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Strong Motion Recording for Buildings in Japan

Izuru Okawa[a), Toshihide Kashima[b), Kuniaki Yamagishi[c)
and Morimasa Watakabe[d)

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In the first phase of the strong motion recordings in buildings, the number of instruments (recording channels) was quite small. Most of the recording sites were equipped with single instrument on the basement or first floor. However, there were sometimes the cases in which a pair of instruments were found in the bottom and the top of the buildings. In this paper, the strong motion recording system for buildings in Japan was surveyed besides the BRI systems. The properties of those surveyed systems were summarized and the features of those currently on-going systems were reviewed with respect to the structural types, types of pile foundations, locations of recording instruments, etc. In addition, some features and problems were pointed out. This is a part of homework given during the second workshop, Tsukuba, Japan in 2001.

1. INTRODUCTION

The strong motion recordings in Japan started with instrumentation in the buildings about 50 years ago. Since then, strong motion seismometers have been installed in not only buildings but also various structural systems, such as bridges, dams, port harbor facilities, and even in the ground. In the beginning of instrumentation to buildings, it was common that the single instrument was installed on the first floor or basement. The locations of the strong motion accelerometers as of 1962 are shown in Fig.1. Subsequently, the appearance of super-high-rise buildings and base-isolated buildings temporarily increased the number of instrumentation each time. However, it was not followed by the wide spread of the strong

[a) Senior Research Fellow, Department of Structural Engineering, Building Research Institute, Tsukuba, Ibaraki
[b) Senior Research Engineer, International Institute of Seismology and Earthquake Engineering, Building Research Institute, Tsukuba, Ibaraki
[c) Senior Research Engineer, Technical Research Institute, Sumitomo-Mitsui Construction Co. Ltd., Tochigi
[d) Deputy Manager, Structure Division, Technical Research Institute, Toda Corporation, Tokyo

motion instrumentation. Since the structural damage during the period was very few, people regarded that the building system was quake-proof, even though properties of experienced ground motions were quite limited. In addition to this, there is an essential reason for instrumentation was not so spread. In Japan, the instrumentation had not been linked with the design or evaluation procedure of the seismic integrity of structures, or with a mechanism to enhance the incentives to promote the instrumentations. For these reasons, the instrumentation to buildings was not so big in number.

On the other hand, the earthquake recordings in and around ground have been increased after the Hyogo-ken Nambu earthquake in 1995. The National Research Institute of Earth Science and Disaster Prevention (NIED) had started to deploy a thousand strong motion seismometers nationwide called K-Net. The Japan Meteorological Agency (JMA) and the local governments had also installed seismic intensity seismometers. In addition, the NIED had enriched the earthquake observation instruments under ground.

The instrumentation for structures has been managed differently.

The earthquake observation for civil structures such as bridges, dams, port and harbor facilities, are maintained mainly by the public organizations. Therefore, the management of recording system and the dissemination of recorded data is not so difficult.

However, in the building engineering field, the situation is quite different.

Since building owners are mostly from private sectors, there is no incentives for them to install seismometers in their buildings. Even if the owner installed the instrument, there is no guarantee that the data will be brought to the public domain.

This paper summarizes the current situation of the strong motion recording systems of buildings in Japan. The strong motion recording system for buildings besides the BRI systems in Japan was surveyed. The properties of those surveyed systems were summarized and the features of those systems currently on-going were reviewed with respect to the structural types, types of pile foundations, locations of recording instruments, etc.

2. INSTRUMENTATION IN BUILDINGS

The strong motion recording of Japan started in 1953. The details can be found in the reference [1]. The first strong motion seismometer of Japan was installed in the Earthquake Research Institute, the University of Tokyo about 50 years ago. After that, many instruments were installed in various structures such as buildings, roadway bridges, dams, port and harbor facilities, etc.

The BRI played the leading role in developing the strong motion seismometers in Japan. Since then, the strong motion recordings in buildings have been continued for many purposes.

One is accumulating the strong motion records, the other is for verifying the analytical methods used in seismic design and the effectiveness of the methodology. In 1968, the super high-rise building was constructed for the first time in Japan. About twenty years later, the base isolation devices such as rubber bearing and dampers were installed in buildings in 1990's. It was soon followed by the appearance of buildings with high technology such as response control devices.

The 1995 Hyogo-ken Nambu earthquake prompted the adoption of base isolation system in the buildings.

In the building engineering field, the purposes of the instrumentations are for studies of the soil-structure interaction including the underground behavior of foundations especially piles and/or input mechanism from soil to building, for studies of new technologies such as the super high-rise buildings, the base isolation, and the response control. The instrumentation of BRI gave priority to the evaluation of effective input motion in SSI studies [2]. However, the general trend of the instrumentation actually lies in emphasis on the verification of the new technologies and the design method.

3. LITERATURE SURVEY RESULTS

The survey was conducted using the literature survey system of the web site of the Architectural Institute of Japan (AIJ). The relevant literature was picked up with a keyword of 'earthquake recording or observation' among the published technical abstracts for the latest 10 years.

There are many organizations that install seismometers in their own buildings and make analyses using them. Each instrumentation is designed for its own purposes. The data will not be generally disclosed. These situations had not been improved to date. For these reasons, the publicized data had not been increased so quickly, but the accumulation of data is one of the most important tasks in view of the performance-based design trend in the future.

