Analysis on the Mechanical Properties of Viscoelastic Damper and Its Application in Construction Engineering

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Abstract. With the deepening of the structural vibration control technology and theory, all kinds of energy dissipation and vibration reduction equipment have been more and more used in engineering. Using SAP2000 software, the elastic-plastic time period before and after the installation of viscoelastic damper is calculated, and it is compared, which provides a useful example for the future application in high-rise buildings.

Key words: high-rise building; viscoelastic damper; energy consumption and shock absorption.

1. Introduction

The research and application of structural vibration control theory has been more than 30 years to resist the impact of the earthquake, and earthquake control is properly applied on the building the damping mechanism (system), make it share the impact of the earthquake, that is to say, they store and dissipate earthquake together, so that the building itself earthquake response is coordinate and alleviate. Based on the need for external energy input, the structural damping control is divided into passive control, active control, semi-active control, intelligent control, and hybrid control. It is a kind of structural passive shock control, it is generally a non-structural parts, or an energy-consuming component, it will not be the main force structure, it will not make any change to the original structure form, also do not need external energy, can reduce the structure of the earthquake response, and can reduce the structure of wind vibration reaction. The seismic fortification intensity of the building structure is grade 7 levels, and the whole project (building, structure, water, heating, electricity) are designed according to the provisions, and then the earthquake fortification standard of 8 degrees is put forward. In order to reduce the project cost and adopt a new energy consumption vibration reduction technology, this paper proposes a viscoelastic damping energy dissipation vibration reduction control scheme to achieve the purpose of structural seismic design. Eastoplastic time course was analyzed by SAP2000 software, and the change of displacement angle and carrying capacity were analyzed.

2. The SAP2000 analysis model

SAP2000 provides a large library of units for building finite element models, including beam, shear, plate and shock absorption.(1) Frame unit: the general three-dimensional beam and column calculation formula is adopted, including the influence of biaxial bending, torsion, axial deformation, biaxial shear deformation and so on, and the beam, column, inclined support and truss are simulated in the plane and 3 D structure, and the nonlinear characteristics are added.(2) Layer shell: the shear wall or steel mesh in the floor is equivalent to a layer of steel bar embedded in the concrete shell.(3) Vibration damping device: the Kelvin model of elastic element and viscous damping element is used in parallel and analyzed by nonlinear analysis.SAP2000 dynamic time range analysis is a calculation method that can conduct dynamic reaction at any time. Its basic equation of motion is as follows:

$$MU_a(t)+Cu_a(t)+KU_a(t)=F(t)$$

Time range analysis can use modal integral and direct integral, direct integral is step by step, SAP2000 uses Newmark method, Wilson method; arrangement method, Humbert method, Heber Hug-Tower method [1-2].

3. Example calculation and analysis

The total building height is 78.5 meters and has 26 floors. Using reinforced concrete shear wall structure, seismic fortification intensity is 7 degrees, after adding the seismic absorption device, seismic fortification intensity is 8 degrees, according to the overall grade 3 foundation soil damping ratio is 005. In this project, viscoelastic shock absorber is installed between the shear wall of l~28 of layer 6~25. Its layout is shown in Figure 1. The relationship between the force and the deformation of the viscoelastic shock absorber is: $F = CK + KX$

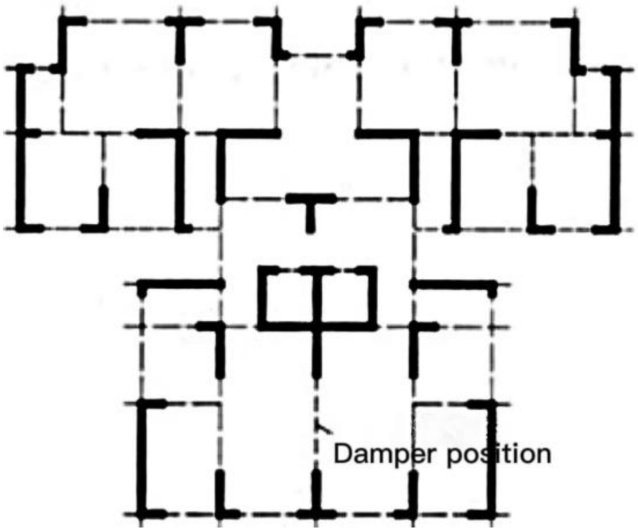

Figure 1. Building standard floor plan

The PVEDxzD0-type viscoelastic shock absorber is selected in this project, and its equivalent vibration damping coefficient is $c = 1.68 \times 10^3 kN \cdot s / m$. The k N·s/m, an equivalent rigidity of $6.75*10^3$kN/m. The working stroke of the viscoelastic shock absorber is ± 50 mm and the output power of 30 kN is shown in Figure 3. Figure 4 shows the calculation pattern for this structure.In view that the site is a level 3 site soil, Lanzhou wave, Taftebo and Elsentembo were selected as the seismic waves of this analysis, and divided into 8-degree earthquakes and rare earthquakes, calculated at 70 gal and 400 gal respectively. The modal changes of controlled and uncontrolled structures and the shear bearing capacity of the structures in multiple and rare earthquakes [3].

