II. EARTHQUAKE RESPONSE OF REINFORCED CONCRETE WEAK-MODEL STRUCTURES DUE TO OCTOBER 4, 1985 EARTHQUAKE

by

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1. INTRODUCTION

Since August in 1983, an earthquake response observation of R/C weak model structures has been carried out, and more than fifty sets of records on accelerations, inter-story displacements and strain of reinforcement bars were obtained by January in 1986. This paper describes the response characteristics to the October 4, 1985 earthquake which was the most severe since the observation had started.

The model structures are five-story building models which are about 1/4 size of actual structure. Two model structures have been utilized for the observation, one was designed to cause yield hinges at column ends and the other at beam ends. The dimensions of the model structure are shown in Fig. 1, and column and beam sections are shown in Fig. 2.

In this paper, the response of horizontal X-axis direction of weak column structure and horizontal Y-axis direction of weak beam structure are described. The locatoin of each structure are shown in Fig. 3.

2. RESPONSE CHARACTERISTICS OF WEAK COLUMN STRUCTURE

The horizontal peak acceleration and maximum inter-story displacement at each floor of weak column structure are shown in Table 1. The maximum acceleration were 74 gals at the 1st floor, and 307 gals at the top floor.

Figs. 4 and 5 show the time history at each floor and Fourier amplitude spectra at 1st, 3rd and top floor of the horizontal acceleration records. Fig. 6 shows the distribution of the response accelerations and displacements when the acceleration at the top floor or at the 4th floor was maximum. It is found that the 2nd mode shape with the node close to 5th floor was mostly predominated. Fig. 7 shows the response spectrum of input acceleration. Input acceleration had two predominated period ; one was about 0.18 sec. the other about 0.40 sec., and the about 0.18 sec.

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component was more excited than another, as shown in Fig. 7. The foundamental and 2nd vibration periods during earthquakes before this earthquake reported in Refs. [1] and [2] had been about 0.42 to 0.43 sec. and about 0.16 sec., respectively. It is considered that the predominated component of the ground motion excited 2nd mode shape.

The fundamental and 2nd vibration periods during the earthquake estimated by the peak periods of Fourier amplitude spectra obtained from 10.0 sec. to 30.0 sec. in the Fig. 4 were about 0.48 to 0.50 sec. and about 0.18 to 0.19 sec., respectively.

The base-shear coefficient at the yield hinge mechanisms for weak column structure calculated by nonlinear frame analysis was 0.16, and the maximum response base-shear coefficient in this earthquake was about 56% of the yield hinge mechanism as shown in Table 1.

Figs. 8 and 9 show the time history at each story and Fourier amplitude spectrum at 4th story of inter-story displacement, and Fig. 10 shows the cracks occurred by this earthquake. The response inter-story displacement of 4th story was greater than other stories, and numbers of the flexural cracks on the columns were observed in the 4th story. The hysteresis loop at the 4th story is shown in Fig. 11. Cracks at the 2nd, 3rd and 5th stories were also observed, but the crack width were smaller than those at the 4th story.

3. RESPONSE CHARACTERISTICS OF WEAK BEAM STRUCTURE

The horizontal peak acceleration and maximum inter-story displacement are shown in Table 2. The maximum acceleration were 83 gals at the 1st floor and 226 gals at the top floor.

Figs. 12 and 13 show the time histories and Fourier amplitude spectra of the horizontal acceleration records. The 1st mode shape was mostly predominated, as shown in Fig. 6. The fundamental and 2nd vibration period derived from Fourier amplitude spectra were about 0.3 to 0.32 sec. and about 0.09 to 0.1 sec., respectively.

Figs. 14 and 15 show the time history at each story and Fourier amplitude spectrum at the 3rd story of horizontal inter-story displacement. The response inter-story displacement of 2nd and 3rd stories were greater than other stories. There are two peaks in Fourier amplitude spectrum ; one corresponds with foundamental vibration period of the structure and the other with the predominated period of the ground motion.

The caluculated base-shear coefficient at the yield hinge mechanisms was 0.21, and the maximum response base-shear coefficient observed in this earthquake was 57% of the yield hinge mechanisms as shown in Table 2.

Fig. 16 shows the cracks occurred by this earthquake. Some hair cracks were observed on the columns in the 4th and 5th stories.

The changes of the vibration periods are shown in Table 3. The vibration periods by this earthquake became a little longer than before.

4. CONCLUDING REMARKS

The weak column structure had numbers of cracks at upper stories due to the predominance of the 2nd mode shape. The damage of the weak beam structure by this earthquake were less than that of the weak column structure.

