Journal of Japan Association for Earthquake Engineering, Vol.4, No.3 (Special Issue), 2004

OBSERVATION OF STRONG EARTHQUAKE MOTION BY NATIONAL INSTITUTE FOR LAND AND INFRASTRUCTURE MANAGEMENT

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ABSTRACT: The National Institute for Land and Infrastructure Management (NILIM) administers the observation of strong earthquake motion at more than 160 civil engineering structures throughout Japan, and dense instrument array strong earthquake motion observations at 98 sites in 9 areas. This paper describes current topics of strong earthquake motion observation at NILIM.

Key Words: civil engineering structure, strong earthquake motion observation, network, array observation, earthquake-resistant design, new observation station

INTRODUCTION

NILIM is part of the Ministry of Land and Infrastructure and Transport (MLIT). The observation of strong earthquake motion at civil engineering structures were initiated in 1957, when a SMAC-type strong-motion accelerograph was installed at Sarutani Dam. Strong-motion accelerograms recorded during the 1964 Niigata Earthquake greatly contributed to the study of damage caused by earthquakes, and the liquefaction of sandy soil ground in particular, demonstrating the necessity of strong earthquake motion observations. Therefore, a nationwide instrumentation plan of SMAC-type accelerographs was drawn up and has been steadily implemented by the Ministry of Construction and other organizations. NILIM (including PWRI, Public Works Research Institute) is in charge of the collection, processing, and analysis of the strong-motion records, and conducts research on earthquake-resistant designs and earthquake disaster prevention based on the accumulated data records.

Currently, NILIM is administering two types of strong earthquake motion observation, in addition to supervising the MLIT Seismograph Network. Table 1 shows an outline and the objective of installing these three types of strong-motion observation systems. Figure 1 shows the locations of the strong-motion observation stations for civil engineering structures.

Table 1　Outline of each type of strong-motion observation administered by NILIM

Type of observation	Description of observation	Number of observation stations
Strong-motion observation of civil engineering structures	1) River management facilities (levees, weirs, water gates) 2) Road facilities (bridges, future construction sites for long-span bridges, ground surface)	About 160 stations (90 river facilities, 70 road facilities)
Dense instrument array observation of strong earthquake ground motion	Observation of amplification or attenuation characteristics caused by variations of local topography and geological conditions	98 stations in 9 areas
MLIT Seismograph Network	The stations are installed on the ground surface and at intervals of 20 to 40 km along rivers and national highways administered by MLIT. The data is sent to responsible sectors by the communications network, for estimating the seismic intensity distribution in the relevant area of jurisdiction.	About 700 stations

