Seismic Designs Based on Pain Points of High-rise Buildings

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Abstract. With the continuous improvement of the degree of urbanization, in order to alleviate the pressure brought by the increase in population, more and more high-rise buildings appear, and high-rise buildings become the symbol and main body of urbanization. Due to the increase of height, horizontal load and other factors, high-rise buildings have higher requirements for safety and stability. However, with the frequent occurrence of earthquakes, the design requirements for high-rise buildings are more stringent. This paper introduces the structural types and characteristics of tall buildings, studies the effects of earthquakes on them, and discusses four suitable seismic design methods. The establishment of multi-level fortification of structural earthquakes is mainly to take relevant anti-seismic treatment measures and monitoring and maintenance programs to improve the anti-seismic ability of buildings. Reasonable arrangement of lateral force resisting members and uniform distribution of overall stiffness of building structure can realize reasonable building structure system to ensure the ability of building to resist earthquake load. The installation of isolation and shock absorption devices can also significantly improve the seismic level of high-rise buildings.

Keywords: High-rise building; Seismic load; Structure system; Frame structure.

1. Introduction

With the rapid development of the economy, high-rise buildings have been increasing to alleviate the pressure of land scarcity and improve the utilization rate of land. At the same time, the application of high-rise building structural systems is becoming increasingly common. The development of high-rise building structure systems and housing height is closely related to the development of the economy and science and technology. Therefore, the design of high-rise buildings is an important link. However, the rapid development of high-rise buildings has also brought many problems to designers, among which the horizontal load greatly impacts buildings, and the wind and earthquake loads are the most significant. With the increase of the height of the house, the displacement of the building increases rapidly. Excessive lateral displacement will not only affect people's comfort level, but also cause damage to non-structural components and structural components. In severe cases, torsion can be formed, resulting in collapse.

Earthquakes are a natural phenomenon that happens almost daily, but most are not obviously felt. Located between two seismic zones, China is a typical earthquake-prone country with high activity frequency, wide distribution, shallow focal point and high intensity, etc. The Tangshan earthquake and Wenchuan earthquake caused a large number of house collapses and life injuries, and the trauma caused to people cannot be healed until now. Therefore, it is of great practical significance to improve the earthquake resistance of buildings [1].

According to the characteristics of high-rise buildings, reasonable design of structures and equipment to effectively ensure the stability of high-rise buildings is an important topic that civil engineers should invest in research. This paper mainly discusses the influence of horizontal load on high-rise buildings and carries out the necessary seismic design according to the pain point of high-rise buildings.

2. Structure type and application

The main structural types suitable for high-rise buildings are frame structure, shear wall structure, and frame-shear wall structure. Each structure type has its characteristics and scope of application.

2.1. Structure type

2.1.1. Frame structure

The frame structure system comprises four load-bearing components: floor, beam, column and foundation. The plane frame is composed of beams, columns and foundations, which is the main load-bearing structure, and the plane frame is connected by connecting beams, that is, to form a spatial structure system, which is one of the commonly used structural forms in high-rise buildings.

2.1.2. Shear wall structure

Shear wall structure system. In order to improve the lateral stiffness of the building structure in high-rise buildings, the reinforced concrete wall set in it is called "shear wall". The main role of the shear wall is to improve the shear strength and stiffness of the whole house, and the wall is also used as a maintenance and room partition component. When designing the section, the designer should choose the combination wall mode of I shape, L shape and T shape, and try to avoid using a word wall. In addition, designers also need to scientifically control the number of short-limb walls to effectively improve the stability of shear walls [2].

2.1.3. Frame shear wall structure

Frame-shear wall structure system. In the frame structure, a certain number of shear walls can be arranged to form a frame-shear wall structure, which has the characteristics of a flexible frame structure layout, easy to use, and greater stiffness and strong seismic ability, so it is widely used in high-rise buildings of office buildings and hotels.

