ON THE SEISMIC DAMPING OF ACTUAL BUILDINGS
(The Case of the San Fernando Earthquake)

by

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SYNOPSIS

The results of the present investigation tell us that the vibrational damping of a building is mostly based on that, during an earthquake, the vibrational energy of a building dissipates into the ground again as in a broad sense the waves which start from the foundation.

In the absence of some form of damping resistance, almost any structure would suffer serious damage in an earthquake, owing to resonance-like phenomena. The questions of damping in the material used in the structure as well as in the foundation have been studied by many investigators, but the dissipation of vibrational energy in the form of seismic waves transmitted into the ground, which seems to be one of the most important parts of the problem(1), has not yet been investigated satisfactorily.

In order to clarify the problem mentioned above, in the present investigation, we deal with the comparison between the seismograms obtained at ten buildings including partially damaged buildings at the time of the San Fernando Earthquake of February 9, 1971(2), and the theoretical results in which the idea of the multiple reflection problem of waves in an elastic body is concerned.

The theoretical result of multiple reflection problem of waves in an elastic body adopted here is as follows(3):

$$u_{z=H}(\tau + \frac{H}{V}) + u_{z=H}(\tau - \frac{H}{V}) = 2\, u_{z=0}(t) \qquad (1)$$

in which, z=H and z=0 express the top and the bottom of the body, τ and t represent the origin of time starting from z=H and z=0, and V is the transmission velocity of waves in that body, respectively. The values of H/V are estimated from the 1/4 of the peak periods of the Fourier's spectra of the seismograms obtained at the top of the buildings.

The constants of the buildings as well as the observational results adopted here are shown in Table 1. As an example, the seismograms recorded at the bottom of a building and the theoretical results calculated by means of Eq. (1) as well as the seismograms recorded at the top of the same building are shown in Fig. 1. The Fourier's spectra of the seismograms recorded at the bottom of the buildings together with the theoretical results calculated by Eq. (1) are shown in Figs. 2-11. From Fig. 1 as well as Figs. 2-11, it has been clarified that the agreement of the observed results with calculated ones is well beyond expectation.

We are now examining such a case of the problem in which the seismograms are devided into two or three parts and the different values of the velocity of waves in each part are adopted. In this case, the agreement

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mentioned above may be expected well entirely, the result of which will be published in the near future.

It is a noteworthy fact that, as neither the solid viscosity nor the other features of attenuation in a body have been assumed from the start of the mathematical treatment in the present problem, the decaying character of the oscillation in the present problem depends entirely upon the fact that the partial emission of the waves into the ground during their multiple reflection gradually diminishes the energy of waves. In other words, the results of the present investigation tell us that the vibrational damping of a building is mostly based on that, during an earthquake, the vibrational energy of a building dissipates into the ground again as in a broad sense the waves which start from the foundation.

Finally we would like to emphasize that the problem presented here is one of the most important fundamental subjects in earthquake engineering.

In conclusion, we wish to express our sincere thanks to Messrs. K. Yamabe, F. Hamayasu and K. Kato for their help. Also thanks are due to Messrs. S. Ono, H. Kobayashi, M. Goto, H. Kusunoki, N. Takahashi, A. Tanaka and N. Yamana who assisted us in preparing this paper.

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FIGURE CAPTIONS

Fig.1-a. Wilshire Square,S00W,T=1.28sec; Fig.1-b. N90E,T=1.05sec.
Fig.2-a. Wilshire Square,S00W,T=1.28sec; Fig.2-b. N90E,T=1.05sec.
Fig.3-a. Ventura Gloria Bldg.,S81E,T=2.73sec; Fig.3-b. S09W,T=3.41sec.
Fig.4-a. Certified Life Tower,S12W,T=1.08sec; Fig.4-b. N78W,T=1.14sec.
Fig.5-a. Beneficial Plaza,N90E,T=1.10sec; Fig.5-b. S00W,T=1.32sec.
Fig.6-a. Millikan Library,N90E,T=1.03sec; Fig.6-b. N00E,T=0.65sec.
Fig.7-a. Valley Pres. Hosp.,S00W,T=1.05sec; Fig.7-b. S90W,T=0.87sec.
Fig.8-a. Farmers Insurance,N15E,T=0.42sec; Fig.8-b. N75W,T=0.61sec.
Fig.9-a. Hollyday Inn(Orion),N00W,T=1.52sec; Fig.9-b. S90W,T=1.32sec.
Fig.10. Hollyday Inn(Marengo),N38W,T=1.03sec.
Fig.11. Bank of California,N79W,T=2.93sec.

