layer.

In the aspect of building parameterization calculation, the calculation and analysis of the overall structure are carried out, and the elastic time history analysis under the multiple earthquakes is carried out according to the artificial seismic wave parameters. Table 1 shows the relevant parameters such as the maximum acceleration value and duration of the seismic wave.

Table 1 Relevant parameters such as maximum acceleration value and duration of seismic wave

Adaptive range	Maximum acceleration (cm/s^2)	Duration (s)	Number of wave values	Time step (s)	Effective duration (s)
Artificial shock wave	85	40	1850	0.02	32.64
Natural shock wave	80	35	1700	0.02	35.69

The first development in the parametric design of high-rise building layout is geometric modeling, geometric modeling to deal with the geometric and shape representation of objects, and the study of graphic data structures. Analyze its path density, number of nodes, and center potential. As the path density increases, the shortest path between nodes increases. as shown in Figure 2.

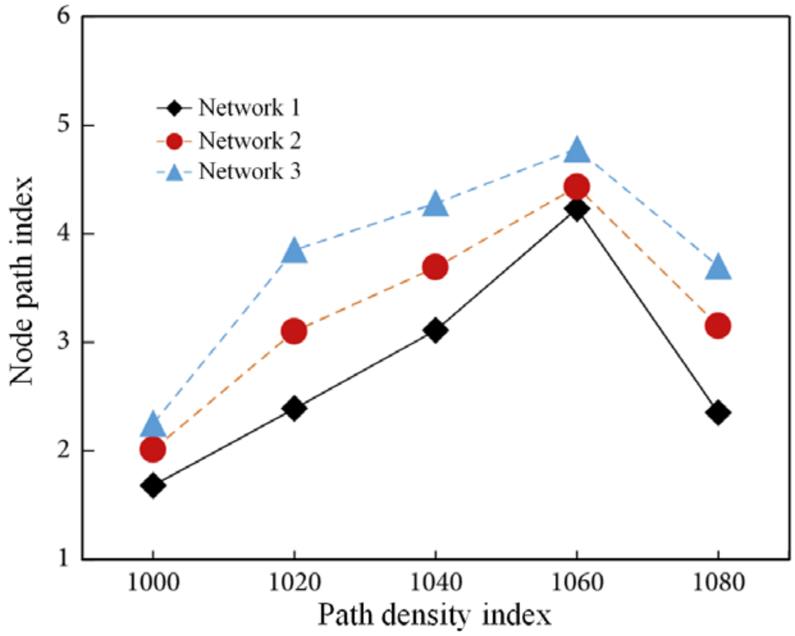

Figure 2 Path density and node path relationship

At the same apex displacement, the joint stiffness of the frame beam and the shear wall is proportional to the base shear of the structure. The greater the connection stiffness between the frame beam and the shear wall, the larger the base shear. The buckling phenomenon occurs when the ordinary support is pressed, and the stiffness and bearing capacity are drastically reduced when the buckling is supported. When the horizontal seismic force is small, the structure or component is in the elastic phase [10]. The horizontal seismic force is mainly carried by the shear wall, but under the rare earthquake. When the two-week tension and compression reciprocating changes gradually reach a critical state, the internal force and stiffness of the support are close to zero. In seismic wave input, the initial loading has its own frequency. However, in the actual seismic process, the structure initially has low frequency, which leads to the plastic characteristics of the initial state of the isolation bearing in the simulation process. It is impossible to fully simulate the shear deformation from elasticity to elasticity and plasticity of the actual support, which lacks rigidity. The stiffness of the connection between the frame beam and the shear wall tube will affect the overall stiffness of the structure to a large extent. The greater the stiffness of the connection between the frame beam and the shear wall is.☐

4. Conclusions

It is more practical to establish a three-dimensional model for seismic response analysis, which can better reflect the coupled response of translation and torsion, and the torsional mode is objective. Composite structure is a newly applied structural form. High-rise steel-concrete composite structure system uses steel and concrete two forms of material, steel frame plays the role of bearing vertical load. Under different thickness of shear wall and stiffness of connection between frame beam and shear wall, the distribution of floor displacement, inter-story displacement angle and floor shear along the floor height is basically the same. Under the action of earthquakes, the analysis of the response to the high-rise structure should be grasped as a whole, and the key control indicator is the response to the displacement. The upper structure is much stiffer than the isolation layer, and it is likely to cause overturning, and the isolation bearing has a general anti-overturning ability. It is also necessary to further analyze the proportion of the shear force of the outer frame and the core and the cylinder, so as to more accurately compare the resistance of the outer frame to the core and the tube to the seismic action of the structure.

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