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ANALYSIS OF ACCELERATION AND HYDRODYNAMIC PRESSURE RECORDS ON OFFSHORE STRUCTURE AND SEABED

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ABSTRACT

Strong-motion and hydrodynamic pressure records obtained on Kamaishi breakwater in deep sea which consists of rock-fill mound of 33m high and concrete caissons of 30m high on the mound were analyzed. Strong-motion records obtained on the ground surface near the breakwater were compared with those on the deep seabed. The natural frequencies estimated from the transfer function between the caisson's top and the seabed are 1.6Hz, 2.1Hz and 5.1 Hz. The frequency of the largest peak of the seabed records' power spectrum was almost same as that of the ground surface records' in the frequency range of less than 8Hz.

KEYWORDS

Strong-motion Earthquake Observation, Accelerogram, Hydrodynamic Water Pressure, Tsunami Breakwater, Fill Type Structure, Deep Seabed, Frequency Transfer Function

INTRODUCTION

Many large structures have been constructed in deep sea area for offshore and waterfront development in recent year. Among these structures, a fill type breakwater that consists of a rock-fill mound and concrete caissons is discussed in this report. Kamaishi fill type breakwater which was designed to attenuate the effects of tsunami in the bay is located at a mouth of Kamaishi bay in the water depth of -63m. As the tsunami breakwater is attacked by earthquake motions before tsunami, it's dynamic stability during earthquake is very important. In order to develop the rational seismic design of offshore structure in deep sea, the earthquake observation has been conducted on Kamaishi breakwater which is under construction. In this earthquake observation strong-motion accelerographs were installed on the breakwater and on the seabed, and hydrodynamic pressure gauges were also installed on the breakwater. This paper describes the analysis of accelerograms and hydrodynamic pressure acting on the breakwater.

KAMAISHI BREAKWATER

Kamaishi breakwater has been constructed at a mouth of Kamaishi bay from 1984. The earthquake observation has been conducted on the center caisson of five caissons which were constructed. The location of