The instrumentation examples are listed in Table 1 (1) through (8). Most of the sites are in the densely populated area such as Tokyo, Yokohama, Chiba, Nagoya, Osaka, and Kobe. The survey results tends to emphasize the research aspect of the instrumentation because the survey was conducted using the abstracts of AIJ annual meetings. Therefore those installed for verifying the design properties such as the cases of high-rise buildings and base-isolated buildings that are mandated to be designed with dynamic analyses using the time history might not be included in the literature.

The authors believe that although there are many instrumentation examples besides the survey results, most of the examples of engineering significance are included in this survey results.

3.1 STRUCTURAL TYPES OF INSTRUMENTED BUILDINGS

The structural types of objective superstructures are classified mainly into several groups, i.e., reinforced concrete, steel and steel reinforced concrete structures in materials, frame or wall system as in structural system. The foundation types are also classified into mat foundation, pile foundation and under-reamed pile etc. These are as shown among the items in Table 1. Most of the buildings are used for offices. The building for personal use such as private housing was not found. Especially, the Japanese traditional wooden houses have never been instrumented and therefore there are no data on their behavior during earthquakes to date. It might be one of the big problems in that the major building type in Japan has never been instrumented and we do not have data of its behavior during earthquakes.

Buildings with base isolation devices are only exception for the instrumented housing.

The other types found in the instrumented buildings are those with response control devices, tall buildings, those densely instrumented for identifying the Soil-Structure Interaction effect in soft soil area.

3.2 DIMENSIONS OF THE INSTRUMENTED BUILDINGS

The number of stories and height of instrumented buildings vary. These are also shown in Table 1. The instrumented tall buildings took measures not only for earthquake but also wind. The highest instrumented building has 70 stories located in Yokohama city.

3.3 INSTRUMENTATION OF THE BUILDINGS

The instrumentation details are determined by the recording purpose. The purpose of the instrumentation for buildings with new technologies are mainly to verify the effectiveness of the newly developed devices. The layout of the instrumentation for the input mechanism in soil, foundation, and basement is rather complicated and generally densely installed. The instrumentation for spatial variation of input ground motion was found along the long layout plan. From the literature survey of the current instrumentation examples in Japan, we ca summarize the survey results as follows.

(1) Earthquake recording for base-isolated building has increased.

(2) Activities are high in lager cities.

(3) Few examples are found on the dense array recordings in a building.

(4) Wind is a main target for super high-rise building at present.

(5) Major records have not been obtained to date.

(6) Buildings of specific type (wooden) cannot be found.

4. CONCLUSIONS

When we focus our attention on the strong motion property variations within the local area or even around one construction site, the nationwide network does not necessarily give sufficient data for evaluating local site effect or effective input motions for specific building structures. The instrumentation density is still quite sparse except for specific large cities. However, it is not easy to increase the number of instrumentations only by appealing the necessity of the earthquake data for buildings. There should be incentives for promoting the instrumentations in buildings.

Meanwhile, the Building Standard Law of Japan has been recently revised in accordance with the performance-based-design oriented scheme. In the scheme, the structural designer is requested to quantitatively evaluate the structural performances for various types of external disturbances including earthquake motions. The developments of detailed evaluation techniques for structural performance should be done and it will become one of the most important tasks of the BRI. We need firstly to show that the earthquake recording gives a reliable tool for evaluating the seismic performance of buildings. The earthquake recording is generally still costly. If earthquake recording is to be utilized for detecting the vibration characteristics of building as one of the crucial performance indices, a cost reduction of instrumentation will be secondly an important issue for wide use. When such situation is realized, more dense locations of instrumentation sites will be possible.

The result shows the current status of the respective recording systems. That does not necessarily means the obtained data will be released to the open public. We need both to increase the instrumentation sites and to disseminate the recorded data

