



Dynamic Behavior of Buildings based on Strong Motion Data during the 2011 Great East Japan Earthquake

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- Strong motion network of Building Research Institute (BRI)
- Strong motion data of the 2011 East Japan Earthquake
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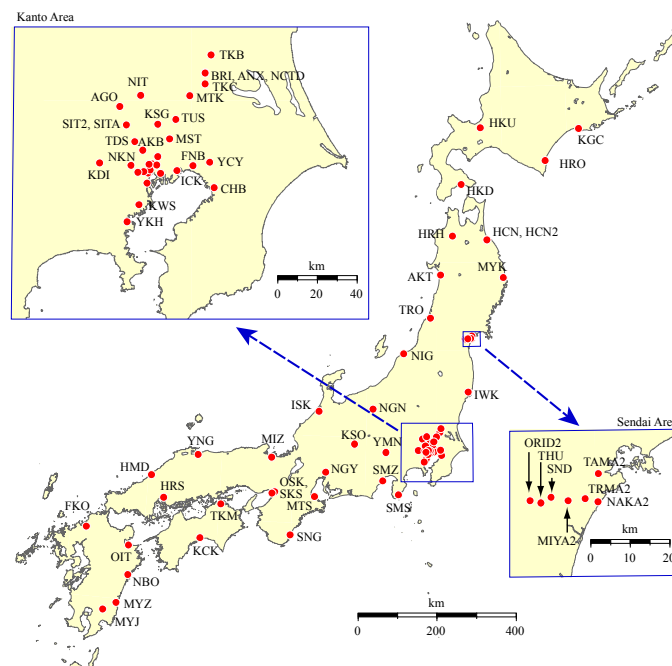


BRI strong motion network Outline

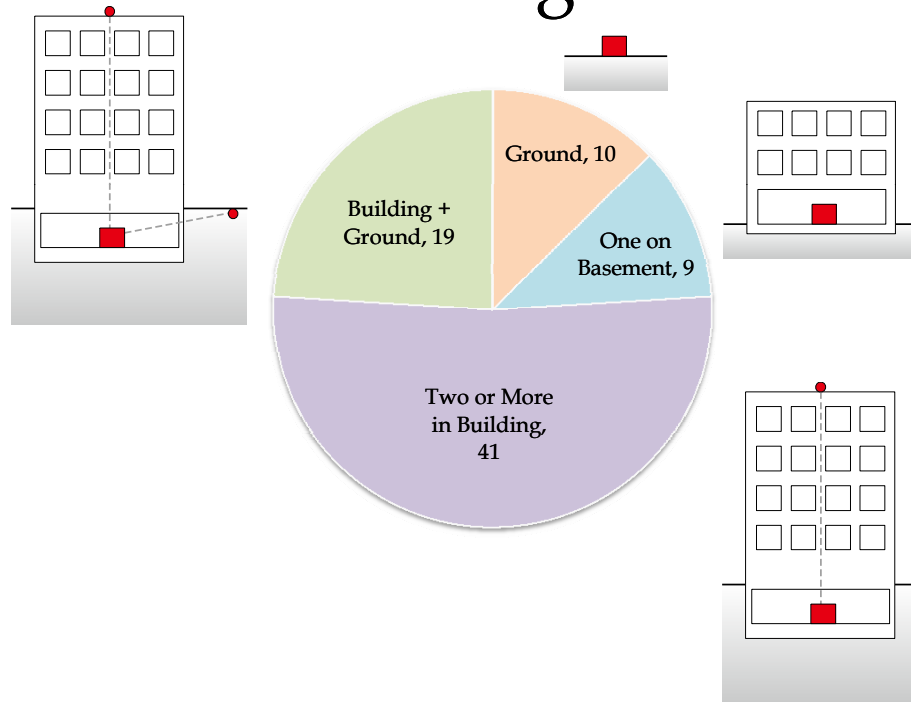
- 79 stations in operation (as of 2011/03/11)
- Half of stations in Kanto (around Tokyo)
- 60 stations with two or more sensors in building
- 6 base-isolated buildings
- 9 super high-rise buildings (higher than 60 meters)



