Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VI)

9-3-8

SEISMIC RESPONSE OBSERVATION OF BUILDING APPENDAGE

Kazutsugu HIRAMATSU[1], Yuji SATO[1], Hisanobu AKAGI[1] and Shinichi TOMITA[1]

[1]Building Engineering Development Office,
Building Engineering Department,
Nippon Telegraph and Telephone Corporation(NTT),
Musashino-shi, Tokyo, Japan

SUMMARY

To investigate the seismic response behavior of building appendages such as telecommunications equipment, antennas and towers, seismic response observation has been carried out at Ito Telephone Office since 1982.

This paper outlines the observation system, and describes the response characteristics of equipment in the buildings obtained through seismic response observation. "Response Ratio" for calculating seismic force data, used for designing an appendage to the building, reported in the 8th WCEE, is compared to the observed results, and the reasonableness is studied.

INTRODUCTION

To perform aseismic design and installation of telecommunications equipment effectively, it is necessary to establish an adequate design policy and aseismic design force. NTT has carried out analytical and experimental research and has developed a method for calculating seismic force data. This can be used for designing and installing telecommunications equipment, reported in the 8th WCEE (Ref. 1). To investigate the seismic response behavior of building appendages such as telecommunications equipment, antennas and towers, seismic response observation has been carried out at Ito Telephone Office since 1982.

This paper outlines the observation system, and the observation building and equipment in the building, and describes the response characteristics obtained through seismic response observation. "Response Ratio" for calculating seismic force data, used for designing an appendage to the building (Ref. 1) is compared to the observed ones, and the reasonableness is studied.

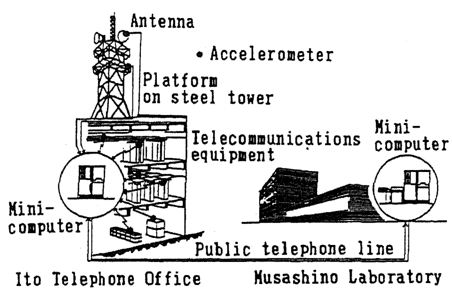


Fig. 1 Observation System with a Digital Mini-computer and a Public Telecommunication Line

SEISMIC RESPONSE OBSERVATION SYSTEM

An Observation system with a digital mini-computer and a public telecommunication line was used. An outline of the observation system is seen in Fig. 1. Digital mini-computers were prepared, both at Ito Telephone Office to record earthquake data and at Musashino Labora-

Table 1 Performance of the System

sensor	servo-type accelerometer (0.0001-2G , 0.0001-5G)	
delaying device	A/D conv	12bit 100Hz sampling
	delaying time	(start) 10 sec (end) variable
seismic trigger	(start) logical sum of arbitrary 3 channels (end) logical product of arbitrary 3 channels	
recording medium	bubble memory (digital)	
recording length	variable (≦320 seconds)	
telemetering	public telephone line, 1200bps	
power supply	AC line with a 30 minute capacity battery	

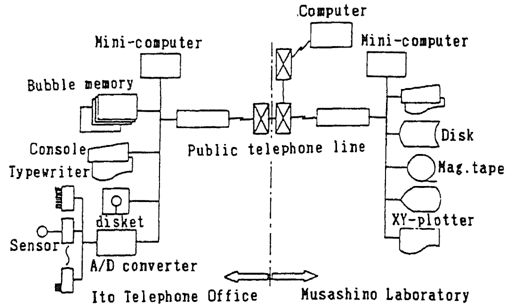


Fig.2 Block Diagram of the System

tory to analyze observed data. They were connected by public telephone line, thus enabling a check of the functions of the system, change of observation condition and transmission of the data to Musashino without site visits.

During strong earthquakes the data is stored in a recording device (bubble memory) in Ito's mini-computer with a 30 minite capacity battery. The data is expected to be reliably stored in earthquake because of stable performance of bubble memory against quake. The data in the recording device can be transmitted to Musashino by a telephone call after the earthquake. Fast data collection and effective use of telephone lines are also expected of this system. Fig.2 shows a diagram of the system. The specifications of the system are shown in Table 1.