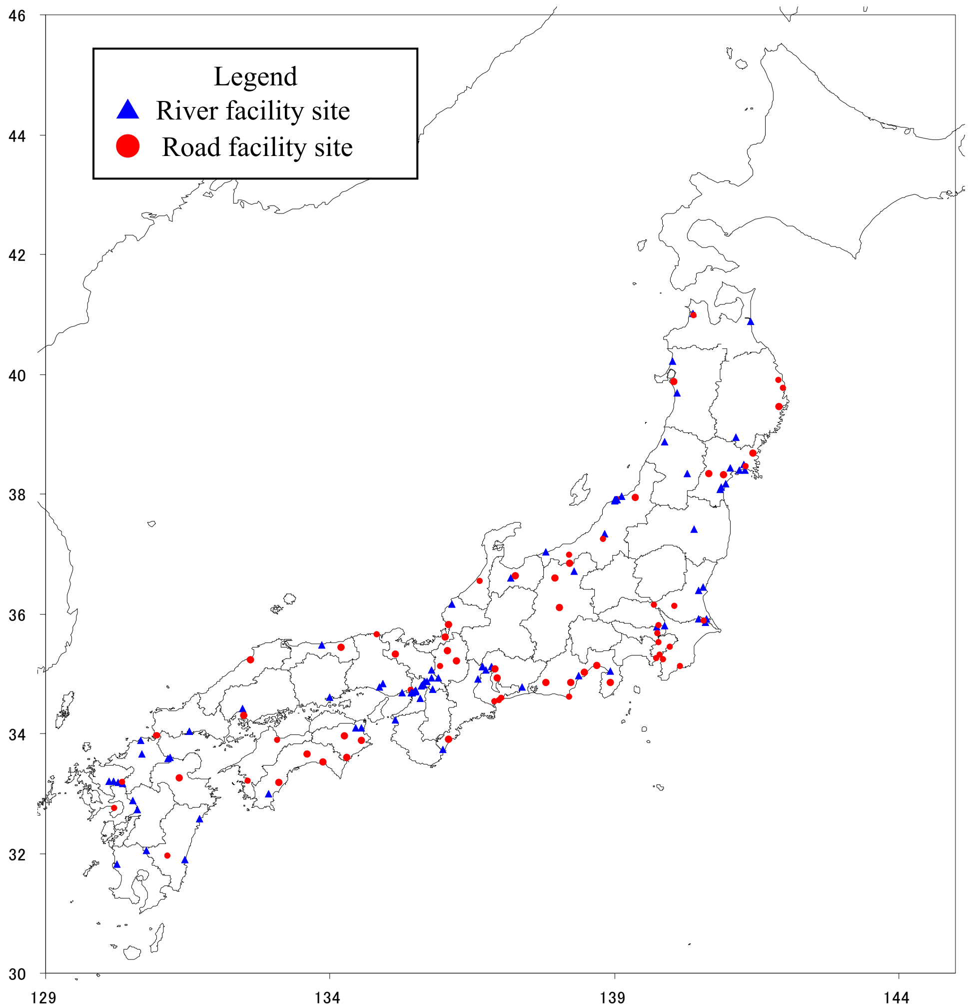

Fig. 1. Locations of strong-motion observation stations for civil engineering structures.
(Note: Plotted points include stations under construction, and stations expected to be suspended)

STRONG-MOTION OBSERVATION OF RIVER MANAGEMENT FACILITIES

Most observation stations at river management facilities are installed at levees, although a few are also installed at weirs and water gates. NILIM supervises about 90 observation stations, which are installed at the levees of major rivers throughout Japan except Hokkaido. Vertical array observations can be conducted at most of the stations, so accelerometers are installed at the crown of the levee, on the ground surface nearby, and on the bedrock layer, in order to observe the effects of strong earthquake motion on river management facilities, and also variations of pore water pressure during earthquakes. Several stations observe the influence of strong motion caused by differences of microtopography, whereas some stations installed at soil improvement areas or anti-earthquake levees observe the effectiveness. Figure 2 shows an example of the instrument configuration at an observation station.

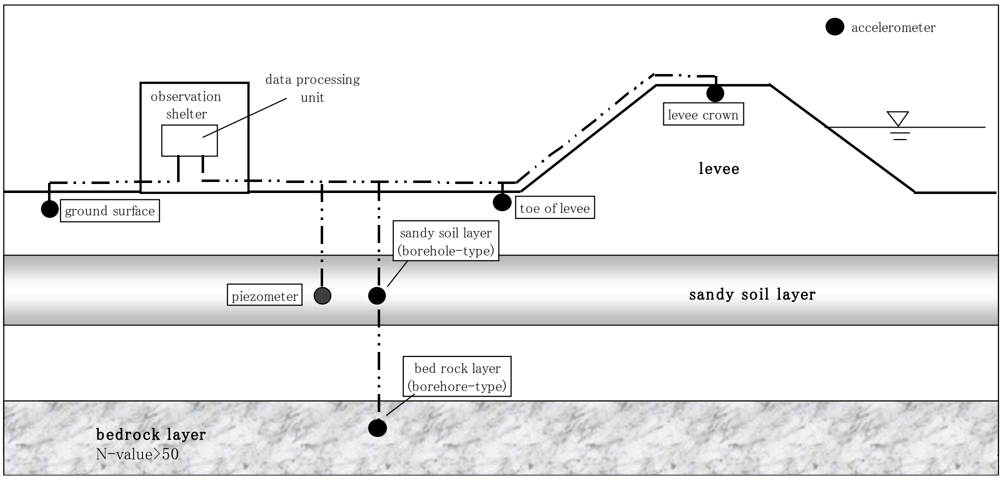

Fig. 2 Typical configuration of instruments at an observation station for a river management facility.

Strong-motion records from the North Miyagi Prefecture earthquake

Table 2 shows an example of the acceleration records during the North Miyagi Prefecture earthquake. (M_{JMA} 6.4).

