The Wind Vibration Analysis of High-rise Isolated Structures Based on Linear Regression Filter Method

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Abstract. Vibration isolation is a fast developing structure vibration control technology. Due to its simplicity and effectiveness, it has been gradually applied to high-rise buildings in recent years, and high-rise isolated structures have a large effect of high-order vibration damping. Compared with high-rise seismic structures, the period of high-rise isolated structures is larger, so the wind load effect is larger than that of high-rise seismic structures. This paper on the damping effect analysis of structures under seismic action, to verify the rationality of the design of vibration isolation, and then by now a mature linear regression filter method to simulate the fluctuating wind, with the average wind speed into wind pressure time history input of high-level structure, to analyze the effect of structure under wind load, in the analysis of the structure of the base shear and top acceleration as investigation object, focus on the guarantee structure has a certain effect of shock absorption effect of wind vibration and its control.

1. Introduction
The traditional seismic method has been a historical progress, but its defect is also obvious: The greater the stiffness, the greater the seismic action, which in turn requires greater stiffness and strength, thus forming a vicious cycle. With the development of social economy, the equipment and decoration inside the building structure are becoming more and more delicate and expensive, and the requirements on the use function are also becoming higher and higher. The traditional seismic structure is adopted. Under the effect of strong earthquake, even if the structure itself does not collapse, its normal use function cannot be guaranteed, and even permanent damage will occur. Now, relying on the plastic deformation of structural components to consume seismic energy to ensure that "major earthquakes do not fail", has not been able to meet the actual needs, now more and more demand is "major earthquakes can repair", or even "major earthquakes do not break". Therefore, Chinese scholars have carried out extensive and in-depth research on the aspects of vibration isolation, shock absorption and vibration control of engineering structures. They have started from theoretical and experimental research, scheme design, to analysis and research in combination with practical projects, and gradually developed from pilot projects to popularization and application.
2. Discussion on damping mechanism of high-rise isolated structures

In order to explain the damping mechanism of high-rise isolated structures, this paper analyzes the damping mechanism of high-rise isolated structures from the perspectives of frequency domain and time domain. Taking two projects as examples, project A is a high-rise frame-shear structure, and project B is a multi-layer frame structure. Etabs finite element analysis software was used to establish the high-rise frame-shear structure model and multi-layer frame-shear structure model respectively. In the frequency domain, the horizontal unidirectional seismic wave is input, and the acceleration time history of the seismic wave and the isolation layer is converted into the acceleration response spectrum by Fourier transform, and the change of response spectrum of Project A and B is compared, so as to explain the damping mechanism of the high-rise isolated structure. Based on the above two analyses, the damping mechanism of two kinds of isolated structures is compared, and finally the dynamic mechanism of high-rise isolated structures is given.

2.1. Engineering model

A project for XXX center building, A total of 30, rc frame shear wall structure, the underlying the height 3.3 meters, the standard layer upon layer 3 meters high, the seismic fortification intensity is 8 degrees, as shown in the figure 1. Based on the preliminary isolation design, the isolation layer is set at the top of the foundation. The isolation layer is 1.5 meters high. A total of 30 GZY900 isolation supports and 6 GZP900 isolation supports are placed under the side columns and corner columns. A GZP500 isolation bearing is placed every 1.8 meters under the shear wall, a total of 36 bearings are placed. A total of 36 ISOLATION bearings (GZP500) were placed at a distance of 1.8m under the central column. A total of 39 were placed under the central column.

![Figure 1. A Engineering model](image-url)

B project for XXX factory dormitory building, a total of 7 layers, reinforced concrete frame structure, the underlying 3.6 meters, the rest of the each layer 3 meters, seismic fortification intensity of 8 degrees, II class field, characteristics of the cycle of 0.4 s. Etabs software was used to model it, as shown in the figure 2. According to the preliminary isolation design, the isolation layer is set between the top of the foundation and the bottom of the first column. The isolation layer is 1.5 meters. Four GZY600 isolation supports are placed under the corner column, and 40 GZP500 isolation supports are placed under the middle column and the side column.
2.2. Frequency domain analysis
For project A and Project B, El Centro wave, Tarzana wave and artificial wave were input along the X direction respectively, and the peak value was adjusted to 400 gal (8 degrees rare). In order to investigate the differences of base-isolated structure before and after vibration and shock absorption, the effect of the movement of the isolation layer can be regarded as a kind of vibration source, extracted by Etabs program software to calculate acceleration time history, isolation layer using discrete Fourier transform, El Centro wave acceleration response spectrum and the corresponding isolation layer of acceleration response spectrum (zeta damping ratio = 0.05).

