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Overview of the Principles and Methods of Seismic Design of Modern Structural Engineering

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Abstract

This paper summarizes the principles and methods of seismic design of modern structural engineering, so as to protect the building and its internal facilities, and reduce the possibility of structural damage and casualties when the earthquake occurs. Through the building classification and design objectives, the selection of building materials and structure form, the importance of seismic design parameters, seismic performance evaluation method, seismic structure reinforcement and improvement strategy, displacement control method, comprehensive protective measures and comprehensive analysis of seismic planning and regulations, comprehensively expounds the theory and practice of modern seismic design.

Keywords

Modern Structural Engineering; Seismic Performance Evaluation; Structural Reinforcement; Comprehensive Protection Measures.

1. Foreword

Earthquake is a natural disaster that often causes serious casualties and property losses. In order to reduce the impact of earthquake disasters, the seismic design of modern structural engineering becomes particularly important. The seismic design is designed to ensure that the building has sufficient toughness and stability in the earthquake to protect the building and its internal facilities and minimize disaster losses. This paper will review the principles and methods of seismic design of modern structural engineering [1,2], including building classification and design objectives, selection of building materials and structure form, the importance of seismic design parameters, seismic performance evaluation methods, seismic structure reinforcement and improvement strategies, displacement control methods, comprehensive protective measures and constraint of seismic planning and regulations [3].

2. Building Classification and Design Objectives

The first step of seismic design is to classify the buildings reasonably, and determine the appropriate seismic design target [1]according to its factors such as use, height, geographical location and geological conditions. Different types of buildings have different requirements for seismic performance. For example, key facilities (such as hospitals, emergency rescue centers, etc.) and high-rise buildings can withstand greater earthquake force in earthquakes, so their seismic design targets are relatively strict.

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3. Selection of Building Materials and Structural Forms

Choosing the appropriate building materials and structural form is the basis of seismic design. Reinforced concrete structures and steel structures show better performance in earthquakes, because they have a high strength and ductility, and can absorb and dissipate energy in the earthquake, thus reducing the damage of the structure [2].

3.1 Reinforced Concrete Structure

Reinforced concrete structure is one of the most common structural forms in modern buildings, it has good seismic performance and toughness. Concrete has a certain ductility and durability, while the steel bar can absorb and dissipate energy in the earthquake. This structural form is suitable for small and medium-sized high-rise buildings, industrial buildings and most of the civil buildings.

3.2 Steel Structure

Steel structure because of its high strength and excellent ductility, in the excellent seismic performance. The lightweight and fast construction speed of steel structure also make it widely used in earthquake-prone areas or in high-rise buildings that need higher seismic performance.

3.3 Brick and Concrete Structure and Brick and Wood Structure

Brick and concrete structure is a structure composed of bricks and concrete together, and its seismic performance is weak. Brick and wood structure is the combination of brick wall and wood structure, and its seismic performance is relatively good. However, these structural forms usually require reinforcement and improvement to improve their seismic performance.

3.4 Light Structure

Light structure is a structure built with light materials (such as light aggregate concrete, light steel keel, etc.), its weight is light, and the seismic force is small. This structure is suitable for some earthquake-prone areas or buildings that require reduced seismic action.

Consider the building materials and construction forms:

3.5 Geographical Location And Geological Conditions

The geological conditions and seismic intensity of different regions are different, so it is necessary to choose suitable materials and structural forms according to the actual situation.

3.6 Building Use and Height

Different uses and height of the building face different seismic force, it is necessary to choose the material and structural form that can meet the design requirements.

3.7 Budget and Construction Conditions

The choice of building materials and structural forms also needs to consider the economy and construction feasibility, to ensure that the seismic design objectives are achieved under the budget and construction conditions.

3.8 Existing Building Renovation

For the old buildings, if its original structure does not meet the seismic design standards, they need to be strengthened and improved, so that they have better seismic performance.

In seismic design, engineers need to consider the above factors, scientific and reasonable building materials and structural form selection. Through the appropriate selection, we can maximize the seismic performance of the building and ensure the safety and stability in the earthquake. At the same time, with the development of science and technology and the accumulation of seismic design experience, new high-performance materials and structural forms will continue to emerge, to provide more choices and optimization schemes for seismic design.

