

TELECOMMUNICATIONS EQUIPMENT SEISMIC EFFECT STUDY

by

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SYNOPSIS

On-site vibration tests and earthquake observations were carried out on switch frame-building system. In addition, vibration tests on bay-type equipment and data processing equipment units were conducted, using a shaking table. As a result, the dynamic properties and seismic resistance capacity of telecommunications equipment and installation practices were clarified and some improvement were made on them.

1. INTRODUCTION

Telecommunications facilities are required to have a stronger disaster resistance capacity than ordinary buildings and facilities, because they are essential for a nation's welfare. In NTT, many countermeasures have been put into effect in order to maintain telecommunication service during and after disaster, such as: (1) Reinforcement of facilities to ensure sufficient resistivity to disaster. (2) Improving communication network reliability by multi-routing of communication paths to prevent nationwide communication confusion due to a local damage. (3) Distribution of mobile radio equipment, mobile switching system, temporary cable, etc. to local areas, in order to keep at a minimum, and to restore quickly proper communication function under any circumstances. In particular, for seismic resistivity, the following design goal was established, based on maintaining a balance between reliability and cost: (1) Against seismic intensity^(I) V (ground motion acceleration 0.08 to 0.25g), the equipment and networks should not be affected in any term. (2) Against seismic intensity VI (ground motion acceleration 0.25 to 0.40g), partial damage may occur in equipment, but they must be easily restorable to normal operating conditions. (3) In either case, safety must be guaranteed for personnel concerned. This paper describes the results of examination on seismic resistivity of telecommunication equipment, conducted on the basis of the above-mentioned policy.

2. VIBRATION TEST AND EARTHQUAKE OBSERVATION FOR SWITCH FRAME-BUILDING SYSTEM

2.1 On-Site Vibration Test and Earthquake Observation

In order to understand seismic property of a switch frame-building system, micro-tremor measurement, free vibration test, forced vibration test and earthquake observation were conducted on the three story Nishiya Exchange Building in Yokohama. Forced vibration tests on switch frame were also conducted on the third floor in this building. Free vibration was caused by giving the roof an initial displacement in the building width direction and quickly releasing the tension. Forced vibration was set up

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(I) Japanese seismic intensity scale.

by exciting the roof or reinforcement by changing the sine wave frequency. Figure 1 shows layout of the instruments. Examples of micro-tremor wave-form are shown in Fig. 2. Test results were as follows: (1) The observed resonance frequency of switch frame is shown in Table 1. The resonance frequencies are higher than the primary natural frequency of the building (3.4Hz) and fall in the range of 7 to 20Hz. (2) The primary vibration mode in front-to back direction of switch frame-building system was observed. As shown in Fig. 3, switch frame displacement was 1.5 to 3.5 times larger than the displacement at each floor.

Twenty three earthquakes were observed from January 1972 to December 1975. Table 2 shows an example of maximum acceleration at measurement points. The largest data (M=7.2, Dec. 4, 1972) was digitized and analyzed. These data indicate the following: (1) The maximum acceleration measured at the top of the switch frame was 1.2 to 1.7 times larger than that measured at the floor. (2) Switch frames spectra have a maximum peak at the natural frequency of the building and also approximate those obtained from vibration tests. A response analysis was made on switch frame-building model shown in Fig. 4, inputting the seismic records from the ground floor. The mass and spring constant of building were calculated from actual weight and rigidity of structure. The switch frames mass was calculated from the weight of some frames with a seismometer. The spring constant of switch frame was calculated so that one-mass model of a switch frame will have the same resonance frequency as observed. The comparison in acceleration response of the switch frame, between the observed value and the estimated value obtained by the response analysis, is shown in Fig. 5. This indicates that the response of the switch frame is approximately simulated by such a lumped-mass vibration model.

