SEISMIC DAMAGE MECHANISM AND ENERGY DISSIPATION OF LONG-SPAN CABLE-STAYED BRIDGES

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Although often designed to behave elastically, seismic damage to reinforced concrete (RC) pylons of cable-stayed bridges have been witnessed in history such as the 1999 Chi-chi earthquake. This study aims to assess the transverse seismic failure mechanism of the long-span cable-stayed bridge and investigate the efficiency of passive energy dissipation devices in protecting the long-span cable-stayed bridges using quasi-static model tests, shake table model test and numerical analyses.

In the quasi-static model test (Fig.1), to facilitate the limited laboratorial loading system, a simplified displacement-controlled two-node load-pattern, one at the bifurcation-node and the other at the crossbeam, is first proposed using numerical analyses. It is found the ratio of displacements at the two loading nodes is correlated generally well with the ground motion parameter, bracketed duration. A displacement ratio of 5.0 is then adopted in the test. Test results indicate a flexural damage mode with considerable ductility: plastic hinges were detected first at bottom of the upper column (i.e., above the crossbeam), then at bottom and top of the lower column, successively (Fig.2); multi-level displacement ductility factors are proposed to associate with numbers of plastic hinges formed in the pylon.

Fig.1 Instrumentation and loading for test

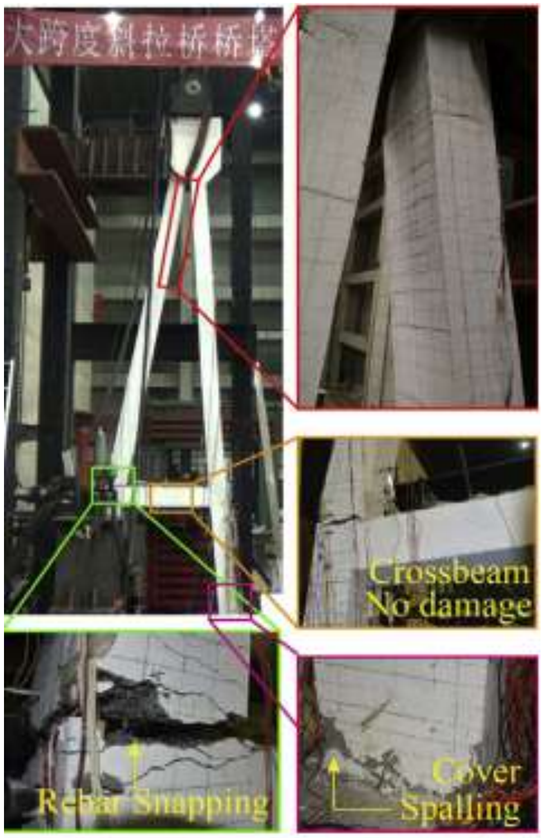

Fig.2 The deformation and local damage to the test model

To study the potential plastic region and possible failure mode of the cable-stayed bridge under earthquakes, a 1/35-scale full bridge model (Fig.3) from the typical inverted Y-shape RC pylons for long span cable-stayed bridges with inverted Y-shape RC pylons was designed, constructed and tested on 4 linear shake tables under near- and far-fault ground motions in the transverse direction. Test results showed that the damage characteristics of the bridge model were as follows: (1) the severe damage was observed at the at bottom of the upper column (i.e., above the crossbeam) as the same location as the quasi-static model; (2) the repairable damage was observed at tower legs at the bottom with large cracking; (3) the minimal damage was observed at the top of upper legs with slightly concrete cracking.

Fig.3 Shake table test model

Fig.4 The damage characteristics of the bridge model

Furthermore, to investigate the efficiency of passive energy dissipation devices in protecting the cable-stayed bridges from severe damages subjected to high intensity ground motions, the 1/35-scall bridge model from a typical inverted Y-shape RC pylon for long span cable-stayed bridges was tested before shake table model failure testing. Transverse Steel Damper (TSD) and Viscous Fluid Damper (VFD) were used as passive energy dissipation devices in the transverse and longitudinal directions, respectively. The bridge models were then excited by for ground motions with different spectral characteristics in transverse and longitudinal directions accordingly, including Chi-Chi earthquake wave and a site specific artificial wave. The seismic responses of the bridge models with and without the passive devices were analyzed and compared. Both numerical and test results show that the TSD applied in the transverse direction could reduce the seismic responses of the towers effectively, and the VFD applied in the longitudinal direction could reduce the displacement of the deck effectively while simultaneously limiting the seismic responses of the towers. Therefore, the proposed energy dissipation system, consisting of TSD transversely and VFD longitudinally in association with the sliding bearing, is suggested to apply in the cable-stayed bridges to achieve better overall seismic performance compared to the traditional system that isolated only longitudinally.

Keywords: Long-span cable-stayed bridge, Shake-table test, Full bridge model, Seismic damage characteristics, energy dissipation