研 究 速 報

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Creation of a Database of Earthquake Records from a Reinforced Concrete Tower and Preliminary Processing of the Data

千葉実験所地震観測棟の地震記録のデータベース化とそれを用いた解析

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1. Introduction

For observation of soil-structure interaction during earthquakes, a reinforced concrete tower is constructed in the Chiba Experimental Station of the Institute of Industrial Science, University of Tokyo. The accelerometers, installed in it, are in operation since August 1983 and have provided records from more than 200 earthquakes. The tower is located near the Chiba seismometer array, the records of which are used for the creation of the Chiba array database[1)~3)]. Using the records from the tower accelerometers and some of the accelerometers, which are part of the ground observation array as well, a database of the observation tower response during different earthquakes is created. This database will be further utilized for studying various dynamic interaction phenomena.

2. Description of the observation tower and surrounding site conditions

The observation tower, which has an octagonal cross-section, consists of four floors and a basement, with a total height of 10 m above the ground level and 2.5 m underground (Fig. 1(a))[4),5)]. A total of 13 accelerometers is attached to the floor slabs of the tower, including the basement floor (Fig. 1(b)). Borehole P5 from the Chiba array is located at an approximate distance of 15 m from the tower. The soil profile at it is relatively simple with rather uniform layering[1)].

3. Recording system

The signals from the tower and borehole accelerometers (each of which has three sensing directions) are recorded every 0.005 s by a 64–channel digital recorder unit[6)]. The recording system is activated when any of the three components at P540 (GL–40 m at borehole P5) exceeds acceleration of 1.0 gal.

4. Development of earthquake acceleration database

4.1 Selection of earthquake records

The triggering level of the recording system is comparatively low, and many of the recorded earthquakes are small and give insignificant information. The earthquake records for creation of the observation tower database are selected according to the same criteria as those for the Chiba array database[1)], since in further research common usage of data is intended. The largest event included is the Chibaken-Toho-Oki (Kujukuri Coast, Boso Pen.) Earthquake of December 17, 1987 with peak ground acceleration of over 300 gal at P501 (GL-1 m at borehole P5) and peak acceleration at the roof of the tower exceeding 700 gal.

4.2 Creation of the database

The procedure of creating the database is illustrated by a flowchart in Figure 2. Similarly to the organization of the Chiba array database, in order to make the records easily utilizable, heading data are assigned to each record. The heading data include event code (IEQK), component code (ICMP), title of the record, the maximum value of the record, sampling interval and the number of time steps[1)]. The last six characters of the title contain information about the location of the accelerometer and the orientation of the data, recorded by the channel. e.g. TRM5EW means a record from the accelerometer at the roof level in the center, oriented along the East–West axis. These notations are shown in Figure 1(b).

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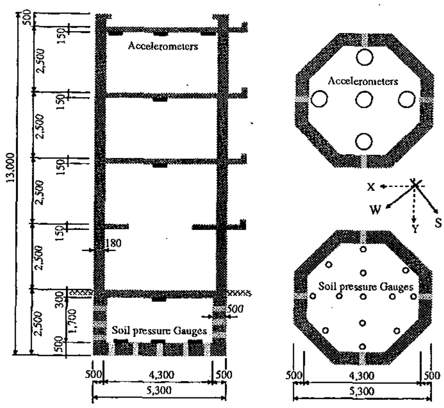

Fig. 1(a) Plan and cross-section of the tower [4]

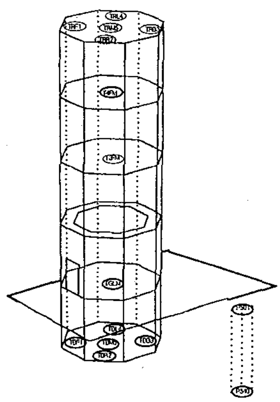

Fig. 1(b) Locations of the Accelerometers

Considering the characteristics of the accelerometers, a baseline correction and a high–cut filtering of the raw data are carried out (Fig. 2.)

The such obtained data are oriented according to the local XY coordinate system, shown in Figure 1(a). A transformation of all records is necessary, in order to orient them according to a North–South–East–West coordinate system, which is used in the Chiba Array Database, and also to remove possible error, due to inaccurate installation. The positive directions for the rotated data are fixed in the horizontal plane from North to south and from West to east. The positive vertical direction is preserved to be upwards, like in the local coordinate system. The evaluation of the angles between the respective coordinate axes is done by means of the maximum cross–correlation method.[3] The determined rotation angles for each accelerometer are shown in Table 1.