2.2 Building Floor Motion during Earthquakes

In order to understand the behaviour of telecommunication buildings during earthquakes, eighty seven SMAC type strong motion seismographs have been installed in 34 buildings and observation has been continued. An examination was conducted for 436 records observed at 2- to 9- story ordinary telecommunication buildings. This indicates the following: (1) Each floor vibration of a building has a predominant frequency mainly at 1.4 to 6.0Hz which agrees with a primary resonance frequency of the building. This trend seems more significant in higher floor. Peaks were also found at secondary or third natural frequency of the buildings (approximately 6.6 to 14.4Hz). (2) Lower floors seem to be affected by lower frequencies, ranging from 0.7 to 4.1Hz which would depend on the foundation ground property. (3) The acceleration level increases 1.2 to 4.1 times, mostly 1.5 to 2.5 times, from the first floor to the highest floor. With these results, and referring to the acceleration amplification data of SAN FERNANDO EARTHQUAKE⁽¹⁾, the seismic behavior of building floors can be assumed as follows: Frequency range is 1 to 20 Hz; Maximum acceleration amplitude is 0.30 to 0.60g for intensity V and 0.60 to 0.80g for intensity VI.

3. VIBRATION TEST BY SHAKING TABLE

Vibration tests were conducted, using a large shaking table, on four bay-type equipment such as crossbar switch etc., twenty six data processing equipment such as CPU etc. and installation practices. The shaking table performance is shown in Table 3. Excitation condition was as follows: (1) Sine wave: frequency is 1 to 20Hz, acceleration level is 0.1 to 0.5g,

(2) Calculated floor motion of a typical building, maximum acceleration level is 0.40 to 0.80g. Acceleration, and displacement for some devices, was measured at about 10 to 20 points. Mechanical irregularities were observed and some electrical functions were monitored during the tests. Results of the experiment are summarized below:

3.1 Bay-type Equipment Unit

Bay-type equipment units were installed, securing the top and bottom, in a steel frame which was assembled on the shaking table as shown in Fig. 6. An example of maximum acceleration distribution is shown in Fig. 7. The maximum observed acceleration was approximately 1.6 to 2.0g at the center part of switch frame. No particular damage was observed, except for the following: Noises occurred or subscriber connection was impossible only a few times during the telephone call tests, at an operation acceleration of 1.20 to 1.60g. However, after the vibration tests, no irregularity could be found in the speech test. From this, bay-type equipment units and the installation method used in the test were found to be sufficiently resistant to shocks of up to intensity VI earthquake.

3.2 Data Processing Equipment Unit

Data processing equipment units were installed on a raised full access floor mounted on the shaking table, as shown in Fig. 8. Table 4 lists the type of tested devices and installation method. Acceleration response curves are shown in Fig. 9. Figure 10 plots the relationship in measured resonance frequencies and damping constants. The acceleration amplification factor reached 2 to 7 times at a resonance point. As shown in Fig. 9, the peak of acceleration was rounded off with an increase of input, indicating certain nonlinear characteristics of acceleration response. The maximum observed acceleration in devices was approximately 1.0 to 1.5g in cabinets and approximately 1.0 to 2.3g in logical packages. No particular damage, such as breaking of wiring or damage to component parts, was observed, except the following: (1) Magnetic catches on most devices were disengaged at an operation acceleration 0.2 to 0.6g, resulting in opened cover or door. Heavy resonance was found at logical packages, resulting in slipping out of the packages or the insulator sheets which had been inserted between packages, at an operation acceleration of 0.3 to 2.0g. (2) Parity check error occurred partially in logical operation, when logical devices and magnetic recording devices were excited at near the resonance point. The parity error checks, however, had no reproducibility and seemed random.

All devices were found to have a trend toward rocking and sliding, when not secured on the floor (shaking table). The maximum slip reached 85cm. Excessive rocking was observed on four devices, which required stopping of the test before the planned acceleration level was reached. In order to protect the telecommunication devices from slipping or falling down, the devices must be secured to the floor, by any means. A new installation practice, using inclined steel plate fittings, shown in Fig. 11, was developed and tested. At the maximum 0.5 to 0.8g floor acceleration, the device started heavy vertical motion, causing the floor panel with the fittings to swing. However, the fittings protected the device from trouble. The installation practice was proved to sufficiently withstand shocks of up to intensity VI.