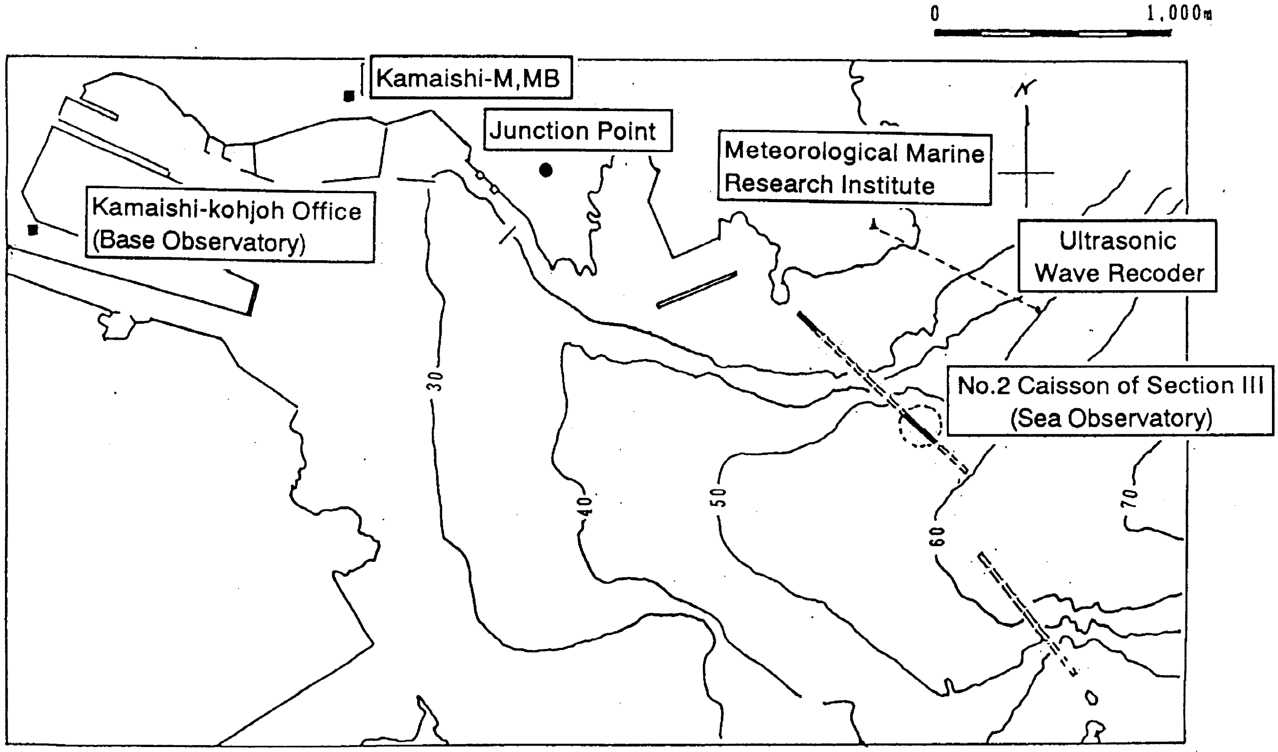

Fig.1. Location of Kamaishi breakwater

these caissons in Kamaishi bay is shown in Fig.1. Figure 2 shows the section of Kamaishi breakwater which consists of a rock-fill mound of 33m high and concrete caissons of 30m high on the mound. The shape of the caisson is trapezoid to reduce wave pressures and hydrodynamic water pressures during earthquake.

STRONG-MOTION EARTHQUAKE OBSERVATION

Installation Site

Three strong-motion accelerographs were installed on the seabed, on the top of mound and on the top of caisson shown in Fig.2. The seabed is sand layer shown in Fig.3, and the strong-motion accelerographs was installed at the depth of 2m from seabed surface. There is the vertical array of earthquake observation other

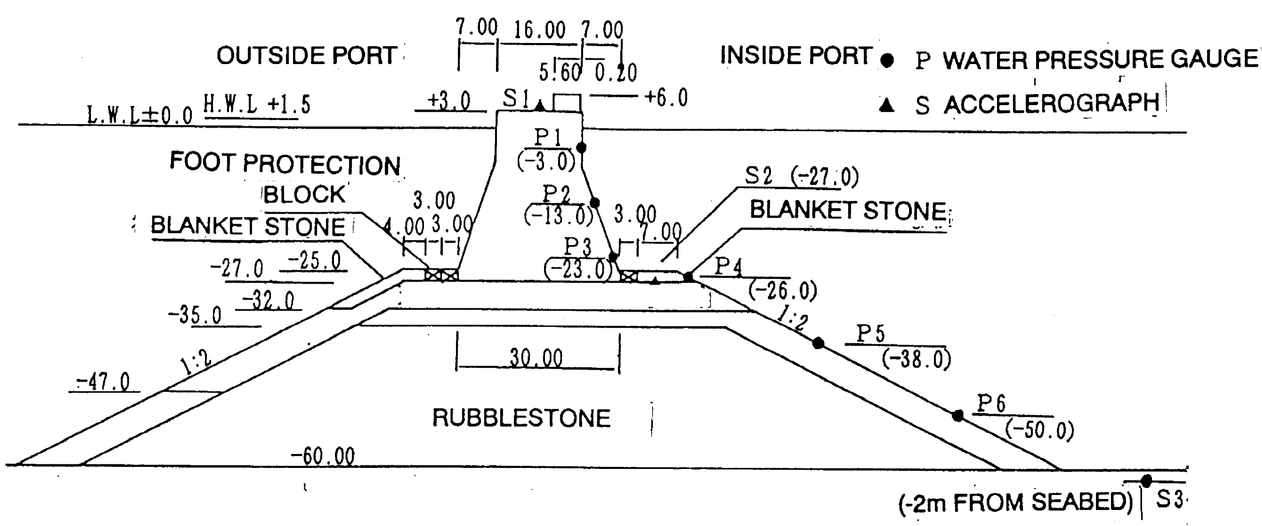

Fig.2. Section of Kamaishi breakwater

Level (m)	Elevation (m)	Depth (m)	Thickness (m)	Field observation: Soil mark	Field observation: name of soil	Field observation: Color	Field observation: Reference column
1-	-58.80	1.0	1.0		medium gravel	dark graish blue	
2- 3-	-60.80	3.0	2.0		gravelly fine sand	dark graish blue	Bad classification Mainly medium and coarse sand
4- 5- 6- 7-	-63.50	7.5	4.5		fine sand	dark graish blue	Good classification Partly include very fine sand Also include shell and mica
8- 9-	-67.30	9.5	2.0		medium gravel	dark green	Upper part:mainly medium gravel and fine sand Lower part:medium and coarse sand

