Response of Yokohama-Bay Cable-Stayed Bridge in the 2011 Great East Japan Earthquake

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Introduction

At 14:46 P.M. on 11 March 2011, Japan was struck by the most devastating earthquake in 130 years. Its epicenter was located at N38.1, E142.9 about 130km off the Ojika peninsula in Tohoku, northeast of Japan with the focal depth of 24km. The JMA magnitude of the earthquake is 9.0. Yokohama Bay located about 400km from the epicenter and about 180km from the fault also experience large shaking. JMA declared the highest seismic intensity of 5 in this area. This paper describes the important characteristics of Yokohama-Bay Bridge response during this event. The records were obtained from the strong-motion instrumentation provided by the Tokyo Metropolitan Expressway.

1. Bridge Description

The Yokohama Bay Bridge is located at the entrance of Yokohama harbor. It is a double-deck steel–truss box cable-stayed bridge with a central span of 460m and two side spans of 200m each. The bridge (Fig.1), completed in 1988, has two H-shaped towers 172m high and 29.2 m wide. Eighty-five sensors measuring acceleration and displacement are installed at 36 locations throughout the bridge. Along the girder, sensors are installed at nine locations with spacing of 115 m. The bridge, along with several long-span bridges that belong to Tokyo metropolitan expressway, has undergone seismic retrofitting program in 2005.

2. Bridge Recorded Response

Main shock was recorded at 14:46 JST and three aftershocks with magnitude larger than 7 were also recorded later that day. The main shock shows a very intense shaking that lasts for about three minutes (Fig. 2). In the table below maximum acceleration recorded at three locations are listed. The largest vibration of the girder and tower was observed in transverse direction due the vibration mode at 0.32Hz (Fig.2.c). As shown by the Fourier spectra (Fig.2b) this mode has a very sharp peak indicating a small modal damping. Girder displacements calculated from acceleration record at the middle of midspan reach the maximum of 24cm, 61.8cm, and 20cm, in longitudinal, transverse, and vertical direction, respectively. The tower also experienced very large vibration, where the main vibration is in lateral (out-of-plane) direction. The maximum displacement of the tower top is 25cm in in-plane direction and 54.6cm in out-of-plane direction.

	JMA	Maximum Recorded Acceleration (cm/s/s)									
		Bottom of Tower 1 (K3)			Middle of midspan (S5)			Top of Tower (T1)		Top of Tower (T2)	
	Magnitude	Long	Trans.	Vert.	Long.	Trans.	Vert.	Long.	Trans.	Long.	Trans.
Main shock March 11, 14:46	9.0	38.32	32.74	27.77	51.14	299.17	194.24	253	635.94	418.67	656.87
After shocks (M>7)											
March 11, 15:08	7.4	2.16	3.14	1.76	5.75	17.78	21.12	21.58	41.11	26.87	47.95
March 11, 15:16	7.7	15.83	18.9	13.18	22.4	137.61	70.36	107.17	299.22	107.11	252.71
March 11, 15:25	7.5	2.31	2.54	1.91	4.98	9.03	20.12	22.83	29.84	13.48	30.82

3. Acceleration Response Spectra of the Input Ground motions

Acceleration response spectra defined as the maximum acceleration of a single-degree-of-freedom system with prescribed damping ratio when subjected to a ground motion are computed. Records from the bottom of pier no.1 (K1), tower no.1 (K3) and tower no.2 (K5) are utilized and the results are compared with the standard design acceleration spectra and the spectra used in seismic retrofit generated by simulations. The seismic retrofit spectra were obtained by simulating several scenarios of possible and credible earthquakes near Yokohama-Bay Bridge. Sensor K1 and K3 is 200m apart, while sensor K3 and K5 is 460m apart so spatial variation of ground motion may occur. The spectra show that: 1) spatial variation among ground motions measured on the bottom of piers and towers and free field are relatively small, especially at long-period component, and 2) spectra of recorded ground motions are still below the ground motions used for retrofit design.