5. REFERENCES

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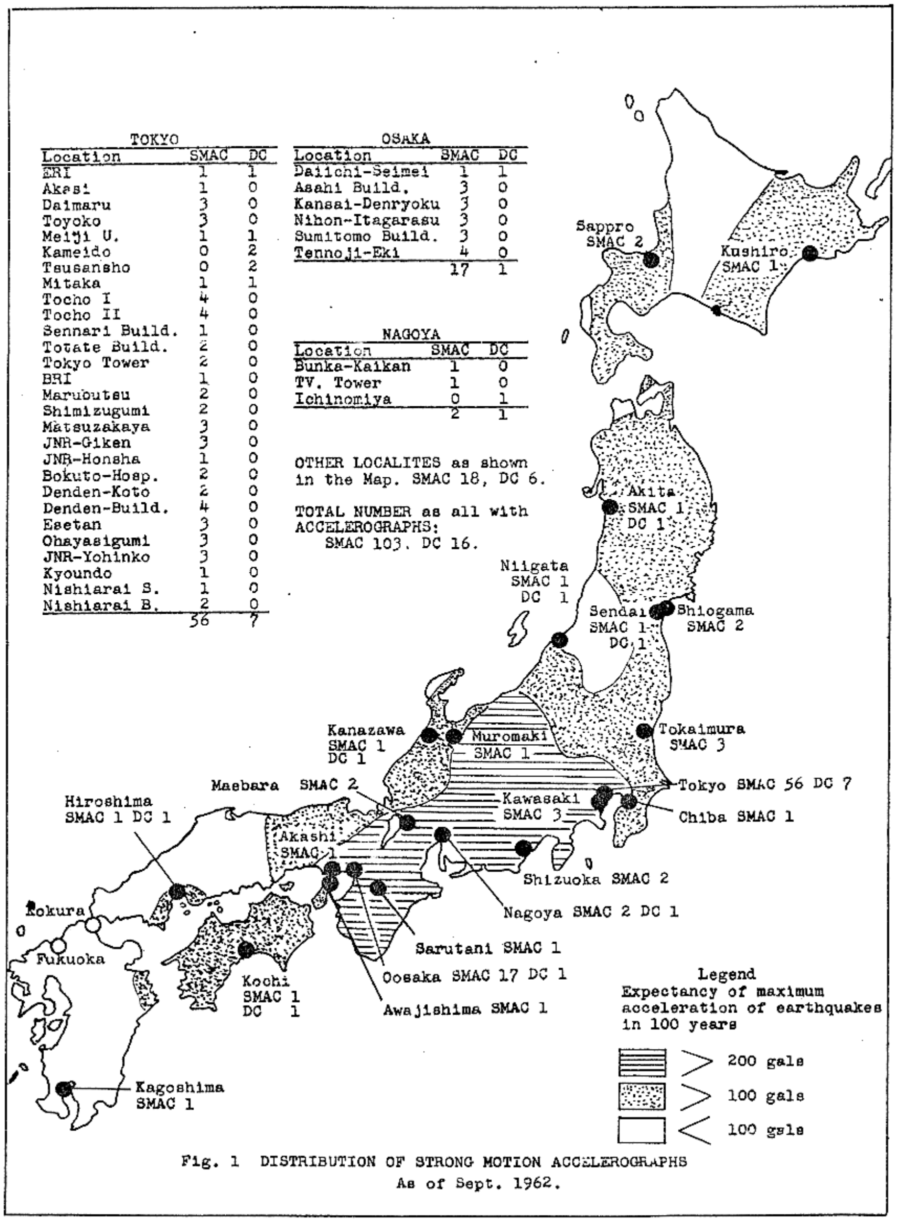

TOKYO

Location	SMAC	DC
ERI	1	1
Akasi	1	0
Daimaru	3	0
Toyoko	3	0
Meiji U.	1	1
Kameido	0	2
Tsusansho	0	2
Mitaka	1	1
Tocho I	4	0
Tocho II	4	0
Sennari Build.	1	0
Totate Build.	2	0
Tokyo Tower	2	0
BRI	1	0
Marubutsu	2	0
Shimizugumi	2	0
Matsuzakaya	3	0
JNR-Giken	3	0
JNR-Honsha	1	0
Bokuto-Hosp.	2	0
Denden-Koto	2	0
Denden-Build.	4	0
Esetan	3	0
Ohayasigumi	3	0
JNR-Yohinko	3	0
Kyoundo	1	0
Nishiarai S.	1	0
Nishiarai B.	2	0
	56	7

OSAKA

Location	SMAC	DC
Daiichi-Seimei	1	1
Asahi Build.	3	0
Kansai-Denryoku	3	0
Nihon-Itagarasu	3	0
Sumitomo Build.	3	0
Tennoji-Eki	4	0
	17	1