Fig.3. Soil profile of seabed

than the earthquake observation of Kamaishi breakwater shown in Fig.1. This vertical array observation consists of two accelerographs installed on the ground surface and at the depth of -11.2m, and called as Kamaishi-M and Kamaishi-MB respectively. This site is sand gravel layer. Three hydrodynamic gauges were installed on the vertical surface of the caisson' side wall, and three hydrodynamic gauges were installed on the slope surface of the mound.

Table 1. Specification of accelerographs and water pressure gauge

	Accelerograph		Water Pressure Gauge
	ERS-C	STBH-3CK	S-PW
Component	2 horizontal & 1 vertical	2 horizontal & 1 vertical	-
Transducer type	Moving coil	Force-ballance servo	Semiconductor strain gauge
Maximum amplitude	500 Gal	1000 Gal	1.04, 1.76, 3.52, 7.04 kgf/cm^2
Natural Frequency	3 Hz	3.5 Hz	-
Damping	17	More than 30	-
Diameter of cell	-	-	19 φ mm
Output sensitivity	-	2.5 V/G	20 mV/V
Antivibration	-	-	50G
Frequency range	0.1～50 Hz	0.05～25 Hz	DC～25 Hz
Digitized accuracy	0.2 Gal	0.1 Gal	0.86 gf/cm^2 for 7.04kgf/cm^2
A/D Conversion	-	16bit, 100 Hz	16bit, 100 Hz
Pre-event memory	No	10 second	10 second
Starter threshhold	5 Gal	5 Gal	Synchronize with accelerograph
Recording duration	2.5 min.	1～8 min.	25 min.
Recording medium	Oscillograph	Bubble memory (1 M byte)	Bubble memory (1 M byte)
Absolute time	No	Yes	Yes
Power supply	Rechargeable battery	Buckup supply (2 hours)	Buckup supply (2 hours)

