Seismic Response Analysis of Large Span Spatial Structures

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Abstract

Three kinds of response analysis methods of large-span spatial structures under multi-dimensional multi- point earthquake are compared, the necessity of multi-dimensional multi-point seismic input and multi-directional seismic effect consideration in long-span spatial structures is expounded, and the application of seismic isolation and various fast algorithms in seismic resistance is introduced.

Keywords

multi-dimensional multi-point input;Random vibration method; Reaction spectroscopy; Time history analysis

1. Introduction

Due to its advantages of large span, light weight and simple structure form, the spatial structure has been widely used in large public buildings such as gymnasium, airport and parking lot. Considering that the above-mentioned structures will cause huge economic and personnel losses when the earthquake collapses, how to improve the seismic capacity of the spatial structure becomes the key problem to be considered in the design of the spatial structure. The analysis of structural seismic response has gone through three stages: static, response spectrum and dynamic. At present, people on the structural analysis of structural responses under the seismic action of much behind in two phases, this article will mainly introduce the current main methods of spatial structure seismic response analysis, the analysis and comparison the similarities and differences between them, and summarize the latest research status of earthquake input, research direction and large-span spatial structure seismic aspects of other major problems.

2. Seismic Response Analysis Method

2.1 Random Vibration Method

The random vibration method is also called the power spectrum method. It can fully consider the statistical probability characteristics of earthquake occurrence[1]. However, when the structure was complex and with many degrees of freedom, the traditional CQC was used.

Aiming at the defects of the traditional stochastic vibration power spectrum method, Lin jia hao et al[2]from the point of view of computational mechanics, an efficient algorithm for calculating random response of large structures is proposed, namely virtual excitation method. This method automatically contains the correlation between all modes of parametric oscillations, and is a precise and fast CQC method. Xue suduo and others[3]Will the pseudo-excitation method applied in the multidimensional space grid structure more non-stationary random seismic response analysis and multi-dimensional virtual excitation random vibration analysis method was deduced theory formula, peak response estimation method are given, and discusses the multi-dimensional seismic stochastic model and parameter selection, through the analysis of the special computer program compiled the random seismic response of reticulated shell structure.

2.2 Reaction Spectrum Method

Because the change rule of the true seismic wave cannot be predicted in the seismic calculation, the design response spectrum is often used in engineering calculation to simulate the seismic wave. The response spectrum method is a simple and effective method to approximate the seismic response of linear structural system. The response spectrum method has become the most mature method in the seismic code of all countries. The response spectrum method is a linear superposition method. When it is applied to multidimensional seismic analysis, if the rotation action is taken into account, the kirschner coupling effect exists, and the superposition principle will fail. However, in engineering calculation, the colonic coupling effect is not considered and the response spectrum method is still used. The combination mode of the response spectrum is usually obtained from the analysis of the stationary random process. In fact, ground shaking is a strong non-stationary random process. Even though ground shaking is a stationary random process, the structural reaction transitions from transient reaction to stationary process. When the damping ratio is 5% ~ 10%, it takes about 4 ~ 5 cycles, and when the damping ratio is 1% ~ 2%, it takes about 20 cycles. For large-span structures, such as suspension Bridges, their fundamental period and ground motion duration are of a magnitude, so the assumption of a stationary random process is obviously inappropriate.It is difficult to draw a correct conclusion by this method.Therefore, the method has the following disadvantages: analysis and results have certain limitations, that is, the calculation results are only the response of the seismic wave.