2.2. Structure application

We should strictly choose a reasonable structure type according to the height, floor area and specific functions of high-rise buildings. Firstly, considering various types of materials, safety and durability based on structure and function. Compared with low-rise buildings, high-rise buildings are more susceptible to earthquake and wind loads. The structure should be selected according to the load conditions. Whether the local area is in an earthquake area, the earthquake impact and wind loads should be comprehensively considered, while wind loads should be mainly considered in non-earthquake areas. In addition, the actual costs, such as the amount of steel used per unit area of various structural types, the amount of concrete, and the amount of labor, are different. Under the premise of ensuring safety, we should pay attention to the economy and resource conservation of structural design. Finally, construction efficiency should be considered. With the development of construction technology, new technologies and new equipment suitable for different structural types are constantly emerging, such as deep foundation pit support, combined formwork, sliding formwork and other technologies, and the selection of structure should also be comprehensively considered in combination with the construction level [3].

3. Factors affecting the stability of high-rise buildings

The stability of high-rise buildings is affected by some factors such as building height, load condition, and failure form. Before the seismic design work starts, our first task is to analyze the architectural characteristics of tall buildings according to their development situation.

(1) The height gradually increases. The frame structure is the basic structure in the super high-rise building system, which is widely used. The frame structure is composed of beams and columns. The advantage of this structure is that it can arrange the plane flexibly and the overall space is larger. (2) Horizontal load becomes the main control factor. When the height of the high-rise building structure exceeds a certain standard, the horizontal load becomes a key factor to consider. Wind will produce lateral and horizontal pressure on the high-rise building structure, which will cause the dynamic change of the high-rise building structure and form a horizontal shear effect, which will affect the stability of the high-rise building structure. (3) Vertical load cannot be ignored. Vertical load is the

main form of high-rise building structure, in which the building self-weight and the weight of appendages are the main types of vertical load. In designing and constructing high-rise building structures, practical measures to control its vertical load should be formed from the Angle of saving materials and reducing material weight. (4) Ductility has become an important index of structural design. The critical index of ductility is mainly aimed at the deformation or collapse of high-rise building structures. Structural forms with good ductility can often absorb a large amount of seismic energy through structural deformation to ensure the structure's overall stability [4].

4. Seismic impact and design

Earthquakes have a greater impact on tall buildings than flat buildings. In order to ensure the safety of high-rise buildings, a series of effective seismic measures must be taken to improve their seismic performance. This paper analyzes 4 kinds of seismic measures, aiming to provide useful suggestions for ensuring the seismic performance and safety of high-rise buildings.

4.1. Seismic impact

The ground motion during the earthquake is transmitted to the building through the foundation-shaking back and forth. However, the mass of the building will prevent this movement, and the inertia force is generated in the entire building structure, which is the earthquake action. The seismic force on the building can be divided into horizontal and vertical forces. The horizontal seismic force, like the wind load, produces horizontal vibration in the structure. Because the force is transmitted from the bottom to the top, the flexibility of the structure in the horizontal direction is very high. The horizontal seismic force also has second-order effects, which increase the horizontal displacement of the building, increase the center of gravity shift of the structure and the risk of toppling and destruction of the structure. The horizontal seismic force and wind load work together to produce irregular force forms and fatigue damage to the structure.

When the horizontal and vertical seismic forces act together, the irregular tall buildings will also have a twisting effect. When the earthquake period is consistent with or similar to the self-earthquake period of high-rise buildings, a resonance effect could occur, and the deformation of the structure will reach the maximum, resulting in massive damage to the structure. Although earthquake does not often occur, their destructive power can reach the maximum when it appears. The general seismic design is based on the design principle of "small earthquake is not bad, medium earthquake can be repaired, and large earthquake does not fall" and considers the importance factor of the structure.