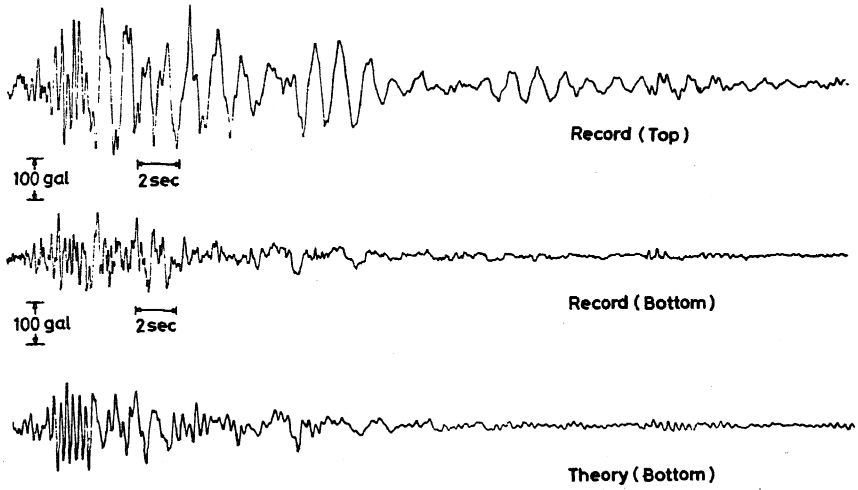
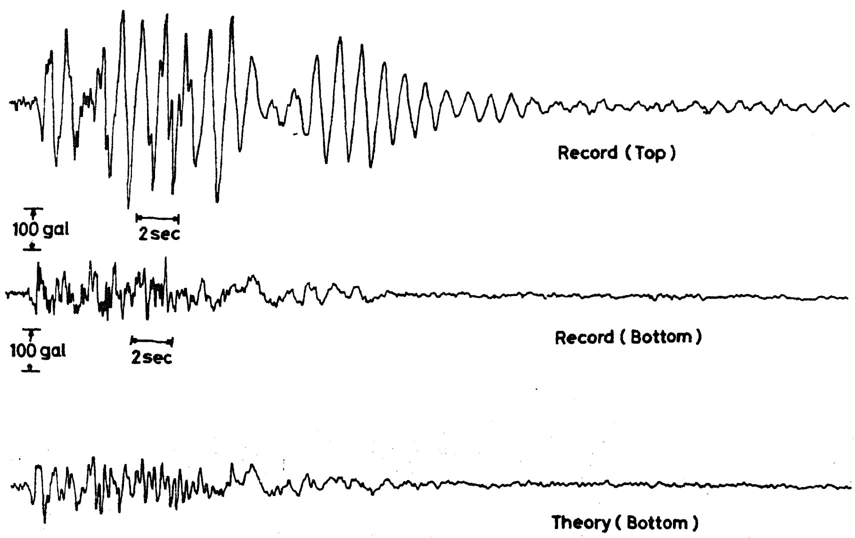


Fig. 1-a.



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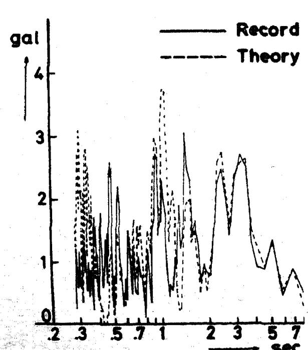

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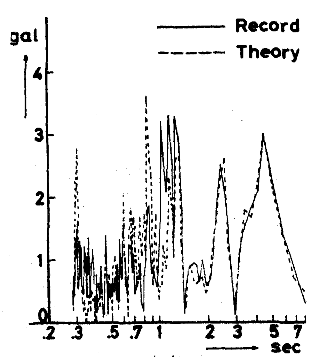

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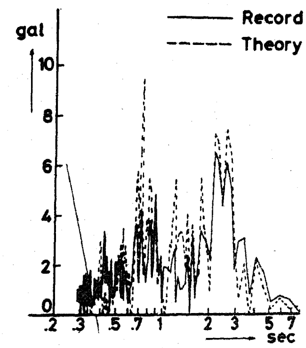

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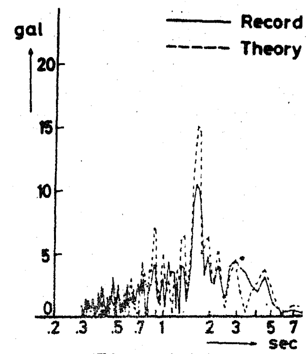

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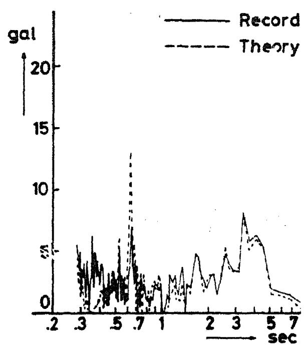

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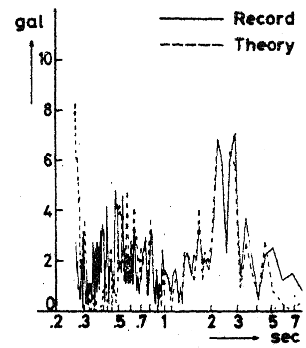