OUTLINE OF OBSERVING BUILDING AND EQUIPMENT IN THE BUILDING

The observation building is shown in Photo.1. It is a 5-storied steel framed,


Photo.1 Ito Telephone Office

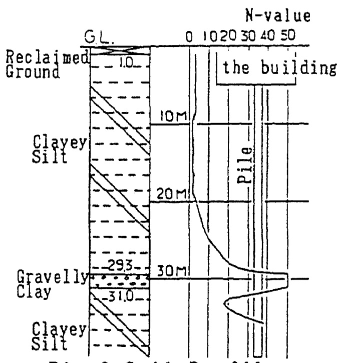


Fig.3 Soil Profile

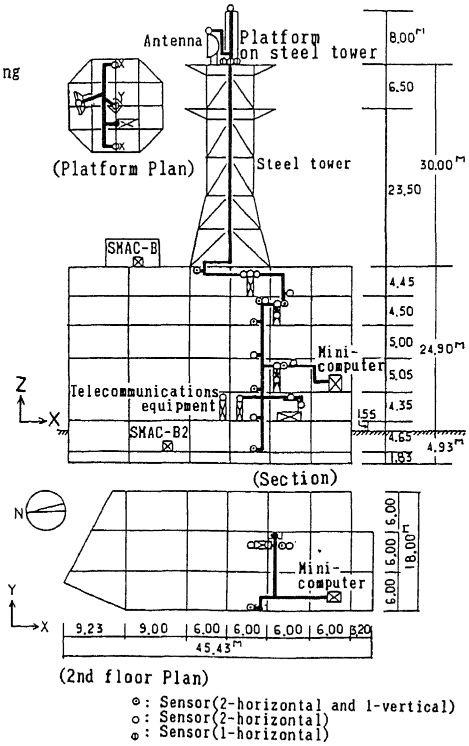


Fig.4 Plan and Section of the Building

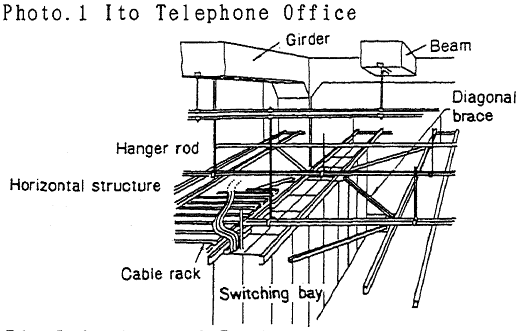


Fig.5 Outline of Equipment Supported by an Overhead Trussed Frame

reinforced concrete structure with a basement and pile foundations. The soil profile and standard penetration resistance values(N-value) are shown in Fig.3. The soil is very soft alluvial soil. A plan and section of the building are shown in Fig.4. Accelerometers are installed on the building floor at 7 points (18 components), on the equipment at 16 points (35 components), the steel tower at 2 points (5 components) and the antenna at 1 point (2 components), as shown in Fig.4. In this study, seismic response behavior of two pieces of self-standing equipment on the 1st floor, and equipment supported by an overhead trussed frame (see Fig.5) on the 2nd floor, 4th floor and 5th floor are investigated. Both of them are bolted to the concrete floor using bolts and concrete anchors.