NAGOYA

Location	SMAC	DC
Bunka-Kaikan	1	0
TV. Tower	1	0
Ichinomiya	0	1
	2	1

Figure 1 Strong Motion Observation Sites as of 1962

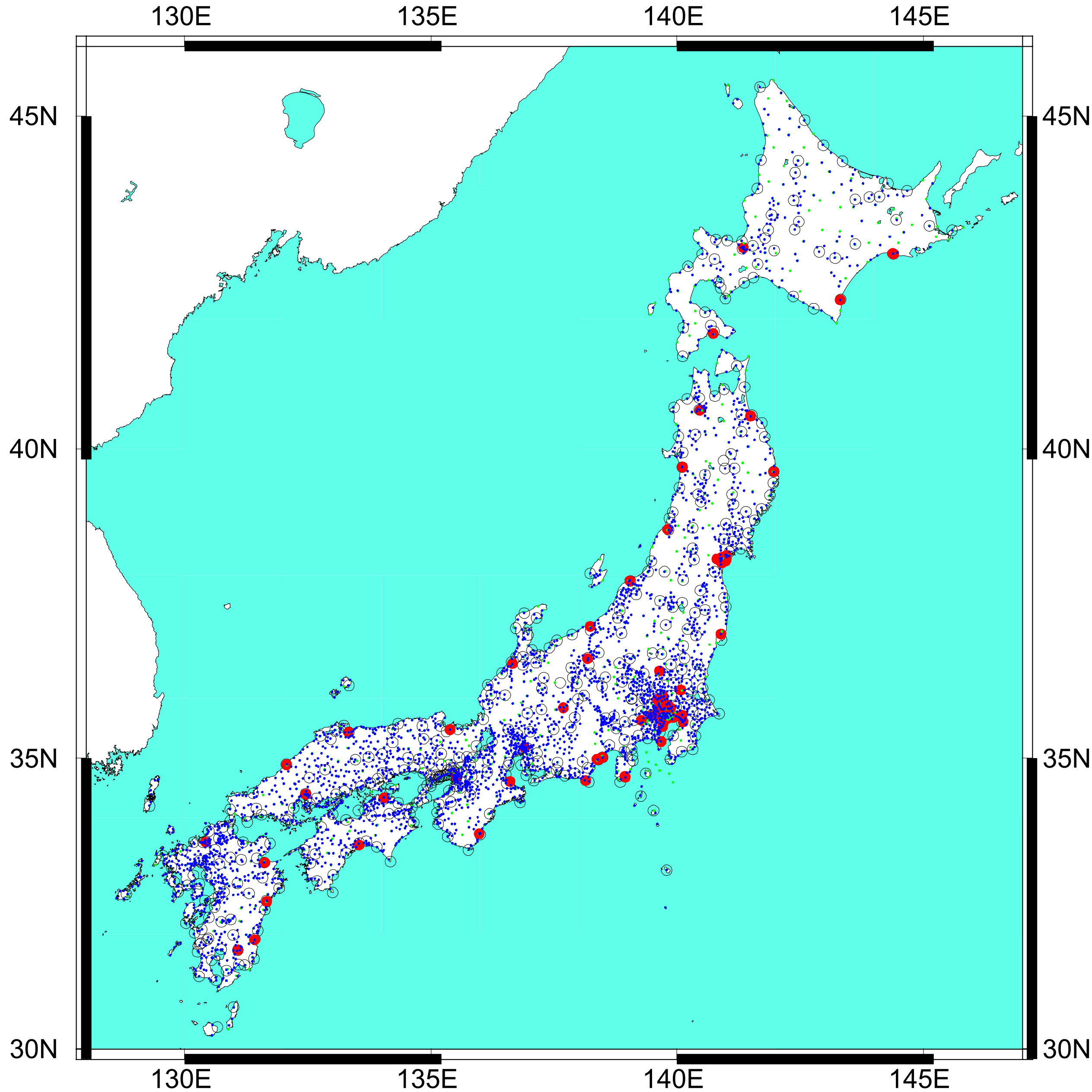

Figure.2 Strong Motion Observation Sites of K-Net and JMA. The red solid circles show sites of BRI with instrumentation in Buildings.

Table 1 The Strong Motion Recording Sites in this Study (1)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
1	7	0	PC panels	19.8	Prestressed	12	Chiba pref.	RF, 1F GL-4m -12m -24m			fb≒fg	SSI
2	11	0	SRC	30.95	Benoto	22	Tokyo	12F, 1F Pile GL-13m -26m GL-13m	GL-2m -13m GL-2m -5.5m -9m -13m -26m -100m	EPM 2 WPM 2	fb > fg	SSI
3	5	0	S	151	cast in place	18	Fukuoka	P2(1),P2(2), 1F(2) velocity meters	-	-	fb>fg	TMD
4	4	0	S	125.2	steel pipe	-	Chiba pref.	P2(2), 1F(2) accelerometer	-	-	fb>fg	TMD
5	8	6	SRC	40.6	-	16.5	Fukushima pref.	8,4,1F	GL-1.5,5.8,16.5m		Tg=0.15,0.16,0.44,0.57 Tb=0.51,0.48	SSI
6	10	0	SRC	33	RC cast in place	26	Tokyo	PH(11F), 1F, GL-8, 14, 26m	GL-8,26,70m	EPM 4, steel bar (pile)6	fb=1.5 Tb=0.7s	Earth pressure in pile cap
7	12	1	S	46.6	RC cast in place	34.9	Yokohama	RF,7F,B1F	GL-2,6,20,40m	GL-2,6,20,40m	Micr:Tb=1.19,1.11 Earthw:Tb=1.26,1.32 Tg=0.93,0.85 SSI:Tb=1.3,1.38	
8	5	1	RC	25	Earth Drill		Saitama	RF,1F GL-4,7,10,15,23,31ｍ(pile)	GL,interm. Sandy layer, base layer	WPM 7, PSM 4	Tg=0.93,0.85s Tb=1.26,1.32 s	
9	25	3	S	95	Diaphragm wall	32	Tokyo	25F,3F,B3F	GL-25m	Column axial force meter		
10	3	-	RC	10.83	-	-	Kanagawa	IP, 1F,3F IP,1F	GL-1,-30m	12locs., 23chs.(acc.) 3locs., 4chs.(dis.) 2locs., 6chs.(acc.)		Base isolation
11	10	-	RC	29.5	RC cast in place	30	Saitama	Foundation,1F,5F,10F	GL, GL-30m	16chs.(acc.)		Base isolation
12	28	0	SRC	80.3	Under-reamed pile	60	Tokyo	1F,15F,28F	GL-1,-30,-60m	6locs., 14chs.(acc.) 3locs., 9chs.(acc.)		L-shaped building on soft soil
13	11	0	S+ PC panel	29.6			Chiba pref.	1F,6F,11F	GL-1,12,30m	11locs.,14chs.(acc.) 5locs.,10chs.(acc.)		torsion
14	4	0	RC	16	-		Saitama	1F,RF	Ground surface	6locs., 8chs. 1loc., 2chs.		Spatial variation
15	5	0	RC	27.75	mat foundation	-	Sendai, Miyagi pref.	roof,foundation,3F,1F	GL±0m			Comparative recording of base isolated and non-base-isolated bldgs
16	25		SRC	76.85	RC cast in place	32	Osaka	25F,14F,B1F	GL-1m,-25m,-40m (pile)	-	-	input loss