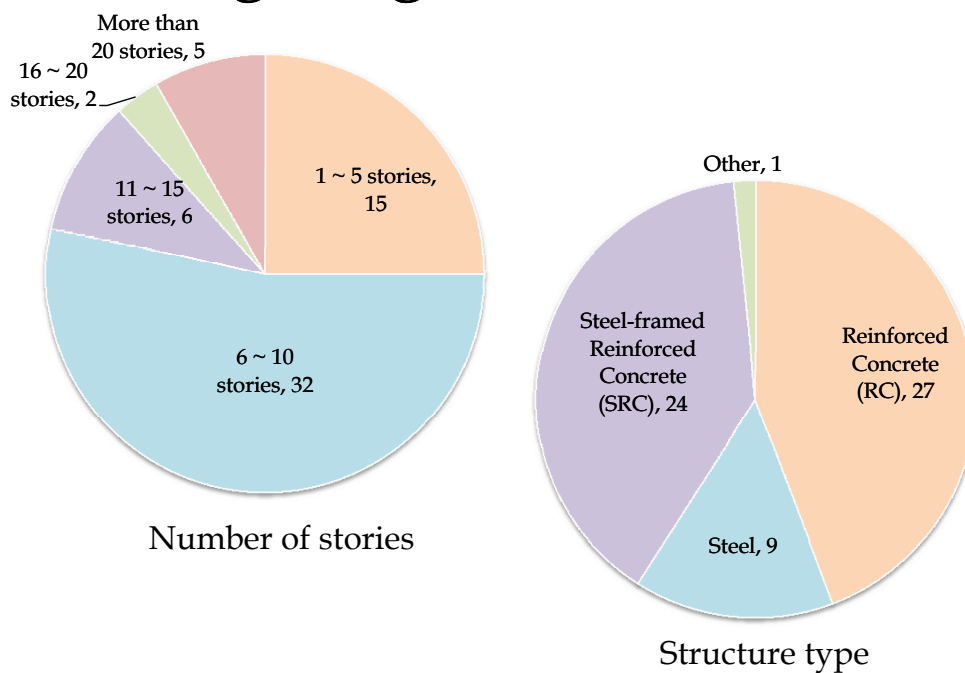
BRI strong motion network Stations



BRI strong motion network Sensor configurations



BRI strong motion network Building heights and structures



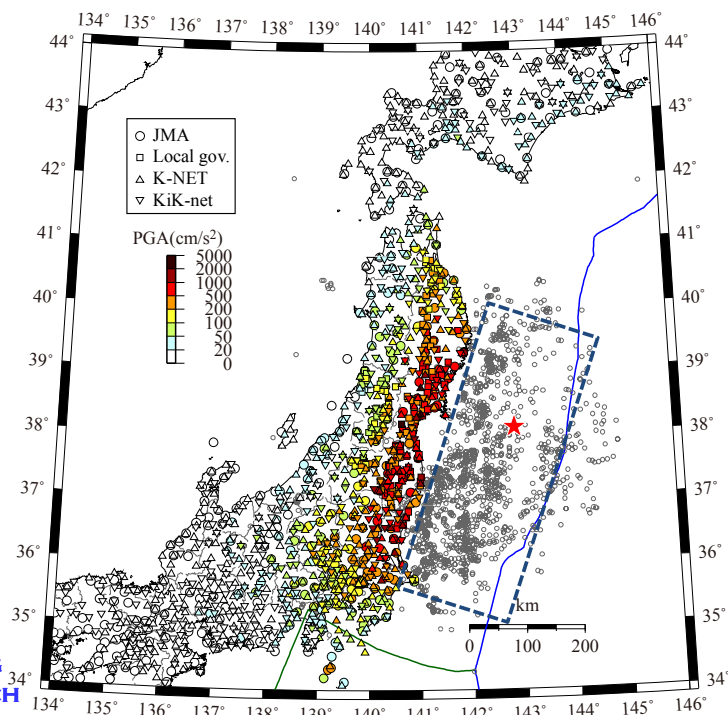
BRI strong motion network

The 2011 East Japan Earthquake

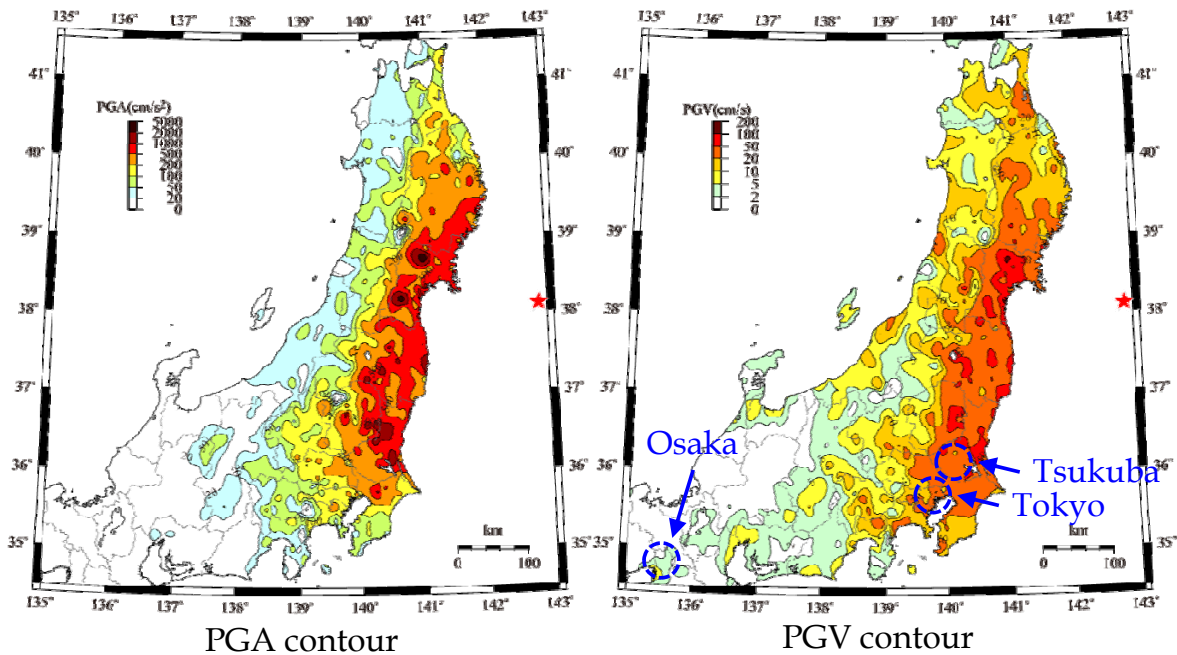
- Time: 14:46:18, March 11, 2011 (JST)
- Location: 38.103°N, 142.860°E (JMA)
- Depth: 24 km (JMA)
- Magnitude: Mw9.0 (JMA)
- Mechanism: Reverse