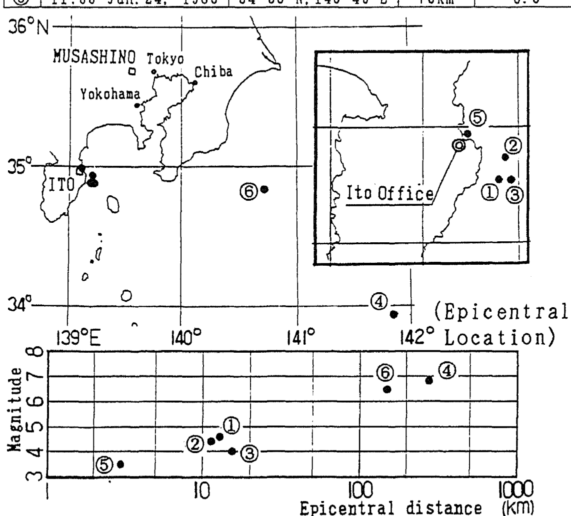
SEISMIC RESPONSE CHARACTERISTICS OF EQUIPMENT IN THE BUILDING

OUTLINE OF OBSERVED EARTHQUAKE Observed earthquake and the earthquake parameters are shown in Table 2. Epicenters of these 6 earthquakes from Jishin Kazan Gaikyo published by the Japan Meteorological Agency are shown in Fig.6 by solid circles. In addition, the relation of epicentral distance and Magnitude is seen in Fig.6.

CHARACTERISTICS OF FLOOR RESPONSE Response spectra in a horizontal direction for basement and roof are shown in Fig.7. Table 3 shows natural frequency of the building based on observed seismic response, together with that based on micro tremor measurement. Response spectra in a vertical direction for the basement, 2nd floor and roof are shown in Fig.8. The difference is less significant in the shape of the response spectra in a vertical direction for both basement and roof.

Table 2 Earthquake Parameters

No	Time	Hypocenter	Depth	Magnitude
①	0:43 Jan.20, 1983	34°53'N,139°12'E	0	4.6
②	1:59 Sep. 1, 1984	34°56'N,139°13'E	0	4.4
③	15:13 Sep. 5, 1984	34°53'N,139°14'E	20km	4.0
④	2:03 Sep.19, 1984	33°56'N,141°51'E	46km	6.8
⑤	15:20 Oct.21, 1985	34°59'N,139°07'E	1km	3.5
⑥	11:53 Jun.24, 1986	34°50'N,140°43'E	73km	6.5



(Magnitude vs. Epicentral Distance)
Fig.6 Outline of Observed Earthquakes

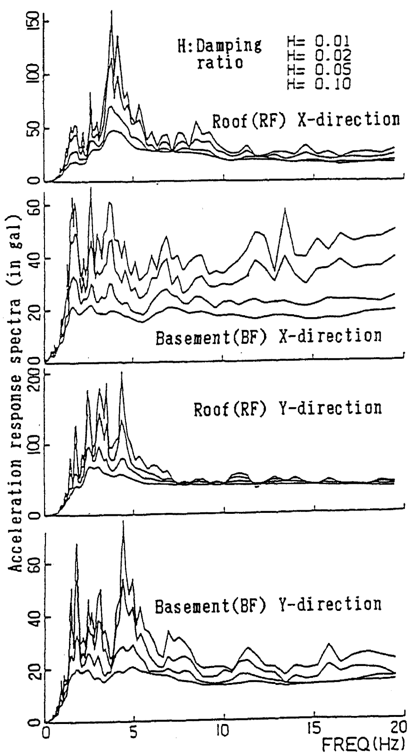


Fig.7 Floor Response Spectra (No④) (Horizontal Components)

Table 3 Natural Frequency of the Building

	X-dir.	Y-dir.	torsion
Seismic Observation	3.93Hz	3.30Hz	
Micro Tremor Measurement	3.76Hz	3.32Hz	4.79Hz

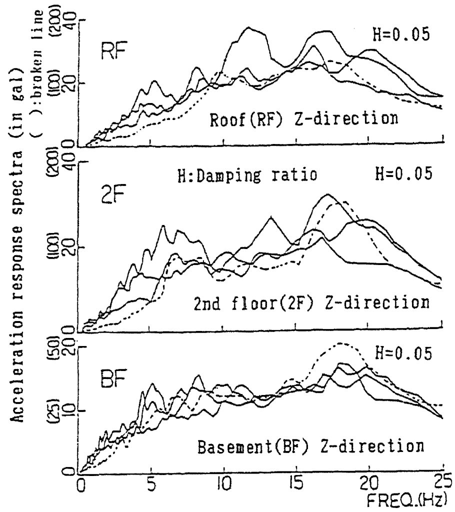


Fig.8 Floor Response Spectra
(No②～⑤) (Vertical Component)