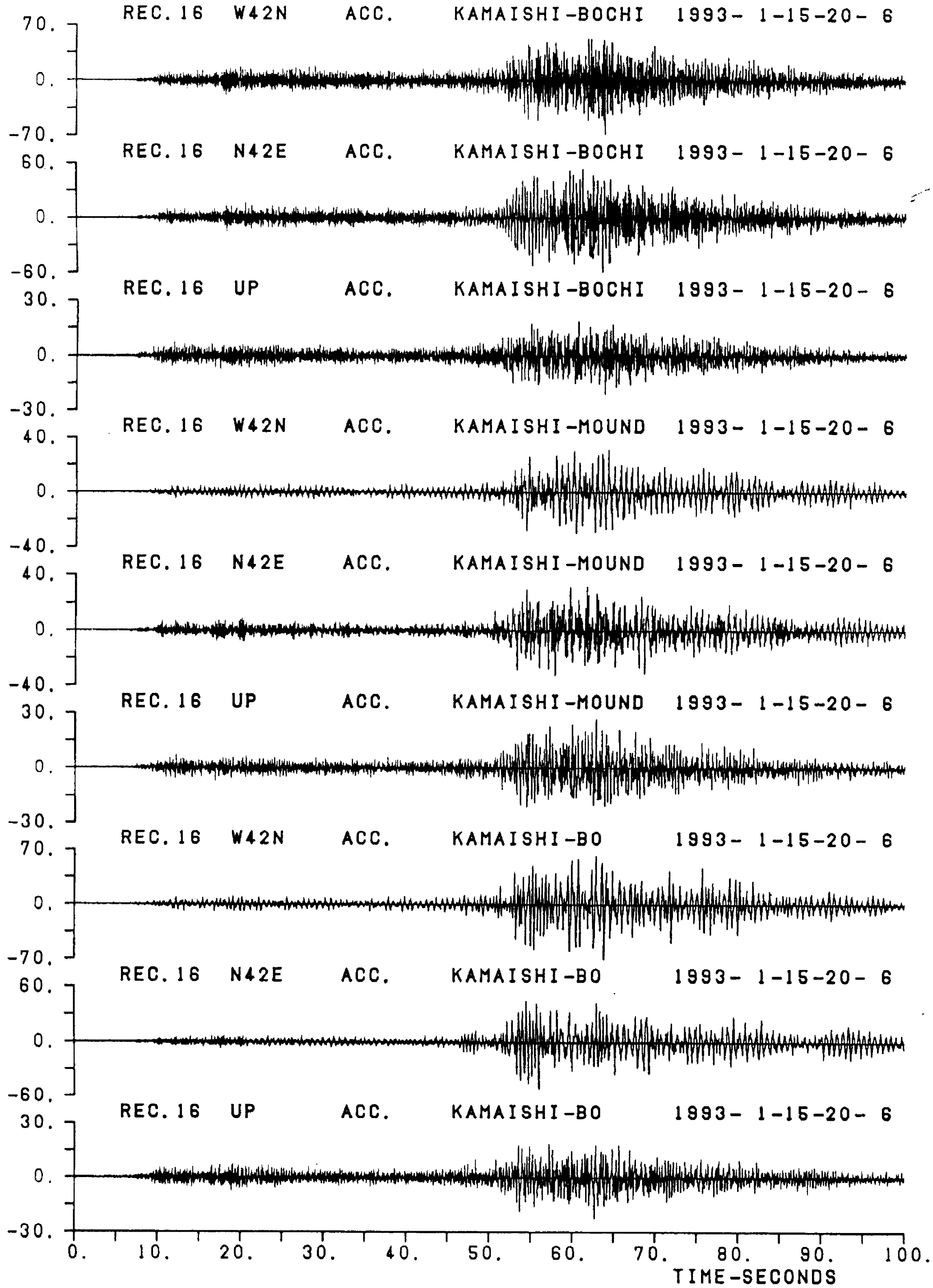

Fig.4. Accelerograms of Kamaishi breakwater

Strong-motion Accelerograph and Hydrodynamic Water Pressure Gauge

Table 1 shows the specification of accelerograph and water pressure gauge. The direction of one horizontal component of the accelerographs is parallel to the center line of breakwater(W42N direction) and another is right angles to the center line(N42E direction). Two horizontal components of the accelerographs at Kamaishi-M and Kamaishi-MB are east to west direction and north to south direction respectively.

Field Observation System

The field observation system consists of the sea observatory on the caisson, the junction site on land which