Keywords : 2011 Great East Japan Earthquake, Cable-Stayed Bridge, Seismic Response, Instrumented Bridges
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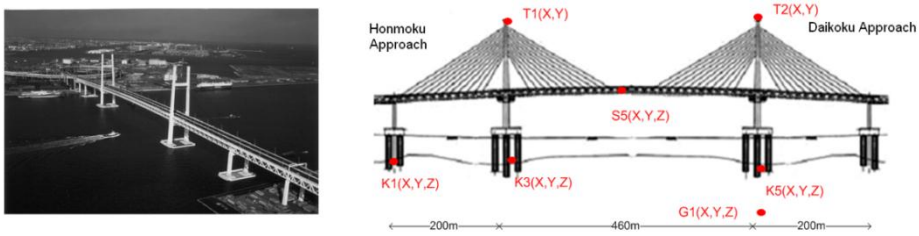
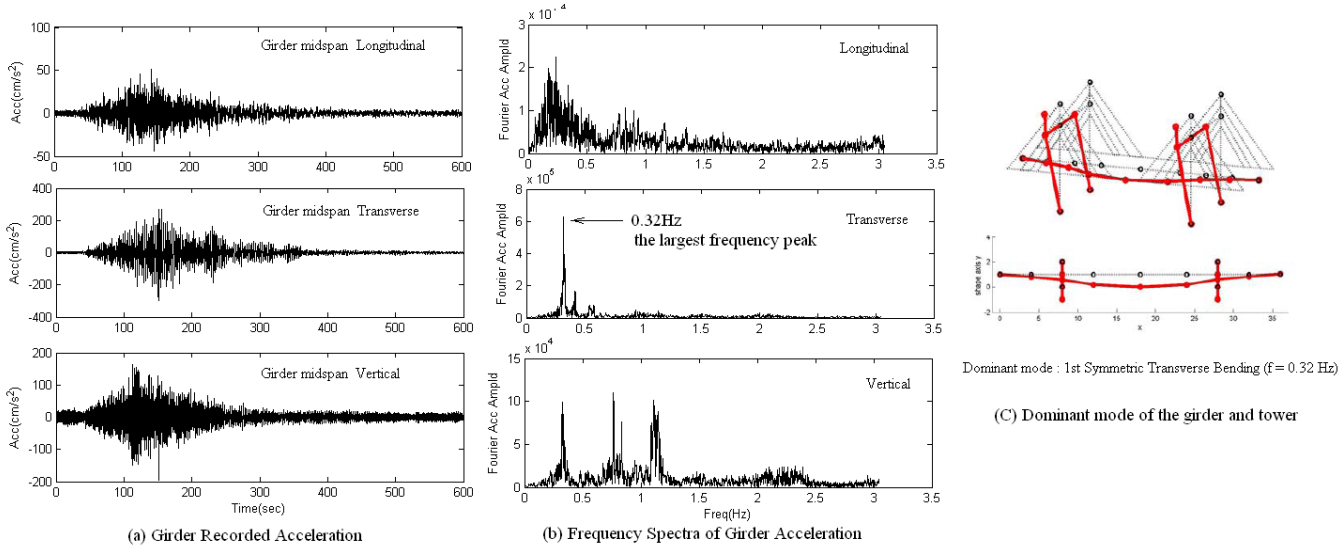


Figure 1. Yokohama-Bay Bridge and locations of sensors whose data is used in this paper



(a) Girder Recorded Acceleration (b) Frequency Spectra of Girder Acceleration (C) Dominant mode of the girder and tower

Figure 2. (a) Accelerations recorded in the middle of girder, (b) their Fourier spectra and (c) mode shape of dominant mode

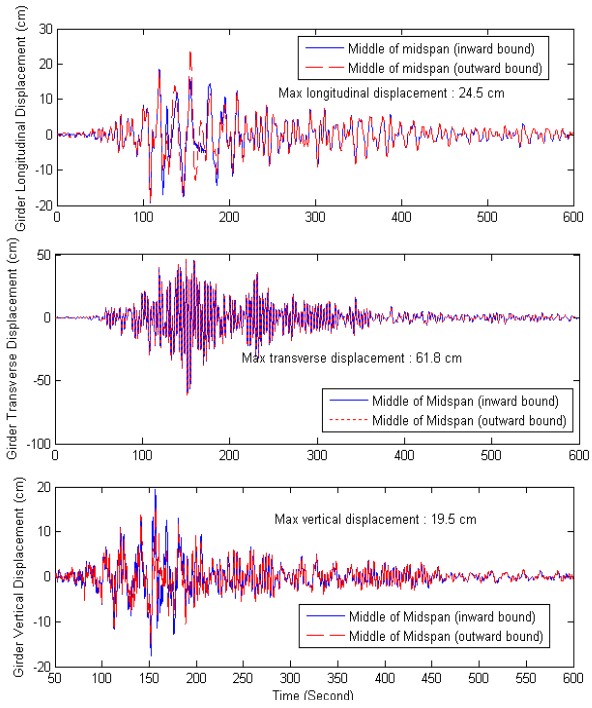


Figure (3). Displacements of Girder

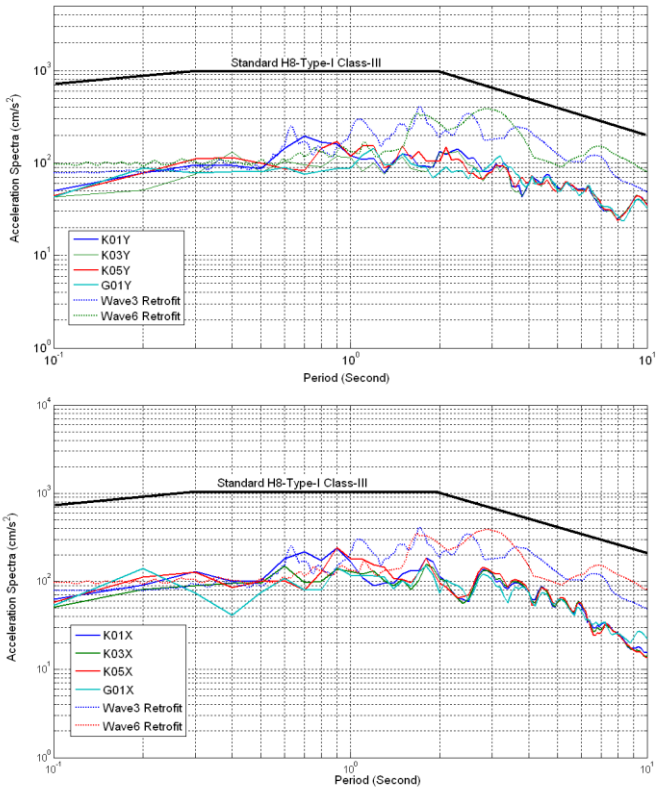


Figure (4). Acceleration response spectra for recorded ground motions and comparison with ground motion used in seismic retrofit design (h=2%).