Summary of Research on Shock Absorption Design of Long-Span Cable-Stayed Bridges

Tieyi Zhong¹*, Fan Zhu¹, Fang Chen¹ and Haiyang Yang²

¹ School of Civil Engineering, Beijing Jiaotong University, Beijing, 100044, China
² Railway Engineering Consulting Group Co., Ltd., Beijing, 100000, China

*Corresponding author’s e-mail: tzyzhong@bjtu.edu.cn

Abstract. Long-span cable-stayed bridges are a kind of bridge type that has developed rapidly in recent years. It is always the focus of research to take reasonable measures and take effective measures to ensure the safety of bridges in earthquakes. In order to improve the shock absorption performance of long-span cable-stayed bridges, scholars from various countries have carried out a series of experimental exploration and theoretical analysis. According to the number of cable-stayed bridge towers, this paper systematically combs and summarizes the shock absorption design of the three types of cable-stayed bridges of single tower cable-stayed bridge, double-tower cable-stayed bridge and multi-tower cable-stayed bridge. On the one hand, it is the design and theoretical study of shock absorption, on the other hand, it is the design and effect study of shock absorption measures. It summarizes some conclusions of the shock absorption design of various types of long-span cable-stayed bridges, and puts forward suggestions for the future shock absorption design.

1. Introduction
China is a country with many earthquakes. With the continuous development of the economy, people's requirements for transportation are also increasing, and the long-span cable-stayed bridge is an important part of the transportation hub project. Therefore, it is particularly important to study the seismic performance of long-span cable-stayed bridges. This paper will systematically comb and summarize the existing researches on the shock absorption design of various types of long-span cable-stayed bridges from two aspects. On the one hand, it is the design and theoretical study of shock absorption, and on the other hand, the design and effect study of shock absorption measures. Some conclusions on the shock absorption design of various long-span cable-stayed bridges are summarized, and suggestions for future shock absorption design are put forward.

2. Unique tower cable-stayed bridge shock absorption design

2.1 Conceptual design and theoretical study of damping for single tower cable-stayed bridge
Chen Dewei [1] analyzed the performance of the three structures by comparing the forces between the cantilever T-structure, the symmetrical single tower and the asymmetric single-tower cable-stayed bridge, and the relative length of the cable-stayed cable-stayed bridge Parameters such as length are analyzed to show the influence on the deflection and internal force of the main beam and the tower, so as to obtain reasonable structural arrangement proposals and economic structural forms.

Jiang Chonghu [2] et al. studied the influence of the longitudinal restraint system on the seismic behavior of the single tower cable-stayed bridge, and added viscous damping to the rigid frame system,
the floating system, the vertical support system, the vertical support plus elastic cable system and the vertical support. Huang Xiaoguo and Li Jianzhong [3] studied the force transfer mechanism of the single tower cable-stayed bridge in the longitudinal bridge and the transverse bridge to the restraint system. The analysis shows that considering the sliding friction of the bearing can significantly reduce the longitudinal displacement of the main beam and the main tower of the single tower cable-stayed bridge. Camara A [4] conducted a static elastoplastic analysis of the seismic response of a single tower cable-stayed bridge under multi-directional excitation. The applicability of nonlinear time history analysis and static elastoplastic analysis in seismic response of cable-stayed bridges is discussed and compared.

2.2 Design and effect study of damping measures for single tower cable-stayed bridge
Quan Wei [5] carried out the optimization design of the longitudinal and lateral damping of the viscous damper, and obtained the following conclusions: Under normal circumstances, the larger the damping coefficient is, the better the damping effect is, but after the damping coefficient increases to a certain extent, if the reduction is small, and the damping coefficient is too large, the damping force is too large, which will be difficult for the damper arrangement and the local connection design. For the lateral seismic system, the damper system with the damper laterally can minimize the internal force response of the bridge. And the lateral displacement control is within a reasonable range, and its seismic performance is the most reasonable. Huang Minshui [6] studied the influence of damper parameters on the displacement of key nodes and the internal forces of key sections of a single tower cable-stayed bridge. The results show that the damping index \( \alpha \) and the damping coefficient \( C \) have opposite trends on the displacement of key nodes and the internal forces of key sections of the cable-stayed bridge. Du Peng [7] studied the influence of the viscous damper parameters on the seismic response of a single tower cable-stayed bridge. The results show that by adding a viscous damper between the tower towers of the single tower cable-stayed bridge, it is found that increasing the structural damping can effectively reduce the seismic response of the cable-stayed bridge foundation.