4.2. Seismic design

4.2.1. Establish multi-level fortification of structural earthquakes

The concrete measures of multi-layer fortification include two aspects: (1) adding anti-seismic performance treatment measures in structural design. (2) Strengthening the monitoring and maintenance of the structure during construction and use. In the structural design, it is necessary to comprehensively determine the level of seismic performance by considering the structural materials, structural structure and structural form, and increase the corresponding seismic performance treatment measures in the design, such as increasing the reinforcement, increasing the size of the component, and setting isolation supports. In the construction and use of the building, it is necessary to strengthen the monitoring and maintenance of the structure, check the stress of the structure in time, ensure that the structure does not appear to have obvious damage or deformation and carry out necessary maintenance and reinforcement in time [5].

For example, in the design of the high-rise basement, in order to increase the anti-shock effect, the 180mm floor can be selected and configured on the floor with a double two-way, reinforcement rate of 0.25% of the steel bar in the construction process also need to be reinforced according to the relevant regulations. In the design of the frame beam, secondary beam and dark beam, the width of the dark beam can be designed as a wall width, and it can be embedded in the shear wall between the

frame columns. The dark beam participates in the overall calculation of the structure and should be calculated according to the frame beam. The shear wall in the core tube area is equipped with corresponding border dark beams and the part of the structure needs to be reinforced according to seismic structure. In addition, in order to improve the seismic ability of the floor as a whole, a floor with a thickness of 180mm can be appropriately used for construction in some floor-weakening areas, while the thickness of other parts of the board needs to be increased by 30mm based on this part of the area. The upper longitudinal bar of the flat beam structure is anchored into the floor, and the anchoring length should be fixed at the edge of the floor following relevant seismic standards [6].

4.2.2. Adopt a reasonable building structure system

(1) Reasonable arrangement of anti-lateral force components

The lateral force-resisting component of high-rise building structure is the main component to bear the lateral seismic load, and its layout should be reasonable. In the high-rise building structure, the installation of lateral stress components is usually divided into frame, shear wall, frame-shear wall combination, cylinder and other forms, among which the frame structure is the most widely used seismic system. In the specific design, appropriate forms of lateral force-resistant components should be selected according to the actual situation. Parameters such as quantity, layout and position should be ensured to meet the specifications and actual needs, and detailed design and construction of components should be carefully controlled [7]. For example, as the most basic component of lateral force resistance, the wall should be strictly controlled in its layout. The wall is generally divided into horizontal wall and vertical wall. Whether it is a horizontal or vertical wall, it is necessary to ensure that every part is stressed evenly during construction and that each part can bear the overall weight of high-rise buildings. The entire building becomes less earthquake-resistant. Many buildings in backward areas still adopt a single horizontal or vertical wall to bear weight. The entire space has weak load-bearing capacity, short service life, and cannot withstand any minor earthquake, let alone withstand the damage of high earthquake magnitude. In order to improve the stability and load-bearing capacity of the wall, the horizontal wall and vertical wall should be scientifically and reasonably combined in the architectural design stage to ensure the stability of the wall, avoid deformation, and improve the overall stability and safety of high-rise buildings [8].

(2) Ensure the integrity of the structure

The integrity of high-rise building structure refers to the overall performance of the building structure that can maintain relative stability when subjected to earthquake loads. In the actual design, the continuity, uniformity and stability of the structure should be met as much as possible. Especially in the connection nodes of the building structure, reasonable structural connection forms, appropriate connection components and connection materials should be used to improve the overall performance of the structure. In addition, in the selection and construction of building structures, attention should also be paid to improving the overall performance. For example, when selecting structural materials, materials with uniform strength and stiffness should be selected to improve the overall mechanical performance of the structure.

