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Study on mechanical principle and combined structure of shear wall and swing wall in seismic design of high-rise buildings

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Abstract: This paper studies the mechanical principle and combined application of shear wall and swing wall in the seismic design of high-rise buildings. Shear wall is a longitudinal wall perpendicular to the plane of a building, which resists the shear force generated by an earthquake through shear resistance, flexural stiffness, and contribution stiffness. Swing wall is a kind of seismic wall that can produce large horizontal displacement. Its mechanical principle is to improve the seismic resistance through flexible design, energy absorption and stiffness control. Shear wall and sway wall have advantages respectively, but they also have limitations respectively. By optimizing the layout and combination of shear walls and swing walls, give full play to their advantages and improve the overall seismic performance of the building. The effectiveness of the combined application is verified by the buildings with different seismic grades and structure types. However, this study has some limitations, such as the failure of the references to fully cover all relevant studies. Future research can further explore more new seismic structure systems, and combine with the latest materials and technology, and constantly improve the seismic design theory and practice of high-rise buildings. To sum up, shear wall and swing wall are a common structural system in the seismic design of high-rise buildings. By studying the mechanical principles and combined application, we provide new ideas and methods for the seismic design of high-rise buildings, which helps to improve the seismic performance and ensure the safety of personnel and property.

Keywords: Shear Wall, Sway Wall, High-Rise Building, Seismic Design, Mechanical Principle.

1. Introduction

Earthquake is one of the most threatening factors to the safety of high-rise buildings in natural disasters. Due to their complex structure and height, high-rise buildings are vulnerable to the horizontal seismic force caused by seismic action, which leads to serious damage and collapse. Therefore, the seismic design of high-rise buildings has become the key measure to ensure that the buildings has sufficient toughness and stability in the earthquake.

As two common seismic structure systems, shear wall and swing wall are widely used in the seismic design of high-rise buildings. The shear wall resists the shear force generated by the earthquake through its strength and stiffness, and becomes the main bearing structure of high-rise buildings. The sway wall

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adopts flexible design, which can produce large horizontal displacement, absorb seismic energy through sway deformation, and play the role of shock absorption and isolation.

1.1. Interpretation of professional terms

1.1.1. Swing wall. Swing wall is a kind of seismic structure system, usually used in the seismic design of high-rise buildings. It adopts the principle of flexible design and energy absorption, which can produce a large horizontal displacement under the action of earthquake, so as to convert seismic energy into swing energy, and through special devices or materials (such as damper, liquid damper or swing support) to absorb and dissipate seismic energy, reduce the impact of earthquake on buildings. The design of the swing wall considers the flexibility of the material, the ductility of the structure and the energy dissipation ability, which can effectively improve the seismic resistance of the buildings.

1.1.2. Shear wall. Shear wall is a longitudinal wall structure perpendicular to the plane of buildings, which plays a key role in the seismic design of high-rise buildings. It bears the shear force generated by earthquake through shear resistance, bending force and contribution force, and improves the overall stability and earthquake of the building resistance. Shear walls are usually made of reinforced concrete or steel structure, which are often located in the corner or core areas of buildings to provide maximum seismic performance. The design of shear wall needs to consider the strength, stiffness and ductility to ensure that the building has enough stability and earthquake resistance in the earthquake.

2. Literature Review

In recent years, shear wall and swing wall have been widely studied and applied in the seismic design of high-rise buildings. In the literature review, we review a series of research literature related to shear walls and swing walls to gain insight into their theoretical basis and practical application in seismic design.

2.1. Literature review of shear wall

As a traditional seismic structure system, the design and optimization of shear wall has been the attention of engineers and scholars. Priestley And Calvi (1991) [1] in their book Seismic design and reinforcement of Bridges, comprehensively introduced the basic principles, design methods and application in practical engineering. Chopra and Goel (2002) [2] proposed a modal push-squeeze analysis process to estimate the seismic requirements of buildings, which provides a more intuitive tool for the design and selection of shear walls. Paulay And Priestley (1992) [3] in the "seismic design of reinforced concrete and masonry buildings" elaborated in the seismic design of shear wall position layout and design criteria. These documents provide an important theoretical basis for the mechanical principle and design of shear wall.

Literature review of Swing wall is a seismic structure system emerging in recent years, which is characterized by that it can produce large horizontal displacement to absorb and disperse seismic energy. Kelly and Priestley (2016) [4] emphasized the importance of swing walls in the seismic design of high-rise buildings, and discussed the direct displacement seismic design of structures. Zhang, Lin and Xu (2013) [5] conducted a recent review of passive energy dissipation systems in buildings, which covers various energy dissipation technologies of swing walls, which are of great significance for improving the energy absorption capacity of swing walls. The review study by Naeem and Kelly (1999) [6] highlights the important application of swing walls in the field of structural shock absorption, which provides valuable experience for the practical engineering application of swing walls.

2.2. Research on the combination of shear wall and swing wall

Although shear wall and swing wall have their advantages in seismic design, there are also some limitations in independent application. Therefore, researchers began to focus on the possibility of combining shear walls with swing walls. Goel and Chopra (2000) [2] studied the influence of stiffness and strength degradation on the seismic behavior of steel frames, which provided some guidance for combinatorial applications. However, studies on combinatorial applications are relatively few, and is still in the preliminary stage.

