ANALYSIS OF SEISMIC RECORDS FROM FULL-SCALE MONITORING OF AN ASYMMETRIC BASE-ISOLATED BUILDING

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1. INTRODUCTION

This paper describes analysis of seismic monitoring of an asymmetric base isolated building located in Tokyo Bay area during March 11, 2011 earthquake and various levels of earthquakes recorded between year 2010 and 2012. Seismic responses recorded during three years are of prime interest as they provide comprehensive database to study the seismic performance of an asymmetric base isolated building.

2. DESCRIPTION OF BASE ISOLATED BUILDING AND SEISMIC MONITORING SYSTEM

The monitored building is SIT building located in Tokyo Bay area. It consists of two parts, one is seven floor building B which is 81m long, 21.6m wide and 31.2m high and the other is fourteen floor building C which is 97.2m long, 31.2m wide and 67.5m high (Fig. 1). Both buildings are of braced steel frames and connected at the corner to form an L-shaped asymmetric structure. Building C has vertical opening in the middle starting from the second to the seventh floor, which divides the building into the northwest (NW) and northeast (NE) section. The eccentricity ratio that is defined as ratio of eccentricity in X and Y direction with respect to building length in corresponding direction exceeds more than 10% which indicates an asymmetricity of the building.

The isolation system consists of 37 natural rubber bearing (NRB), 34 sliding bearing (SB), lead dampers (28 units) and U-shaped steel dampers (33 units) (Fig.1). The building seismic monitoring system consists of 21 triaxial accelerometers and 4 triaxial displacement-meters located at the basement, 1st, 4th, 7th, 9th and 14th floor of the building, Siringoringo et al. (2012). Vibration sensors are denoted by various channels with channel 101 corresponds to input ground motion and channel 105, 110, 111 corresponds to sensors placed at top floor of building B and NW and NE sections of building C respectively (Fig. 2).

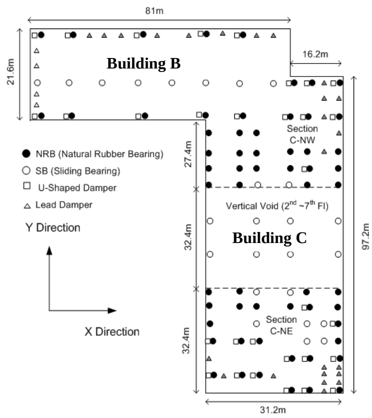

Fig. 1: Plan view of Building and Layout of Isolators

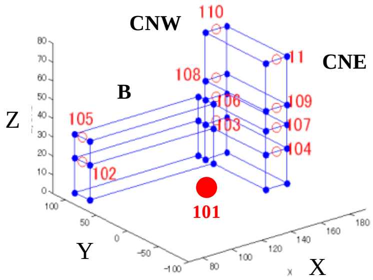

Fig. 2: Location of vibration sensors

3. BUILDING RECORDED RESPONSES

The building seismic responses were analyzed for three year monitoring data, and detail information of ten largest earthquakes recorded between 2010 and 2012 is given in Table 1. The building experienced strong shaking during March 11, 2011 earthquake with JMA seismic intensity 5- (5 lower). Fig. 3 shows the time histories and frequency spectra of recorded ground acceleration and recorded responses at top floor of building B and NW and NE sections of building C during the main shock. The maximum ground acceleration is 0.11g recorded in Y direction. The largest horizontal vibrations at top floor were recorded in building B in Y direction and in building CNW and CNE in X direction with peak accelerations of 0.3g, 0.24g and 0.21g respectively.

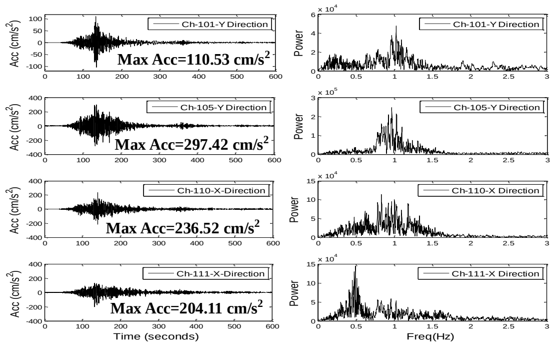

Fig. 3: Recorded Ground Acceleration, Responses and Frequency Spectra for March 11, 2011 earthquake

The system identification using System Realization Information Matrix (SRIM) technique is employed to identify the predominant modes of the building during the main shock, Siringoringo et al. (2008). The system identification yielded three predominant modes (Fig. 4), the first mode is the 1st translational mode (0.44Hz-0.55Hz) with large modal displacement at the isolator level while the second and third modes are 1st torsional mode (0.58Hz-0.68Hz) and 2nd torsional mode (0.85Hz-0.95Hz) with characteristics of large modal displacements on the superstructure of building C and B respectively.