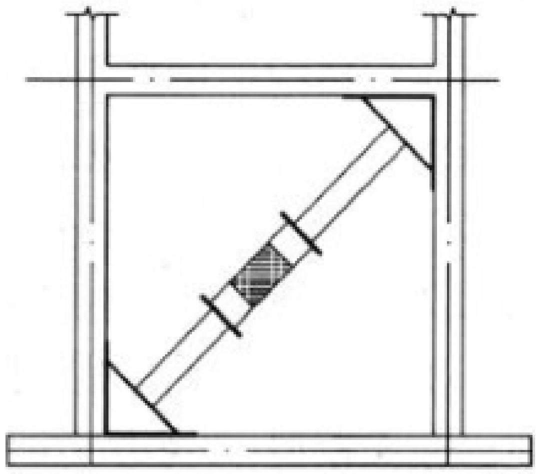

Figure 3. Damper arrangement mode

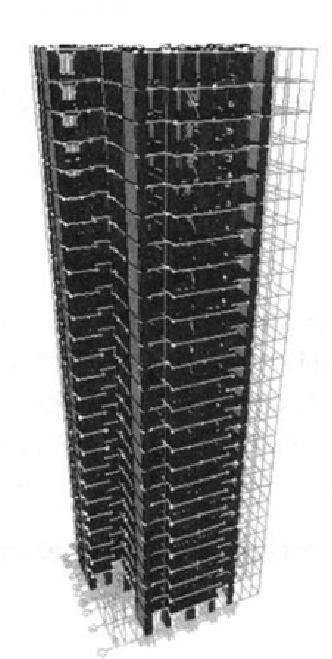

Figure 4. structure calculation model

The period of the first vibration type of the structure is shortened from 2.2217s to 2.0415s, indicating that the stiffness of the structure increased significantly due to the addition of the damper. The calculation results are shown in Table 1.

Table 1. Comparison and analysis of the periods of uncontrolled and controlled structures

Vibration model	Uncontrolled structure period / S		Controlled structure period / s
	SATWE	SAP2000	SAP200
1	2.352	2.2217	2.0415
2	2.2763	2.0787	2.078
3	1.4497	1.6479	1.6475
4	0.6708	0.4662	0.4652
5	0.5799	0.417	0.416
6	0.4464	0.2526	0.2516
7	0.3402	0.2277	0.2267
8	0.2575	0.2158	0.2148
9	0.2156	0.1865	0.1855

Due to its soft rigidity, the Y-direction interlayer displacement angle exceeds the specification requirements under the action of multiple earthquakes. The analysis shows that the displacement angle of the layers can be well controlled. The interlayer displacement angles of the shear wall structure are 1/1000 and 1/120, respectively. Under the action of x-direction seismic waves, the interlayer displacement Angle of the uncontrollable structure meets the design requirements. Under the action of Y-direction earthquake, the horizontal displacement angle of the uncontrollable structure cannot meet the specification, and the interlayer displacement angle can be well controlled after increasing the viscoelastic damper in y-direction.

In the engineering, layered shear test of structure using SAP2000v141 and interlayer shear test using sATIV E data. Through the analysis of the structure, it is concluded that when the shear ratio of x and y to the shear bearing capacity is more than 1.0, they all meet the design specification.

In this paper, through the study of energy consumption and vibration reduction characteristics of high-rise shear wall structure, the following results are obtained: (1) the time course analysis of Lanzhou wave, the selection of taft wave and the classical Elsom wave. Through its analysis, it is found that the viscoelastic shock absorber can both reduce the vibration and adjust the scraping degree, which can significantly change the dynamic performance of the structure, and thus adjust the overall stiffness of the structure.(2) The results show that in the 8 degrees of multiple earthquake, the maximum interlayer displacement angle of the energy dissipation shock absorption structure is less than 1 / 1000. In the rare 8-degree earthquake, the maximum interlayer displacement Angle of each layer is below 1 / 120, and the energy attenuation can be used with a viscoelastic damper.