Table 2 Peak acceleration records during the North Miyagi Prefecture earthquake (main shock)

Station Name	Epicenter Distance (km)	Accerelograph Installed	Peak Acceleration (cm/s^2)			Peak Acceleration (cm/s^2)			Peak Acceleration (cm/s^2)		
			NS	EW	UD	NS	EW	UD	NS	EW	UD
Nakashimo	2.3	GL-10.0m end of SCP	409.7	547.3	262.4	-518.6	-490.2	362.0	27.5	38.8	14.4
		GL-5.0m SCP	376.7	399.5	295.3	-345.9	414.6	494.3	38.9	40.8	25.3
		Berm of levee	365.2	429.7	366.4	-370.8	-383.2	-629.0	25.5	45.8	20.8
		Crown of Levee	482.4	399.9	277.1	379.0	415.2	-556.0	379.0	415.2	-556.0
		GL-10.0m bedrock layer	560.0	482.0	258.2	578.6	-423.8	403.2	578.6	-423.8	403.2
Koduka	13.3	Crown of Levee	337.1	443.0	248.1	337.1	443.0	248.1	337.1	443.0	248.1
		Toe of levee	117.3	-299.0	229.6	117.3	-299.0	229.6	117.3	-299.0	229.6
		GL-6m Sandy soil layer	-196.3	-167.4	-123.8	-196.3	-167.4	-123.8	-196.3	-167.4	-123.8
		GL-13.0m bedrock layer	222.8	-168.0	-131.5	222.8	-168.0	-131.5	222.8	-168.0	-131.5
Kanan	13.9	GL-77.0m bedrock layer	-266.9	-249.0	184.2	-266.9	-249.0	184.2	-266.9	-249.0	184.2
		Crown of Levee (backmarsh)	-352.4	-417.9	289.0	-352.4	-417.9	289.0	-352.4	-417.9	289.0
		GL-8m Sandy soil layer	159.9	-189.3	135.2	159.9	-189.3	135.2	159.9	-189.3	135.2
		Crown of Levee (old channel)	278.7	332.5	-277.5	278.7	332.5	-277.5	278.7	332.5	-277.5

STRONG-MOTION OBSERVATION OF ROAD FACILITIES

Currently, almost all observation stations at road facilities are installed at bridges built on national highways. At most of the observation stations, accelerometers are installed on the bridge piers, girders, abutments, and ground-surface near the bridge in order to observe the effects of strong earthquake motion at each part of the bridge structure. However, a few stations are located at future construction sites of long-span bridges, such as at Futtsu, Kanonzaki, and Cape Irago.

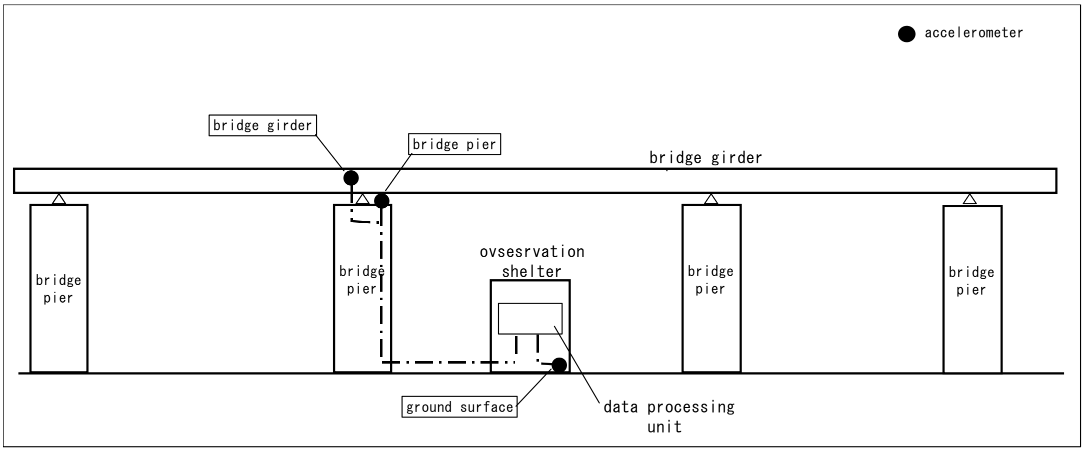

Fig. 3 Typical configuration of instruments at an observation station for a bridge structure.

Installed new observation stations and instrument replacement

Many useful strong-motion acceleration records have been obtained by these stations, and have been used for research on earthquake-resistant designs and earthquake disaster prevention. However, the accelerographs installed at the stations are starting to deteriorate and need to be replaced. NILIM therefore drew up a new plan for observation stations, including the construction of about 40 new stations.