The 2011 East Japan Earthquake Epicenter and PGA distributions



The 2011 East Japan Earthquake Contour maps of PGA and PGV

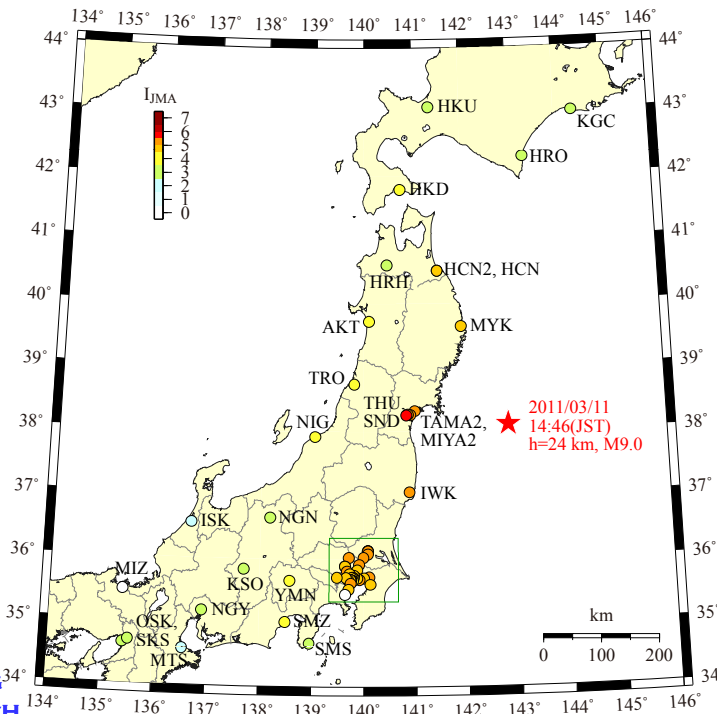


Strong motion data of BRI network Outline

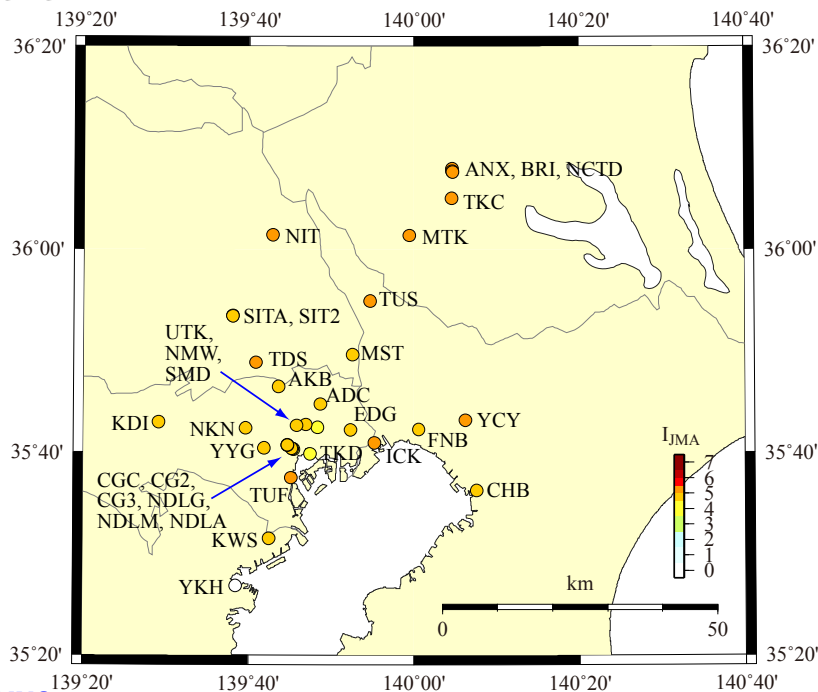
- 61 stations (out of 79) were triggered
 - I_{JMA} 6-: 1 stations
 - I_{JMA} 5+: 17 stations
 - I_{JMA} 5-: 18 stations
- 9 super high-rise buildings ($H \geq 60m$) and 6 base-isolated buildings
- 30 buildings in 29 stations suffered severe earthquake motions with I_{JMA} 5- or higher



Strong motion data of BRI network Triggered stations

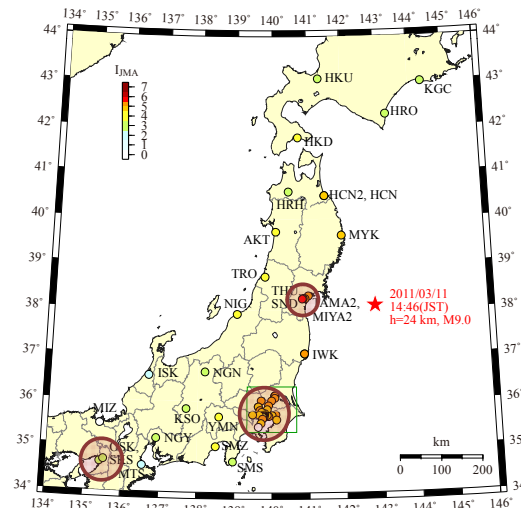


Strong motion data of BRI network Triggered stations in Kanto area



Strong motion data of BRI network Super high-rise buildings

- All of 9 stations were triggered
 - I_{JMA} 5+: 1 station (Sendai)
 - I_{JMA} 4: 6 stations (Tokyo metropolitan)
 - I_{JMA} 3: 2 stations (Osaka)



Strong motion data of BRI network Records in super high-rise bldg. #1

Code	Station	Δ (km)	I_{JMA}	Place	A_{max} (X)	A_{max} (Y)	A_{max} (Z)
SND	Sendai Government Office Bldg. #2 (S/15F)	175	5.2	B2F*	163	259	147
				15F	361	346	543
SIT2	Saitama Government Office Bldg. #2 (S/27F)	378	4.4	B3F*	74	63	42
				27F	248	503	107
SMD	Sumida Ward Office (S/16F)	380	4.3	B1F*	69	66	34
				20F	385	290	81
TKD	Kosha Tower Tsukuda (RC/37F)	385	4.4	01F*	87	98	41
				37F	163	198	108
CGC	Central Gov. Office Bldg. #6 (S/20F)	386	4.2	01F*	90	86	45
				20F	208	148	173



Strong motion data of BRI network Records in super high-rise bldg. #1

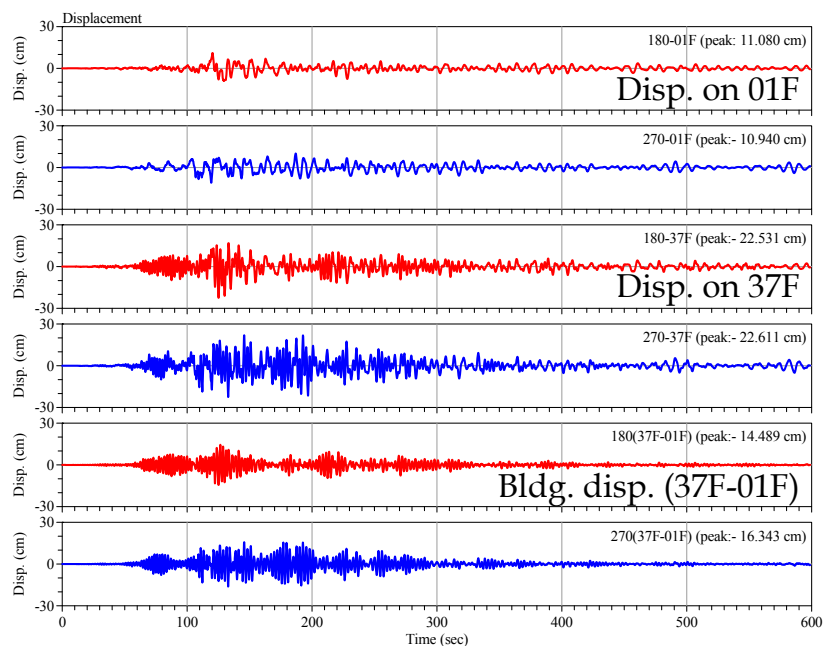
Code	Station	Δ (km)	I_{JMA}	Place	A_{max} (X)	A_{max} (Y)	A_{max} (Z)
CG2	Central Gov. Office Bldg. #2 (S/21F)	386	4.2	B4F*	75	71	49
				21F	121	131	104
YKH	Yokohama Gov. Office Bldg. (S/22F)	412	≥ 4.2	B2F*	60	-	30
				23F	162	-	72
OSK	Osaka Government Office Bldg. #3 (S/15F)	759	2.9	B3F*	11	9	15
				18F	65	38	7
SKS	Sakishima Office, Osaka Prefecture (S/52F)	770	3.0	01F*	35	33	80
				52F	127	88	13