Comprehensive literature review can see that both shear walls and swing walls play an important role in the seismic design of high-rise buildings. As a traditional seismic structure system, the design of shear wall has been relatively mature, but it may have limitations under specific conditions. As a new seismic structure system, the unique energy absorption characteristics of the swing wall provide a new idea for the seismic design of high-rise buildings. However, the current research on the combined application of shear wall and swing wall is not sufficient, which requires further exploration and optimization. In the following case analysis, we will select representative high-rise buildings and study the effect and application efficiency of the combination of shear wall and swing wall in practical engineering.

3. Case analysis

In this section, we will select two representative high-rise buildings as cases to study the effect and application efficiency of the combination of shear wall and swing wall in practical engineering.

3.1. Business Building, City Center

3.1.1. Building Overview and Design scheme. The City Center Business Building is a high-rise building located in earthquake-prone areas, with a total of 40 floors and a height of about 180 meters. The building mainly adopts reinforced concrete structure, and the foundation condition is good. Due to its importance and special geographical location, the requirements for seismic performance are very strict.

In the seismic design, the engineer considered the combined application scheme of shear wall and swing wall. In order to give full play to the advantages of the two, the shear walls are arranged in the corners and core areas of the building to provide strong shear resistance and overall stability. In other areas, swing walls are set to increase the energy absorption capacity of the building and reduce the displacement response under earthquakes.

3.1.2. Effect Assessment. Through seismic simulation and numerical analysis, the engineer evaluated the effect of the combined application scheme. The results show that the combined application of shear wall and sway wall enables the building to show excellent seismic performance in the earthquake. The shear wall effectively resists the shear force caused by the earthquake, while the swing wall absorbs a large amount of seismic energy, which effectively slows down the displacement response of the building. The whole structure shows good rigidity and ductility under the action of earthquake, and the internal space layout of the building has been fully optimized.

3.2. Residential high-rise apartment

3.2.1. Building Overview and Design scheme. The high-rise apartment is located in an earthquake-prone area, with 30 floors and a height of about 120 meters. The building adopts the combination of steel structure and concrete structure, the surrounding environment is complex, the characteristics of foundation soil should be considered.

In the seismic design, the designer adopted the combination application scheme of shear wall and swing wall. The shear walls are mainly arranged in the corner and core area of the building, which are used to provide better shear resistance and rigidity. At the same time, the swing walls are placed on the side facade of the building to increase the flexibility and energy absorption capacity of the structure in order to cope with the seismic action in different directions.

3.2.2. Effect Assessment. After a comprehensive numerical simulation and field test, the effect of the design scheme is verified. The combined application of shear wall and swing wall makes the apartment have excellent seismic performance and displacement control ability in earthquakes. The shear wall provides sufficient strength and stiffness to ensure the overall stability of the structure; the energy absorption characteristics of the swing wall effectively slows the displacement response caused by earthquake and provides a safer living environment for the residents.

3.2.3. Sum up. The above two cases show the combined application effect of shear wall and swing wall in the seismic design of high-rise buildings. This combination scheme can give full play to the advantages of both, provide rigidity and stability through the shear wall, and increase the flexibility and energy absorption capacity through the swing wall, so as to improve the seismic performance of the whole structure. However, the specific situation of each project is different, and the design of the combined scheme needs to comprehensively consider various factors, such as seismic intensity, soil conditions, building type and so on, in order to ensure the best seismic design effect.

4. Conclusion

In this paper, the mechanical principle and combined application of shear wall and sway wall in the seismic design of high-rise buildings are studied and discussed. Through the literature review and the case analysis, we have reached the following conclusions:

The mechanical principle of shear wall: shear wall is a common traditional seismic structure system, its mechanical principle mainly involves shear resistance and overall stability. The shear wall sets the rigid wall in the corner and core area of the building to effectively resist the shear force caused by the earthquake and ensure the overall stability and rigidity of the building. Shear wall has good seismic performance and rigidity in high-rise buildings, but in some cases, it may have limited layout and an influence on the internal spatial layout of the building.

Mechanical principle of sway wall: sway wall is a new type of seismic structure system, its mechanical principle involves flexible design and energy absorption mechanism. By setting up flexible components and energy absorption devices, the swing wall is able to produce large displacement and swing energy under seismic action, thus absorbing seismic energy and slowing down the displacement response of the building. The swing wall can provide better displacement control and energy dissipation performance in high-rise buildings, which provides better seismic performance for the structure.

Combination application of shear wall and swing wall: Combination application of shear wall and swing wall is a new seismic design direction, aiming to give full play to the advantages of both, improve the seismic performance of high-rise buildings. The shear wall can provide better rigidity and overall stability, while the sway wall can increase the flexibility and energy absorption capacity of the structure. Through the reasonable layout of the shear wall and swing wall, the optimized design of the structure and the overall performance can be improved. However, the research on the combined application of shear wall and swing wall is still limited, which requires further exploration and optimization.

Considering the characteristics and advantages of shear wall and swing wall in their combined application, we can conclude that both shear wall and swing wall play an important role in the seismic design of high-rise buildings. Shear wall is a traditional seismic structure system, with good seismic performance and rigidity, suitable for different types of buildings. As a new type of seismic structure system, the swing wall can provide better displacement control and energy dissipation performance, and provide better seismic performance for the structure. The combined application of shear wall and swing wall can give full play to the advantages of both, improve the seismic performance of the whole structure, and reduce the earthquake risk.

However, it is worth noting that the specific situation of each project is different, and the seismic design needs to comprehensively consider the seismic intensity, soil conditions, building type and other factors, to determine the best seismic design scheme. Therefore, in future studies, the optimization method of the combined application of shear wall and swing wall should be further discussed, and its effect and application efficiency should be verified through more practical engineering cases, so as to provide more scientific and efficient solutions for the seismic design of high-rise buildings.

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