REFERENSES

[1] T. OKADA and R. TAMURA, "Observation of Earthquake Response of Reinforced Weak Model Structures (Part 1)", Seisan-kenkyu (Journal of IIS), Institute of Industrial Science, University of Tokyo, Vol. 35, No. 9, Sep. 1983.

[2] T. OKADA and R. TAMURA, "Observation of Earthquake Response of Reinforced Weak Model Structures (Part 2)", Seisan-kenkyu (Journal of IIS), Institute of Industrial Science, University of Tokyo, Vol. 36, No. 9, Sep. 1984.

[3] R. TAMURA et al., "Observation of Earthquake Response of Reinforced Weak Model Structures (Part 5)", Proc. of the Annual Convention of A. I. J., Architectural Institute of Japan, Oct. 1985.

[4] T. OKADA and R. TAMURA, "Observation of Earthquake Response of Reinforced Weak Model Structures", Bull. of ERS, No. 18, March 1985.

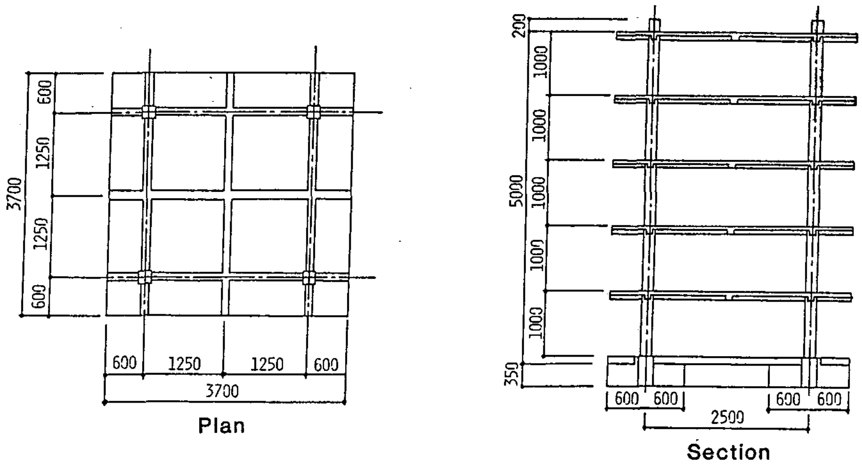


Fig. 1 Plan and Section of Weak Model Structure

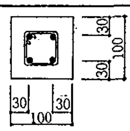
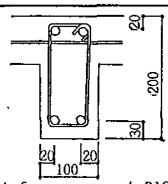
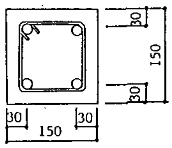
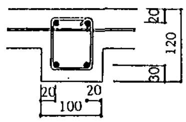
	Column Section	Beam Section
Weak Column Structure	 Reinforcements: 4-D6(SD30) Hoop: 2φ @30(SR24)	 Reinforcements: 4-D10(SD30) Stirrup: 2φ @30(SR24)
Weak Beam Structure	 Reinforcements: 4-D10(SD30) Hoop: 2φ @30(SR24)	 Reinforcements: 4-D6(SD30) Stirrup: 2φ @30(SR24)

Fig. 2 Column and Beam Sections of Weak Model Structures

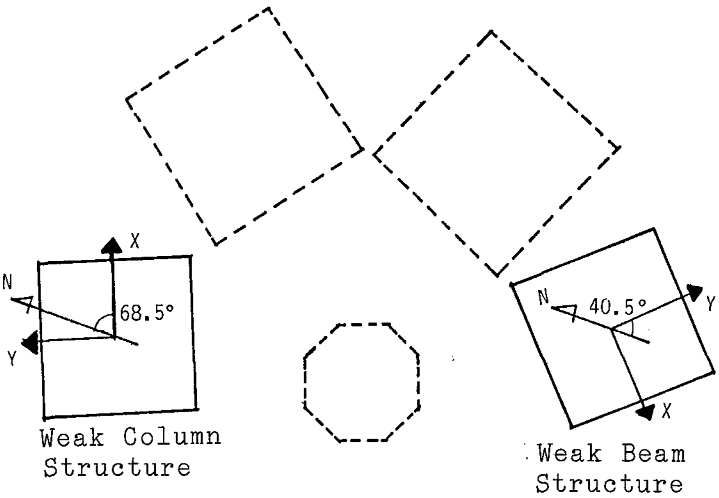


Fig. 3 Layout

Table 1 Maximum of Response of Weak Column Structure in October 4, 1985 Earthquake