2.3 Time History Analysis

The deterministic dynamic analysis method includes time domain and frequency domain analysis method, among which time history analysis method is more mature and widely used. It can accurately consider the structure, the interaction between soil and deep foundation, the phase difference effect of seismic wave and the multi-component multi-point input of different seismic waves. At the same time, the effects of geometrical and material nonlinearity as well as the nonlinear properties of various shock absorber and isolation devices on the seismic response of structures can be considered. Time series method is a direct integral method, including linear acceleration method, Wilson- surface method and Newmark method[4]. Compared with the response spectrum method, the time series method is more extensive

The universal applicability, such as considering the structural non-linearity, determine the order of plastic hinge occurrence and the position of structural weak links; The drawback is the lack of statistical significance, only select specific seismic waves. Because of the large deviation of the results obtained by different seismic waves, the time-history method is often used in the nonlinear analysis of structures as a supplement to the response spectrum method. Many researchers have analyzed the response of large span structures under multi-dimensional earthquake action using time-history method[5]. Because time-history analysis is based on real seismic waves, it can be used to test the rationality of other methods and provide basis for further research. Chu ye, ye jihong[6]Using time history analysis of long-span spatial grid structure, respectively, in the more consistent and input the elastic-plastic seismic response analysis of the structure response under two kinds of input methods were compared, found that both broadly in line with a plastic to carry out the law, but under multi-point input into the plastic bar significantly greater than the number of input, at the same time, the plastic bar distribution more uniform.

2.4 Advantages and Disadvantages of the Three Methods

Studies have shown that[7]: the spatial variation effect of seismic ground motion has considerable influence on the response of large-span structures. The response spectrum method based on mode superposition is essentially a linear method, which may cause large error when applied to strong nonlinear problems, and the random vibration method has similar limitations. Therefore, the time history method should be used for seismic analysis, while the other two methods should be used for comparison.

The biggest advantage of stochastic analysis method is that it takes into account the statistical rule of each reaction, so it is not restricted by the input function. But this method is too complex for engineers. In the current code, the response spectrum is mainly used in the structural design rather than the power spectrum density, which also indicates that the random vibration method is difficult to be applied in practical engineering.

3. Seismic Input

For large-span structures, there is a big difference between the multi-point seismic input mechanical mechanism and the consistent seismic input. Under the action of multi-point input, the motion equation of the structure cannot simply apply to the motion equation of consistent input, and the calculation formula must be deduced again[8].

Reticulated shell structure is commonly used in large span architecture. The dynamic performance and design of reticulated shell structure under earthquake action are also concerned by many researchers. However, most studies only consider the effect of one-way seismic action on the structure. Even when considering three-way seismic action, the effect of each direction is considered as independent from each other, and the correlation between the three directions is not considered[9]. As a kind of space structure system, the reticulated shell presents obvious characteristics of space stress and deformation. Therefore, it is more reasonable to consider the combined action of horizontal and vertical earthquakes in seismic response analysis of reticulated shell structures.

Cao zhi, xue suduo, etc[10]The multi-dimensional virtual excitation theory is extended, and the multi-dimensional seismic response law of K6 monolayer spherical reticulated shell is studied systematically by computer program. The results show that the 3-d seismic internal force of the main stressed members of the reticulated shell is much greater than that of the single-dimensional seismic internal force.

4. Some Research on Other Issues

Wei-xing shi etc.[11]In this paper, the characteristics and damping principle of high isolation are introduced by taking the study of high isolation of the news center of Shanghai international racing track as an example, the seismic isolation bearing is optimized, and its characteristics are analyzed. Marsh[12]By actively controlling the isolation, the position of strain gauge is on the propagation path of vibration.A fast algorithm for the solution of response spectrum theory is proposed. This method can directly write out the seismic response displacement solution relative to the vibration modes of the structure, so as to save the calculation time and avoid the calculation precision error generated in the solution process.

5. Conclusion

Multi-dimensional multi-point seismic response analysis of large span spatial structures is an inevitable trend of seismic research development, but there are still many problems to be solved. One is the study of the multi-component earthquake action model and its correlation. The key to solving the multi-dimensional seismic action of structures is to study the stochastic model of each seismic component and the correlation between each component when considering the multi-component interaction. The second is how to consider the soil-structure interaction. At present, the main consideration is the effect of soil on the structure. In fact, the structure will react to soil. Third, how to propose the calculation method suitable for engineering application. The current calculation methods are very complex and suitable for scientific research. How to incorporate these methods into the norms needs further research.

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