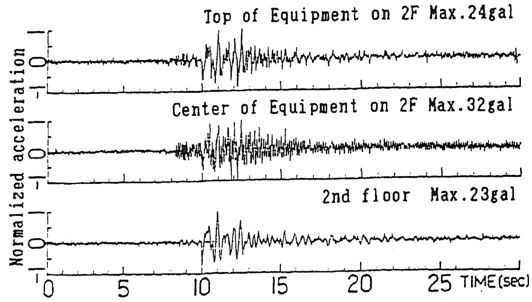


Fig.9 Earthquake Wave Records
(No①) (X-direction)

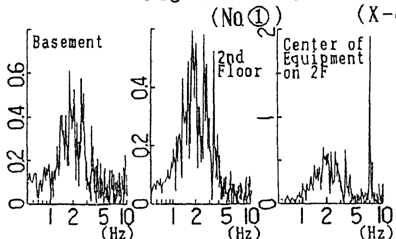


Fig.10 Fourier Spectra
(No①) (X-direction)

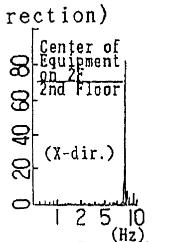


Fig.11 Transfer Function(No①)

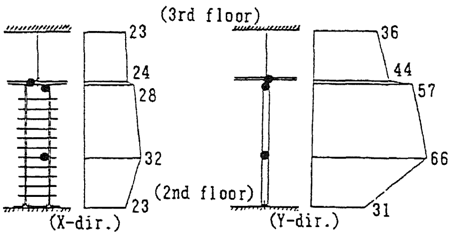


Fig.12 Maximum Acceleration(in gal) Distributions (No①)

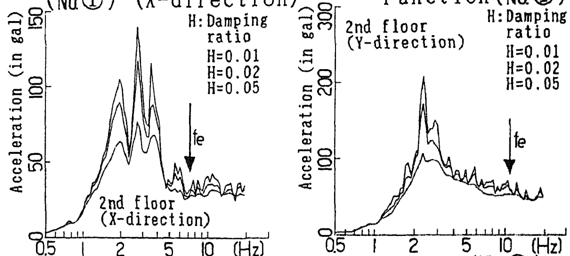


Fig.13 Floor Response Spectra (No①)

RESPONSE CHARACTERISTICS OF EQUIPMENT IN THE BUILDING Accelerograms in a horizontal direction for the equipment on 2nd floor are shown in Fig.9, together with that for the floor itself. The movement of the floor and the shorter movement in natural frequency of the equipment can be seen.

Fourier spectra in a horizontal direction for the equipment on the 2nd floor and for the floor itself and transfer function between the two are shown in Fig.10 and 11 together with that for the basement. Ground motion (basement acceleration) effects equipment acceleration as seen in the fourie spectra. A predominant peak existed as seen in the transfer function. It seems to be the natural frequency of the equipment.

Observed maximum response acceleration of the equipment on 2nd floor in a horizontal direction is shown in Fig.12. Response spectra in a horizontal direction for the 2nd floor is shown in Fig.13. The observed maximum response acceleration of the equipment agrees with the value of the response spectra corresponding to the natural frequency of the equipment "fe"