	ACCELERATION (gals)	MAX.OF SHEAR COEFFICIENT
Top	306.92	—
5 th	149.33	0.31
4 th	230.60	0.21
3 th	206.09	0.12
2 nd	208.74	0.09
1 st	73.59	0.09

	INTER-STORY DISP. (cm)
5 th	0.22
4 th	0.39
3 rd	0.20
2 nd	0.19
1 st	0.22

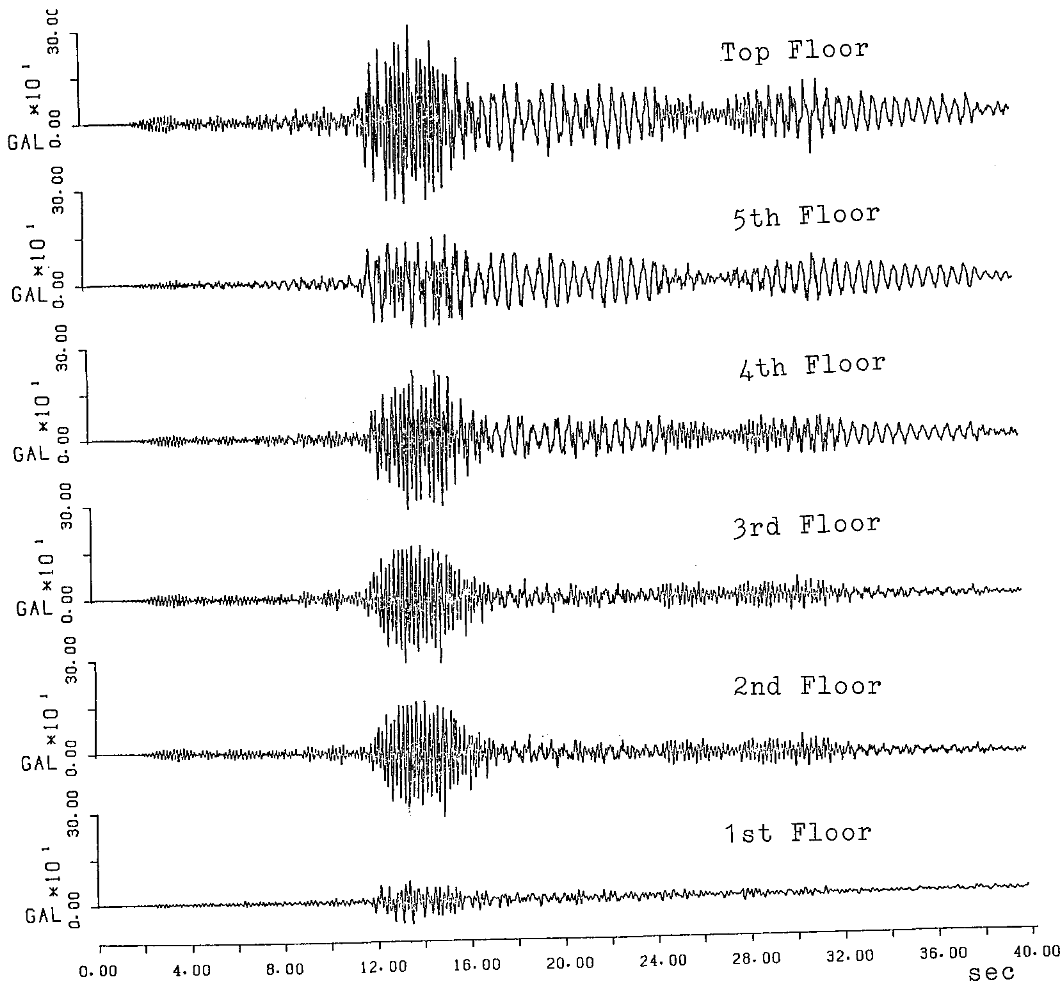


Fig. 4 Recorded Time Histories of Acceleration of Weak Column Structure in October 4, 1985 Earthquake