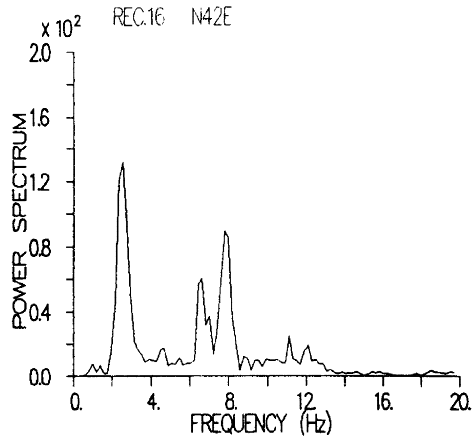

Fig.5. Power spectrum of acceleration at seabed

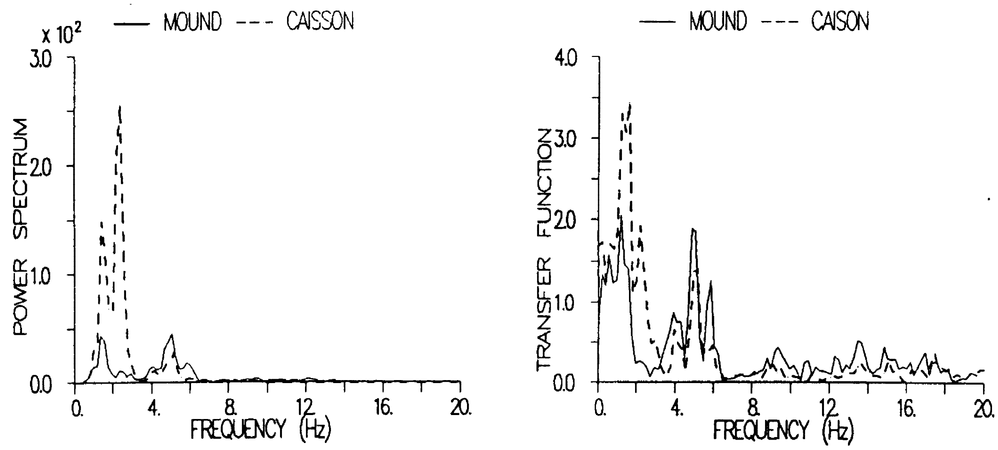

Fig.6. Power spectra and transfer function(mound and caisson)

relays the radio of observation data, and the base observatory on land where the record system of observation data is installed. The sea observatory on the caisson consists of the cabin with a diesel generator and the tower with observation apparatus. The power sources are a solar battery at the top of the tower(12KW), a lead battery in the cabin (3000AH) and a diesel generator (3KVA). The LAN system for digital telecommunicating (64kbps) with 50 KHz micro wave is used for radio transmission of the observation data. Although the radio transmission is suitable to the transmission of large data, the attenuation of micro wave is large. Then the junction site was constructed. When an earthquake occurs and the accelerograph at the seabed shows the maximum acceleration of 5 Gal, strong-motion data and hydrodynamic pressure are recorded on the magnetic bubble memory of observation apparatus at the sea observatory. And two minute later after an earthquake the data of the magnetic bubble memory is transmitted to the base observation through the junction site. After an earthquake the magnetic bubble memory is recovered from the tower on the caisson and mailed to the Port and Harbour Research Institute(PHRI). The magnetic bubble memory is processed by the standard processing system of the strong-motion earthquake observation network in Japanese port area.

ANALYSIS OF OBSERVED RECORDS

The earthquake observation started in 1992, and 38 sets of accelerograms and hydrodynamic pressure records were obtained until March 1995. The maximum acceleration of records on the seabed among those sets of records is 59 Gal. This records were obtained at the Kushiro-oki earthquake and shown in Fig.4. This figure shows the time histories of three component acceleration obtained on the seabed, on the top of mound and on the top of caisson. The maximum acceleration of N42E horizontal component is 59 Gal on the seabed, 32 Gal on the top of mound and 51 Gal on the top of caisson. The maximum acceleration ratio of the top of caisson to the seabed is less than 1.0.

Figure 5 shows the power spectrum of acceleration on the seabed, and Fig.6 shows the power spectra of the

