Performance-Based Structural Seismic Method in High-rise Building Design

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Abstract. The rise of intelligent buildings in China is based on two reasons. One is that with the reform and opening up, China's national economy has continued to develop rapidly, its overall national strength has been continuously enhanced, and people's living standards have been improved. People urgently need to improve and enhance their working and living environments. Architecture is just one of the important ways to meet this demand. Performance-based seismic design is based on the investment-benefit criterion as a basic principle, reflecting an important change in the seismic design thinking of modern structures, that is, focusing on structural safety from the past. To develop a comprehensive focus on structural performance, safety and economy. It makes the seismic design transition from macroscopically qualitative goals to concretely quantified multiple goals. Designers can choose the required performance goals, which is conducive to the innovation of building structures, using new structural systems, new technologies, and new materials; it is beneficial to adopt different performance goals and earthquake resistance for different fortification intensity, site conditions, and the importance of the building Measures. It is a change in the design concept and plays a significant role in the design and development of engineering structures. This paper explores the characteristics, composition, and design requirements of high-rise intelligent buildings, analyzes their superiority and social benefits, and studies their architectural principles and future development trends. High-rise intelligent buildings were born to meet the higher requirements of office and living environments. It is a combination of architectural art and information technology. It is the four basic elements of structure, system service and optimal combined system management, providing a safe, efficient, comfortable and convenient built environment. At present, only the uncertainty of the load, the strength of the material, the geometric dimensions and the uncertainty of the calculation model are usually considered. For the artificial uncertainty, the complexity and uncertainty of the economic loss estimation due to the complexity of earthquake damage As a result, it is very difficult to accurately estimate economic losses, especially the estimation of indirect losses. Therefore, the establishment of a performance-based reliability optimization decision-making model for high-rise intelligent buildings requires further research and improvement. To build more detailed and specific models for different types of requirements.
Keywords: High-rise Intelligent Building, Performance-based Structural Earthquake Resistance, Investment-benefit Criterion, Structural Selection, Performance Evaluation

1. Introduction

Based on the concept and method of performance seismic design, it has risen in the United States since the 1990s and has received widespread attention from the engineering community. Suggestions for using multiple performance objectives in structural evaluation and force stabilization of buildings and design methods are provided. American engineer Massimiliano Gioffrè has proposed a new performance-based seismic design of buildings. In 1998 and 2000, American engineers published documents related to performance-based seismic design. In 2003, the United States issued performance guidelines for buildings and facilities, covering building functions, structures, normal use of non-buildings and equipment, and various disasters. Construction process and long-term performance. The code clearly specifies important guidelines based on performance design methods. Japan has also started to formally incorporate the idea of seismic performance design into design and reinforcement standards, and performance standards have been proposed by the National Institute of Architecture. European engineers released displacement-based seismic design reports for reinforced concrete building structures. Australia has conducted extensive research on performance-based overall frameworks and building fire performance design, and has proposed corresponding building codes. In China, many papers have been published for the research and discussion of performance-based seismic design.

Performance-based seismic design is based on the investment-benefit criterion as a basic principle, reflecting an important change in the modern structural seismic design thinking, that is, from focusing on structural safety in the past to focusing on structural performance, safety, and economy in all aspects Development [1-3]. It makes the seismic design transition from macroscopically qualitative targets to specific quantitative multiple targets [4]. Designers can choose the required performance goals, which is conducive to the innovation of building structures, using new structural systems, new technologies, and new materials; it is beneficial to adopt different performance goals and earthquake resistance for different fortification intensity, site conditions, and the importance of the building Measures. It is a change in the design concept, which plays a significant role in the design and development of engineering structures [5-6].

So far, purely theoretical calculations of high-rise intelligent buildings in terms of seismicity have not made it possible for buildings to have good and satisfactory seismic effects, so people need to gradually develop a design that focuses on the overall seismic resistance of the building structure. For this reason, based on a lot of Chinese and foreign literatures, this paper reviews the seismic design system and design ideas and methods of the building through the study of the guidelines and policies for seismic design of buildings. Further research. A new concept design of earthquake resistance is proposed, and the performance-based seismic design method is applied to the seismic measures of high-rise intelligent buildings. The performance-based seismic design is applied to the design of non-structural components of high-rise intelligent buildings to improve the reliability of seismic design.

