Seismic Analysis for a Novel Super High-pier and Multi-span Cable-Stayed Bridge in China

Sicong HU
PhD Candidate
College of Civil Engineering
Changsha, Hunan, China
eric731hu@gmail.com
Sicong Hu, born 1990.

Lifeng LI
Professor
College of Civil Engineering
Changsha, Hunan, China
Lilifeng@hnu.edu.cn
Lifeng Li, born 1971, received his civil engineering degree from Hunan Univ.

Wenpeng WU
PhD Candidate
College of Civil Engineering
Changsha, Hunan, China
Rocewu@gmail.com
Wenpeng Wu, born 1985.

Summary

Super High-pier Multi-span Cable-Stayed (SHMCS) bridges has been used to span the wide canyon terrain around the world, such as the Millau Viaduct in France, the Mezcala Bridge in Mexico and the Chishi Bridge in China. To study the seismic behaviour of SHMCS bridges that rare literature mentioned previously for practical application, the Chishi Bridge is taken as an example in this work. We first introduced the unique characters of this bridge. To study the seismic behaviour of SHMCS bridges, we built the finite element dynamic model of the case-study bridge by considering complex nonlinearities of structure. Then, according to the specification standard spectrum, three motions are selected to perform the nonlinear time history analysis. The structure dynamic responses for different connection conditions between the girder and the tower are compared to determine appropriate connection conditions for SHMCS bridges. It is concluded that the influence of connection conditions on the deformation of bridge is more remarkable than internal force due to the flexible super high piers and the isolation measure of suspend the girder isn't suitable for SHMCS bridges. Non-uniform connection conditions should not be used because it will lead to irregular distribution of internal force. Damper can expedite the ability of dissipating energy and but can't decrease the maximum displacement or deformation significantly.

Keywords: bridge; super high-pier; multi-span cable-stayed bridge; connection conditions; dynamic behaviour.

1. Introduction

Cable-stayed bridges had an increasing development all over the world in past decades for its excellent spanning capability and simple construction technology [1]. Today, more and more novel structural forms are designed to satisfy various demands. When the cable-stayed bridges cross the wide canyon, it would be designed to have super high piers and more towers, such as the Chishi Bridge[2] and Tie luoping Bridge[3] in China, the Millau viaduct in France[4] and the Mezcala Bridge in Mexico. For most of SHMCS bridges, a serious threat they will suffer is seismic hazard because the sites are usually near the earthquake prone. It is important to keep the security of the transport net by decreasing the damage of SHMCS bridges during the strong earthquake. Previous research investigated the effect of different connection conditions on the seismic response [5,6] and reveals that an appropriate connection conditions between the towers and the girder can improve the seismic performance of cable-stayed bridge. However, the effect of different constraint conditions on SHMCS bridges may not the same as the SDCS bridges and the selection of suitable connection conditions of SHMCS bridges need to further investigate. In this study, the Chishi Bridge, which is a novel four-spans high-pier concrete cable-stayed bridge (Figure 1), is taken as an example and the finite element dynamic model is built by considering complex nonlinearities of structure . Three kinds of connection conditions are researched in this paper. Further, each connection condition considers two cases, including the without dampers case and with dampers case (Table 1). Three ground motions are selected to perform the nonlinear time history analysis according to the specification standard spectrum [7]. The structure dynamic behavior and seismic responses for different connection conditions between the girder and the tower are compared in this work.

Figure 1: Elevation view of the Chishi Bridge

Table. 1: Longitudinal connection conditions

	Without Dampers			With Dampers		
	FL	FL-CS	CS	FL	FL-CS	CS
P4	0	0	0	0	0	2
T5	0	0	1	2	2	1
T6	0	1	1	2	1	1
T7	0	1	1	2	1	1
T8	0	0	1	2	2	1
P9	0	0	0	0	0	2

*Noted: 0 means the constrained stiffness is zero; 1 means the constrained stiffness is extreme great; 2 means the viscous fluid dampers is added between tower and girder.

2. Conclusion

From the analysis result, the following conclusions may be drawn: (1) SHMCS bridges present lower frequencies than Short-pier Double-spans cable-stayed (SDCS) bridges with similar spans because of the super high tower and numerous spans. (2) The influence of connection conditions on deformation is more remarkable than internal force for SHMCS bridges. The isolation effect of suspend girder without link to tower is not obvious for SHMCS bridges and will lead to large displacement. Therefore, consolidation the girder with towers is more suitable. (3) Non-uniform connection conditions between girder and each tower will lead to the irregular distribution of response and the damage concentrate seismic demand on the tower which was consolidated with girder. So it is not an appropriate selection for the SHMCS bridge. (4) The dampers can expedite the ability of dissipate energy but can’t decrease the maximum displacement or deformation significantly. Therefore, the seismic performance of structure can’t improve remarkable by simply adding dampers. In conclusion, the girder consolidation with all the four towers and set viscous fluid dampers at the end of girder is an appropriate selection for the Chishi Bridge.

3. References

[1] VIRLOGEUX M., “Recent evolution of cable-stayed bridges”, *Engineering Structures*, Vol. 21, No.8, 1999, pp.737-755.

[2] LONG H.B., HU J.H., “The design and research on the key technology of Chishi bridge on RuChen highway”, *Journal of China and foreign highway*, Vol.33, No.1, 2013, pp.181-185.

[3] GUO A.H., ZHANG M.Z., “Design of Tieluoping bridge on Shanghai-Chengdu expressway”, *Bridge Construction*, Vol.42, No.4, 2012, pp.64-68.

[4] BUONOMO M, DEL FORNO J.Y., “The Design and Construction of the Millau Viaduct”, *Steelbridge*, 2004, pp.1-18.

[5] OKAMOTO Y., NAKAMURA S. Static and seismic studies on steel/concrete hybrid towers for multi-span cable-stayed bridges. *Journal of Constructional Steel Research*, Vol.67, No.2, 2011, pp.203-210.

[6] YE A.J., HU S.D., FAN L.C. “The research on the seismic structure system of cable-stayed bridge”. *Bridge construction*, Vol.1, No.4, 2002, pp.1-4.

[7] *Specification of seismic design for highway engineering*, China Communications Press, Beijing, 2013.