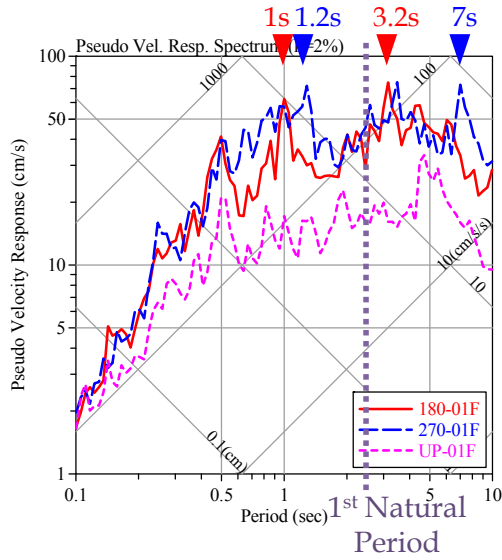
Strong motion data of BRI network Records at station TKD, Tokyo



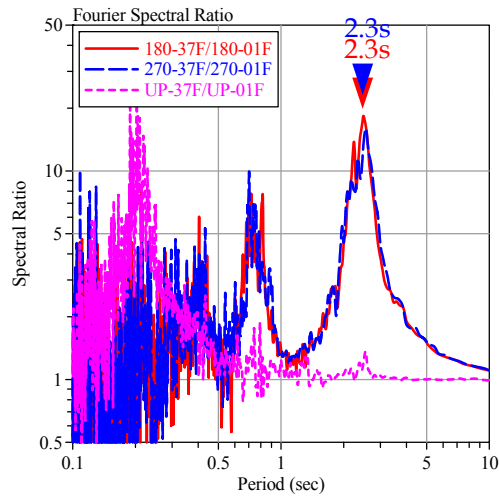
37-story RC bldg.



Strong motion data of BRI network pSv and Fsp ratio (TKD)



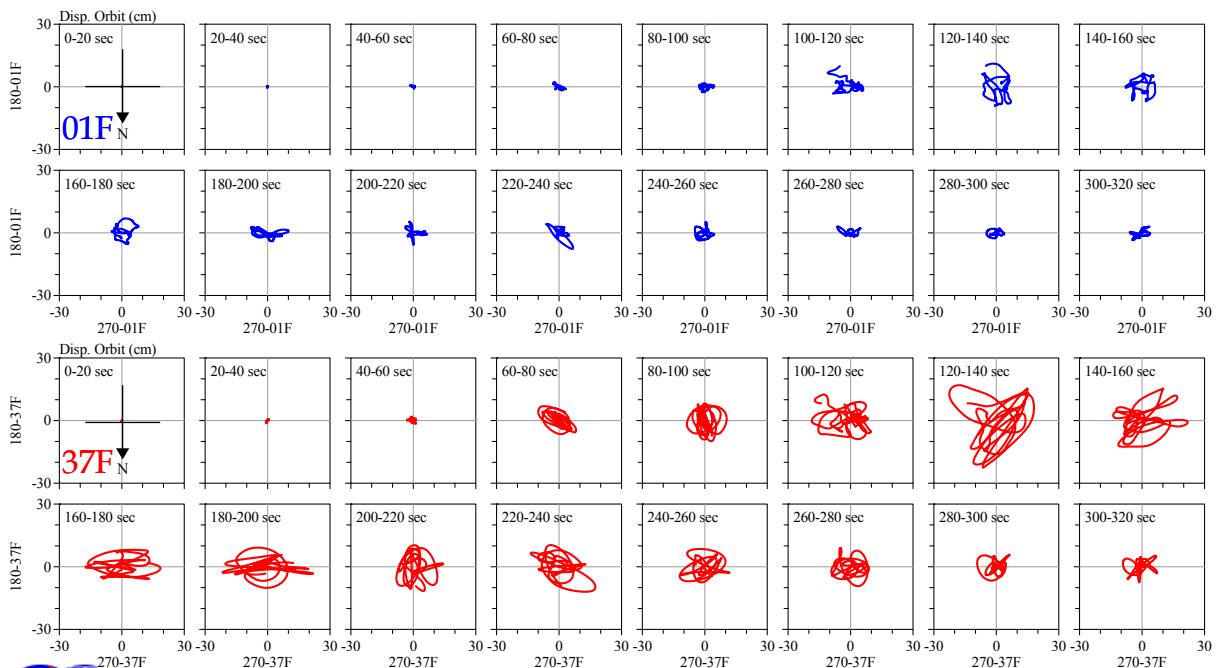
Pseudo velocity response Spectra
(01F, $h=2\%$)



Fourier amplitude ratios
(37F/01F)



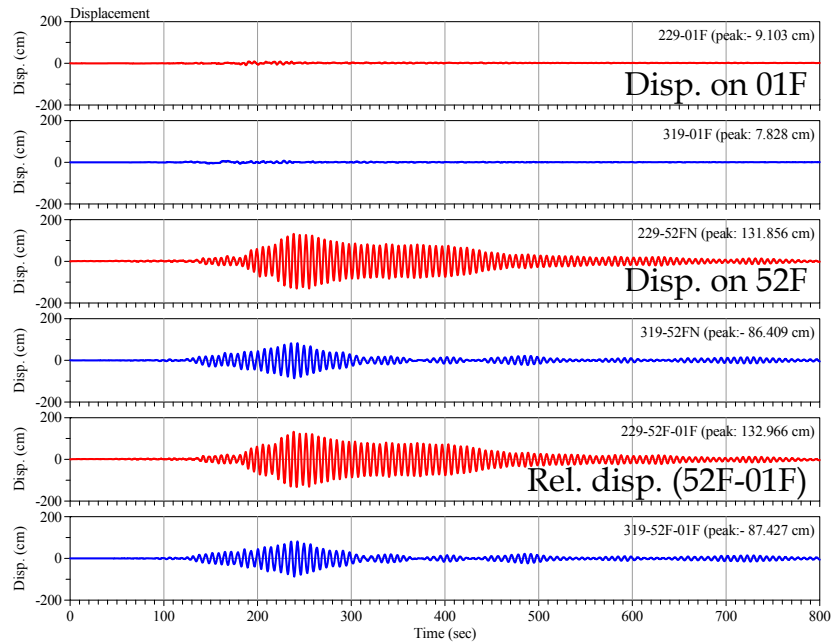
Strong motion data of BRI network Lissajous curves (TKD)