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4. Importance of Seismic Design Parameters

In the seismic design, it is crucial to determine the appropriate seismic design parameters. Design seismic parameters (such as seismic intensity, design seismic acceleration, etc.), the quality of the building, the nature of the foundation and the period of the structure directly affect the seismic performance of the building [1]. The correct selection of these parameters is the premise to ensure good performance in earthquakes. The following is the importance of the seismic design parameters:

4.1 Design Seismic Parameters

Design seismic parameters include seismic intensity, design seismic acceleration, etc., which is the basis for determining the size of the seismic force. Seismic intensity is the ground motion intensity when seismic waves propagate to the position of buildings, and designing seismic acceleration is an important parameter used to calculate seismic action force. Reasonable selection of these parameters can ensure that the building can withstand the predetermined earthquake force in the earthquake, so as to ensure the safety of the structure.

4.2 Building Quality

Building quality is an important index to measure the seismic performance of a structure. The greater the mass, the inertia force and seismic force of the building will also increase accordingly. Therefore, in the seismic design, it is necessary to reasonably determine the quality of the building according to the use and seismic grade to ensure its stability and safety.

4.3 Foundation Properties

Foundation is the foundation to withstand the gravity and seismic force of the building. The properties of the foundation directly affect the dynamic characteristics and seismic performance of the structure. Through geological exploration and foundation testing, engineers can understand the bearing capacity and settlement properties of the foundation, so as to carry out targeted seismic design.

4.4 Structural Cycle

The structural cycle refers to the time required for the building from the earthquake to the disappearance of structural vibration. The structural cycle is related to the stiffness and quality of the building. A larger structural cycle means a slower vibration, which is conducive to reducing the seismic force. In the seismic design, the structural cycle is needed to control the seismic displacement.

4.5 Seismic Performance of Materials

The seismic performance of building materials directly affects the toughness and ductility of the structure. Reinforced concrete and steel structures usually have good seismic performance, which can absorb and dissipate seismic energy in earthquakes. For some old buildings, their material performance may be poor, so the reinforcement and improvement need to be considered.

Reasonable selection of seismic design parameters can make the building have good seismic performance in the earthquake, and maintain the structure integrity and stability. Through the scientific analysis and calculation of these parameters, engineers can predict the response of buildings in the earthquake, and provide an important basis for the seismic design of the structure. Seismic design parameters are the foundation of seismic design and the key step to achieve the seismic design goals.

5. Seismic Performance Assessment Method

Seismic performance evaluation is an important link in the process of seismic design, which can be completed by numerical simulation, test and empirical formula. These assessment methods help engineers to understand the performance of buildings under different earthquakes and to make the necessary optimization and improvement of [3]. Here are some common methods for seismic performance assessment:

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5.1 Numerical Simulation Method

Numerical simulation is to establish the finite element model of the building and use the numerical calculation method to simulate the structural response under the action of earthquake. This method can consider the complex geometry of buildings and the nonlinear properties of the material, and can analyze the internal force, displacement and other parameters of the structure in detail. Numerical simulation methods are suitable for the performance of complex structures and special seismic action.

5.2 Test Method

The test is to evaluate the seismic performance of the building by simulating the physics on the seismic simulation platform. The test can directly observe and measure the response of the structure under seismic action, including displacement, acceleration, stress and other parameters. The test methods are usually used to verify and study the seismic properties of new structures or special structures.

5.3 Empirical Formula Method

Empirical formula is a simplified calculation formula based on a large number of historical earthquake and structure actual performance data. This method is relatively simple and is suitable for preliminary evaluation or seismic performance estimation of simple structures. However, empirical formulation methods usually do not consider the complexity and nonlinear behavior of the structure, with relatively low accuracy.

5.4 Performance Evaluation Index

Performance evaluation index is to evaluate the performance level of a structure in an earthquake by defining a series of performance targets and evaluation criteria. For example, the building displacement limits, interlayer displacement Angle, shear level, etc. These indicators can assist engineers in the quantitative assessment and comparison of the seismic performance of buildings.

5.5 Injury Assessment Method

Injury assessment is to assess the damage degree of a building in an earthquake. By checking and evaluating the damage of the structure, the seismic performance and safety of the structure can be judged. Injury assessment methods are usually used for the seismic performance assessment of old buildings and for the development of improvement strategies.

Using the above different seismic performance assessment methods, engineers can fully understand the situation of the response of the building in the earthquake, identify the weak links and possible problems of the structure, and take corresponding reinforcement measures and optimization design to improve the seismic performance of the building. It is worth noting that the selection of seismic performance evaluation method should be based on the specific situation, combined with the building type, use, scale and seismic requirements and other factors, a reasonable comprehensive application.