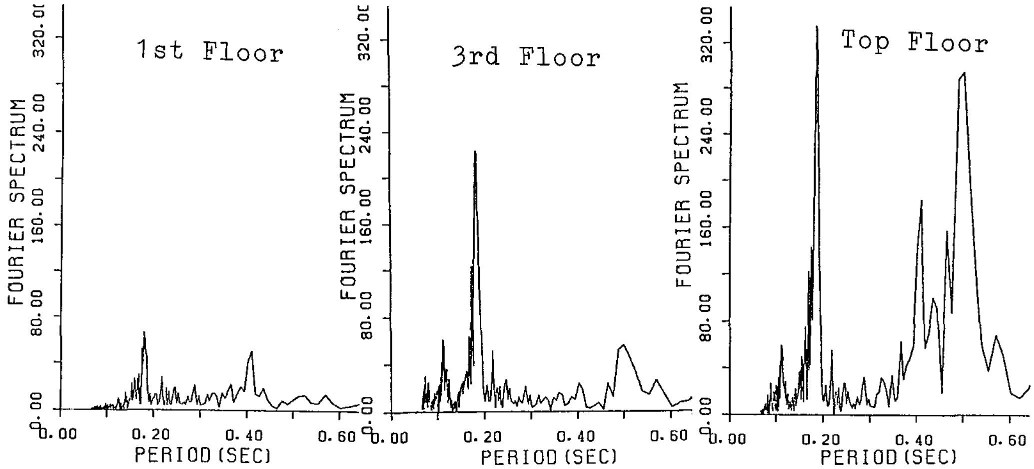


Fig. 5 Fourier Spectrum of Acceleration
of Weak Column Structure
in October 4, 1985 Earthquake

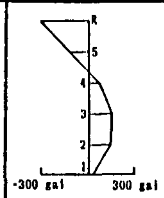
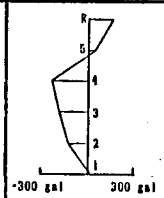
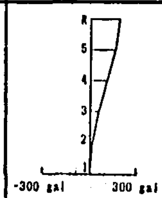
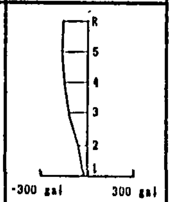
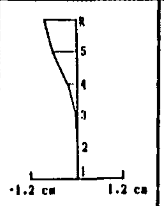
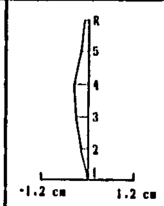
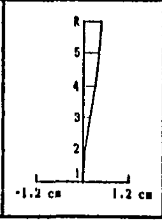
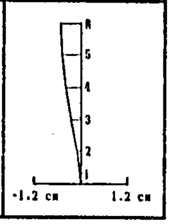
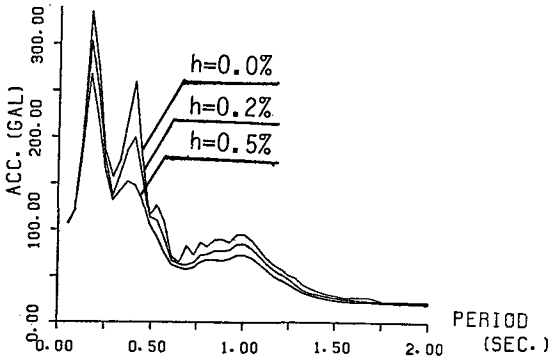
	Weak column structure		Weak Beam Structure	
	Top Floor	4th Floor	Top Floor	4th Floor
Distribution of Acc.				
Distribution of Displ.				

Fig. 6 Distribution of Acceleration and Displacement
in October 4, 1985 Earthquake

Fig. 7 Response
Acceleration spectrum of
Base Motion of Weak
Column Structure
in October 4, 1985
Earthquake