2. Proposed Method

2.1 High-rise intelligent Building Building Structure System

The division of high-rise buildings varies from country to country. In general, when the height of a building

When it is different from multi-level buildings in terms of planning, design, construction, equipment and fire protection, it is divided into high-rise buildings. Intelligent building refers to the use of system integration methods, management of information resources, and information services to
users and their optimized combination with buildings. The investment obtained is reasonable, suitable for the needs of the information society, and safe, efficient, comfortable, convenient and flexible. Characteristics of buildings [7], which determines the trend of intelligent buildings towards high-rise intelligent development. High-rise intelligent buildings and super-high-rise intelligent buildings have become current architectural hotspots.

In high-rise buildings, resistance to horizontal forces has become the main contradiction in design. Design and design have become key issues in structural design. The basic lateral force resistance units in high-rise buildings are frames, shear walls, solid webs (wellbore), frame tubes, and supports.

(1) Frame structure system
The frame structure consists of beams and columns. The entire structure is composed of beams and columns, which is called a frame structure

The system is sometimes called a pure frame structure. Its advantage is that the layout of the building is flexible. It can be made into conference rooms, restaurants, workshops, business rooms, classrooms, etc. with large spaces. When needed, it can be divided into small rooms by partitions, or it can be dismantled into large rooms. However, it also has disadvantages. The lateral stiffness of the frame mainly depends on the cross-sectional size of the beam and column. Usually, the beam-column section has a small moment of inertia, large lateral deformation, small lateral stiffness, and limited construction height [8].

In short, the frame structure is a good system in a small high-rise building. suitable
Used for shopping malls, hotels, hospitals, schools, etc. below 60m.

(2) Shear wall structure system
The use of building walls as a structure that supports vertical loads and resists horizontal loads is called a shear wall structure

system. The wall also serves as a maintenance and room divider. The cast-in-situ reinforced concrete shear wall structure has good integrity, high rigidity, small lateral deformation under horizontal loads, and easy bearing capacity requirements, so this kind of shear wall structure is suitable for the construction of high-rise buildings.[9] In general, the advantages of shear wall structure are: load bearing, wind resistance, anti-stretching, enclosure and separation as one, economical and reasonable structural materials, strong integrity, large lateral displacement stiffness, small lateral deformation, and good seismic. Compared with the frame system, the construction is relatively simple and fast. The self-weight of the structure absorbs large amounts of seismic energy, and its disadvantages are: it is difficult to meet the functional requirements of large space buildings, and the structure is self-heavy. The applicable scope of the shear wall structure is: suitable for residential, apartment and hotel buildings with many partition walls [10].

(3) Frame-shear wall structure (frame-cylinder structure and frame-shear wall structure) system
Part of the shear wall is in the frame structure, which combines the frame and the shear wall, complements each other, and resists horizontal loads together to form a frame-shear wall structure system [11]. If the shear wall is arranged as a cylinder, it can also be called a frame-cylinder structure system. The load-carrying capacity, lateral stiffness and torsional capacity of the cylinder are greatly improved compared to single-piece shear walls. In terms of structure, this is a way to improve the utilization rate of materials. In terms of building layout, it is often reasonable to use the cylinder as a passage for the elevator, stairwell, and vertical pipes.

2.2 Experimental Methods
(1) According to the purpose of the structure, the special requirements of the owner and the user, the investment-benefit criterion is adopted to define the target performance of the building structure (which can be a "personalized" target performance that is higher than the requirements of the code).