4. The status quo of our country

Because China is a large earthquake country, many houses have not been seismic design, due to the increase of seismic grade, so that the original low-intensity houses have been unable to meet the corresponding seismic standards. At the same time, due to the negligence of design and construction, the use of some buildings changes; due to the existence of building adding and auxiliary equipment, the lateral force under the earthquake is not enough to achieve the purpose of seismic. In order to ensure their safe operation, they must be identified and strengthened by the earthquake. In addition, from the static theory to the reaction spectrum theory, and then to the current dynamic analysis, are according to the earthquake reserve and energy consumption of the building itself, to meet the requirements of seismic fortification, namely: small earthquake is not bad, the earthquake can be repaired, big earthquake does not fall. Due to the lack of self-control power, it will inevitably cause certain damage to the building, and even lead to the house collapse, belongs to the passive, passive seismic measures. According to the seismic performance requirements, the traditional reinforcement method can be divided into "strength reinforcement" and "ductility reinforcement". For reinforced concrete structure, the existing seismic reinforcement measures are: (1) the use of steel support reinforcement method, that is, in the frame or outside the installation of several steel brackets, improve the strength and deformation of beams and columns.(2) Add reinforced concrete or wing-shaped wall to the frame to enhance its seismic performance.(3) Use external Angle steel frame to reinforce the beam and column, and add reinforced concrete on the beam and column.(4) Reinforcement the bent and tensile components with external adhesive steel. However, due to the uncertainty of seismic action, the actual seismic load exceeds the design value, so that the reinforcement can not guarantee the safety of the structure: (2) with the increase of the structure deflection, seismic performance improvement, only rely on the bearing capacity, rigidity and other factors on the seismic performance is not economic.(3) Conventional reinforcement method construction is complicated, sometimes need foundation reinforcement, new foundation, and the construction period is long, which affects the user.(4) Strengthen the high project cost. Reasonable and effective earthquake prevention measures are: the building needs to be strengthened to install energy dissipation and shock absorption equipment, under the action of wind load and small earthquake, energy consumption equipment to maintain elasticity, the lateral rigidity of the system is enough to meet the normal work requirements. Under the strong earthquake, when the structure of force and deformation increase, energy dissipation mechanism first in the inelastic deformation stage, it can effectively dissipate the seismic energy of the input structure, avoid the structure into obvious inelastic state, and can quickly reduce the seismic response of the structure, so as to prevent the structure by strong earthquake damage. Compared with the conventional seismic reinforcement method, energy consumption shock absorption technology has the following advantages: (1) use energy consumption shock absorption equipment for seismic reinforcement, use non-bearing components as energy dissipation rod, the damage process is to protect the main structure, so safe and reliable.(2) Energy dissipation shock absorption equipment easy materials, simple structure, using energy dissipation shock absorption equipment, save materials, has a good economic effect: (3) the construction technology is simple and easy to operate, the construction cycle is short, can be quickly restored to use.(4) The energy dissipation shock absorber plays a good buffer role on the seismic performance of the building. Due to its advantages, all kinds of energy-consuming equipment has been widely used in new construction projects, building earthquake reinforcement and post-earthquake recovery projects, and has produced good economic and social benefits, and has become a new seismic reinforcement technology.It can be predicted that energy dissipation and shock absorption technology will be a major way of earthquake mitigation in the 21st century, it will make outstanding contribution to the mitigation of human disasters [4].

5. Conclusion

When a strong earthquake occurs, due to the increased force and deformation of the structure, the viscoelastic damper will consume a lot of energy, so that it will not appear obvious inelasticity, but also will quickly attenuate the seismic response of the structure, to ensure that the structure will not be damaged in the strong earthquake. The research results show that: (1) the use of conventional reinforcement method can improve the seismic performance of the building in many earthquakes, but in rare earthquakes, its shock absorption effect is not ideal. In multiple earthquakes, the maximum interlayer displacement decreased 25%, lowest 5%, maximum 38% and lowest 17%.However, under strong earthquakes, the maximum displacement is decreased by 23%, the minimum is 6.2%, the maximum interlayer displacement is 24%, the minimum value is 12%, and the conventional reinforcement method can only ensure its safety.(2) After setting energy consumption support, no matter in multiple or rare earthquakes, its seismic performance is better than the conventional reinforcement structure, and compared with the original structure, it has a greater shock absorption effect, especially in large earthquakes, the shock absorption effect is more obvious. In multiple earthquakes, the maximum drop in maximum interlayer displacement is 46%, lowest 30%, maximum 46% and lowest 30%.In strong earthquakes, the maximum interlayer displacement decrease is 47%, minimum 31%, maximum 47%, minimum 31%, maximum 47% and minimum 29%.Through the elastic-plastic finite element calculation of the hollow steel plate structure, the hollow steel plate shock absorber has simple structure, convenient material production, high initial stiffness, high bearing capacity, sufficient hysteresis line and the largest surrounding area, so its ductility and energy consumption performance are good.

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