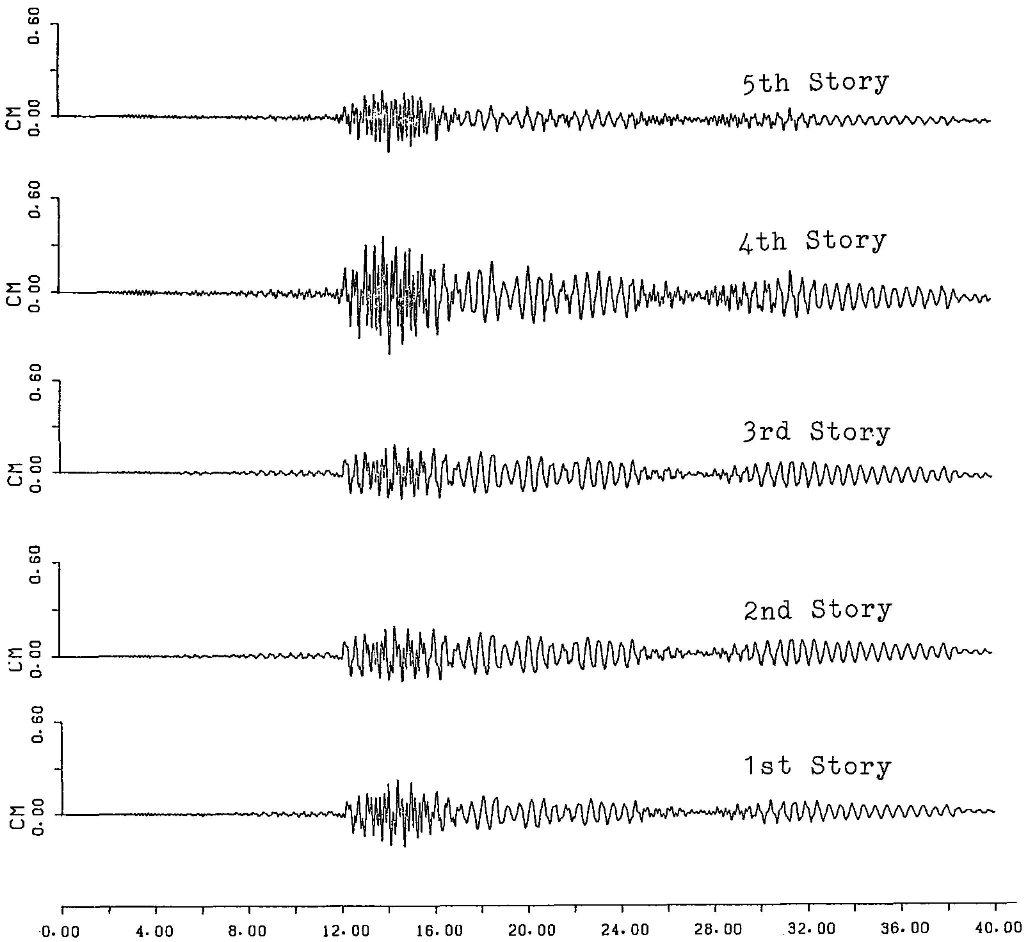


Fig. 8 Recorded Time Histories of Inter-Story Displacement of Weak Column Structure in October 4, 1985 Earthquake

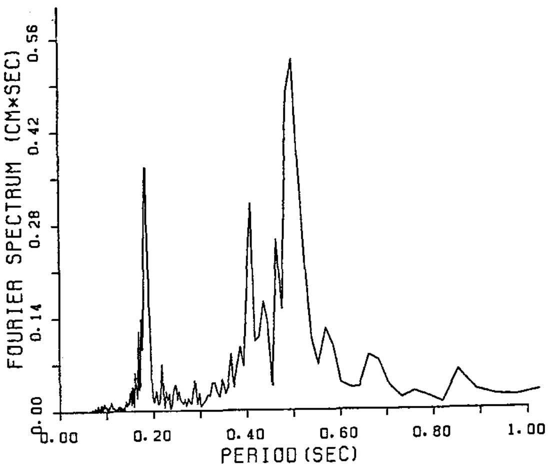


Fig. 9 Fourier Spectrum of Inter-Story Displacement of 4th Story of Weak Column Structure in October 4, 1985 Earthquake