2.3 Relevant shock absorption suggestions and conclusions of the single tower cable-stayed bridge
According to the summary of the shock absorption system data of the single tower cable-stayed bridge and the conclusions of the relevant papers, the following points of attention in the shock absorption design of the single tower cable-stayed bridge are obtained:

(1) Most of the existing single-tower cable-stayed bridges are tower-beam consolidation, which should be fully and fully calculated when using the floating system damping design.
(2) When using the vertical floating system design, the bearing friction resistance greatly improves the seismic performance of the structure, especially the displacement of the main beam and the tower top. It is recommended to use the vertical direction with longitudinal sliding ability in the design. Support.
(3) For the laterally restrained single tower cable-stayed bridge, the main tower has an absolute control effect on its lateral displacement, and the side pier and auxiliary pier have less influence.
(4) Viscous damper has a significant effect on improving the seismic performance of the single tower cable-stayed bridge, which can effectively reduce the seismic response of the cable-stayed bridge foundation. Damping index \( \alpha \) and damping coefficient \( C \) have opposite trends on the displacement of key nodes and the internal forces of key sections of single tower cable-stayed bridges.

3. Double tower cable-stayed bridge shock absorption design

3.1 Conceptual design and theoretical study on damping of double-tower cable-stayed bridge
Qiao Xiaoshuai [8] conducted a more comprehensive analysis of the seismic concept design of the twin-tower cable-stayed bridge. It is concluded that the arrangement of the cable-stayed bridges has a significant influence on the longitudinal flight period of the structure. As the average inclination of the
main beam and the stay cable decreases, the longitudinal stiffness gradually increases and the longitudinal frequency increases. The period of the mode is decisive for the displacement of the main beam and the top of the tower. Therefore, when controlling the displacement of the bridge along the bridge, it is necessary to choose a reasonable cable shape.

3.2 Design and effect study of damping measures for double tower cable-stayed bridge

Wen-Hsiung Lin [9] details the mechanical properties of nonlinear fluid viscous dampers in seismic response. Ye Aijun, Fan Lichu [10] analyzed the effect of additional fluid viscous dampers on the reduction of super-long span cable-stayed bridges. The results show that the fluid viscous damper can significantly reduce the longitudinal displacement of the beam end, and the damping effect depends on the damper parameters. Hu Qingan, Cui Gang [11] introduced the application of viscous damper in the damping design of cable-stayed bridges. They perform time-history analysis of floating system, elastic restraint system and semi-floating system with viscous damper under the same seismic wave. In this process, they compared the horizontal displacement of the beam ends of the three systems and the pylons, the horizontal inertial forces and the force of the pylons. The research shows that the viscous damper can improve the dynamic characteristics of the cable-stayed bridge, not only minimizes the displacement and stress of the structure, but also improves the seismic capacity and durability of the cable-stayed bridge. This system can best match the cable-stayed bridge. The shock absorbing design idea; the viscous damper can greatly reduce the horizontal displacement of the main beam of the cable-stayed bridge, and at the same time reduce the main stress of the pylon, and achieve the purpose of reducing the displacement and the force at the same time. Yuan Wancheng, Qu Xiaowei [12] further explored the influence of the combination of cable retainer and viscous damper on the seismic response of the longitudinal bridge of the cable-stayed bridge. The results show that the cable retainer can control the structural displacement more effectively than the viscous damper, and the viscous damper has certain advantages in internal force control; the combined use method can help to play their respective advantages.

3.3 Double-tower cable-stayed bridge related shock absorption suggestions and conclusions

The double-tower cable-stayed bridge is the most common and the largest-scale design of the cable-stayed bridge. The following recommendations and conclusions can be obtained by studying the damping technology of the existing long-span cable-stayed bridge:

1. For large-span cable-stayed bridges, it is recommended to use a longitudinal floating system; when using a floating system, it is recommended to use a longitudinal viscous damper at the joint of the tower and beam. For the lateral direction, the cable can be considered for limiting.

2. When a longitudinal viscous damper is provided at the joint of the pier and the beam, the damping effect for the long-span cable-stayed bridge depends on the damping coefficient C and the velocity index $\alpha$. When taking values for both, it is recommended that the speed index $\alpha$ be between 0.2 and 0.5. The values of C and $\alpha$ should be calculated by actual calculation.

3. For long-span cable-stayed bridges, due to their large span, the traveling wave effect and the near-field earthquake impact should be considered in the seismic analysis.