4. CONCLUSION AND RECOMMENDATIONS

Through the above-mentioned on-site vibration tests, earthquake observations and vibration tests by shaking table, the dynamic properties and aseismic capacity of telecommunications equipment were investigated and clarified. Based on these studies, improvements have been made in aseismic resistivity of equipment units and installation practices.

The recommendations about aseismic design of telecommunications equipment obtained from the examination results were summarized as follows: (1) Telecommunications equipment should have its aseismic capacity ascertained by the shaking table test. As the input waveform for the test, time history should be used, in principle, that is generated to reflect predominant earthquake frequencies and building properties. The sine wave can also be used that affects the specimen equivalently to the time history. The vibration test specification for the telecommunication equipment installed in ordinary buildings is proposed in Table 5. The test is composed of two stages, A and B. Test A corresponds to intensity V earthquake, and test B corresponds to intensity VI earthquake. The test results should be judged by the criteria mentioned in Section 1. An example of the time history generated for the test is shown in Fig. 12. The power spectra given for the generation is also shown in Fig. 13. (2) Rather than a magnetic catch, a mechanical locking is preferable for covers or doors. Plugged-in parts should not depend on the friction force only, but, clamps or other means should be preferably used to protect the parts from slipping out. (3) As a principle, devices should be securely mounted. For comparatively simple I/O devices, which are not usually secured, protection measure to prevent slipping out or turning over should be considered.

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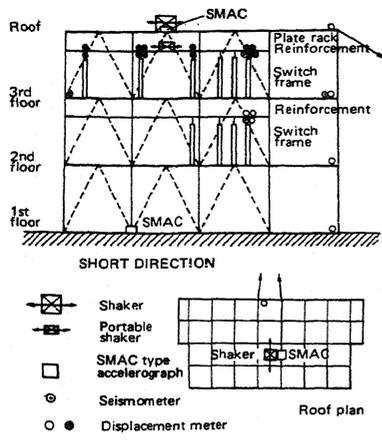


Fig. 1 Instrument Layout

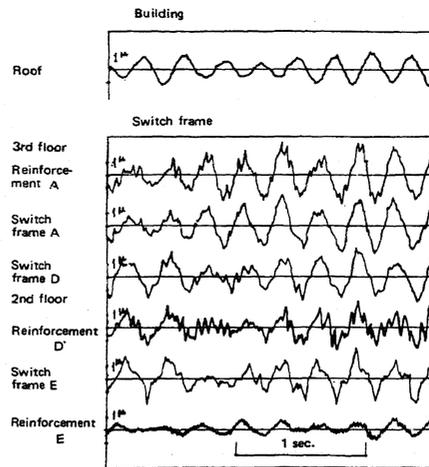


Fig. 2 Microtremor Measured (short direction)

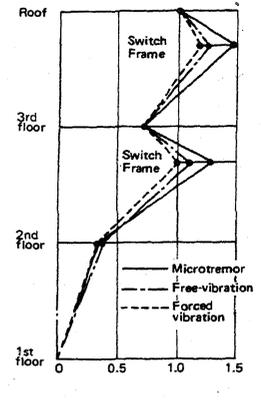


Fig. 3 Primary Mode of Switch Frame-Building

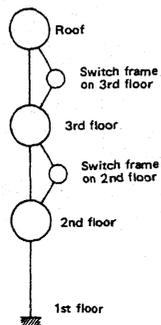


Fig. 4 Switch Frame-Building Model

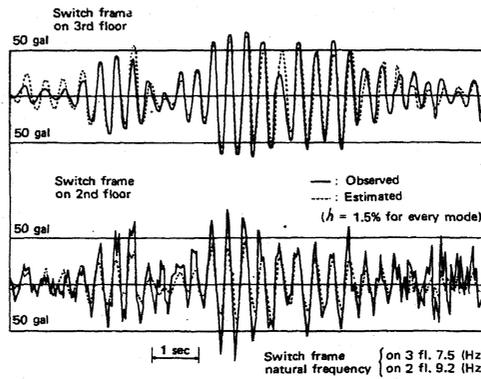


Fig. 5 Acceleration Response on Switch Frame (short direction)