Table 1 The Strong Motion Recording Sites in this Study (2)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
17	8	6	-	40.16	Diaphragm wall	-	Tokyo	PH2F 1F B3F B6F	GL-1.5m, -12.9m, -25.9m, -26.2m, -42m -142m	acc. 1loc. Vel. 11locs. EPM 12locs. WPM 8locs.	-	SSI
18	21	0	RC	61.85	RC piles	51	Misato, Saitama Pref.	RF, 15F, 8F, 1F GL-4.6m(in pile)	GL-1m, -11m, -29m, -45m, -67m	Acc. 10locs. Vel. 2locs. WPM 1loc. SM 14locs.	Tb=0.93sX Tb=0.97sY	Pile-supported Tall building on soft soil
19	31	6	S, SRC, RC	114.97	mat foundation	-	Tokyo	29F, 22F, 16F, 8F, 1F, B6F	-	-	fb=0.38HzX fb=0.36HzY	
20	2	0	RC	6.1	cast in place	13.3	Tokyo	RF, 1F, Basement	GL-18m -50m	Acc. 12locs.	-	Base isolation
21	3	0	RC	9.25	-	-	Kanagawa	RF, 1F, Basement	GL-58m	Acc. 4locs.	Tb=0.72s Tb=0.77s	Base isolation
22	3	0	RC	8.38	-	-	Tokyo	3F, 1F, Basement	GL-2m	-	fg=3 ~ 4Hz	Site effect regarding topography
23	2	0	RC	6.95	mat foundation	-	Ichikawa, Chiba pref.	RF, 1F, Basement	GL-5m -55m	Acc. 10locs. Dis. 4locs. WPM 2locs.	Tb=3.02 for only RB Tb=1.58 for RB+Damper Tb=0.56 for Lead add	Base isolation
24	2	-	RC	7	-	-	Kanto area	ＲＦ, 1Ｆ, ＭＦ	GL-1m -20m	none	-	Base isolation
25	4	-	RC	11.9	mat foundation	2.5	Kanagawa	ＲＦ, 1Ｆ, ＭＦ	GL-4.6m -8.8m -32.1m	-	0.62sec (microtremor)	Base isolation
26	10	-	RC	29.5	RC cast in place	25.5	Saitama	10F,5F,1F,IP,GL-30m	GL	-	Tg=0.6	Base isolation
27	12	2	RC	43.1	RC cast in place	6.55	Tokyo	11F,6F,1F,IP		-	Tg=0.6	Base isolation
28	11	2		58			Tokyo	RF,12F,6F,B1F		-	Ts=1.7	response contro;
29	3	2	S	12			Tokyo	RF,3F,2F,1F		-	-	response contro;
30	31	6	S	123.45	mat foundation	30.2	Tokyo	29F,22F,16F,8F,1F,B6F		-	-	Tall building
31	41	1	RC	129.83	Diaphragm wall, pile	35	Osaka	41F,30F,20F,1,B1F	160m apart from the building GL 8.5m, 35m, 70m	-	fs=0.55,0.56	Tall building
32	12	1		64.2	pile GL-32	32	Kobe	11F, 5F, B1F	GL-40, GL-25, GL-3	GL-32 GL-15.5	Tb=1.1s	SSI of Pile-supported building
33	36	1	S	150	Steel pipe pile GL-42	42	Tokyo coastal zone	36F, 19 F , B1F	GL-42, GL-32, GL-13, GL-1		Fb=0.3Hz Fg=1.1Hz	SSI of pile-supprted building