4. For the side piers, it is recommended to use longitudinal sliding and laterally constrained seismic isolation bearings. For lateral restraints, elastic lateral restraints should be adopted. For transition piers, two-way seismic isolation bearings or longitudinal viscous dampers are recommended.

5. Compared with the viscous damper, the cable stopper can control the structural displacement more effectively, and the viscous damper has certain advantages in the internal force control; the combined use method can help to exert their respective advantages.

4. Multi-tower cable-stayed bridge shock absorption design

4.1 Conceptual design and theoretical study of damping for multi-tower cable-stayed bridge
Chen Wei, Zhang Deping [13] showed that the increase of the stiffness of the middle tower is an ideal way to improve the overall stiffness of the structure. Under the premise of the vertical support of the side tower, the hinge between the middle tower and the beam is superior to the complete consolidation. Qi Fangfang [14] systematically studied the damping control method of multi-tower cable-stayed bridge under the action of near-fault ground motion. The dynamic characteristics of the dynamics of the mid-long period are proposed for the medium-long period structure under the action of near-fault ground motion.

4.2 Design and effect study of damping measures for multi-tower cable-stayed bridges

Li Xiaozhen, Tan Qingquan et al. [15] studied the influence of bridge structure system and additional liquid viscous damper on the seismic performance of the bridge. Qi Fangfang et al. [16] studied the seismic response characteristics of the multi-tower cable-stayed bridge using the longitudinal partial restraint system. Based on this, the damping control characteristics of the longitudinal restraint system of the multi-tower cable-stayed bridge using viscous dampers were studied. Peng Wei and Li Jianzhong [17] proposed a viscous damper damping parameter selection method suitable for the longitudinal part restraint system of multi-tower cable-stayed bridge. The research shows that: (1) The multi-tower cable-stayed bridge adopts the constraint system of longitudinal consolidation of some tower beams. The damping control objective is to reduce the “internal force concentration effect” caused by the consolidation of the tower beam, so that the internal force distribution of each tower bottom tends to be uniform. (2) The viscous damper of the multi-tower cable-stayed bridge can significantly reduce the internal force response of the tower bottom and the longitudinal relative displacement reaction between the tower and the main beam, but the internal force reacts and slightly increases the longitudinal relative displacement response between the main beam and the pier. The results of Peng Yu [18] show that: (1) Generally speaking, as long as the value of the parameter is reasonably selected, the damper has a good damping effect in the bridge structure, which can significantly reduce the displacement of most parts of the structure, especially the relative displacement between the pier and the beam body can be greatly reduced; (2) The viscous damper can reduce the seismic response of the upper structure of the high pier multi-tower cable-stayed bridge, and the internal force of the pier bottom is generally reduced and uniform. Distribution is beneficial to improve the seismic performance of the structure.

4.3 Multi-tower cable-stayed bridge related shock absorption suggestions and conclusions

(1) The stiffness of the tower has little effect on the stiffness of the full bridge, and it is not recommended to design the stiffness of the tower too large in the design.

(2) Compared with the longitudinal floating and pier, the tower and the beam are all consolidated, and the multi-tower cable-stayed bridge is more recommended to adopt the vertical support system of the side tower.

(3) When the longitudinal viscous damper is used, the internal force reaction of the tower bottom and the longitudinal relative displacement reaction between the tower and the main beam can be significantly reduced, but the tower bottom freely increases the tower bottom. The internal force reacts and slightly increases the longitudinal relative displacement reaction between the main beam and the pier, so the damper parameters need to be specifically set.

(4) The relationship between the damping coefficient of the viscous damper and the total internal force of the tower bottom of the multi-tower cable-stayed bridge is a single-peak concave-convex curve. The relationship between the damping coefficient and the uneven distribution coefficient of the internal force of the tower bottom and the maximum output force of the damper is a monotonous curve.

(5) For longitudinal bridge damping, the viscous damping effect of the viscous damper is better than that of the elastic cable.
5. Conclusion
This paper introduces the researches on the shock absorption design of the single tower cable-stayed bridge, the double-tower cable-stayed bridge and the multi-tower cable-stayed bridge. The paper also summarizes the shock-absorbing design and recommendations for future applications of various cable-stayed bridges. At the same time, the long-span cable-stayed bridge is a very competitive bridge type. The theoretical research and shock absorption measures are far from mature, and the following problems remain to be solved. The shock absorption research and analysis of the cable-stayed bridge structural system still stays in the overall analysis, and further analysis is needed for the local component damping effect; At present, the use of damping measures for long-span cable-stayed bridges is relatively simple, and there are few applications for combining multiple damping measures. There are few studies on the effects of different damping measures.

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