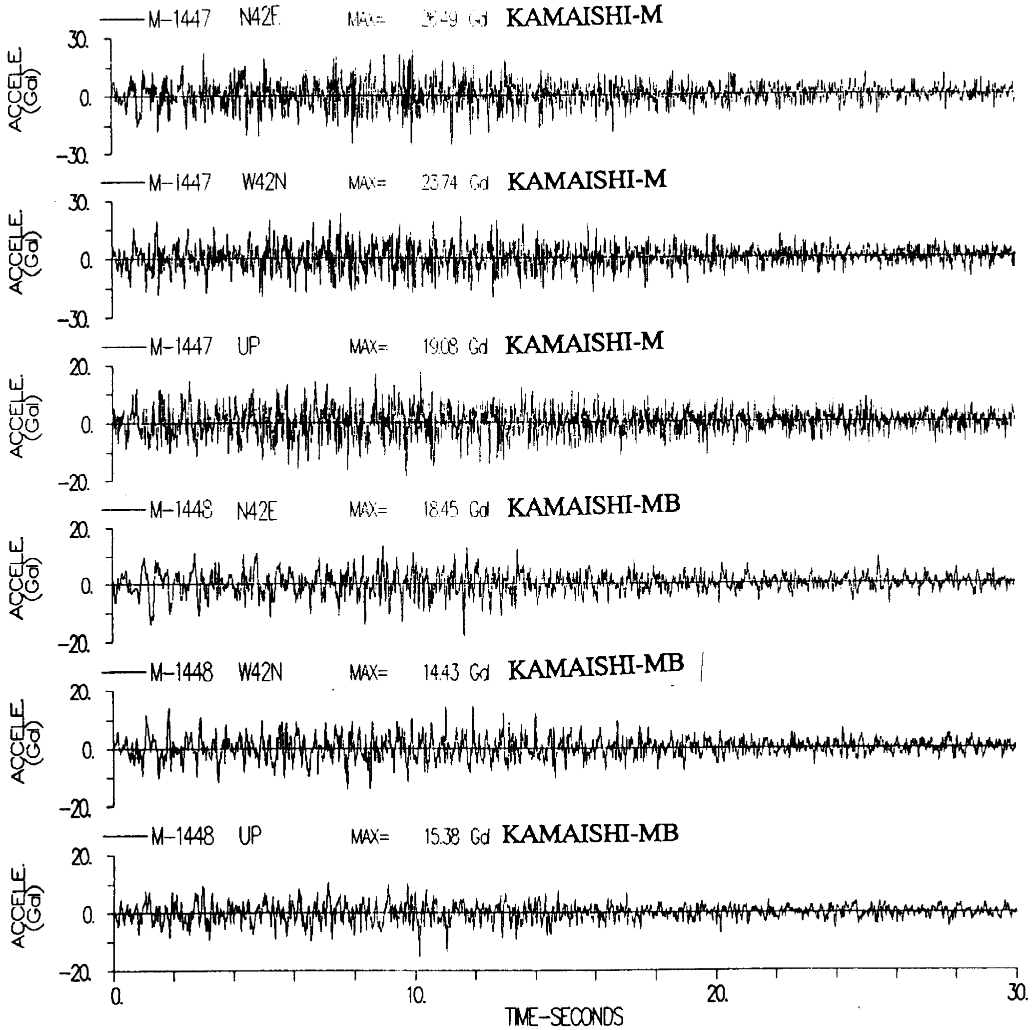

Fig.7. Accelerograms of Kamaishi-M and -MB

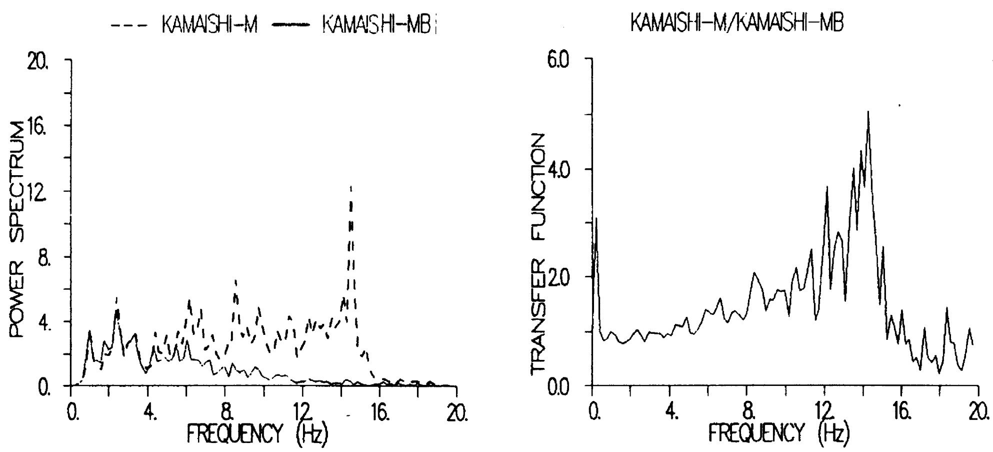

Fig.8. Power spectra and transfer function (Kamaishi-M and -MB)

top of mound and the top of caisson. The power spectrum of acceleration on the seabed shows large peaks of 2.3 Hz and 7.9 Hz. The power spectra of the mound's top and the caisson's top show large peak of 1.5 Hz and have less high frequency component than those on the seabed. Figure 6 shows frequency transfer functions whose input is the acceleration on the seabed, and whose outputs are the acceleration on the mound 's top and that on the caisson's top. These frequency transfer functions show large peaks of 1.6 Hz, 2.1 Hz and 5.1 Hz.