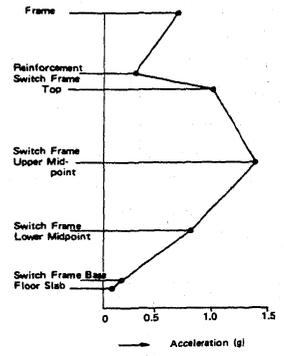


Fig. 7 Maximum Acceleration Distribution of Switch Frame

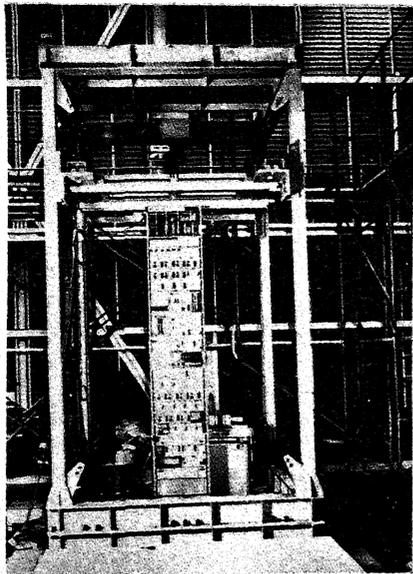


Fig. 6 Switch Frame

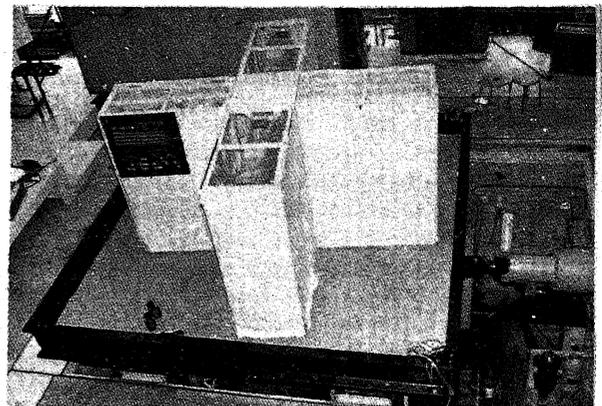


Fig. 8 Data Processing Equipment.

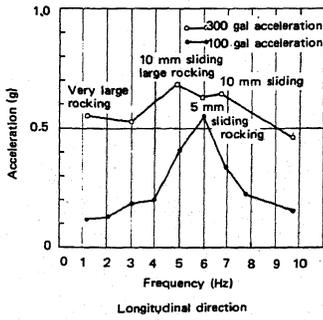


Fig. 9 Acceleration Response

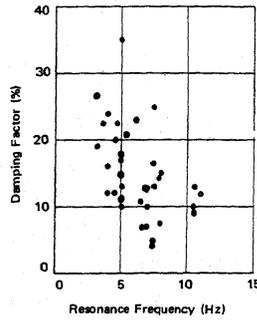


Fig. 10 Relation Between Damping Factor and Resonance Frequency

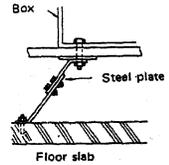
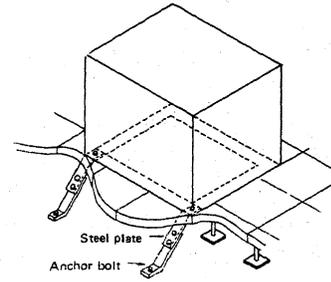


Fig. 11 New Equipment-installing Method

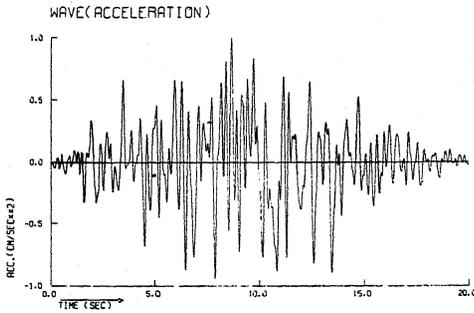


Fig. 12 Time History

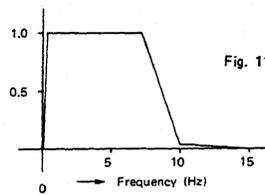


Fig. 13 Power Spectra

Table 1 Resonance Frequencies of Switch Frame [Hz]

