Shake Table Studies of Seismic Damage of a Kilometre-scale cable-stayed Bridge

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Abstract

To investigate the transverse seismic damage of a kilometre-scale cable-stayed bridge, a cable-stayed Bridge with two inverted Y-shaped reinforced concrete towers and a main span of 1088 m was selected as the prototype and a 1/35 scaled bridge model was designed, constructed and tested on 4 linear shake tables at Tongji University, Shanghai, China. Sliding bearings which allow the longitudinal movement of the main girder with little friction effect while prevent the transverse movement were used at the towers and the piers. The bridge model was tested up to failure by using a site specific artificial wave from low to high intensity in transverse direction. Test results showed that: (1) flexure failure occurred at the right tower leg of tower 1 at the level just above the crossbeam; (2) the maximum transverse displacement response of the tower was observed at the mid-height; (3) 4 peak sectional curvature responses were observed along the tower.

Keywords: cable-stayed bridge; shake table test; seismic damage.

1 Introduction

Since the first modern cable-stayed bridge established in Sweden more than 60 years ago, cable-stayed bridge become popular worldwide owing to its large span capacity when compared to girder or arch bridge, aesthetically appearance and structural efficiency. In recent 10 years, the span capacity of cable-stayed bridge has even exceeded 1000 m, such as the Stonecutters Bridge (1018 m) in Hong Kong, China. Cable-stayed bridge is characterized by long fundamental periods, large flexibility and low structural damping [1-2]. Generally, for a cable-stayed bridge design, floating or semi-floating system is used in longitudinal direction. But this unavoidably results in large longitudinal seismic displacement of deck as well as large transverse seismic forces of towers and piers. During 1988 Saguenay Earthquake in eastern Canada, the Shipshaw cable-stayed bridge suffered significant structural damage [3-4]. One of four anchorage plates underneath the deck failed due to large longitudinal vibration of deck coupled with lack of rotation of the tie-rod hinges and the abutment concrete was damaged due to pounding of deck against abutments. More recently, during 1999 Chichi Earthquake in Taiwan, China, severe damage was observed on the Chi-Lu cable-stayed bridge [5]. Severe concrete spalling happened on the tower at the level above the roadway, and a crack along the height of the tower from the level of roadway till to the level of the lowest cable was observed, the height of the plastic region of the tower almost reached 2 m, additionally, pounding damage was found at the end span supports.

However, the seismic design of cable-stayed bridge is not detailed in many seismic codes, such as AASHTO Guide Specifications for LRFD Seismic Bridge Design [6].The seismic behavior of cable-stayed bridge had been studied by many researchers. W X Ren [7] studied the elastic-plastic

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