Figure 7 shows the time histories of accelerograms obtained at Kamaishi-M and Kamaishi-MB. The direction of horizontal component of these accelerograms in Fig.7 was adjusted to the same direction of accelerograms obtained at Kamaishi breakwater. Figure 8 shows the power spectra of Kamaishi-M and Kamaishi-MB, and the frequency transfer function whose input and output are Kamaishi-MB and Kamaishi-M respectively. The value of frequency transfer function is about one in the range less than about 6 Hz.

Comparing the accelerogram on the seabed with that of Kamaishi-M in Figs 4 and 7, the maximum acceleration of the seabed is larger than that of Kamaishi-M . And comparison of the power spectrum in Fig.5 with that in Fig.8 shows that both power spectra are considered to have same frequency characteristics in the frequency range of less than 8 Hz. Clear difference of the vertical acceleration between the seabed and Kamaishi-M was not found.

Figure 9 shows the time histories of the hydrodynamic pressure obtained at Kushiro-oki earthquake. Figure 10 shows the maximum hydrodynamic pressures acting on the side wall of caisson. In this figure hydrodynamic pressure curves given by Westergaard's formula and Zanger's are also shown. In the calculation by these formulas the water depth is the depth of the top of mound and the seismic coefficient is average value of the maximum acceleration of the mound's top and that of the caisson's top. Figure 10