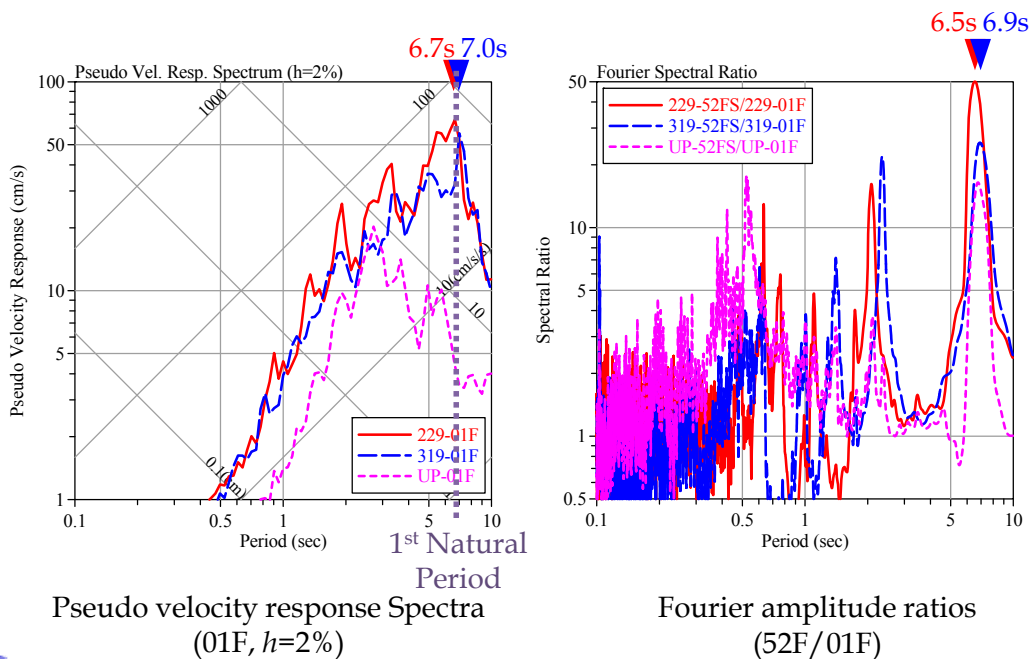
Strong motion data of BRI network Records at station SKS, Osaka



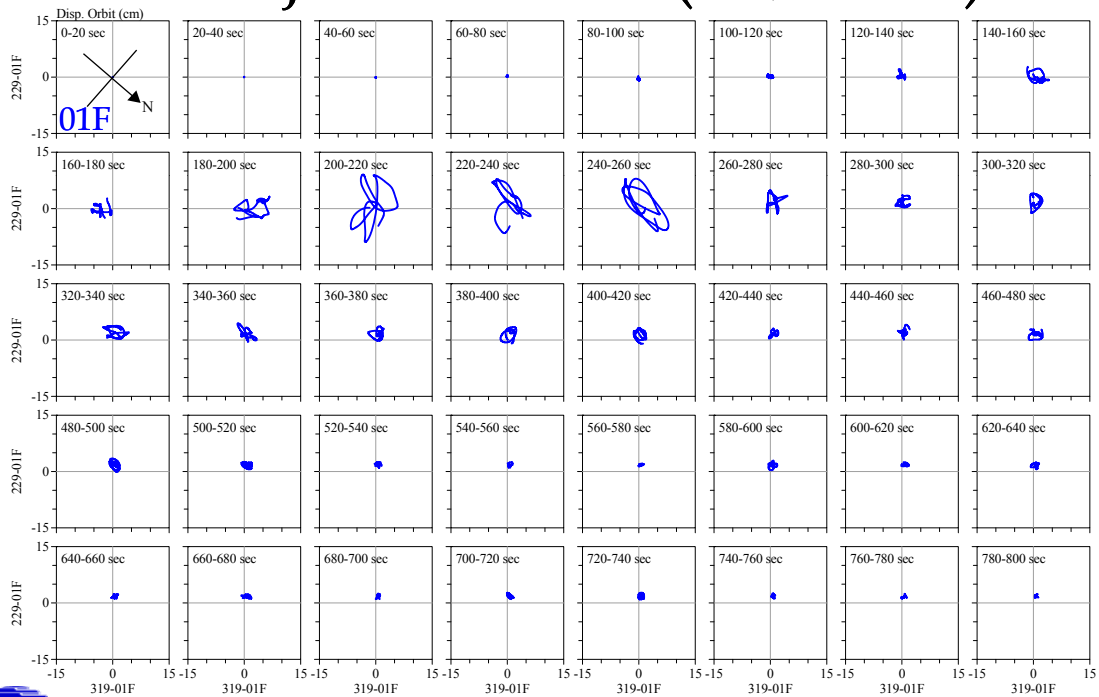
52-story Steel bldg.