Table 1 The Strong Motion Recording Sites in this Study (3)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
34	55	5	S	216	mat foundation		Tokyo	54F, 28F, 1F, B4F(S), B4F(N)			N:Tb=0.27 ~ 0.29 S:Tb=0.53 ~ 0.54	SSI
35	38	4	S	123	mat foundation		Tokyo	37F, 7F, B4F			N:Tb=0.27 ~ 0.29 S:Tb=0.53 ~ 0.54	SSI
36	25	3	S		Diaphragm wall GL-34	34	Tokyo	25F B3F		Column axial force etc.	Tb=2.34sX Tb=2.21sY	SSI
37	20	3	S	82.5	mat foundation	18	Tokyo	17F, 9F, B3F				Damping, Natural period
38	31	4	S	136.55	Pile	50	Tokyo	RF, 13F, 1F				Damping, Natural period
39	24	2	S	97.7	Pile GL-39		Tokyo	RF, 12F, 1F, B2F	GL-1, -20, -45m			SSI
40	12	1	S	46.6	Pile GL-39		Yokohama	RF, 7F, B1F	GL-40, GL-20m		Fb=0.71Hz Fb=0.74H z	SSI
41	4	0	RC	18.3			Ibaraki	4F(RF), 1F, B1F	GL-1m, -4m ，-26m		fb=1.625Hz	Base isolation
42	50	-	S	200				PH1F, 36F, 29F, 12F, 1F, B3F	GL-55m		fb=0.263Hz	Response control
43	21	5	S	130			Tokyo	21F, 16F, 10F, 6F, 1F, B5F			Fbx=0.338Hz Fby=0.337Hz	HMD
44	9	-	SRC	30.65	RC cast in place		Tokyo	9F,4F,1F			Fbx=1.228Hz	Response control
45	26	3		106.35			Tokyo				Fbx=0.50Hz Fby=0.48Hz	Response control
46	31	5	S	106.35	Mat foundation		Tokyo	P1F, 31F, B5F			Fb=0.35Hz	
47	4	0	RC	16	-		Saitama	RF(3), 1F(3), GL(1)	GL-15m (3点)			Torsional vibration
48	4	0	S	29.5	-		Osaka	RF, 3F, 1F	GL		Fb=1.67Hz	Large-scale building
49	-	-	RC	206.5	-		Osaka	GL+193.5m, GL+131m GL+65m			Fb=0.53Hz	Large-scale building
50	30	6	S	123.45	mat foundation		Tokyo	28F, 22F, 15F, 8F, B6F			fb>fg	Torsional vibration
51	29	3	S	145.45			Osaka	25F, B1F				Response control
52	8	3	SRC		PortIsland , mat foundation GL-18m		Kobe	8F, B3F				
53	12	1	SRC	56.8	Steel pipe	30	Kobe	11F、5F、BF pilr:GL-15.5m, GL-32m	30m apart from building GL-3m、-25m、-40m		Tb:1 sec.	

Table 1 The Strong Motion Recording Sites in this Study (4)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
54	36	0	Column:SRC、Beam, girder:S	103.3	Benoto	23	Osaka	RF, RFW, 24F, 13F, 1F	GL-46.5m		fb<fg	
55	5	1	RC	21.9	Earth Drill	32	Omiya, Saitama	RF、B1F pile:GL-10m、31m	GL-1.0m, -10m, -33m	SM 8locs. (with 2 piles)	fb>fg	
56	31	1	RC	92.5	RC cast in place	22.75	Osaka	31F、16F、1F pile tip:GL-30m	GL-1.0m		fb<fg	
57	17	2	Column:SRC、Beam, girder:S	74.27	RC cast in place supprted at GL-63m		Osaka	RF B2 Pile tip	-	-	Tb=1.5~2sec	Pile-supproted tall building
58	41	1	RC	129.83	diaphragm wall ℓ=24.2m (embeddment 8.3m)		Osaka	41F, 30F, 20F, 1F, B1F	GL-8.5m GL-35m GL-70m	-	NS Tb=1.79sec EW Tb=1.81sec from manpower forced vibration	CFT tall building (40 stories)
59	55	5	S	216	Mat foundation		Shinjuku, Tokyo	54F, 41F, 28F, 15F, 1F, B4F(3)	-	-	X:Tb=4.97s Y:Tb=6.0s Z:Tb=0.53s	Tall building
60	17	2	S	76.5	RC cast in place		Osaka	RF 1F	-	-	Tb=1.9 ~ 2.2sec	Tall Steel structure
61	3	-	RC, S, Base-isolation		mat foundation	2.8	Kobe	RF, 1F, Basement, RF	GL-1.5m(in fill) GL-15m(in rock)	-	fb<fg Tb=1.2sec, 1.4sec Tg=0.19sec	Base isolation
62	16		SRC	65.65	Under-reamed pile	25.5	Osaka	RF, 1F, Pile:GL-14.5m Pile-25.5m	GL-1.5m GL-25m	GL-14.5m, GL-25.5m	Tb:0.95~1.2sec, Tb=1.05 ~ 1.3sec	SSI
63	12	2	RC	43.1	RC cast in place		Tokyo	11F, 6F, 1F, BF	-	-		Base isolation
64	5		RC		Mat foundation		Tochigi	Non-iso.: RF Iso.: RF, 1F, Basement	-	-		Base isolation
65	52		S	226.5			Tokyo	52F,39F,30F,20F 10F,1F,B5F				Response control
66	43	2	S	154.3			Miyazaki pref.	42F,30F,B1F				HMD, TMD
67	4					6	Nagoya	1F, RF	GL-1m			
68	6					12	Nagoya	1F, RF	GL-1m			
69	10					48	Nagoya	1F, 6F, RF	GL-1m,10m,57m			
70	25	1	SRC	77.25	not available	29	Hyogo	25F，1F	-	pile GL-15m， pile GL-29m	fb=1.2s, 1.4s	-
71	8	3	SRC	44	Raft foundation	18	Kobe	8F,B3F				Stractural response, Damage
72	-	7	-	-	Diaphragm wall	41	Tokyo	1F,B3F，B7F Accelerometer	GL-1.5m,-3.04m, -17.09m,35.52m, -40.0m,-40.49m Acc.	GL-4.9m,-14.5m, -24.1m,-31.6m,-41.0m EPM	fg=0.5s	Deep embedment