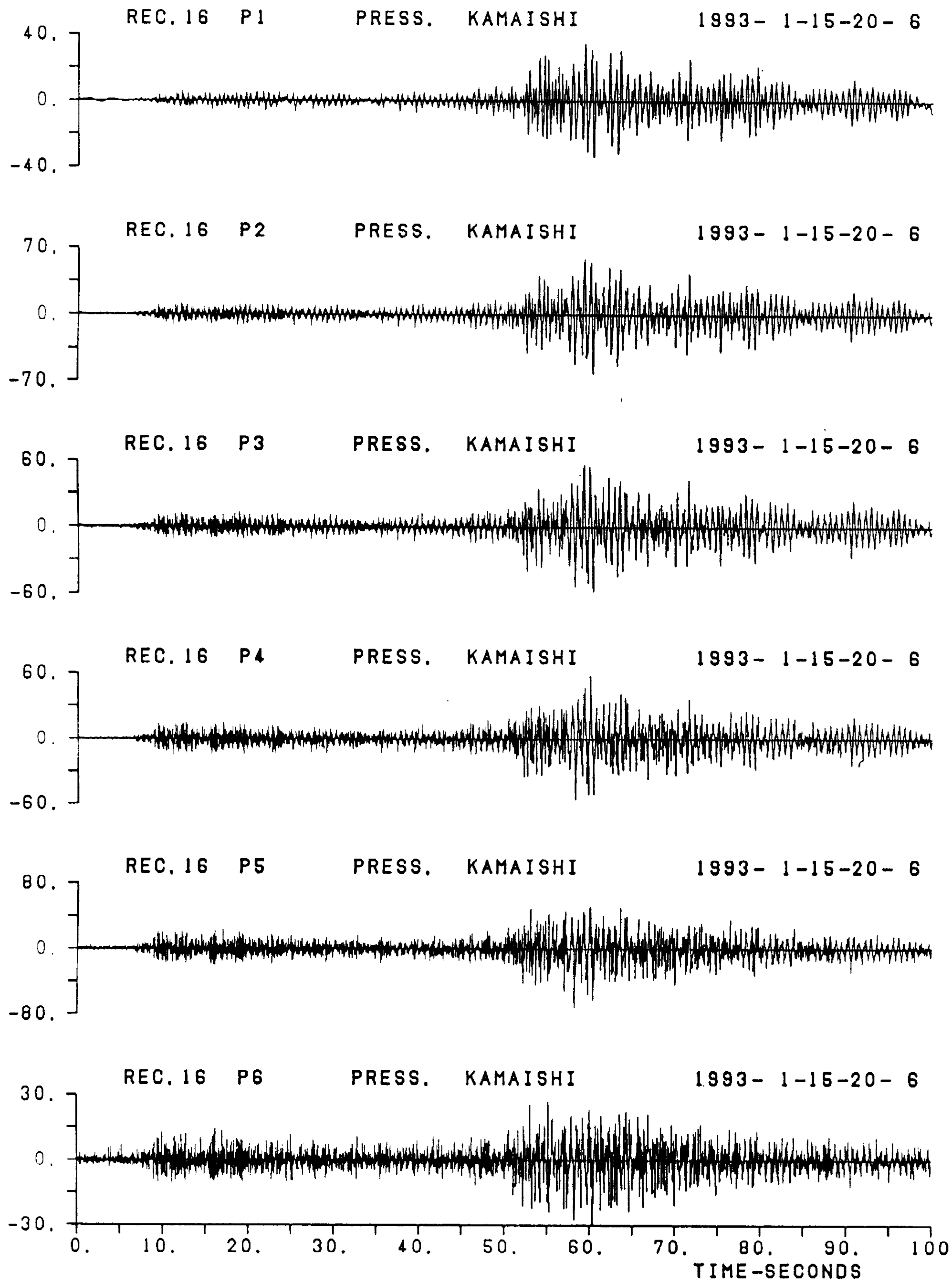

Fig.9. Records of hydrodynamic pressure

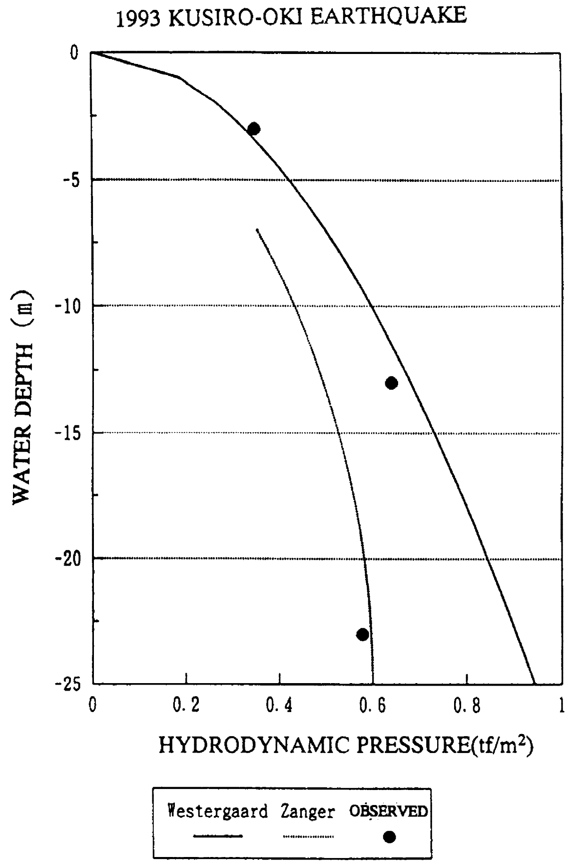

Fig.10. Hydrodynamic pressures versus water depth

shows that the observed hydrodynamic pressure on the vertical side wall is equal to the calculated value of Westergaard's formula and the observed hydrodynamic pressure on the inclined side wall is equal to the calculated value of Zanger's formula.

CONCLUSION

Strong-motion and hydrodynamic pressure records obtained on the Kamaishi breakwater in deep sea which consists of rock-fill mound of 33m high and concrete caissons of 30m high on the mound were analyzed. Strong-motion records obtained on the ground surface near Kamaishi breakwater were compared with those on the deep seabed.Comparing the accelerograms of the caisson's top with those of the seabed, the top of caisson shows clear response. The values of natural frequency estimated from the transfer function between the caisson's top and the seabed are 1.6Hz, 2.1 Hz and 5.1 Hz. The frequency of the largest peak of the seabed records' power spectrum was almost same as that of the ground surface records' in the frequency range of less than 8 Hz.

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