Control and research of lead shear damper in a typical energy dissipation high-rise structures

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Abstract: To study the lead dampers damping effect in the High-Rise frame-shear wall structures, a High-Rise structure is adopted as engineering background. Firstly, the dynamic performance of the structure is analyzed by SAP2000. Secondly, the energy dissipation suspension design is done in this paper. Finally, the nonlinear finite element analysis software ABAQUS is used to analyze the seismic performance of a High-Rise frame-shear wall structure with lead shear dampers under the action of the rare earthquake and compare the elastic-plastic analysis results under the action of different seismic wave. Analysis results show that the structural seismic performance has been improved significantly, A successful engineering case was provided for the application of lead shear dampers in the damping design of high-rise frame-shear wall structures.

Keywords: Lead damper; High-Rise frame-shear wall structures; Seismic control; Elastic-plastic time history analysis.

1. Preface
Earthquake is a kind of sudden natural disaster. With the development of social economy, people have higher and higher requirements for the seismic performance of high-rise building structures with large chassis. The high-rise building structure is designed as a large chassis multi-tower structure, which can not only meet the requirements of building energy saving and livability, but also take into account the comprehensive supporting functions of residential areas and the requirements of landscaping and beautification of surrounding environment, so it has a large development space and application prospect. However, compared with other structures, the seismic response of this kind of structure is very complex, and the rationality of structure design depends on the accurate analysis of the seismic response of the structure to a large extent. Therefore, it is very important to improve its seismic safety and minimize the damage caused by 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, and the structure of the damage in the earthquake after the earthquake the cost of maintenance and recovery is huge, So energy dissipation shock absorption technology.

It has been gradually used to remedy this problem and successfully applied in engineering [1].
Energy dissipation and shock absorption technology [2] uses additional substructures or energy dissipation devices to consume the energy transmitted to the structure by earthquake. Shear lead damper [3] is a kind of metal shock absorber that dissipates vibration energy by plastic deformation of lead. It has excellent hysteretic performance, simple structure and convenient manufacture, and has been attached great importance to by researchers and engineers all over the world. Robinson et al. [4-5] from New Zealand were the first to study lead dampers that dissipated energy by shear deformation of lead. Pay back strong [6], respectively, the pure frame structure, frame - support structure, the lead shear damper - frame structure three different schemes, simulation in more severe earthquake and under the action of the rarely met earthquake seismic behavior and comparison, analyzes the layout mode of lead shear damper and the matters needing attention, verify the good performance of lead shear damper; Peng Lingyun et al. [7-8] proposed a plate-type lead shear damper, in which the lead block was directly embedded between the grooves of sliding steel plate and fixed steel plate, greatly simplifying the processing technology on the premise of ensuring the energy consumption effect, and successfully applying it to practical engineering. In order to effectively improve the seismic capacity of the complex high-rise structure with large chassis, the analysis and design of energy dissipation and shock absorption of a large chassis structure with lead damper are carried out by using the large universal finite element software ABAQUS, which provides a strong basis for the design and engineering application of the shock absorption of this type of structure.

2. Project Overview
This project is located in the 8 degree seismic fortification area, with 13 floors on the ground, 3 floors in the podium and 1 floor underground. The building height is 58.80 meters, and the main structure is reinforced concrete frame-shear wall structure, as shown in Figure 1. The design service life of this project is 50 years, the site soil is classified as II, the seismic group is the first group, the characteristic period is 0.35s, and the seismic action is selected according to the Code for Seismic Design of Buildings (GB50011-2010) [8].

3. Selection of ground motion
The Code for Seismic Design of Buildings [9] stipulates that no less than two groups of actual strong earthquake records and one group of artificial simulated acceleration time-history curves shall be used in time-history analysis, and the average seismic impact coefficient of the multi-group time-history curves is statistically consistent with the seismic impact coefficient curves used in response spectrum method of mode decomposition. In this paper, the following methods are adopted to select seismic waves that meet the requirements of the code:

1) According to the maximum value $\alpha_{\text{Max}}$ (15) and characteristic period $T_g$ (8) given in the code, the damping ratio $\zeta = 0.05$ was assumed to calculate each seismic impact coefficient curve.