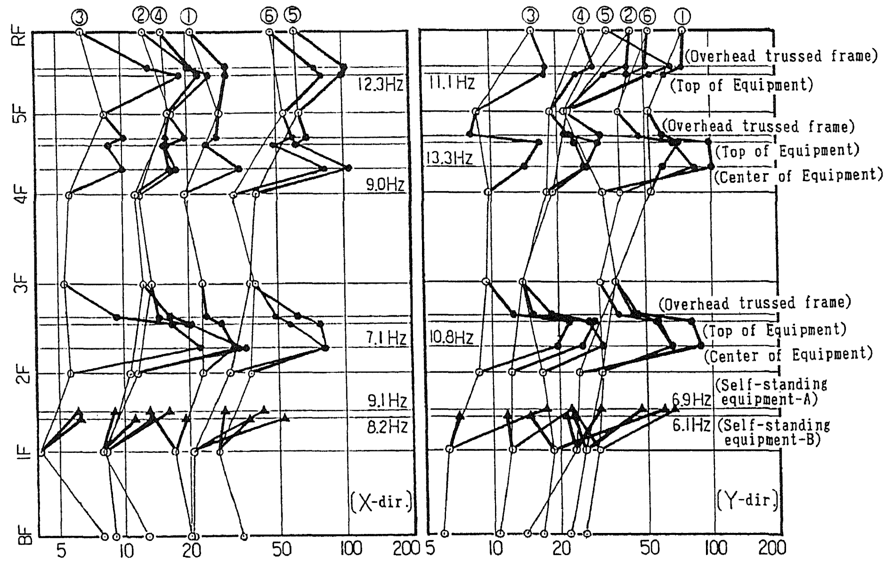
HORIZONTAL NATURAL FREQUENCY OF EQUIPMENT The natural frequency of equipment based on observed seismic response (time history, fourier spectrum, transfer function) is shown in Fig.14. Those of self-standing equipment varied between 6 and 9 Hz. Those of equipment supported by an overhead trussed frame varied between 7 and 13 Hz.

ACCELERATION RESPONSE RATIO FOR APPENDAGE GRAVITY CENTER TO THE FLOOR All of the observed maximum response accelerations are shown in Fig. 14. The floor acceleration and acceleration response ratios (equipment/floor response) in a horizontal direction are shown in Fig.15. The ratios are widely distributed, and are inclined to decrease slightly with increase in floor acceleration. The acceleration response ratio of self-standing equipment "B" on the 1st floor in Y direction is less than any others, because it is supported by the wall using a angle steel. Examples of accelerograms in a vertical direction, the acceleration response ratio of which is more than any other ones, are shown in Fig.16.

COMPARISON BETWEEN THE OBSERVED RESULTS AND "RESPONSE RATIO"(REF.1) The seismic forces in a horizontal direction:P (Ref.1) can be represented by eq.(1).

$$P = K0 \cdot K1 \cdot K2 \cdot W \cdot I \qquad (1)$$

where K0: the standard seismic coefficient (seismic coefficient:



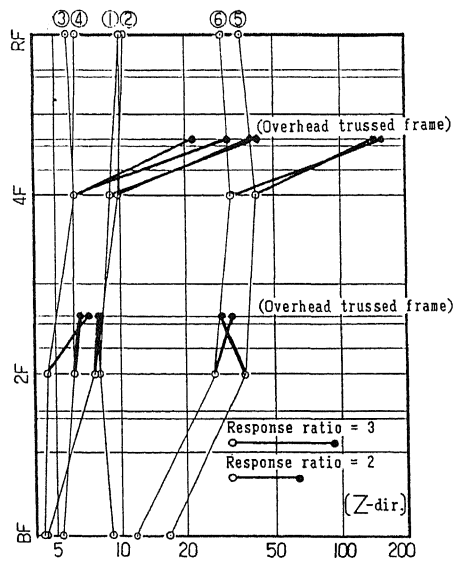


Fig.14 Maximum Acceleration(in gal) Distribuions and Response Ratio

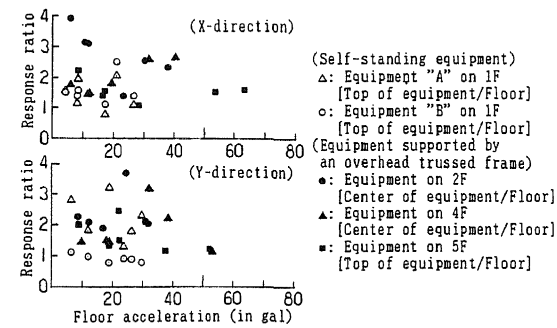


Fig.15 Relation of Floor Acceleration and Acceleration Response Ratio for Appendage