These observation stations are installed near national highways, too, but the difference is the subject of observation, i.e., base-isolated bridges, continuous bridges (many spanned), slopes, and utility tunnels. Some of the new stations are to be installed in the Tokai region, Miyagi prefecture, Kii Peninsula, the Pacific coast of Shikoku, and the Itoigawa-Shizuoka Tectonic Line.

Photo 1 Kakuan viaduct observation station

At the observation stations, the observation shelters are made of aluminum panels sandwiching heat-insulating material, therefore the shelters are lightweight and offer effective heat insulation.

The installed instruments are the latest digital strong-motion accelerographs, which have an accelerometer resolution of 10^{-5} m/s/s, and are connected to NILIM via the Integrated Services Digital Network (ISDN). Photo 1 shows a new observation station at the Kakuan viaduct in Niigata prefecture. At the station, accelerometers are installed on the girders, crown of the piers, and ground surface (within the observation shelter).

DENSE INSTRUMENT ARRAY OBSERVATION OF STRONG GROUND MOTION

NILIM started dense instrument array observation of strong ground motion in 1979, and now has 98 observation stations in 9 areas. All stations are connected to NILIM via ISDN in order to acquire observation records immediately after an earthquake and to enable the instruments to be maintained efficiently. Table 3 shows the specifications of each observation area

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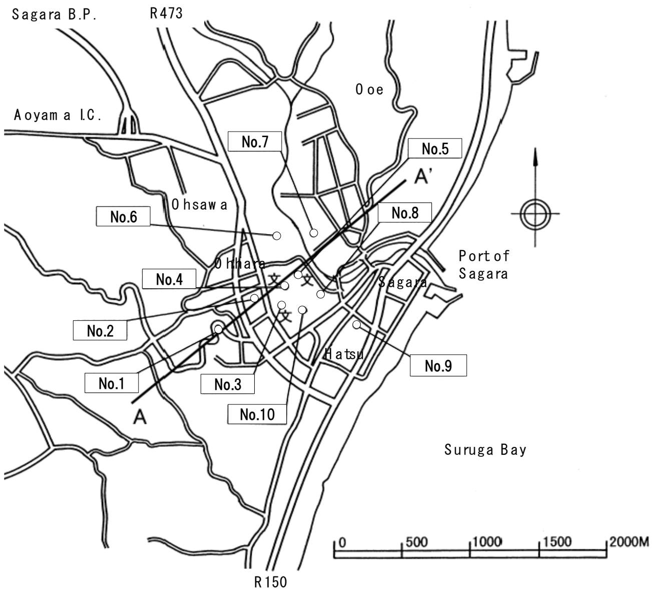
Table 3 Summary of dense instrument array observation stations

Region	Place of observation	Number of stations	Number of accelerographs		Shape of instrument array	Mean Disatance between stations	Deph of underground installation	Obaervaion started
			Ground-surface	Under-ground				
Suruga Bay	Sagara	10	10	6	Cross-shaped	200m	-8m～-36m	1979
	Yaizu	12	11	6	Cross-shaped	300m	-10m～-112m	1983
	Numazu	14	12	8	Combination of straight line and cross shape	300m	-9m～-32m	1983
	Matsuzaki	8	11	9	Straight line and one point	300m	-5m～-52m	1985
Kobe	Kobe-west	13	10	12	Folding line	500m	-7m～-102m	1996
	Kobe-east	9	9	11	scattered	400m	-8m～-100m	1996
Sagami Bay	Odawara	11	11	25	scattered	400m	-7m～-90m	1996
Tokyo Bay	Makuhari-Narashino	11	11	15	Straight line	300m	-6m～-100m	1996
	Tateyama	11	12	10	scattered	200m	-7m～-47m	1996

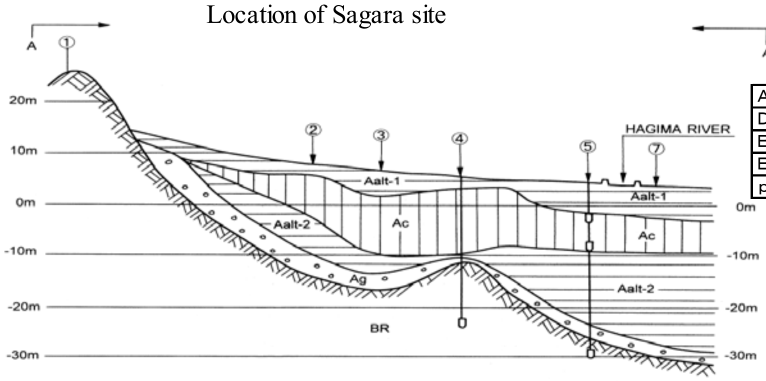
Table 4 shows an example of an observation record obtained at Sagara during the Shizuoka prefecture earthquake (M_{JMA}5.3) on April 3, 2001. Figure 5 shows the location and topology conditions of the Sagara site.