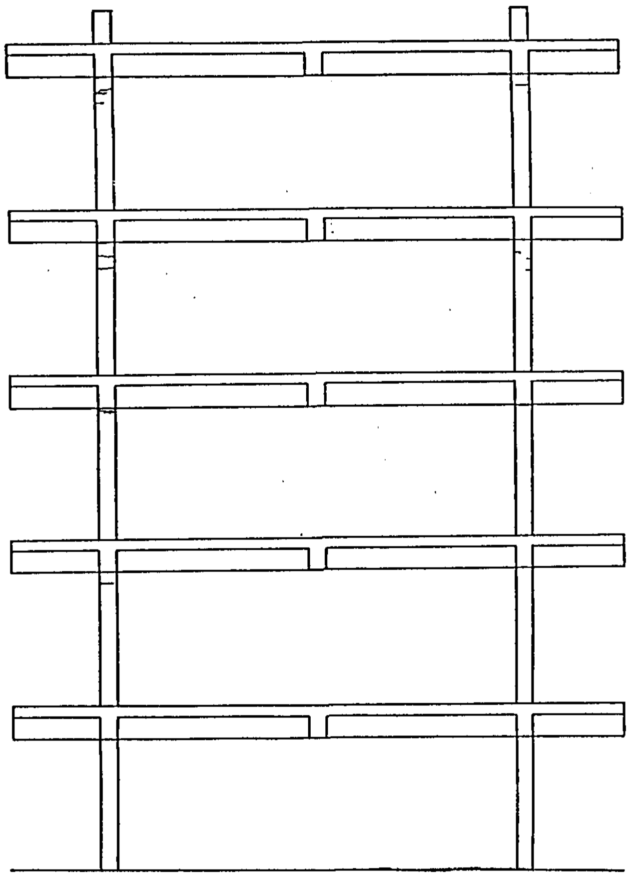


Fig. 10 Obserbed Cracks
of Weak Column Structure
in October 4, 1985 Earthquake

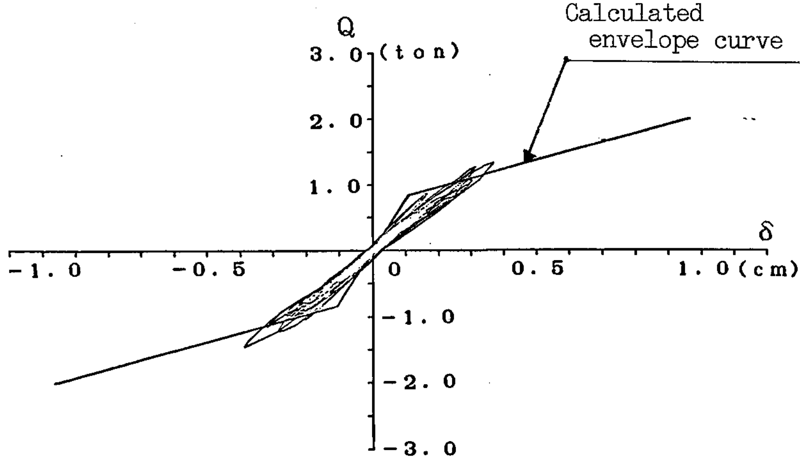


Fig. 11 Hysteresis Loop of 4th
Story of Weak column Structure
in October 4, 1985 Earthquake

Table 2 Maximum of Response of Weak Beam Structure in October 4, 1985 Earthquake

	ACCELERATION (gals)	MAX.OF SHEAR COEFFICIENT
Top	225.96	—
5 th	184.92	0.23
4 th	127.63	0.20
3 rd	120.37	0.17
2 nd	85.00	0.14
1 st	82.89	0.12