Finally, the absolute starting time and duration of the

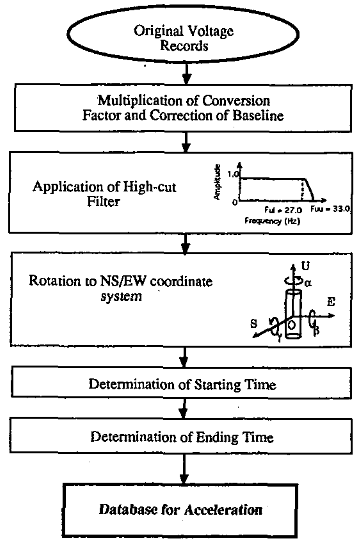

Fig. 2 Procedure for creating the database.

Table 1. Rotation angles with respect to EW-NS coordinate system

Accelero-meters	Rotation Angles		
	α (deg)	β (deg)	γ (deg)
TRF1	-34.5	-0.3	3.5
TRL4	-33.2	-6.2	7.6
TRB3	-36.4	-6.4	1.0
TRR2	-34.3	-1.7	-1.6
TRM5	-33.5	-2.9	1.7
T4FM	-35.0	-2.9	2.7
T3FM	-39.4	1.2	0.8
TGLM	-33.5	0.3	-0.6
TBF1	-33.9	5.9	0.2
TBL4	-36.0	-1.5	3.7
TBB3	-35.7	-1.2	-3.0
TBR2	-33.0	7.4	-7.5
TBM5	-34.9	1.9	-1.3
P501	- 2.0	2.8	2.4
P540	12.9	0.4	0.1

records are equalized to that of the corresponding records of the Chiba array database, with regard to the future common usage of both databases.

Table 2 presents a list and basic information about the largest nine events in the thus created database.

5. Results of preliminary processing of data

Figure 3 shows Fourier spectra of acceleration at some points of interest evaluated from records of the largest event, included in the database - the Chibaken–Toho–Oki Earthquake (IEQK 8722) together with the respective accelerograms. The multidirectional motion, to which the structure was subjected by the propagation of the seismic waves, is visualized in Figure 4. The displacement orbits of the measuring points at the basement and the ground level floor have similar shapes and range as that of the

Table 2 Basic Information on the Earthquake Records

Nº	IEQK	Trigger Time at P540		Focal Depth	JMA Magn	Azimuth	Epicentral Distance	T_D/T_R	Max Acceleration at P501 (gal)			Max Acceleration at TRM5 (gal)		
		Date	h/min/s	(km)		(deg)	(km)	(s)	EW	NS	UD	EW	NS	UD
1	8525	85.11.06	00:31:00	63	5.0	158.2	32	35/80	80.0	67.5	29.5	140.6	183.2	41.2
2	8717	87.06.30	18:17:21	57	4.9	358.2	62	43/68	15.7	24.0	12.4	34.6	46.8	15.8
3	8722	87.12.17	11:08:27	58	6.7	128.1	45	39/282	218.6	393.3	120.3	577.9	703.0	159.6
4	8723	87.12.17	11:15:14	52	4.6	128.2	46	51/64	22.9	26.8	11.3	23.4	45.7	21.0
5	8726	87.12.17	15:30:07	42	4.0	128.8	52	24/39	24.0	34.1	18.7	11.4	41.5	20.0
6	8802	88.01.05	10:09:17	42	4.2	128.3	37	17/39	32.2	47.7	10.6	18.6	67.3	15.6
7	8806	88.01.16	20:42:20	48	5.2	133.3	38	37/81	51.4	96.0	19.6	82.9	148.0	27.3
8	8808	88.01.18	19:37:24	32	4.1	243.6	17	19/34	26.6	28.7	7.2	28.3	14.1	9.0
9	8816	88.03.18	05:34:45	96	6.0	276.3	42	59/138	58.0	42.0	42.3	115.4	163.5	37.0

T_D-Duration of Database Record; T_R-Duration of Original Record; Azimuth-clockwize from North