Location of Sagara site

Table 4 Peak acceleration records

Station Number	Accerelograph Installed	Peak Acceleration (cm/s^2)		
		NS	EW	UD
No.1	GL-2.0m	56.9	80.6	42.5
No.2	GL-2.0m	118.2	81.3	23.4
No.3	GL-2.0m	145.3	103.8	33.7
No.4	GL-2.0m	129.9	61.8	29.5
	GL-30.1m	56.4	23.7	16.4
No.5	GL-2.0m	134.8	71.5	34.7
	GL-8.2m	126.7	50.8	27.8
	GL-12.0m	83.5	59.6	22.7
	GL-32.3m	57.1	26.4	19.0
No.6	GL-2.0m	130.9	75.0	35.4
No.7	GL-2.0m	213.4	87.6	40.8
No.8	GL-2.0m	182.6	90.4	42.2
	GL-36.3m	49.1	31.3	14.7
No.9	GL-2.0m	77.6	65.2	17.8
No.10	GL-2.0m	153.3	75.4	40.3
	GL-30.3m	54.9	25.4	19.8



Legend

A : Alluvial	s : Sand
D : Diluvial	c : Clay
B : Backfill etc.	g : Gravel
B R : Bedrock	l : Loam
p : Humus	alt : Alternation

Topology conditions of Sagara site

Fig. 5 Location and topology conditions of Sagara site

MLIT SEISMOGRAPH NETWORK

After the Hyogoken Nanbu earthquake, the Ministry of Construction (presently MLIT, Ministry of Land Infrastructure and Transport) installed approximately 700 online seismographs throughout Japan to facilitate urgent inspection of its facilities such as national highways and river management facilities. At the time, these accelerographs were installed on the ground surface and placed at intervals of 20 to 40 km along the rivers and national highways administered by MOC.

After an earthquake, these seismographs send the SI value, peak ground acceleration value, and equivalent JMA seismic intensity work, to the headquarters and divisions of MLIT via MLIT's exclusive communications network. NILIM is able to acquire the data of all stations and release SI values and peak ground acceleration values on its website. (http://www.nilim.go.jp). Figure 6 shows the distribution of the MLIT seismograph network.

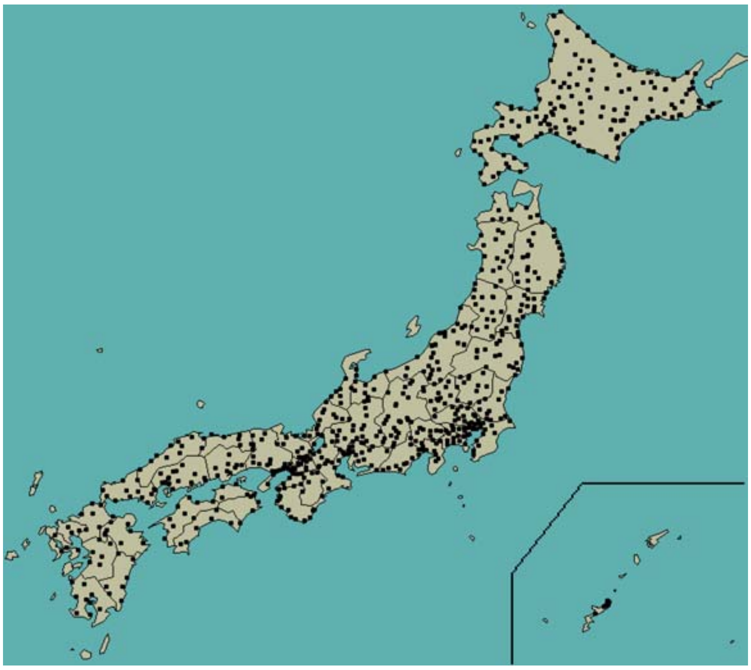


Fig. 6 Distribution of MLIT seismograph network

CONCLUSIONS

Strong earthquake motion observations have gathered much useful data for the seismic-resistant design of civil engineering structures, and for developing earthquake prevention technology. NILIM is necessary to maintain these observation systems and collect useful records.

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(Submitted: March 31, 2004)
(Accepted: June 22, 2004)