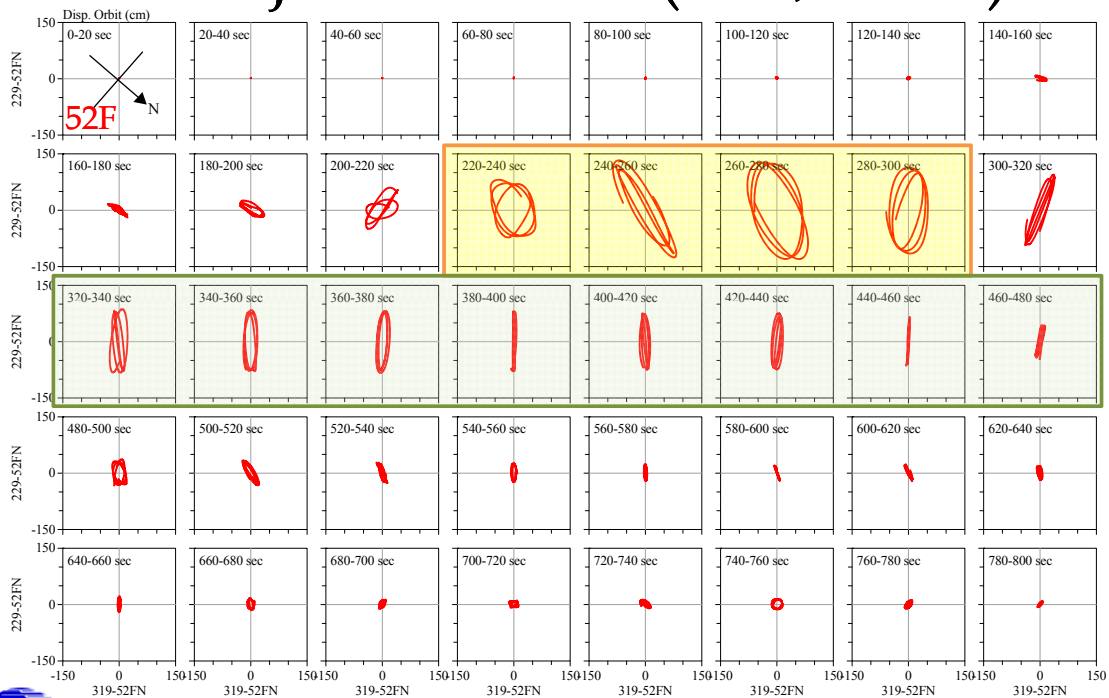
Strong motion data of BRI network pSv and Fsp ratio (SKS)



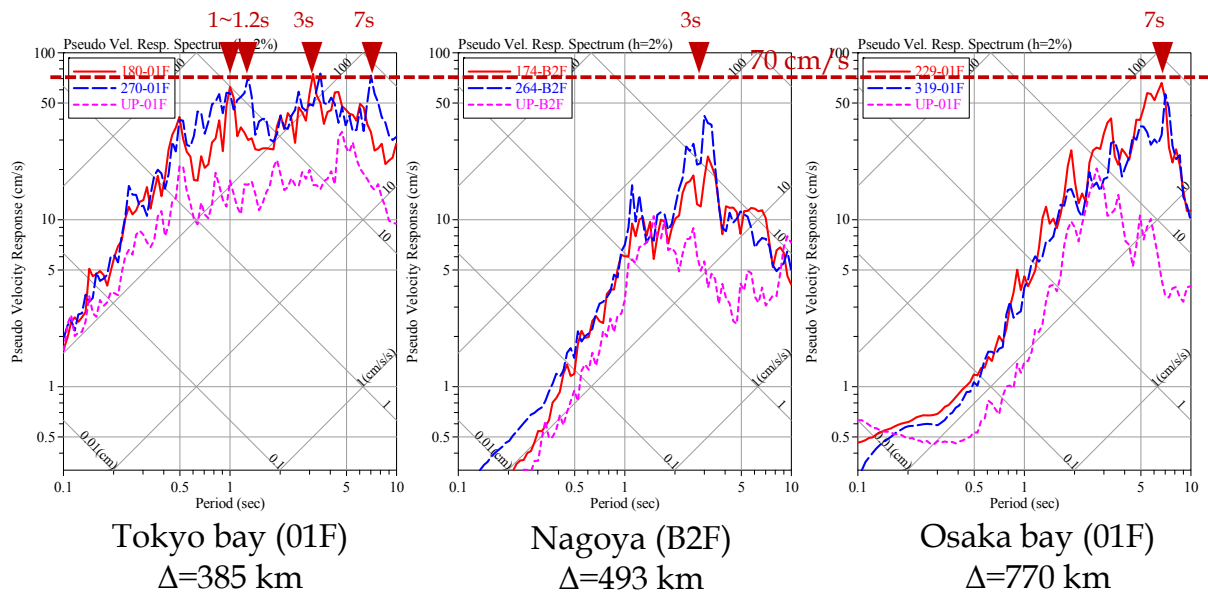
Strong motion data of BRI network Lissajous curves (1F, TKD)



Strong motion data of BRI network Lissajous curves (52F, TKD)

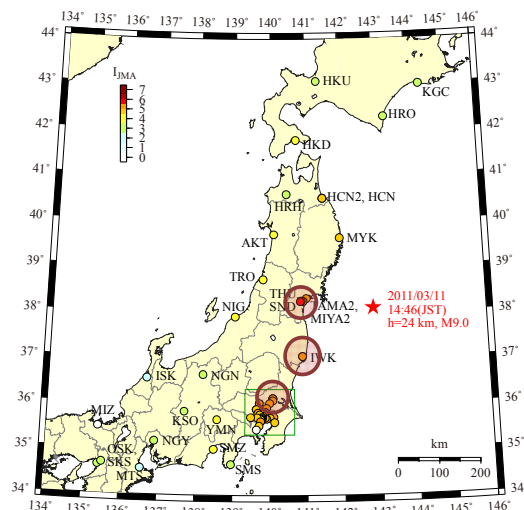


Strong motion data of BRI network pSv in Tokyo, Nagoya and Osaka



Strong motion data of BRI network Damaged buildings

- 1 seriously damaged SRC building
 - I_{JMA} 6- (Sendai)
- 3 slightly damaged SRC buildings
 - I_{JMA} 5+: (Iwaki and Tsukuba)



Strong motion data of BRI network Records in damaged buildings

Code	Station	Δ (km)	I_{JMA}	Place	A_{max} (X)	A_{max} (Y)	A_{max} (Z)
THU	Tohoku University (SRC/9F)	177	5.6	01F*	333	330	257
				09F	908	728	640
IWK	Iwaki City Hall (SRC/8F)	210	5.3	B1F*	175	176	147
				09F	579	449	260
ANX	BRI Annex Building (SRC/7F)	330	5.3	GL*	279	227	248
				B1F	194	191	136
				8F	597	505	344
	BRI Main Building (SRC/8F)			B1F	203	206	152
				8F	682	585	311