4.2.3. Application of Energy Dissipation and Damping Technology

The application of energy dissipation and shock absorption technology in the seismic design of high-rise building structures is mainly to design non-load-bearing structural components into energy dissipation components or install energy dissipation devices in some nodes, such as dampers. In the event of small earthquakes, energy dissipation devices are in an elastic state, and high-rise building structures have sufficient lateral stiffness to meet the regular use needs. With the increasing deformation and stress of the structure, the energy dissipation device enters the state of inelastic deformation, which could produce significant damping, which can consume the energy generated by the earthquake and rapidly attenuate the seismic response of the structure to prevent the obvious damage of the main structure. Energy dissipation and shock absorption technology protects the main structure at the expense of energy dissipation components. After the end of the earthquake, energy dissipation components can be repaired and replaced to restore the regular use of high-rise buildings.

Compared with the traditional seismic system, this reflects stronger practicability and flexibility, and the most important thing is better seismic effect.

4.2.4. Design isolation layer or isolation device

The isolation layer is usually set at the bottom of the building. By setting isolation devices such as rubber, spring and ductile iron, the building can be isolated from the excitation force of the earthquake, so as to reduce the impact of the earthquake on the building. The design of the isolation layer and the isolation device needs to be rationally selected and arranged according to the actual situation of the building and the seismic wave characteristics to achieve the best seismic effect.

(1) Structural concept of traditional architecture

The structural materials commonly used in traditional buildings are steel, concrete, wood, etc., designed with sufficient strength and toughness to resist the destructive power brought by earthquakes. Although most of the destructive energy of earthquakes can be eliminated, when the intensity of earthquake energy is large to a certain extent, it will still cause damage to the walls of non-structural components and even the structures [9].

(2) Main design points of isolation device

The location of the isolation device should be based on the calculation of structural mechanics. When a high-rise building has a basement, setting a seismic isolation layer on the top of the basement column is appropriate. When the high-rise building is a large chassis structure, due to the use of functions and the rationality of vertical components, it is advisable to set a separate isolation layer not higher than 2 m between the large chassis and the superstructure.

The installation of isolation supports should follow the principle of "same layer, same height and same type." Due to the particularity of the material of the isolation device, the tensile stress should be avoided and the overturning moment should be distributed reasonably. The position of the shear wall and column should be arranged more reasonably. The tensile stress at the wall or column end should be checked individually during model calculation, and the order of torsional vibration mode should be increased as much as possible. It should be ensured that the isolation layer has sufficient self-stiffness, the reinforcement strength of the beam plate of the layer should be greater than that of the ordinary floor, and the transfer beam should have sufficient binding force on the shear wall in the layer so that the isolation layer can be regarded as the embedded end equivalent to the foundation. The bottom column of the upper layer of the isolation layer should be reviewed according to the unconstrained column primary reinforcement and stirrup reinforcement, and the effect of no land lateral constraint should be considered [10].

5. Conclusion

As the inevitable result of urbanization, the seismic performance of tall buildings is significant. This paper studies four seismic design methods suitable for high-rise buildings.

Establishing multi-stage seismic fortification for tall buildings can significantly enhance their ability to resist seismic loads. In the structural design combined with seismic standards, the first comprehensive inspection to make a comprehensive evaluation of the level of seismic performance of the structure, and then in the design of the structure to increase the corresponding seismic performance treatment measures, and in the construction and use of the building, strengthen the monitoring and maintenance of the structure, to improve significantly the stability of high-rise buildings under seismic loads.

A reasonable building structure system is an important factor that must be considered in modern high-rise buildings. The installation of anti-lateral force components can effectively improve the building's anti-lateral force ability. In the design, special attention should be paid to selecting anti-lateral force components to avoid uneven installation. Reasonable installation of anti-lateral force components can significantly improve the stability of high-rise buildings. The overall stiffness of the structure is also a major focus in the design, and regular buildings should be preferred. Irregular

buildings should be avoided as far as possible to prevent high-rise buildings from twisting or collapsing in an earthquake.

Installing shock absorption and isolation components is also necessary in the seismic design of high-rise buildings. Shock absorption and isolation design can consume or isolate seismic energy before the earthquake damages the building, thereby reducing the earthquake's impacts on the building and achieving the best seismic effect.

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