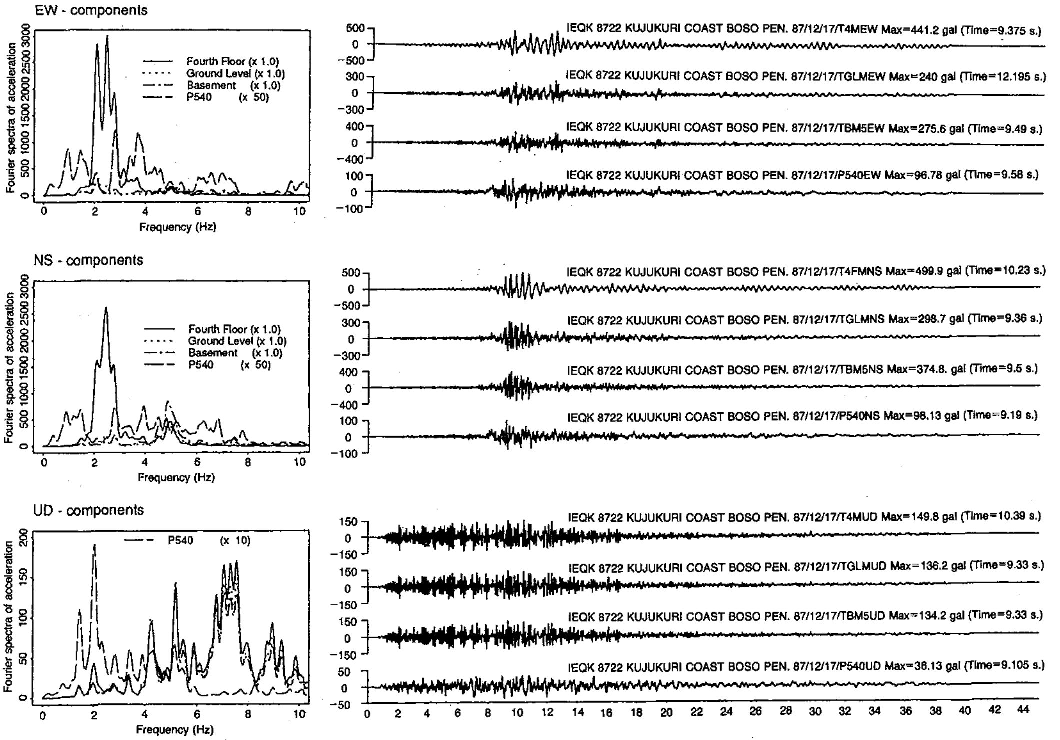

Fig. 3 Fourier spectra and wave forms (IEQK 8722)

surrounding soil, but greatly differ in both aspects from those at the upper part of the tower. This is quantitatively represented by the displacement diagrams, plotted at fixed time moments (Fig. 5). Figure 6 presents perspective plots of the vertical displacements of the basement floor slab at different events. The time moments are chosen such that the difference between the displacements of two oppositely located points is the biggest. As the basement floor slab is very rigid, there is almost no bending, but a noticeable rocking effects is observed, in accordance with the results of previous research[7].

The plots of Fourier spectrum ratios between the two borehole acceleration records (GL–40 m and GL –1m) indicate a soil amplification at about 2,3, 5.5 and 9.0 Hz (Fig. 7(a)) showing good coincidence with the values, obtained by one-dimensional shear-wave propagation theory[7]. The spectrum ratio between the basement and the deep borehole records, shown in Figure 7(b), has peaks at these same frequencies. The crests at 2.5–3.0 Hz, observed in the Fourier spectrum ratio between P540 and T4FM (Fig. 7(c)), represent the effect of the rocking on the horizontal displacement. Namely, the stronger rocking (IEQK 8722) decreases the value of the natural frequency. Filtering of high frequency components can

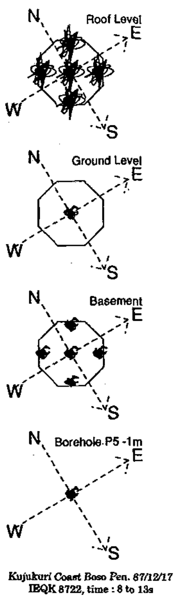

Fig. 4 Displacement orbit graphs

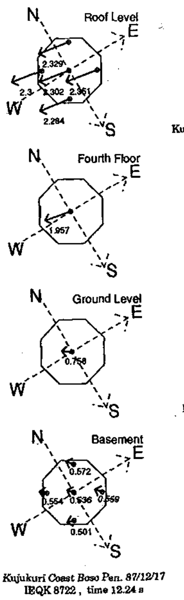

Fig. 5 Diagrams of displacements (cm)