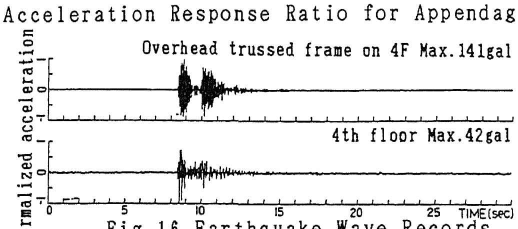


Fig.16 Earthquake Wave Records (No.⑤) (Vertical Component)

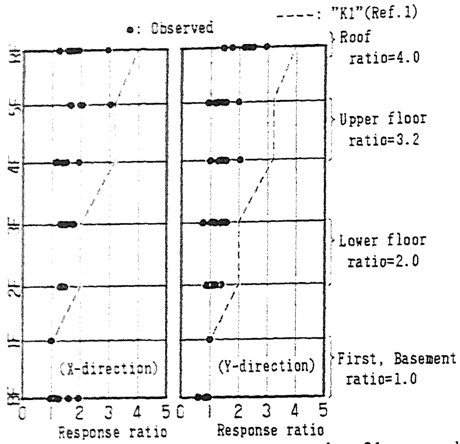


Fig.17 Comparison between the Observed Results and Acceleration Amplification Ratio for Building Floor,"K1"(Ref.1)

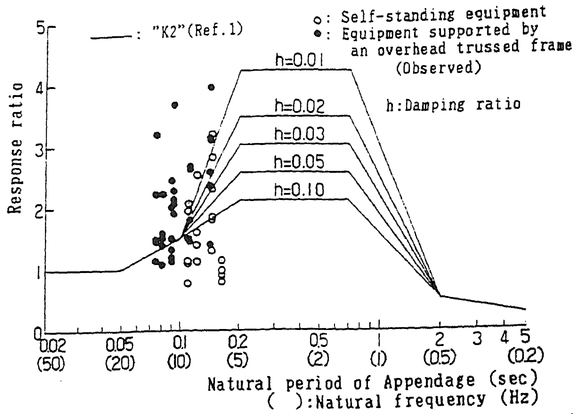


Fig.18 Comparison between the Observed Results and Acceleration Response Ratio for Appendage Gravity Center to the Floor,"K2" (Ref.1)

acceleration/acceleration of gravity), K1: Acceleration amplification ratio for building floor (see Fig. 17), K2: Acceleration response ratio for appendage (see Fig. 18), W: Weight of appendage, I: Importance factor

Acceleration Amplification Ratio for Building Floor,"K1" (Ref.1) is indicated in Fig.17 by a dotted line. Observed ones are shown in Fig.17 by solid circles. All of them are equal to, or less than "K1".

Acceleration Response Ratio for Appendage Gravity to the Floor,"K2" (Ref. 1) is indicated in Fig.18 by a full line. Observed acceleration response ratios for appendage to the floor are shown in Fig.18 by solid circles (equipment supported by an overhead trussed frame) and open circles (self-standing equipment). They are widely distributed, and are distributed both above and below "K2". They approximately corresponds with "K2", except for ones with very small floor acceleration.

CONCLUDING REMARKS

To investigate the seismic response behavior of building appendages such as telecommunications equipment, antennas and towers, seismic response observation has been carried out at Ito Telephone Office since 1982.

This paper outlines the observation system, and describes the response characteristics of equipment in the buildings obtained through seismic response observation. "Response Ratio" for calculating seismic force data, used for designing an appendage to the building (Ref. 1) is compared to the observed results, and the reasonableness is studied.

Observed response ratios approximately agreed with "Response Ratio" (Ref.1) except for observed ones with very small floor acceleration. The maximum acceleration of these 6 earthquakes for the basement is equal to or below 30 gal. It is necessary to continue seismic response observation and investigate in more detail the seismic response behavior of building appendage.

REFERENCE

1. Sato, Y. et al.,"Building Appendage Seismic Design Force Based on Observed Floor Response," Proc. 8th World Conf. on Earthquake Engineering, 1984