The Method of Improving the Seismic Reliability of Building Structure Based on Kriging Optimization Theory

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Abstract. The development of social economy accelerates the process of urbanization and makes the population denser. Once the earthquake happens, it will cause serious harm to people. The building constructed by traditional methods cannot meet the seismic requirements. Based on Kriging optimization theory, this paper studies the method of improving the seismic reliability of building structure, introduces the principle of the method, and establishes the seismic model of building structure. Compared with the traditional methods, it can be found that the optimized seismic method can effectively improve the seismic capacity of the building structure, provide a better guarantee for the safety of citizens' property and life, and has a very good use value.

Keywords: Kriging Optimization Theory, Building Structure, Seismic Reliability, Reliability Improvement Method

1. Introduction
Earthquake is also known as earth motion or earth vibration. If the crust releases energy too fast when it moves, it will cause earth vibration. Earthquake is very destructive, which can cause serious damage to people's lives and properties. Some toxic gases will leak with the occurrence of earthquake, bacteria and radioactive substances continue to spread, and then fire, flood, tsunami, landslide, collapse, ground fracture and other secondary disasters will be caused. According to the statistical results of Geological Survey Bureau in 2016, there are more than five million earthquakes every year and tens of thousands of earthquakes every day in the world. However, most of the earthquakes are hard to be felt by people because of their small vibration amplitude. There are about 10 to 20 earthquakes that actually cause harm to people every year. There are about one to two earthquakes that cause serious disasters [1].

After entering the 21st century, with the rapid development of social economy, the acceleration of urbanization and the increasing density of population, a natural disaster may cause great harm to human beings. In this case, how to improve the seismic reliability of the building structure and ensure the safety of the residents has become a topic of close attention. In particular, the quality and safety
problems of engineering structures in China are very serious. Many builders, driven by their interests, cut corners on work and materials. The "jerry-built project" occurs frequently. It is important to improve the safety of buildings for Chinese residents [2]. In conclusion, based on Kriging optimization theory, this paper studies the method of improving the seismic reliability of building structure and determines the method by establishing the model. Practice shows that the method can effectively improve the seismic reliability of the building structure and provide security for people's lives.

2. The Establishment of Seismic System Model of Building Structure
Before establishing the seismic system model of building structure, the life process of building structure should be analyzed. The life of building structure can be divided into three stages: construction stage, normal use stage and aging and maintenance stage. The whole use process of the building will be subject to multiple influences of nature and man-made forces, among which there are a lot of uncertain factors, which may directly or indirectly damage the structure of the building, threaten the safety of life and property of the whole social residents, and delay the progress of industrial production [3]. Most buildings use concrete frame structure or reinforced concrete frame structure, but if the large-scale disaster occurs, the concrete structure lack of ductility or without ductility is likely to be damaged, or even has house collapse accidents.

After analyzing the life of the building structure, the seismic system model of the building structure can be established. The modeling process is shown in Figure 1 [4]:

![Figure 1](image)

**Figure 1** Establishing process of seismic system model of building structure

According to the analysis of Figure 1, the establishment of the structural model can be divided into two steps: the first step is to design a reasonable structural scheme and building form; the second step is to determine reasonable details according to the overall scheme and make accurate calculation. Among them, the second step can be divided into the following small steps: (1) firstly, find out the reasonable seismic calculation theory of building structure, which is Kriging optimization theory in this paper; (2) secondly, get the load effect combination by calculating the effect of load and internal force; (3) then, analyze the relationship between structure and each section, and carry out the overall design and checking calculation; (4) finally, according to the relationship obtained, choose the building size and the best materials for houses. Many parameters need to be involved in the establishment of seismic structure model, and the main parameters are: the interaction between the building structure and each component, such as bending moment, shear force, torque, stress and deformation force; the ability of the structure and material to bear the action is called resistance, which is determined by the material strength, section size, connection conditions and other factors [5].

