Research of Damper Parameters of Large span Suspension Bridge

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Abstract: This paper research the parameter selection range of large span suspension bridge dampers. The finite element model of the Puli Bridge was established by using ANSYS software. Under consideration of the pile-soil interaction, the cross analysis of 16 dampers with different parameters under the action of longitudinal + vertical earthquake was carried out. The bending moment and shear force at the bottom of the tower, the relative displacement of the tower and the girder, the maximum speed and the maximum damping force of the dampers under different working conditions are analyzed. Therefore, the suggested range of each parameter of a single damper is proposed.

1. Introduction
Most mass of the suspension bridge is concentrated in the deck system, so the seismic inertial force is also mainly concentrated in the deck system. The seismic inertial force of the bridge deck system is transmitted to the main tower through stay cables and supports, and then transmitted from the main tower to the foundation, and then to the ground. Therefore, the weak parts of the suspension bridge are located in the supporting connecting device, the main tower and the foundation. Therefore, it is necessary to analyze the parameters of the dampers of the suspension bridge\cite{1-3}, and the prototype test analysis of the damper \cite{4}, Tang Guangwu et al. conducted experimental research on seismic stations\cite{5}.

The Puli Bridge’s longitudinal displacement of the girder is large, due to the floating system in the longitudinal direction of the main tower. Longitudinal dampers are installed at the connection position of the tower and the girder to reduce the longitudinal displacement of the girder, it also has an impact on the internal force of the main tower. In the selection of parameters and models of the damper, it is necessary to set a series of calculation conditions and comprehensively study its influence on the internal force of the main tower and the displacement of the girder before giving recommendations for selection.

2. Project Overview
Puli Bridge is a steel box girder suspension bridge with a main span of 628m. The main girder is
28.5m wide and the main tower heights are 153.5m and 138.5m respectively. The size of the bottom of the high tower is a section with an outer diameter of 8.25×5m, and the top of the tower is a section with a section of 6.2×5m. The wall thickness is generally 0.9, 0.8 and 0.7m, with local thickening to 1.5–2m.

The viscous dampers are installed longitudinally on the bridge, the vertical supports are bidirectional movable supports, and the wind-resistant supports are arranged horizontally, which are arranged at the centerline of the stiffening girder.

3. Calculation model and Working conditions

3.1 Calculation model

In the finite element model of the bridge, the main cables and booms are simulated by cable elements, and the towers, girders, and piers are simulated by spatial girder elements, and the main girder is simulated by the ridge girder model. The connection between the main girder and the cable is realized by extending a rigid arm. The influence of the approach bridge on the dynamic characteristics and seismic response of the main bridge is considered in the model. The structural finite element model is shown in Figure 1.

The pile foundation of the main bridge and the approach bridge takes into account the influence of the pile-soil interaction by setting the vertical and horizontal soil springs at the corresponding positions of the pile foundation. Only the stiffness of the soil spring is considered in the model, and the influence of damping and mass characteristics is ignored. The spring is simulated by Combin14 unit, the spring stiffness is calculated according to the m value of the soil layer, the overall 6-degree-of-freedom stiffness of each pile foundation is calculated, and the coupling between horizontal rotation and horizontal force is considered, which is equivalent to 6 springs. It acts on the bottom of the cap and serves as a model for nonlinear time history analysis of the bridge.

3.2 Calculation conditions

In the selection and analysis of the dampers between the tower and girder of Puli Bridge, the damping coefficient and velocity index are shown in Table.1. Considering the pile-soil interaction, the cross analysis of different dampers parameters is carried out under the action of longitudinal + vertical earthquakes. The result is the average of the 7 sets of seismic wave results from the E2 earthquake. A total of 16 different parameter dampers are calculated and analyzed. The results are shown in Figures 2 to 7.

| Table 1. Damper parameter analysis condition table |
|------------------|----------|----------|----------|----------|
| Damping coefficient (C) | 1000 | 2000 | 3000 | 4000 |
| (kN/(m/s)^n) | Speed index (n) | 0.1 | 0.1 | 0.1 | 0.1 |

![Figure 1. Finite element model](image-url)
4. Result Analysis

Figure 2～3 lists the relative displacement of the tower and the girder, that is, the maximum stroke of damper. Figure 4～7 lists the maximum velocity and maximum damping force of the damper.

In this chapter, the selection and parameter research of longitudinal dampers are carried out by setting 16 working conditions for the main bridge dampers of Puli Bridge, and the conclusions are as follows:

It can be seen from Figures 2 to 3 that a larger speed index is beneficial to reduce internal force, however, if the speed index is too large, the relative displacement of the tower and the girder will increase. For the damping coefficient, the structural displacement will decrease with the increase of the damping coefficient, but the effect is not significant. The internal force of the main tower increases with the increase of the damping coefficient, and gradually approaches the internal force without dampers.

Figures 2～7 list the maximum damping force and maximum displacement of the position dampers of Puli and Xuanwei Tower under the action of earthquake in various working conditions, which can be seen from the figure: (1) The maximum damping force of the damper increases with the increase of the damping coefficient C, and the smaller the speed index, the greater the damping force; (2) The maximum displacement of the damper decreases with the increase of the damping coefficient. When the damping coefficient is constant, it decreases with the increase of the speed index; (3) The maximum speed of the damper decreases with the increase of the damping coefficient, and when the damping coefficient is constant, it increases with the increase of the speed index.

Comprehensive comparison of internal force and displacement changes, it is recommended that the damping coefficient C of a single longitudinal damper is 2000～3000kN/(m/s)n, and the speed index n is 0.2～0.3. At this time, the shear force and bending moment of the tower bottom are relatively smaller, the reduction in shear is about 13.8%～26.4%, the reduction in bending moment is about 7.5%～29.7%, and the reduction in relative displacement of the tower and the girder is about 84.8%～93.1%. The damping force of the Prita damper is 902～1478kN, and the damper stroke is 0.010～0.022m; the damping force of the Xuanwei tower damper is 855～1441kN, and the damper stroke is 0.008～0.018 m. At the same time, the damping coefficient of a single damper is finally determined according to factors such as cost and other load requirements.
Figure 4. Maximum damping force of the Pu Li tower damper

Figure 5. Maximum damping force of the damper in Xuan Wei tower

Figure 6. Maximum velocity of the Pu Li tower damper

Figure 7. Maximum velocity of damper for Xuan Wei tower

5. Conclusion
Comprehensive comparison of internal force and displacement changes, it is recommended that the damping coefficient of a single longitudinal damper is $2000 \sim 3000 \text{kN/(m/s)}$, and the speed index is $0.2 \sim 0.3$. At this time, the damping force of the Puli Tower damper is $902 \sim 1478 \text{kN}$, the damper stroke is $0.010 \sim 0.022 \text{m}$; the damping force of the Xuanwei Tower damper is $855 \sim 1441 \text{kN}$, and the damper stroke is $0.008 \sim 0.018 \text{m}$. At the same time, the damping coefficient of a single damper is finally determined according to factors such as cost and other load requirements.

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