The elasto-plastic analysis of the structure of a main factory building by setting up the isolation device

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Abstract. The lead damper is a kind of energy dissipating device with stable hysteretic performance, good shock absorption performance and simple structure. To study the lead damper damping effect in the main machine hall, the nonlinear finite element analysis software ABAQUS is adopted to analyze the seismic performance of a main machine hall with lead damper under the action of the rare earthquake and compare the elastic-plastic analysis results under the action of different seismic wave in this paper. The results show the structural seismic performance has been improved significantly, "no collapse under strong earthquake" can be achieved. A successful engineering case was provided for the application of lead damper in the damping design of main machine hall structures.

Keywords: large thermal power plant; Foundation isolation; Elastoplastic time-history analysis; Seismic performance evaluation.

1. Introduction
Compared with other structures, the seismic response of the main structure of a thermal power plant is very complex, and the rationality of the structure design depends on the accurate analysis of the seismic response of the structure to a large extent. Therefore, it is particularly important to improve its seismic safety and minimize the damage caused by the earthquake. Traditional anti-seismic design method by adjusting component is the basic train of thought of cross section, increasing the reinforcement measures, such as storage and consume the earthquake energy use structure itself, so as to ensure the safety of the structure of main body, but because of structures that may be encountered in the future of the ground motion intensity and features cannot be accurately estimated, so energy dissipation damping technology is gradually used to compensate for this problem, and successfully applied in many engineering practice [1].

The isolation layer is set between the superstructure of the building and the foundation to extend the natural vibration period of the structure, increase the damping and reduce the seismic energy input to the superstructure, so as to meet the expected fortification requirements. The setting of isolation layer changes the natural vibration period of superstructure and decreases Due to the low seismic response of the structure, a "weak layer" is artificially set, so that the deformation is mostly concentrated in the isolation layer, so as to ensure that the superstructure can still be in the elastic state or only slightly damaged during a large earthquake. Fixed the traditional anti-seismic structure foundation, upper
structure bending or shear deformation, displacement between layers is opposite bigger, and the isolation structure between the foundation and upper structure set the isolation bearings, isolation bearing of large displacement, but at the same time, the upper structure basic translation form, interlayer displacement is small, the acceleration response of superstructure can be reduced to 1/5 ~ 1/3 of traditional anti-seismic structure. Therefore, when the isolation structure is subjected to a rare earthquake, the horizontal force borne by the superstructure is much smaller than that of the general building, so it is easy to carry out elastic design on the superstructure. So by the isolated buildings are usually able to maintain their upper junction even during strong earthquakes Structure of the normal use function, to ensure the normal operation of large thermal power plants, to protect people's life safety.

In literature [2], Chen et al. analyzed and designed a complex frame structure located in the 9 degree high intensity area with isolation technology, and the results showed that the selected arrangement of isolation bearings was reasonable, and the use of isolation technology could significantly reduce the floor shear force and inter-floor displacement of the superstructure Angle and torsional deformation. In literature [3], Jiang Yujian takes a project as an example to discuss the basic principles and methods of seismic isolation design, and the analysis results show that the application of seismic isolation design has obvious economic and social benefits. Fan Shikai in ref. [4] in a nuclear power plant emergency command center for base isolation design, established the floor response spectrum of the floors, the analysis results show that the earthquake isolation structure obviously reduce the seismic response of the emergency command center, at the same time, the floor response spectrum is also greatly reduced, and ensure that nuclear power plant emergency command center in the emergency rescue and give full play to its functions. In the literature [5], Xie Lili et al. focused on how to apply this kind of quite mature isolation technology to the very special, very important, very sensitive and very complex projects such as nuclear power. In order to effectively improve the seismic capacity of large thermal power plant structure, this paper uses the large general finite element software ABAQUS to compare the seismic performance of the main building structure of thermal power plant before and after seismic isolation under the action of large earthquakes.

2. Project summary

Due to the special requirements of the building function, the structure layout of the main building of large thermal power plant is irregular, with many staggered floors, many kinds of loads and complex loads, and uneven mass distribution. The main structure adopts cast-in-place reinforced concrete frame structure longitudinally, cast-in-place reinforced concrete frame framing structure laterally, and steel truss structure for roof truss structure. Typical flat elevation of the structure is shown in Fig. 1–2. The site characteristic period $T_g=0.25s$, the maximum horizontal seismic influence coefficient is 0.12, the fortification intensity is 7 degrees 0.15g, and the site type of the project is class I. According to the relevant provisions of "Seismic Fortification Classification Standard for Building Engineering", the fortification category of thermal power plants should be divided into key fortification category, that is, they belong to Class B buildings.