1) Parameter planning method

\[
\text{find } x, \left[p_{ai}\right]_i = 1, \ldots, n_p
\]  

(1)
\[
\min W(x) = C_0(x) + C_m(x) + \sum_{i=1}^{n_p} (1 - [P_{si}(x)]) C_{fi} \quad (2)
\]
\[
s.t \ g_j(x) \leq 0, \ j = 1, \ldots, m \quad (3)
\]
\[
[P_{sk}] - P_{sk}(x) \leq 0, \ k = 1, \ldots, n_p \quad (4)
\]

In the formula, x represents the design variable vector of the structural design scheme. Depending on the optimization level, it can be variables related to the structure layout, topology, shape, size, etc. In the objective function, \(C_0(x)\) and \(C_m(x)\) are the initial cost and inspection of the structure. The maintenance cost is a function of the structural design plan x. In the third structural failure loss expectation, \(P_{si}(x)\) is the reliability of the structural system based on the performance i of the design plan x, and \(C_n\) is the loss value when the performance fails. Among the constraints, \(g_j(x) \leq 0\) is a deterministic constraint related to the design scheme, such as the strength constraints of components, constraints on structural requirements, etc., and \([P_{sk}] - P_{sk}(x) \leq 0\) is a reliability constraint of performance-based structural systems.

2) Constraint relaxation method

\[
\text{find } x, [P_{si}]_{i = 1, \ldots, n_p} \quad (5)
\]
\[
\min W(x) = C_0(x) + C_m(x) + \sum_{i=1}^{n_p} (1 - [P_{si}(x)]) C_{fi} \quad (6)
\]
\[
[P_{sk}] = P_{sk} \left( x^{opt} \right) \quad k = 1, \ldots, n_p \quad (7)
\]

The meanings of the terms in the formula are the same as those of model 2. Solve the optimal model 3 to get the optimal design solution \(x^{opt}\), then

The target reliability of the structural system based on performance can be obtained by the following formula

\[
[P_{sk}] = P_{sk} \left( x^{opt} \right) \quad k = 1, \ldots, n_p \quad (8)
\]

Model 2 is to relax the constraints of the entire optimization model; then optimize the structure to obtain the corresponding optimal design plan; finally, the reliability of the performance-based structural system calculated by the optimal design plan is the optimization goal Reliability.

(2) According to the above target performance, adopt appropriate structural system, building materials and design methods (but not limited to the methods specified in the code) for structural design.

(3) Perform a performance evaluation of the designed building structure. If the performance requirements are met, the actual performance level of the designed structure is clearly given, so that the owner and the user can understand (this is different from the conventional design of the target); otherwise return to the first One step with the owner to adjust the target performance, or return directly to the second step to redesign.

3. Experiments

3.1 Experimental Object

This article uses high-rise intelligent buildings as objects, considering factors such as function, span, support conditions, loads and construction technology.
The requirements of intelligent systems must also be taken into consideration, and the problem of seismic fortification should be considered. The safety of such non-structural components has been neglected for a long time, but multiple earthquake disasters have shown that the destruction or loss of function of many non-structural components will cause serious economic losses have caused the loss of the use of houses, endangered the lives of people, and even affected people's social life. Therefore, we must find a new earthquake-resistant method that is safe and can protect the internal equipment of the building, and can connect itself to the main structure of the structure to run normally and economically.

3.2 Experimental Process
In accordance with its seismic fortification standards, according to the investment-benefit criterion, the optimization decision of the fortification intensity of the building structure also reflects the target performance level of the structure to some extent. This is the optimal fortification intensity.

Establishing a one-to-one correspondence between fortification intensity and structural cost is also very difficult. The initial cost of the structure is actually directly related to the specific design scheme. Given the same fortification intensity, you can design multiple Different schemes have different costs. That is, the design scheme cannot be uniquely determined by the fortification intensity of the structure, and thus the initial cost of the structure cannot be uniquely determined. The same difficulties also exist in the estimation of structural maintenance costs. The design that meets the requirements of the specification and has the lowest cost is discussed. According to the fortification requirements of "small earthquakes are not bad, moderate earthquakes can be repaired, and large earthquakes cannot fall," the structure is properly. When an earthquake with random intensity n is encountered, \( I_1, I_2, I_3 \) can approximate the mode value intensity, fortification intensity, and large earthquakes. intensity.

The initial cost of the structure is expected to achieve an optimized balance with the future loss of the structure. The design goal it pursues is to minimize the total cost of the structure throughout its life cycle.