	INTER-STORY DISP. (cm)
5 th	0.05
4 th	0.09
3 rd	0.21
2 nd	0.12
1 st	0.08

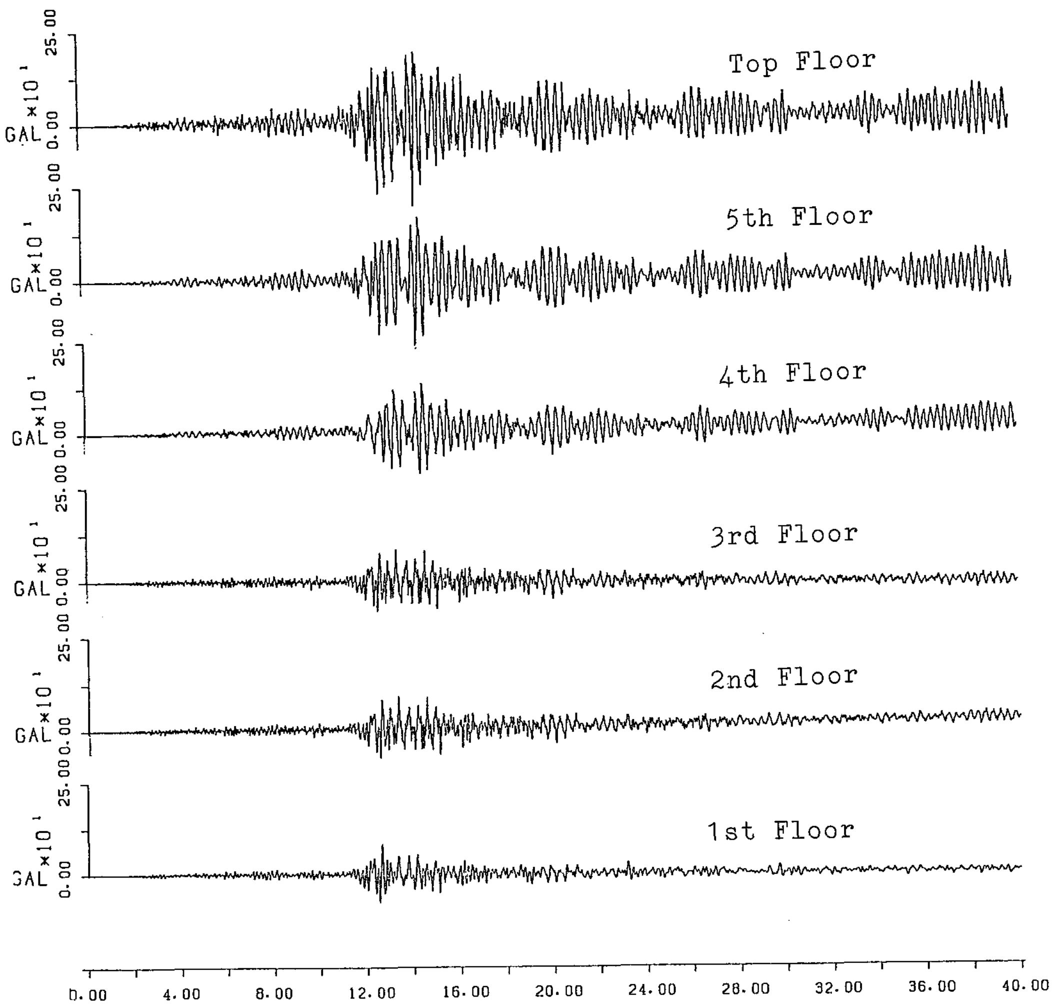


Fig. 12 Recorded Time Histories of Acceleration of Weak Beam Structure in October 4, 1985 Earthquake

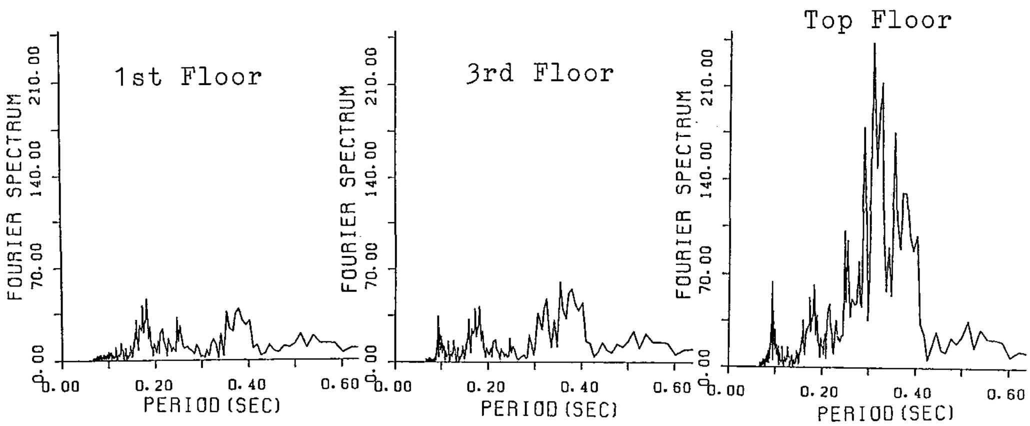


Fig. 13 Fourier Spectrum of Acceleration of Weak Beam Structure Column Structure in October 4, 1985 Earthquake