![Fig. 1 The structural plan](image)
3. Selection of ground motion

The Code for Seismic Design of Buildings provides that, when using time-history analysis method, the time-history curve of actual strong earthquakes and artificial simulated acceleration should be selected according to the type of building site and the design earthquake grouping, and the number of actual strong earthquakes should not be less than 2/3 of the total. The project selected the 2 set of natural ground motion records and 1 set of artificial wave are analyzed in the schedule, working condition of each analysis adopts two-way input, the main direction of seismic wave intensity and time than press 1:0.85 to determine, severe earthquake peak acceleration take 310 gal, figure 3 to figure 5 shows the three groups respectively acceleration spectrum of seismic wave corresponding damping ratio (5%), frequency spectrum analysis showed that the selected seismic wave spectrum characteristics meet the requirements, it can be seen that the three groups of wave response spectrum in accordance with the standard response spectrum in the key period of good ("00", and "90" to the east, and west respectively from the ground motion).

4. Layout of isolation support and damper

According to the function of the structure and the requirements of the building, the foundation isolation scheme is determined. The scheme places the isolation support on the top of the foundation, so as to separate the building from the foundation.

The design principles of foundation isolation are as follows:

In this calculation model, if only the isolation bearing is set, the displacement of the isolation layer under the action of a major earthquake is calculated to exceed the limit specified in the code. Therefore, viscous dampers are considered to increase energy dissipation, so as to reduce the energy input of the superstructure.
Again, it is assumed that the damping index $=0.30$. Through trial calculation of different damping coefficients, the interlayer shear force is taken as the control target to determine the relevant parameters of the additional damper.

Finally, after repeated trial calculation, the final arrangement scheme is shown in Figure 6 (GPZ800, GPZ600 and GPY100 are the selected isolation bearing models).

![Fig. 6 The plan of isolation bearing and damper](image)

5. **Elastoplastic time-history analysis of structures under rare earthquakes**

Taking the main building of a thermal power plant with isolation device as an example, this paper analyzes its response under rare earthquake, and investigates the seismic performance of the structure before and after isolation from the aspects of interstorey displacement, floor acceleration and energy consumption.

5.1. **Comparison of interlayer displacement and displacement Angle**

Seismic code [6] stipulates that for the concrete frame isolation structure, the limit of elastoplastic displacement Angle between the lower layer under rare earthquake action is $1/100$. The inter-layer displacement comparison before and after isolation is shown in Fig. 8. As can be seen from the figure:

1) Under the action of seismic wave, the maximum inter-storey displacement angles of the structure before isolation are respectively $1/124, 1/136$ and $1/80$, which meet the requirements of the code $1/50$.

2) Under the action of seismic waves, the maximum inter-storey displacement angles of the superstructure after seismic isolation are respectively $1/215, 1/256$ and $1/232$, which all meet the requirements of the specification $1/100$.

3) Compared with the traditional seismic structure system, under the rare earthquake action, the isolation layer has obvious damping effect on the superstructure, and can effectively reduce the inter-layer displacement of the small building, and the horizontal displacement of the floor is mainly concentrated at the isolation bearing.
6. Conclusion

In this paper, the main building of a thermal power plant with isolation device is taken as an example to analyze its response under rare earthquake, and the seismic performance of the structure before and after isolation is investigated from the aspects of interstorey displacement, floor acceleration and energy consumption, etc. The conclusions are as follows:

(1) According to the above calculation results, the peak acceleration of the top floor of the main powerhouse structure with isolation device is only 40%~60% of the peak acceleration of the traditional structure, which greatly reduces the building’s violent shaking under the action of strong earthquake. When the strong earthquake, the layer deformation is small, far less than the standard limit, the upper part of the main plant structure is generally in a normal elastic working state or into a slight plastic state, for the power supply project as a lifeline project, can ensure that it can be used normally in the strong earthquake.

(2) Under rare earthquakes, the deformation of the upper part of the structure is small, and most of them are concentrated in the isolation layer. Damage is only the isolation bearing, the upper structure of the components of the damage is very small or no damage, after the earthquake only to replace the damaged rubber bearing, can be restored to normal use, greatly reducing the cost of repair after the earthquake. The addition of viscous damper in the isolation layer has a good effect on controlling the maximum horizontal displacement of the structure, which improves the safety reserve of the structure to a certain extent.
(3) the application of seismic isolation technique in power plant is still in the phase of theoretical research, the late can through to the isolation device performance and optimization design and test of exploration to enhance the energy shock absorption effect of vibration isolation structure, more effectively improve the seismic performance of large-scale coal-fired power plant main building structure, the popularization and application for isolation technology in power plant in this paper provides the beneficial reference.

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