2) The relative error method was used to compare and analyze the actual spectrum and the standard spectrum, and the formula was as follows (in the selection process, the degree of conformity between the reaction spectrum and the standard spectrum within the period of 1s~4s was emphasized).

$$\Delta = \left| \frac{x_1 - x_0}{x_0} \right|$$

Where, $x_1$ -- the actual reaction spectrum value;
$x_0$ -- standard reaction spectrum value;
$\Delta$ -- Relative absolute error

3) Make a program to calculate the actual seismic response spectrum curve, and use the above indexes to measure the difference between the actual seismic response spectrum and the standard spectrum one by one. In the actual calculation, the period interval is set as $\Delta T=0.05s$, and the difference between the platform segment and the structure period range of concern is mainly compared. If the
relative error between the target point and the standard spectrum is no more than 20%, it is considered as an alternative record for engineering application.

Based on the above theory, this project selects two groups of natural ground motion records and one group of artificial waves for time-history analysis. Bidirectional input is adopted for each analysis condition. The intensity ratio of seismic waves in the main and secondary directions is determined at 1∶0.85, and the peak acceleration of rare earthquakes is set at 310 Gal. Fig. 1~3 respectively show the acceleration time history corresponding to the three groups of seismic waves ("00" and "90" represent the eastward and westward ground motions).

![Fig. 1 The spectral characteristics of artificial wave](image1)
![Fig. 2 The spectral characteristics of natural wave No 1](image2)
![Fig. 3 The spectral characteristics of natural wave No 2](image3)

4. Elastoplastic time-history analysis of structures under rare earthquakes

The damping structure with shear lead damper is usually designed to be unyielding under frequent earthquakes or wind loads, and the damping support only provides the effect of elastic stiffness. Under rare earthquakes, the damper plays the function of capacity dissipation and provides additional damping and a certain equivalent lateral stiffness for the structure. Therefore, in the first stage of design, the elastic analysis is sufficient, while in the second stage of design, the elastoplastic behavior of structural members and dampers should be considered, so the analysis model should consider the material nonlinearity of structural members and the hysteretic performance of dampers. The results of time history analysis of structural elastoplastic seismic response under rare earthquakes are described in the following section. (It should be noted that the Rayleigh damping ratio of the structure is set at 5%. In the calculation and analysis in this section, the second-order effect of gravity is considered, but the vertical seismic effect is not considered, and only the input of horizontal bidirectional seismic action is considered.)

4.1. The shear wall pressure loss chart

Fig. 4 shows the cloud map of concrete compression loss of shear wall at typical locations under the action of natural wave 2. The red part represents the place where the damage is more serious. As can be seen from the figure:

1) Under the action of natural wave 2, the damage of shear wall is mainly concentrated at the joint beam, and the main wall limbs outside the shear wall are basically intact, and the shear wall can still play a good role in resisting lateral force.

2) Most of the wall limbs occur bending failure, that is, the concrete at the edge of the wall limbs yield under compression, and a few of the wall limbs with relatively large height and width occur shear failure, that is, oblique failure occurs in the middle of the wall.

3) The partial pressure loss of the wall limbs occurred to varying degrees, but no penetrating injury was formed. The pressure loss coefficient of part of the bottom wall pieces is close to 1, which is in the stage of serious damage. This may be caused by the large out-of-plane bending of the bottom wall pieces when they are vertically connected to the bottom wall pieces.
5. Conclusion
In this paper, a high-rise frame-shear wall structure is taken as the research object. Based on SAP2000 and ABAQUS, the dynamic characteristics of the structure and the elastoplastic seismic response of the structure under rare earthquakes are studied. Through the systematic design and analysis of the structure's shock absorption, the following conclusions can be drawn:

(1) The shear lead damper has a good shock absorbing effect on the structure. Under the action of rare earthquake, the connecting beams first yield. At the end of the earthquake, most of the connecting beams have been destroyed, and the wall limbs and frame members are slightly damaged, but the structure still has a strong lateral force resistance.

(2) Under rare earthquake action, the inter-storey displacement Angle of the structure is less than 1/100, which meets the standard limit requirements. The results show that the structure design is reasonable, and the structure can meet the requirement of "not falling down under 8 degree earthquake".

(3) The design method of frame-shear wall damping structure with shear lead damper needs to be further studied. The energy dissipation and damping effect of shear lead damper can be enhanced by optimizing the number and layout of dampers, and the seismic performance of high-rise frame-shear wall structure can be improved more effectively.

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