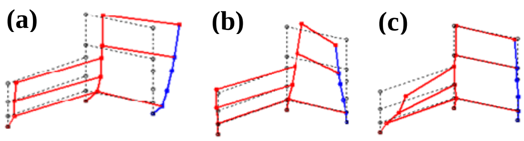

Fig. 4: (a) 1st Translational mode (f=0.44Hz-0.55Hz)
(b) 1st Torsional mode (f=0.58Hz-0.68Hz)
(c) 2nd Torsional mode (f=0.85Hz-0.95Hz)

Keywords: Seismic response, Seismic monitoring, Base isolated building, Earthquake records, 2011 East Japan Earthquake
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Table 1: Ten largest earthquakes recorded on SIT Building between 2010 and 2012

Earthquake	Mw	JMA Seismic Intensity	Max Recorded Ground Acc (gal) (Ch 101-Y)	Max Recorded Acc (gal) (Ch 105-Y)	Ratio (Ch105Y/ Ch101Y)
03-11-2011, 14:47 **(Main shock)**	9	5-	110.53	297.42	2.69
03-07-2012, 11:31	5.2	4	57.94	20.92	0.36
11-03-2011, 15:16 **(After shock)**	7.7	4	53.03	239.99	4.53
01-06-2012, 17:48	5.1	4	51.62	15.88	0.31
18-05-2012, 17:19	4.8	4	39.18	14.35	0.37
29-05-2012, 01:36	5.2	4	29.58	32.83	1.11
07-12-2012, 17:19	7.3	4	29.2	49.79	1.71
16-07-2012, 04:31	4.8	4	27.67	7.75	0.28
24-11-2012, 17:59	4.8	4	27.09	44.58	1.65
06-06-2012, 04:32	6.3	4	25.91	13.81	0.53

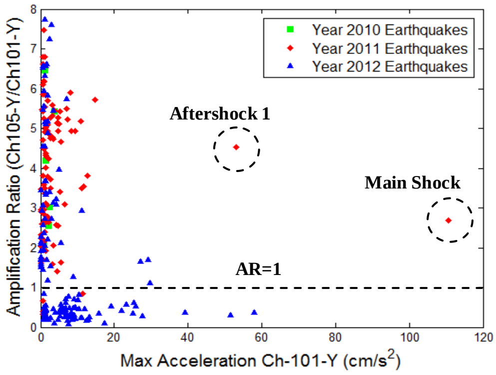

Fig. 5: Amplification ratio plot of Building B top floor (Ch105-Y/Ch101-Y)

4. SEISMIC PERFORMANCE EVALUATION OF BUILDING

In order to check serviceability performance of the building, an amplification ratio is evaluated. The ratio defined as maximum recorded acceleration at top floor of building and the maximum recorded ground acceleration is computed for three years seismic monitoring data. The amplification ratio of top floor of building B is shown in Fig. 5. It can be seen that for some of small earthquakes in the range of 0 and 25 gal, the response amplification reaches about 7 to 8 times the input ground acceleration, but they are still acceptable since the maximum horizontal floor acceleration of the top floors remain small. Meanwhile, for large earthquakes with maximum ground accelerations in range of 25 gal to 140 gal, the amplification can reach as high as 4.5. The large floor amplification is a concern for protection of non structural components inside the building. The amplification ratios for March 11, 2011 main shock and first aftershock are 2.69 and 4.53 respectively, which are unexpectedly large compared to other earthquakes.

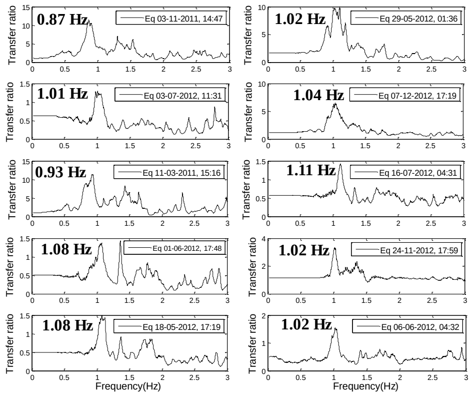

Fig. 6: Transfer functions of Building B top floor (Ch105-Y/Ch101-Y)

5. CHARACTERISTICS OF RECORDED BUILDING RESPONSES

The transfer functions of accelerations of Building B in Y direction are shown in Fig. 6 for ten large earthquakes and it is shown that transfer functions have dominant frequency peaks between 0.8Hz and 1.2Hz. In particular interest is the transfer function of the main shock that shows the largest frequency peak at 0.87Hz, which is the 2nd torsional mode of the building. This indicates that torsional mode governs the acceleration of building B during the main shock.

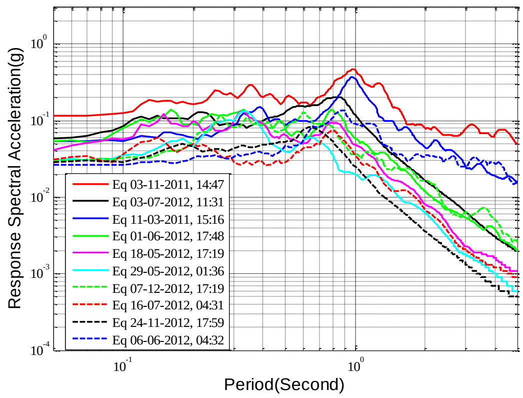

Fig. 7: Acceleration response spectra Ch101-Y for ten large earthquakes

6. CHARACTERISTICS OF RECORDED GROUND MOTIONS

The response spectra of ground motions of ten largest earthquakes are shown in Fig. 7. It is shown that the response spectra of the March 11, 2011 main shock and first aftershock have large amplitude in the period range of 0.8-1.2 sec (0.83Hz-1.25 Hz) compared to other earthquakes. This frequency range coincides with the 2nd torsional mode structural frequency (0.85Hz-0.95Hz) suggesting that resonance between input excitation and building torsional frequency has occurred. This fact explains why transfer function has dominant frequency in torsional frequency range and why the building has large amplification ratio.

7. CONCLUSION

Seismic response of an asymmetrical base isolated building is analyzed for three years monitoring data to investigate seismic performance of base isolation system. It is observed that among ten large earthquakes, the building experienced large superstructure horizontal acceleration responses only in the case of March 11, 2011 main shock and first aftershock earthquake in which amplification of the superstructure is caused by torsional mode. These response amplifications are critical to non structural elements and should be considered for future large earthquake.

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