4. Discussion

4.1 Loss Expectation Assessment

|          | Crowd intensity | Fortification intensity | Strong earthquake intensity |
|----------|-----------------|-------------------------|-----------------------------|
| \( I_1 \) | 17              | 53                      | 27                          |
| \( I_2 \) | 80              | 17                      | 66                          |
| \( I_3 \) | 32              | 61                      | 69                          |
Figure 1. Architectural analysis diagram

As shown in the above table and picture, after connecting the five damage levels specified in the code: basically intact, slightly damaged, moderately damaged, severely damaged and collapsed with "not damaged, repairable and not collapsed", the probability of the structure suffering a certain level of damage can be obtained through approximate treatment, so as to further evaluate the expected failure loss of the structure. In this way, the optimal decision-making model of the optimal fortification intensity.

In addition, the international standard (1502394) points out in the target level model of determining reliability: "from the economic point of view, the target level of reliability should depend on the balance between the failure consequence and the cost of safety measures. The formal approach is to reduce the total cost of life cycle.

4.2 Total Cost Assessment of Structure Life Cycle

When aseismic design of structures is carried out according to the criterion of investment benefit, the problem is transformed into that the total cost of the whole life cycle of the structure is the minimum. The evaluation of the total cost of the whole life cycle of the structure is the key to the implementation of the seismic optimal design based on the investment benefit criterion, and it is also a difficulty. Generally speaking, the total cost \( w \) of the structure in the whole life cycle mainly includes three parts: initial cost or initial cost \( C \); inspection and maintenance cost \( C \); failure loss expectation \( CF \), including direct loss, indirect loss and casualties, etc.

These three items are interrelated. Increasing the initial cost can reduce the cost of maintenance and loss, and increasing the cost of inspection, maintenance and repair can also reduce the expectation of failure loss. In the above assessment model of total cost of structural life cycle, the initial cost generally includes structural material cost, equipment cost, construction cost, decoration cost, etc. The cost of inspection and maintenance is related to the importance of the structure and the degree of damage suffered. It mainly refers to the cost of reinforcement caused by the insufficient bearing capacity of the component and the resulting loss of revenue. The assessment of failure cost is a very complex problem, which is not only an engineering problem, but also involves many factors such as society, economy, politics, humanity and so on.

5. Conclusions

According to the characteristics of high-rise intelligent buildings and the new requirements for earthquake resistance, this paper introduces the latest seismic design method: performance-based seismic design method, and puts forward the performance-based structural seismic design countermeasures for high-rise intelligent buildings. The specific research results are as follows:
This paper discusses the definition, composition, content and advantages of high-rise intelligent building. And the construction principles and future development trend are discussed. The high-rise intelligent building is a subject which integrates many subjects and has the characteristics of system integration. It is equipment oriented and function oriented. It is the inevitable product of adapting to the development of economy and improving living conditions.

Study and analyze the structural system of high-rise buildings, as well as the structural characteristics and design requirements of high-rise intelligent buildings. It is concluded that the design of high-rise intelligent building should meet the requirements of structural function usability, comprehensive aesthetic performance, structural stress rationality, equipment function usability, structural construction and installation performance, life cycle economic efficiency, etc. Then it analyzes the limitations of the traditional anti-seismic structure. For the high-rise intelligent building, the traditional anti-seismic design method can not meet the requirements of its anti-seismic design. We should deeply reflect on the existing seismic design ideas and methods, and work out the seismic design methods suitable for the characteristics of high-rise intelligent buildings.

And in the evaluation of the total cost of structural life, these three items are the cost of a certain time in the future of the structural life cycle, which involves how to add the cost of different time. If a proper discount rate is adopted, the future cost can be converted into present value, so that the present value of the total cost can be evaluated. But how to make a reasonable discount rate is a very complicated problem. Based on this, people put forward to use the fuzzy comprehensive evaluation theory to evaluate the total cost of the structure life cycle, and use the fuzzy comprehensive evaluation theory to evaluate the loss expectation of the structure life cycle, so as to greatly simplify the calculation amount of the loss expectation evaluation of the failure with a certain accuracy.

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