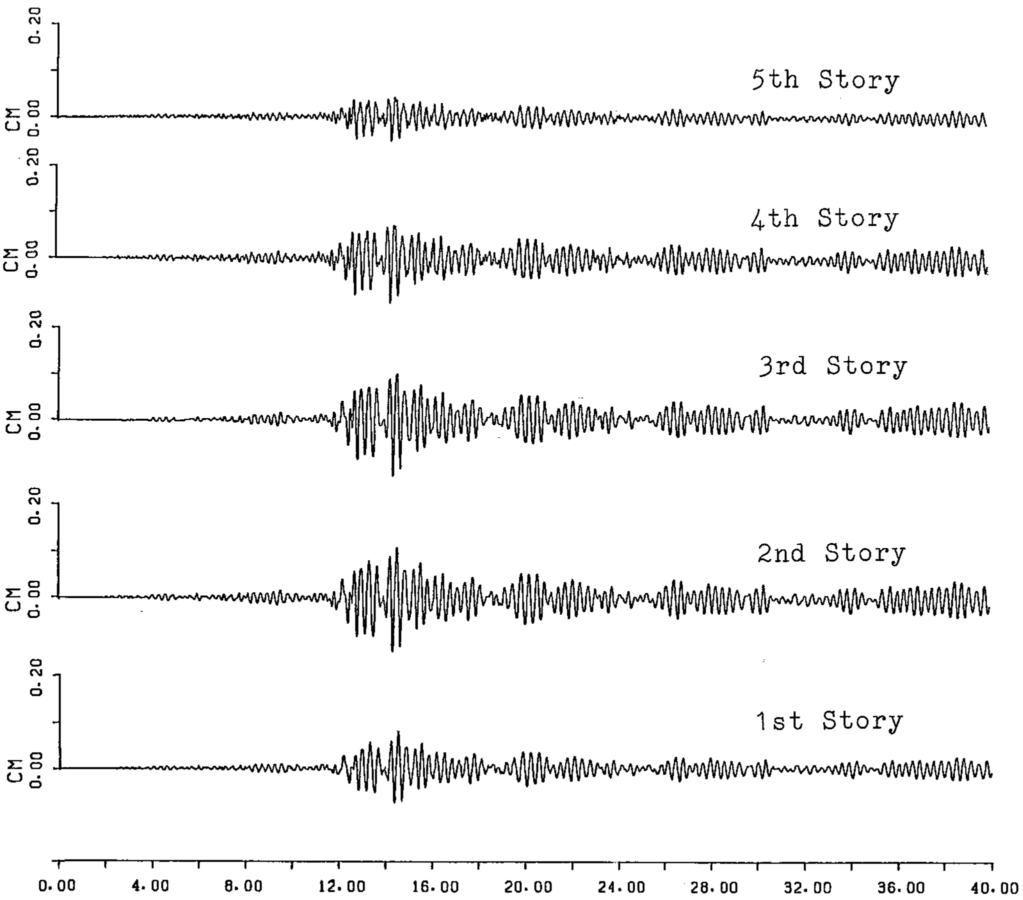


Fig. 14 Recorded Time Histories of Inter-Story Displacement of Weak Column Structure in October 4, 1985 Earthquake

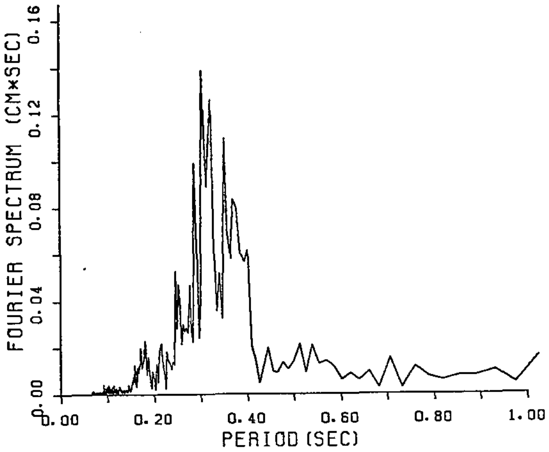


Fig. 15 Fourier Spectrum of Inter-Story Displacement of 3rd Story of Weak Beam Structure in October 4, 1985 Earthquake

Table 3 Changes of Vibration Period of Weak Beam Stracture in October 4, 1985 Earthquake

	Before '85 10 4	'85 10 4
1 st	0.29~0.30	0.31~0.32
2 nd	0.09	0.10

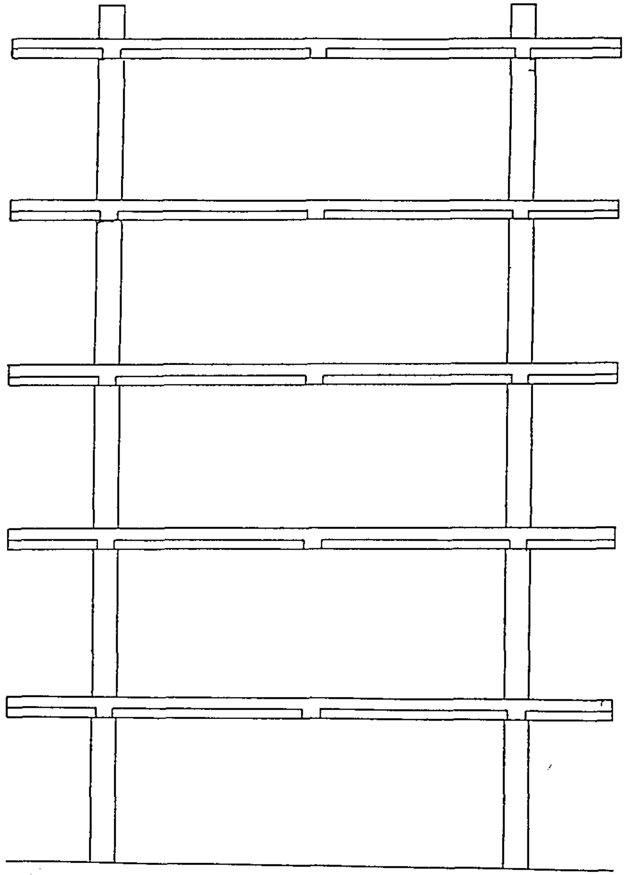


Fig. 16 Observed Cracks of Weak Beam Structure in October 4, 1985 Earthquake