Direction	Measure points Vibration	3rd floor						2nd floor	
		Switch Frame				Plate Rack A,B,C	Reinforcement A,B,C	Switch Frame E	Reinforcement D, E
		A	B	C	D	A,B,C	A,B,C	E	D, E
Short (Front-to-back) Direction	Micro-tremor	7.5 10	-	-	8 14.5	-	7.5 9	9.5 10	9 ~ 9.5 14 ~ 15
	Roof Forced	7.5 9	-	-	10	-	7 9	9 12	9 12
	Switch Frame Forced	10 20	10 24	16 22	15 28	16 ~ 18 22	16 ~ 17	-	-
Long (Length) Direction	Switch Frame Forced	17	12 17	11 24	18	16 ~ 17 20 ~ 25	17	-	-

Table 2 Maximum Acceleration Observed (gal)

Date (Magnitude)	Epicenter Region	Direction	Building			Switch frame	
			1st floor	3rd floor	Roof	2nd floor	3rd floor
Dec. 4 1972 (M=7.2)	E OFF HACHI-JOJIMA	Short	18.4	58.7	76.1	84.9	84.3
		Long	13.6	62.4	74.8	52.9	79.3
Dec. 8 1972 (-)	NORTHERN TOKYO BAY	Short	3.1	45.3	53.8	55.8	66.7
		Long	3.8	53.8	50.0	46.5	63.1
March 27 1973 (M=4.9)	TOKYO BAY	Short	7.8	49.0	43.8	-	67.1
		Long	12.5	31.0	45.0	37.5	51.5

Table 3 Earthquake Simulator Performance

Size of table	3 m x 3 m
Maximum test model weight	10 tons
Maximum exciting force	Horizontal 15 tons.g Vertical 20 tons.g
Direction of vibration	One horizontal direction or Vertical direction (independent)
Input waves	Sine wave, random wave
Maximum acceleration	With no load : 3g With capacity loads : 1g
Maximum displacement	Horizontal direction ± 100 mm Vertical direction ± 120 mm
Maximum velocity	Horizontal direction 65 cm/sec. Vertical direction 40 cm/sec.
Frequency range	0.1 ~ 50 Hz

Table 4 Data Processing Equipment Specimen

Abbreviation	Test Equipment	Numbers	Not Mounted	Mounted
CPU	Central Processing Unit	3	3	1
MTU	Magnetic Tape Unit	6	2	5
MTC	Magnetic Tape Controller	4	0	4
DKU	Disk Unit	1	1	0
DPU	Disk Pack Unit	2	1	1
DRU	DRum Unit	2	1	2
DRC	DRum Controller	1	0	1
TYP	TYPE writer	1	1	0
CR	Card Reader	1	1	0
LP	Line Printer	3	3	0
IJP	Ink Jet Printer	2	2	0
Installation Specimen		12	10	2
TOTAL		38	25	16

* Three specimen were tested twice, both mounted and not mounted.

Table 5 Vibration Test Specification

	Time History Max. Acceleration (g)	Sine Wave		Corresponding Intensity
		Acceleration (g)	Frequency (Hz)	
TEST A	0.30 ~ 0.60	0.40	2 ~ 6	V
TEST B	0.60 ~ 0.80	0.50	2 ~ 6	VI

DISCUSSION

A.R. Chandrasekaran (India)

The shake table has been described to give a sinusoidal excitation at frequencies 1 to 20 Hz and at acceleration levels of 0.1 to 0.5 g. This would imply that the displacement of the table would be at least 25 mm at 1 Hz and 0.3 mm at 20 Hz. What procedure was used to change the amplitude of the table over this range? Was the acceleration level of 0.1 to 0.5 g achieved at very low frequencies?

From Fig. 11, it is seen that the equipment was mounted using a special inclined fixture. What are the advantages of this fixture? Is it also used in prototype?

Author's Closure

Not received.