2.3. The time domain analysis
In a word, the difference in shock absorption mechanism between high-rise isolated structures and multi-storey isolated structures is that the high-order vibration damping effect of multi-storey isolated structures is very small, and the first vibration damping is the main one, while the high-order vibration damping effect of high-rise isolated structures is relatively large, resulting in its multi-mode shock absorption effect.

3. Wind vibration analysis of high-rise isolated structures by linear regression filter method
As can be seen from the fluctuating wind power spectrum in Figure 5-1, the frequency of the building structure is on the right side of the extreme point of the curve, so the fluctuating wind load of the building structure increases with the increase of the period. Compared with high-rise aseismic structures, the period of high-rise isolated structures is larger, so the wind load effect is larger than that of high-rise aseismic structures.
Figure 4. The power spectrum of pulsating wind

The characteristics of fluctuating wind speed can be described by power spectrum and correlation function. The power spectrum of fluctuating wind speed mainly reflects the energy distribution law of various frequency components of fluctuating wind. The power spectrum and the correlation function can be transformed by Wiener-Khintchine formula, namely:

\[ R_y(\tau) = \int_0^\infty S_y(f) \cos(2\pi f \cdot \tau) df \]

The linear regression filter method (AR method) proposed by Iwatani can simulate multiple multi-dimensional random processes at one time. This method has the advantages of small calculation amount, simple calculation and good simulation effect. After solving the regression coefficient matrix S and N, we can solve M spatially dependent stochastic wind processes. Different matrix equation forms can be obtained by separating the formulas according to time. Among them, the matrix expression of ground derivation is:

\[
\begin{align*}
\begin{bmatrix}
u^1(j\Delta t) \\
u^2(j\Delta t) \\
\vdots \\
u^M(j\Delta t)
\end{bmatrix} &= \sum_{k=1}^{p} [\Psi_k] \begin{bmatrix}
u^1(j-k\Delta t) \\
u^2(j-k\Delta t) \\
\vdots \\
u^M(j-k\Delta t)
\end{bmatrix} + \begin{bmatrix}
N^1(j\Delta t) \\
N^2(j\Delta t) \\
\vdots \\
N^M(j\Delta t)
\end{bmatrix} (j\Delta t = 0, 1, \ldots, T; k \leq j)
\end{align*}
\]

4. Wind resistance analysis of high-rise isolated structures

Using the linear regression filter method above to simulate the time history of fluctuating wind speed on the windward side of this high-rise building structure, take Fuzhou region according to the load code for the 30 years, 50 years of basic wind pressure were 0.61 kN/m², 0.7 kN/m², converted to 10 m average wind speed 31.2 m/s, 33.5 m/s, the time step is 0.1 s, the surface roughness is 0.002152, the structure of wind pressure point 1 at the second floor of the pulsating wind speed time history is shown in figure 5 and 6, it can be seen that simulation of fluctuating wind tallies with the specification.
In this paper, the maximum isolation period and the ratio of height to width are 3.82s and 3.7 respectively. The basic period of the high-rise isolated structure in this paper is 3.55s, which is close to the maximum isolation period of the high-rise isolated structure. As mentioned above, the fluctuating wind load of the building structure increases with the increase of the period, so the fluctuating wind load has a greater effect on the structure. The ratio of height to width of this structure is 3.68, close to the limit value of the ratio of height to width of high-rise isolated structure, and up to 78.3m in total. Compared with similar isolated structure, its wind-exposed area is larger, so the average wind load has a larger effect on it. Therefore, the high-rise isolated structure in this paper is an isolated structure with a larger wind load. Therefore, the analysis in Table 5-3 and above indicates that while ensuring the shock absorption effect of high-rise isolated structures, the human comfort level of high-rise isolated structures under wind load can meet the requirements of acceleration indexes.

In summary, the stability of some high-rise isolated structures under wind load can be lost while ensuring certain shock absorption performance of high-rise isolated structures in earthquakes. In the design, it can be considered that the isolation layer does not yield when it encounters wind load that occurs once every 20 to 30 years. The top acceleration of the high-rise isolated structure can generally meet the comfort index of human body.

5. Conclusion

Through the research work of this paper, the main conclusions are as follows:

The difference in damping mechanism between high-rise isolated structure and multilayer isolated structure is: the higher order of multilayer isolated structure. The damping effect of vibration mode is very small, and the main vibration mode is the first vibration mode, while the high-rise isolation structure has a large height. As a result, the multi-mode damping effect is produced.

The wind load effect of layer isolated structure is slightly larger than that of high seismic structure. Under wind load, lead-core rubber, the performance of rubber isolation support is not similar.
to that of hysteretic energy dissipation under seismic action. Ensure high level isolation knot. In the design of seismic damping effect, some high-rise isolated structures can be lost under wind load.

It is suggested that the isolation layer should not yield when wind loads occur once every 30 to 50 years. The top acceleration of the high-rise isolated structure can generally meet the comfort index of human body.

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