Table 1 The Strong Motion Recording Sites in this Study (5)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
73	16	0	SRC	65.65	RC cast in place	20.3	Osaka	RF, 1F, pile:(-14.5m), Pile tip(-25.5m)	GL-1.5m、-25m		Tb=1.2 Tg=0.75	SSI for pile foundation
74	29	2	S SRC RC	120	Earth Drill cast in place	16	Setagaya, Tokyo	26F(3), 1F Pile tip(2), Pile cap(4)		EPM: 4 for pile、7 for diaphragm wall steel bar strain: 13 for pile	Fb=0.3, 1.0Hz	SSI for pile foundation of large-scale building
75	25	3	SRC	82	-		Kobe	24F(NS), 5F(N), 1F(NS)			Tb=2.0 Tg=0.8(1F)	High-SRC building
76	70	3	S+SRC+RC	296	Mat foundation	24	Yokohama	PH1(2), 50F, 30F, 1F, B3F	GL-100m, GL-200m	Anemometer, Anemoscope, wind pressure: 20 for 51F, 1 for 17F,1 for 67F	Fb(VER)1:0.576s, 2:0.40s, 3:0.22s (FFT,RD) 1:5.24s, 2:2.18s, 3:1.20s	Seismic and wind design for tall building
77	20 17	3 2	SRC(underground)S (superstructure)		Mat foundation		Tokyo, Osaka	17,9F,B3F/RF,2F,B2F Pile, B2F, Roof				
78	3	0	S	9.025	-		Tokyo	RF,3F,2F,1F,B1,GL				Comparative observation
79	3	0	RC		Mat foundation		Kashiwa, Chiba pref.	Iso.: B1,1F,RF Non-iso.: 1F,RF			with iso. : fb=1.7, without iso. fb=4.0	Comparative observation
80	3		RC	9.3	Raft foundation	6.1	Musashino, Tokyo	1F,RF BF(relative disp. For isolation story) , 1F,RF			Fb=0.94s	Comparative observation
81	36	2	S	144			Fukuoka pref.	36F,1F			Ts=3.17	TMD for wind force
82	18	3	S	75.8	Mat foundation (partly supported by pile)		Tokyo	16F, 9F, 1F, B3F	GL-1.90, -34.45m		A:X1:2.07s, A:Y1:2.00s D:X1:1.98s D:Y1:1.98s Tb=1.52s	SSI
83	-	-	RC	193.5		70		193.5, 131., 65., 0.0	GL-1 GL-70	3*2 1*3 1*1 2*3		RC chimney vibration
84	10	-	SRC		Pile 45m	45	Nagoya	pile - 10th floor	GL-1m	6locs.		
85	33	2	RC	100	Cast in place : 20 PHC:65		Tokyo	B1F, 17F, 33F Pile	GL-0 ~ 30m			
86	28	-	RC	88.05	Under-reamed pile, diaphragm wall	50	Chiba pref.	1F(2), 10F, 28F, Pile tip(GL-50m)			Microtremor: 1.36(EW), 1.36(NS)	
87	29	6					Tokyo	Mat foundation	B6F, 1F, 8F, 16F, 22F, 28F	GL-100m	Micro Eq.: 2.5(EW) 2.7(NS)	

Table 1 The Strong Motion Recording Sites in this Study (6)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
88	-	-	5×5×1m 3×3×1.4m 2×2×1.2m		Steel pile pile	26	Funabashi, Chiba pref.	Basement, ＧＬ, -3.6m, -6.4m, -10.3m, -25m	GL, -1.8m, -6.8m, -10.3m	Pile	Coupled period (soil-pile):0.15sec	Evaluation of soil spring around pile
89	16	3	?	59.8	not available		Kyoto	Roof, 1F, 2F	GL±0m,-30m			Long spanned frame building
90	4	0	RC	19.2	Mat foundation		-	4F(UD):2 4F(FAF:UD):1 1F,B1				Base isolation
91	7 5	0 0	RC	19.55 14.1	PC pile		Osaka	Iso.:Roof girder,1F,B1 Non-iso.:roof girder	GL GL-30m			Comparative observation
92	3	1	RC	11.8	mat foundation		Kyoto	RF,2F,B1F、 B1	GL-17m GL-26m			Base isolation
93	39	6	S	154			Chiba pref.	39F,B6F 30F,17F,10F			F1=0.34 F1=0.40	APMD
94	10	0	SRC	48.8	RC cast in place	58	Nagoya	RF,6F,1F	GL-1m,-10m, -57m		f1=1.7-1.9(NS) f1=1.8-2.1(EW)	SSI
95	50	2	CFT+SC SRC	158.68	diaphragm wall reverse pile Earth drill pile	19	Water-front, Tokyo	RF, 25F, B2F Pile:GL-25m GL-32m	GL-1m -32m	Acc. 15, Strain 4	Tb=3.62s Tg=0.32sX Tg=0.44sY	SSI
96	6		SRC		pile foundation	10	Nagoya	1F, 6F-ceiling	GL			Cross-SSI
97	3		RC		pile foundation	12	Nagoya	1F, 3F-ceiling	GL			
98	5	1	S	36.65	steel pipe pile	70	Water-front, Tokyo	RF, 3F, 1F, B1F Pile:GL-9.58m -20.00m -40.03m -73.38m	GL-147.24m 240m apart freefield:GL-1.00m -12.90m -53.60m	Acc.:17	fb=2.09HzX fb=1.92HzY	Evaluation of soil spring around pile group, Turbine building of thermal plant
99	9	0	RC	27.59	cast in place	13.5	Tokyo	RF 1F BF	GL-2.0m -21.5m	Vel.:5 WPM:3	Tb=0.475sEW Tb=0.243sNS Tg=0.49s	Base isolation, SSI
100	9	1	RC	-	Earth Drill	-	Tokyo	RF 1F Basement	-	Acc.:3	Tb=0.65s	Base isolation
101	4	0	RC	11.65		GL-38	Funabashi, Chiba pref.	RF 1F Basement	-	-	-	Comparative observation (LRB/HDR)