3. Methods to Improve the Seismic Reliability of Building Structures
Although before the design, the designer can use the computer to predict these parameters, it will still be affected by many unknown factors in the actual project, so these design parameters are also called random variables. People can analyze the random variables according to the known information and
statistical information. Housing construction is a complex project, and the structure constructed is also extremely complicated. The reliability of building structure should be calculated before construction, and the calculation process is as follows [6]:

\[ N_2^\eta = A G_{1,j} x(t) \]  

(1)

In formula (1), \( t \) represents various variables affecting the reliability of building structure, \( A \) represents load constant and \( G \) represents load effect of introduced structural members. Through the above formula, the resistance of building structure \( N_2^\eta \) can be calculated. After the resistance \( N_2^\eta \) is calculated, the reliability of building structure should be calculated. The calculation formula is shown in (2):

\[ Z = N_2^\eta j^{\frac{\mu-\lambda}{\sigma}} - \lambda \]  

(2)

In formula (2), \( Z \) represents the reliability of the building structure and \( \lambda \) represents the functional function. As the resistance \( N_2^\eta \) is a random variable, the corresponding building reliability \( Z \) is also a random variable. When the value of \( Z \) is positive, it indicates that the building structure is in a reliable state and has good seismic resistance capacity, which meets people's living demand and the building expectation; when the value of \( Z \) is zero, it indicates that the building structure is in the limit state, and the safety of the building structure is at the critical point, which is no longer suitable for human living. When the value of \( Z \) is negative, it indicates that the building structure is in the state of structural failure. At this time, the seismic capacity of building structure is very poor, and it may cause danger, which can no longer meet people's living requirements, so residents should evacuate immediately and cannot continue to live in the house [7].

There are many indexes that affect the reliability of building structure, and each factor will produce a series of complex chain reactions. Therefore, under the existing conditions, the most ideal and accurate results cannot be found. In this case, people usually use some approximate methods to calculate the reliability index of the structure, and then use the approximate value analysis to measure the reliability of the structure.

After analyzing the reliability of the building structure, the basic model can be established according to the analysis of the reliability relationship. The seismic system model of the building structure is shown in Figure 2 [8]:

![Figure 2 Seismic system model of building structure](image)

Through the analysis of Figure 2, it can be found that a building is composed of beams, columns, plates, walls and other hybrid systems, so the reliability of the building can also be seen as two types of structures, series and parallel. In the series structure, if a building component fails, the whole building structure will fail, and the seismic capacity will be basically lost, which is not suitable for living. However, in the parallel structure, if a building component fails, and other components are
intact, the building can still be used normally, and the seismic capacity is partially lost, but not to the point where it cannot be used [9].

According to the seismic system model of building structure mentioned above, the reliability of seismic structure is improved by Kriging optimization theory. The methods are as follows: first, find out the fragile components or parts of building structure, evaluate their reliability, record the evaluation results, remove the components with poor seismic capacity and replace them with the components with good seismic capacity; then, according to the recorded evaluation results, determine the service life of the structure, and determine whether the service life meets the load standard; if the load standard cannot be met, the design scheme shall be recalculated; then the safety of the building construction shall be analyzed, and the non-quantitative factors used shall be taken into account; finally, after finishing the overall analysis, the comprehensive structural optimization shall be carried out to improve the seismic structure of the building [10]. The flow chart of improving seismic structure reliability of building is shown in Figure 3 below:

![Flow chart of improving seismic structure reliability of building](image)

**Figure 3** The flow chart of improving seismic structure reliability of building

4. Experiments of Improvement Method for Seismic Structure

In order to determine whether the proposed method can effectively improve the seismic structure of buildings, simulation experiments are carried out. A building adopting concrete structure is selected, and the building is reconstructed according to the traditional method and the method given in this paper. Then simulate the earthquake to impose different degrees of vibration on the building, and observe. The experimental results are shown in Figure 4 [11]:

![Experiment results](image)
By analyzing the experimental results in Figure 4, it shows that the seismic capacity of buildings constructed by the traditional method is far less than that constructed by the method given in this paper. When the earthquake intensity is more than 3.5, the seismic capacity of buildings constructed by the traditional method will show a downward trend; when the earthquake intensity is more than 6, the seismic capacity of buildings will show a sharp decline, which cannot provide guarantee for people's lives. However, the method proposed in this paper has a very high seismic capacity, and with the increase of the earthquake intensity, the seismic capacity is also increasing, which can effectively ensure the safety of citizens' lives and reduce the loss in case of large-scale earthquake damage [12].

5. Conclusion
Through the study of this paper, we can find that earthquake as a large-scale natural disaster will bring great losses to people. Especially at present, the city is centralized, the population distribution is denser, and the harm caused by earthquake is more serious. Therefore, how to effectively improve the quality of buildings has become an urgent problem for people to solve. Based on Kriging optimization theory, this paper studies the method of improving the seismic reliability of building structure. By building the seismic model of building structure, the seismic capacity is improved. Experiments show that the method given in this paper can improve the seismic capacity of building structure more effectively than the traditional method and provide better guarantee for the safety of property and life of citizens with lower work cost, which is the inevitable development direction in the future.

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