6. Seismic Structure Reinforcement and Improvement Strategy

For the old buildings, their seismic performance may not meet the current seismic design standards. Therefore, the reinforcement and improvement of the seismic structure has become particularly important. According to different situations, measures such as strengthening beam and column nodes, adding shear wall or reinforced concrete wrapping can be adopted to improve the seismic resistance of old buildings [2]. The following are some commonly used seismic structure reinforcement and improvement strategies:

6.1 Strengthen the Beam and Column Nodes

The beam and column nodes are the weak links in the building structure, which are easy to be damaged in the earthquake. By adding reinforcement materials such as steel plate, steel bar or carbon fiber at the beam and column nodes, the bearing capacity and ductility of the nodes can be increased, and the seismic performance of the beam and column nodes can be improved.

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6.2 Add the Shear Wall

Shear wall is a kind of special structural wall that can resist seismic shear force. By adding shear wall in the building, the seismic capacity of the whole building can be greatly improved. Shear wall usually adopts reinforced concrete or steel structure, its reasonable layout and connection can effectively absorb and disperse seismic energy.

6.3 Reinforced Concrete Wrapping

For the existing concrete structure, the reinforced concrete wrapping method can be reinforced. By pasting steel mesh on the surface of the concrete member and making new concrete wrapping, the strength and ductility of the member can be increased and its seismic performance can be improved.

6.4 Design and Construction Error Repair

Some old buildings may have errors in the design and construction process, resulting in their substandard seismic performance. By repairing and improving the design and construction errors, the overall seismic capacity of the building can be improved.

6.5 Application of Shock Absorption Device

Shock absorber is a special device that can absorb and consume seismic energy. By setting up shock absorber in the building, the impact of earthquake on buildings can be reduced. Common shock absorber device includes hydraulic shock absorber, friction shock absorber, etc.

6.6 Increase the Horizontal Support

In some cases, the horizontal support of the building is insufficient, resulting in a poor overall seismic performance. The overall stability and seismic resistance of the building can be improved by adding appropriate horizontal support.

6.7 Use of New Seismic Materials

With the development of science and technology, the application of new seismic materials is gradually mature, such as high-performance concrete, nanomaterials, etc. The use of these new seismic materials can effectively improve the seismic performance of buildings.

7. Displacement Control Method

In earthquakes, the displacement of buildings may lead to structural damage or collapse, so the displacement control is a key consideration in seismic design. The method of displacement control includes increasing the damping of the building, absorbing seismic energy by adding earthquake absorption device, or using appropriate shear wall layout to limit the structural displacement, thus reducing the structural damage under earthquake [2].

8. Comprehensive Protective Measures

Seismic design is not limited to the structure itself, but also needs to consider various protective measures to enhance the overall seismic capacity of the building. For example, an earthquake monitoring system is set up in buildings to monitor seismic activity in real time and take safety measures in advance. The application of automatic shutdown device can automatically stop the production line in case of earthquake to protect the safety of workers. At the same time, the installation of automatic fire extinguishing system can prevent earthquake-caused fires and reduce secondary disasters [3].for instance,

(1) Setting up the earthquake monitoring systems in the buildings,

(2) Can monitor seismic activity in real-time,

(3) Take safety measures in advance.

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(4) The application of automatic shutdown device can automatically stop the production line in case of earthquake to protect the safety of workers. At the same time, the installation of automatic fire extinguishing system can prevent the earthquake caused by fire and reduce secondary disasters.

9. Earthquake Planning and Regulations Constraints

Countries and regions usually formulate seismic planning and regulations that require buildings to meet the corresponding seismic design standards. The Engineer must comply with these regulations in conducting the seismic design and ensure that the design scheme complies with the requirements of the relevant laws and regulations. The implementation of seismic planning and regulations is of important guiding significance for improving the overall seismic performance of buildings [3].

10. Conclusion

The seismic design of modern structural engineering is to protect buildings and their internal facilities and reduce the possibility of structural damage and casualties when an earthquake occurs. This paper summarizes the key principles and methods of seismic design, including building classification and design objectives, the selection of building materials and structure forms, the importance of seismic design parameters, seismic performance evaluation methods, seismic structure reinforcement and improvement strategies, displacement control methods, comprehensive protective measures, and the constraints of seismic planning and regulations. By reasonable selection of materials and structure forms, accurate determination of seismic design parameters, comprehensive performance assessment, and comprehensive protection measures, the seismic performance of the building can be improved, and the loss caused by earthquake disaster can be minimized. The continuous improvement and innovation of seismic design will help to build a more safe and reliable building environment and provide more effective protection for people's life and property.

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