Table 1 The Strong Motion Recording Sites in this Study (7)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
102	4	0	RC	16.3	cast in place	18	Nagoya	RF 1F Basement	GL-1m -22m -48m	acc. (8)	Only rubber:Tb=3.61sX, 3.60sY Robber+Damper:Tb=1.30sX, 1.28sY Fixed:Tb=0.42sX, 0.32sY	Base isolation
103	4	0	RC	18.3	Raft foundation	-	Oarai, Ibaraki	RF 1F Basement	GL-1.07m -4.06m -26.15m	Acc.15, Disp. 2	?	Vertical vibration
104	-	-	RC	-	-			Roof(G.L.5.5m)、BF(G.L.-5.5m)	G.L.-52.75 - GL(5)			Effect of adjacent building
105	5	1	RC		Earth Drill pile cast in place		Kanto	GL, Base, Top	GL-31, Pile strain			SSI
106	16	-	SRC	65.65	earth Drill	15	Osaka	RF, 1F, Pile:int, tip	Pile:GL-15.0m, GL-25.5m			SSI with pile
107	25	1	SRC	77.25	RC cast inplace		Osaka	25F,B1F,Pile(GL-29m)				SSI with pile
108	31	1	RC	89.3	RC cast inplace		Osaka	31F,1F,Pile(GL-30m)	GL			SSI with pile
109	4		RC	16.5	pile		Tokyo	1F ~ RF 1F,RF	GL (15m horizonatlly apart from building)	Vertical:5locs. Horizontal:8		SSI with pile using micro tremor
110	1	0			Cast in place		Niigata (?)	Free filed, building	Pile (G.L.-2m,-21m,-44m)、	Pile(3 depth for each of 2 piles)		SSI with pile
111	4	0			Pile		base-isolated office building	RF, Basement	GL, GL-22m, GL-48m	Steel bar strain at pile cap		Base Isolation
112	10	3	Con.(damper)					RF,9F,5F,1F, IP	GL±0m,-15m,-50m			ODE with wind
113	14	2	4F=<: SRC <=5F:S	51	RC cast in place	24	Hiroshima pref.	Roof(3), B2F(3)	-	-	fg=0.87 fb=1.6(observation)	-
114	4	0	RC	18	-	-	Kanagawa	1F(N3 , S3) 4F(Ceiling:3)	GL-6,-35,-70m GL-1,-6m(free field)		fb=2.90Hz	SSI
115	22	1	CFT S	90	-	-	Osaka	Roof(2) , 1F(2) Accelerometer	-	-	fb=3.1,3.3(design) fb=2.5,2.7(microtremor measurement)	-
116	32	2	S	125	-	-	Osaka	B2F(2),15F(2),31F(2) Accelerometer	GL-1m(2) accelerometers	-	fb=3.4,3.7(design) fb=3.1,3.3(microtremor measurement)	-
117	37	2	S	150	-	-	Osaka	Roof(2) , 1F(2) Accelerometer	-	-	Tb=4.4,4.7	Response control
118	-	-	RC:LRB RC, RC:FPS	8.6			Osaka	Roof, 1F, Foundation Roof, 2F Roof, 1F, Foundation	GL,GL-30m GL,GL-24m			Comparison of devices for base isolation

Table 1 The Strong Motion Recording Sites in this Study (8)

No	No of floors above ground	No of bsmnt floors	Stcture Type	Height (m)	Pile type	Pile length (m)	Area (locality)	Location of seismometer in structure	Location of seismometer in Soil	Measurement of pile strain	Freq. Char.	Notes
119	13	-	RC		mat foundation		Sendai, Miyagi pref.	Roof, 1F, Foundation			Fb=1.2Hz	Base isolation
120	9	-	S	44	RC cast in place	30	Tokyo	9F, 2F, foundation, pile tip	GL GL-30m	なし	Tb=1.1~1.3s	
121	10	-	S, SRC	40	S：RC cast in place(49m) SRC(45m)	49, 45	Nagoya					
122	10	-	SRC	39	Ready made pile	50	Nagoya	long term point (building, soil)=21chs. Microtremor	31 chs	accelerometer		
123			S, SRC, RC		Pile, Mat foundation		Nagoya	1F,RF	GL-1m	accelerometer:8		
		EPM	Earth Pressure Meter			TMD	Tuned Mass Damper					
		WPM	Water Pressure Meter			AMD	Active Mass Damper					
		Acc.	Accelerometer			LRB	Lead Rubber Damping					
		Vel.	Velocity-meter			AMPD	Active Passive Mass Damper					
		Dis.	Displacement-meter			HDR	High Damping Rubber					
		Tg	Ground period			SRC	Steel Reinforced Concrete					
		Tb	Building period			S	Steel					
		fg	Ground frequency			RC	Reinforced Concrete					
		fb	Building period			PH	Pent House					