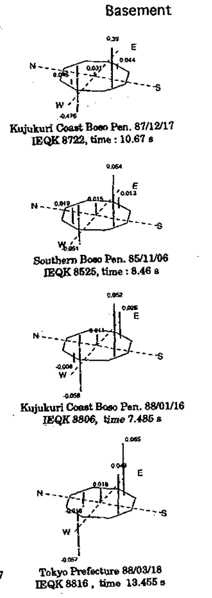

Fig. 6 Vertical Displacements (cm)

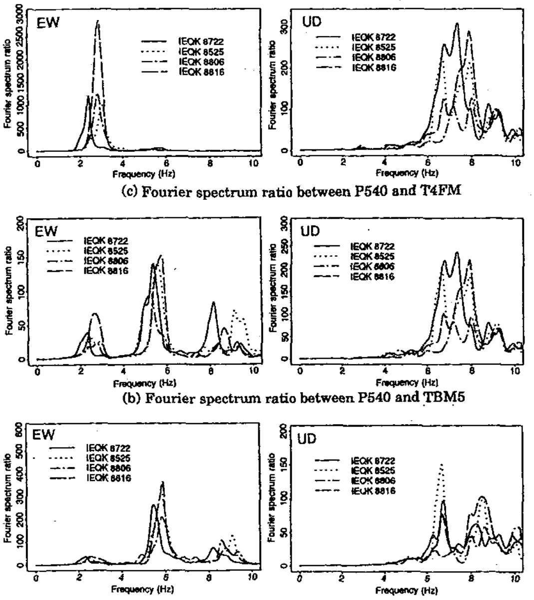

Fig. 7 Comparison of Fourier spectrum ratios

not be noticed for the vertical motion, whose natural frequency is about 7.5 Hz[7]. At the same time there is virtually no amplification of the UD-component within the structure.

6. Conclusions

Creating a structure response database of real earthquake records is an useful tool for obtaining of actual characteristics of a dynamic system and investigation of soil-structure interaction. In this particular case, the availability of the Chiba array immediately close to the tower provides the possibility for obtaining highly reliable results, due to the common ground conditions.

As a result of processing of the earthquake records it is found that the characteristics of the motion of the underground part of the tower up to the ground level are similar to those of the surrounding soil, rather than to those of the upper part of the structure. As the basement floor slab is very rigid, it experiences insignificantly small bending, but a considerable rocking effect is observed. There is no filtering of the high frequency components of the vertical motion, but the vertical components are almost not amplified within the structure. There is a good agreement between the theoretically evaluated parameters of the soil-structure system and those obtained by processing of the earthquake records.

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References

1. T. Katayama, F. Yamazaki, S. Nagata, L. Lu and T. Turker, "A Strong Motion Database for the Chiba Seismometer Array and Its Engineering Analysis", Earthquake Engineering and Structural Dynamics, Vol. 19, pp. 1089–1106, 1990.
2. L. Lu, F. Yamazaki and T. Katayama, "Soil Amplification Based on Seismometer Array and Microtremor Observations in Chiba, Japan", Earthquake Engineering and Structural Dynamics, Vol. 21, pp. 95–108, 1992.
3. F. Yamazaki, L. Lu and T. Katayama, "Orientation Error Estimation of Buried Seismographs in Array Observation", Earthquake Engineering and Structural Dynamics, Vol. 21, pp. 679–694, 1992.
4. Y. Hangai, F. Tatsuoka and N. Sato, "Observation of Soil-Structure Interaction of Towered Structure", Seisan-Kenkyu, Vol. 35, No. 9, pp. 35–38, 1983. (in Japanese)
5. Y. Hangai, T. Tanami and T. Yamagami, "Response Observation of Reinforced Concrete Tower", Seisan-Kenkyu, Vol. 36, No. 9, pp. 24–28, 1984. (in Japanese)
6. K. Takanashi, N. Sato and K. Ohi, "Data Acquisition System and Data Processing System", Seisan-Kenkyu, Vol. 35, No. 9, pp. 18–21, 1983. (in Japanese)
7. T. Yamagami, A Dissertation for Dr. Eng., 1990.