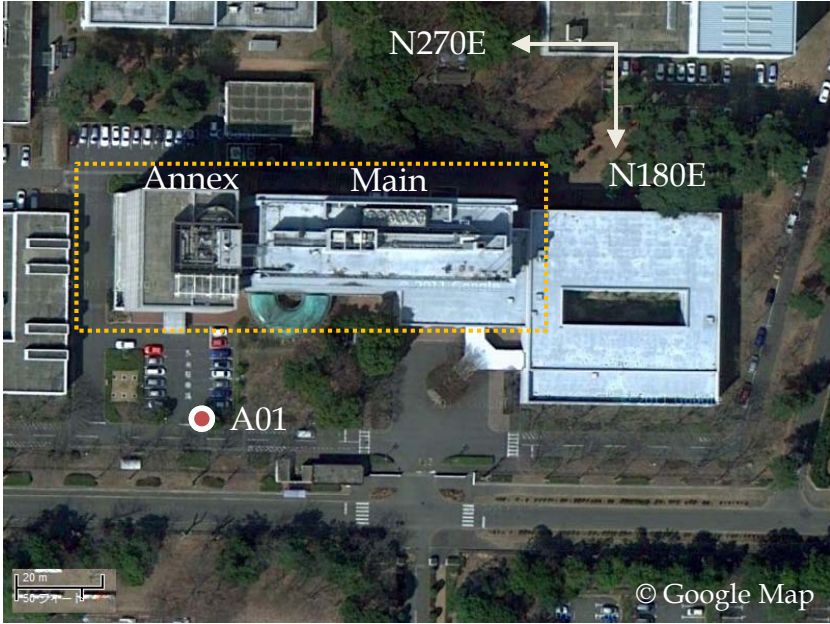


Strong motion data of BRI network ANX: BRI buildings

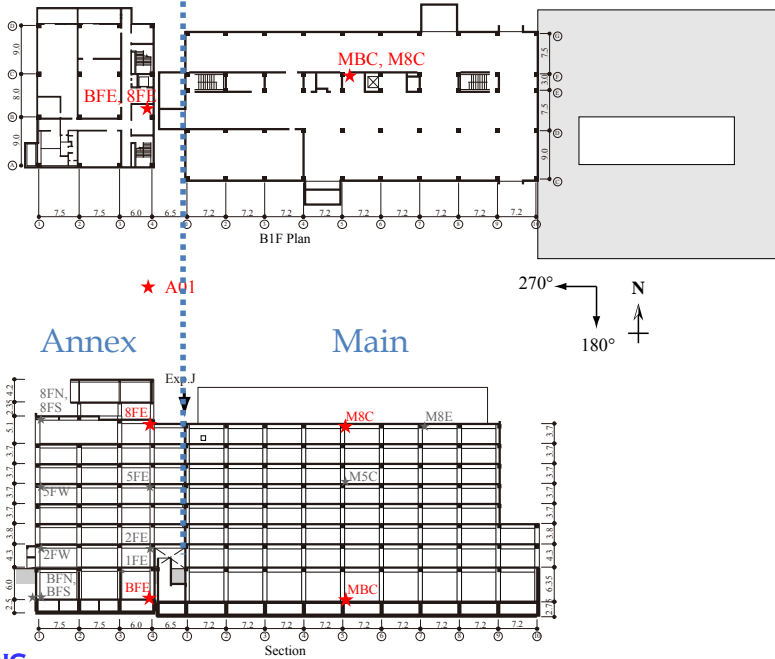
- 8- and 7-story SRC buildings (with B1F)
- 22 sensors in two buildings and ground



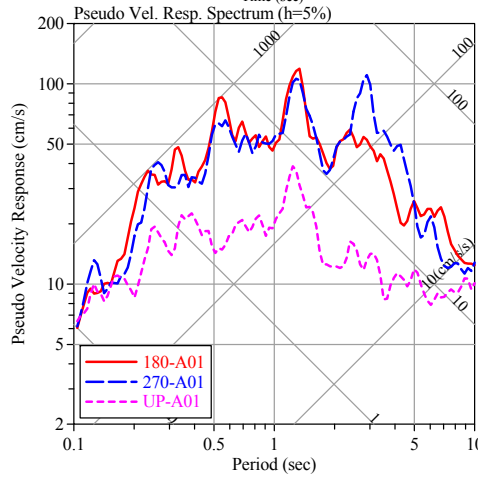
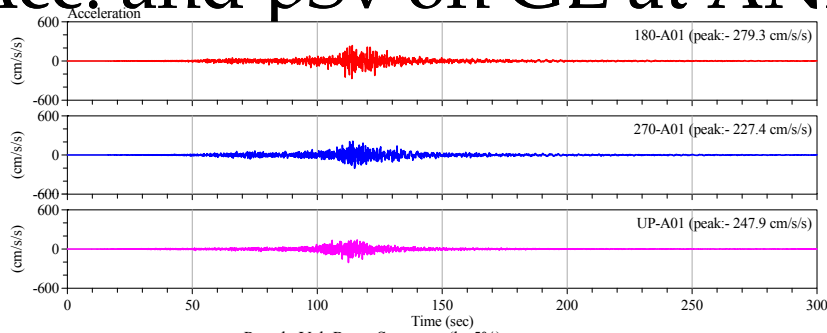
Strong motion data of BRI network Building layout at ANX



Strong motion data of BRI network Sensor configuration at ANX



Strong motion data of BRI network Acc. and pSv on GL at ANX

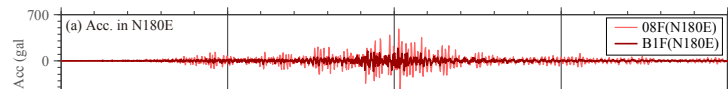


pSv on GL (h=5%)

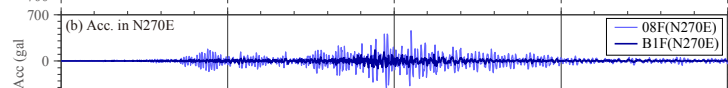


Strong motion data of BRI network Natural periods of annex bldg.

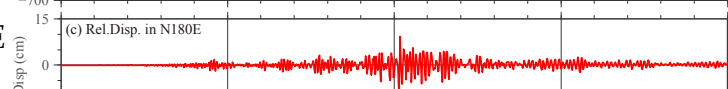
Acc. in N180E



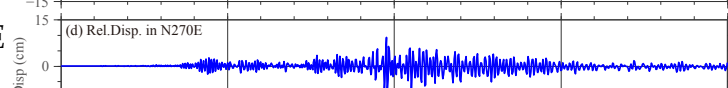
Acc. in N270E



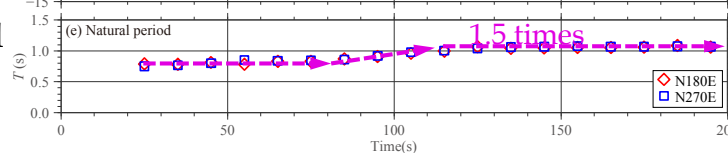
Disp. in N180E



Disp. in N270E



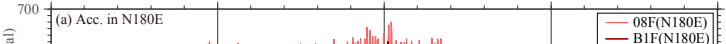
Natural period



Strong motion data of BRI network

Natural periods of main bldg.

Acc. in N180E



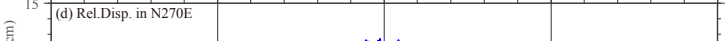
Acc. in N270E



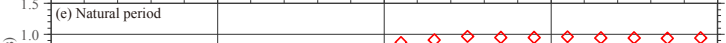
Disp. in N180E



Disp. in N270E



Natural period



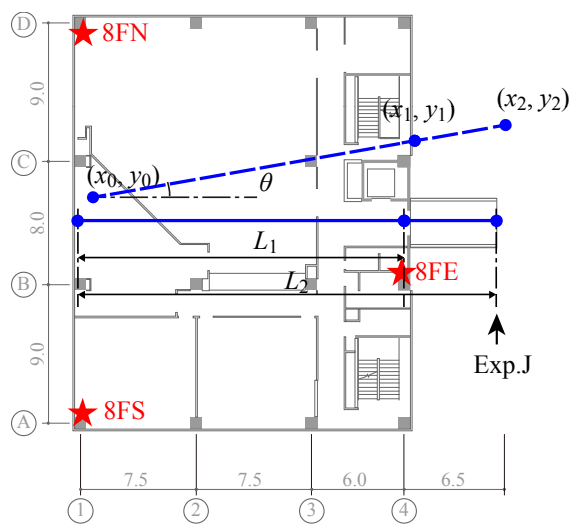
Strong motion data of BRI network

Damage to expansion joint at ANX



Strong motion data of BRI network

Calculation of exp.j. displacement



$$x_2 = x_0 + L_2 \cos \theta$$

$$y_2 = y_0 + L_2 \sin \theta$$

$$\cos \theta = \frac{(x_1 - x_0)}{L_1}$$

$$\sin \theta = \frac{(y_1 - y_0)}{L_1}$$

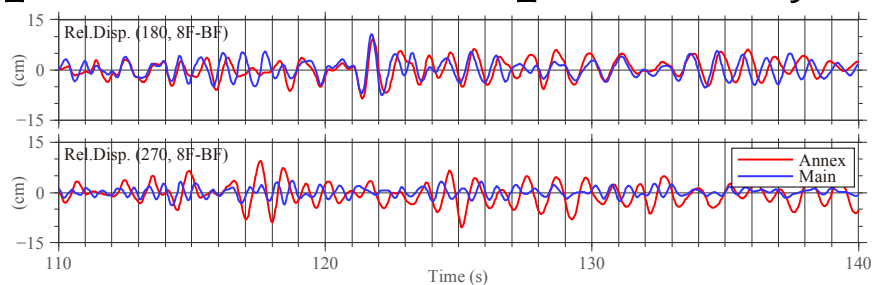
$$x_2 = x_0 + \frac{L_2}{L_1} (x_1 - x_0)$$

$$y_2 = y_0 + \frac{L_2}{L_1} (y_1 - y_0)$$

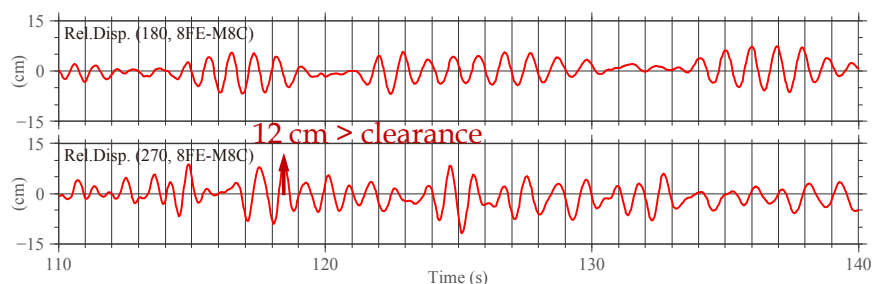


Strong motion data of BRI network

Displacement of expansion joint



Building displacement (8F-BF)



Displacement of expansion joint (8F)



Conclusions

- 61 (out of 79) stations from Hokkaido to Kansai were triggered
- 30 buildings in Tohoku and Kanto area were shaken by earthquake motions with JMA seismic intensity 5- (5 lower) or more
- Long-period motions with long durations and response of high-rise buildings were recorded in Tokyo and Osaka



Conclusions

- SKS building in Osaka bay area showed notable response as a result of resonance and long duration
- 4 buildings suffered damage which can be identified from strong motion data
 - One was serious and other were repairable
 - A collision between adjoining buildings at ANX



BRI Strong Motion Observation

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Related sites
 Building Research Institute (BRI)
 International Institute of Seismology and Earthquake Engineering (IISEE)
 Kashima's office
 ViewWave

Welcome
 Welcome to the Building Research Institute (BRI) strong motion observation web site. We have been conducting strong motion observations for building structures since 1957. Currently, we are operating more than seventy strong motion stations deploying in major cities throughout Japan. One third of the stations are placed in Tokyo metropolitan area and its outskirts. This web site provides recent strong motion data and information related to the strong motion observation.

The 2011 East Japan Earthquake
 Information on the 2011 East Japan (off the Pacific coast of Tohoku) Earthquake of March 11, 2011 (M_w=9.0, h=24 km)

Recent strong motion reports
 • Off Fukushima Pref. Earthquake of August 19, 2011 (M=6.5, h=51 km)
 • S Ibaraki Pref. Earthquake of July 15, 2011 (M=5.4, h=66 km)
 • Off Sanriku Earthquake of July 10, 2011 (M=7.3, h=34 km) [more](#)

Recent topics
 • Database is updated on March 2, 2012
 • Database is updated on February 23, 2012
 • Database is updated on February 17, 2012
 • Database is updated on February 13, 2012
 • Database is updated on January 31, 2012

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