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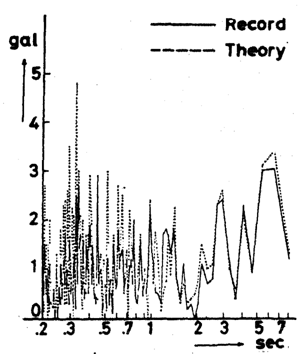

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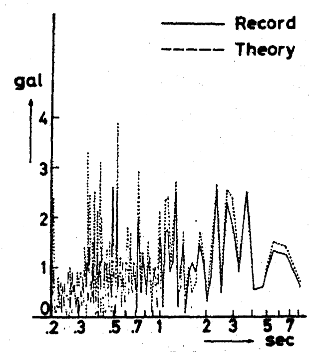

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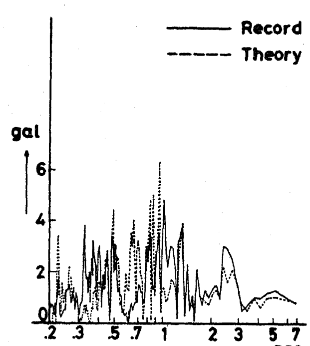

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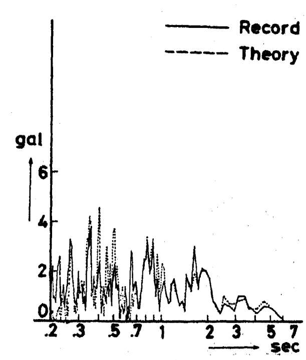

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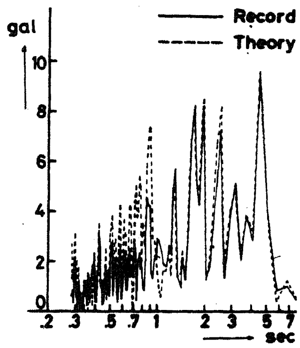

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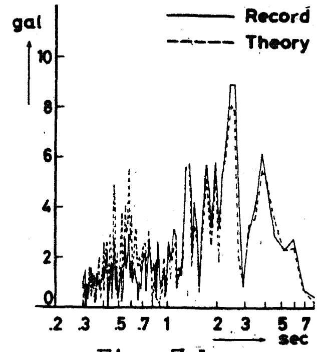
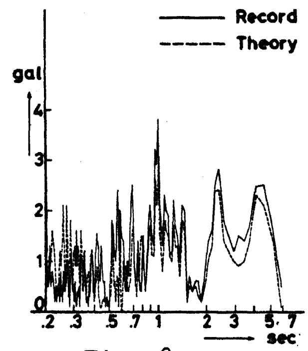


Fig. 7-b.



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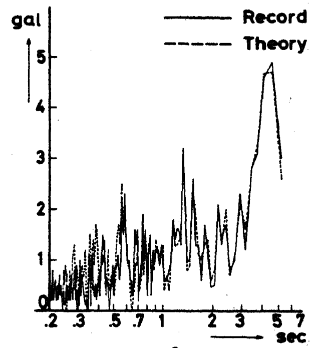

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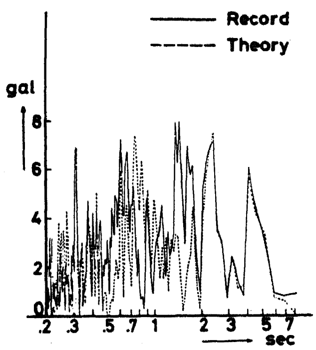

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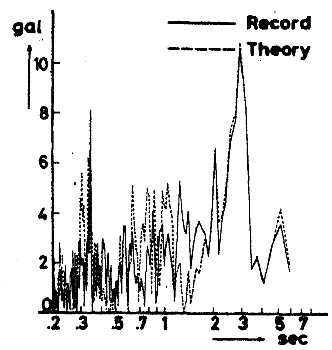

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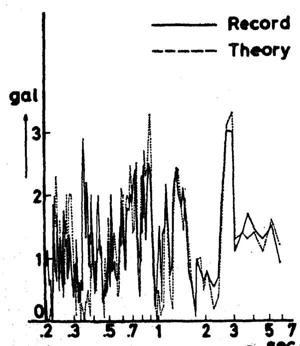

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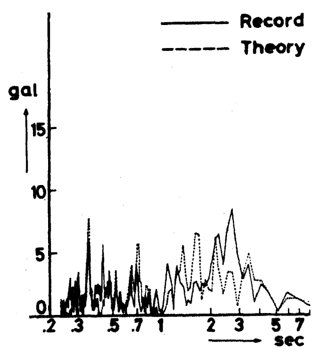

Fig. 11.

Table 1.

Buildings					
Number	Name	Address	Construction	Total Stories Below	Total Stories Above
1.	Wilshire Square.	3345 Wilshire.	RC	3	12
2.	Ventura Gloria Building.	15910 Ventura.	St	1	15
3.	Certified Life Tower.	14724 Ventura.	RC	0	14
4.	Beneficial Plaza.	3710 Wilshire.	RC	3	11
5.	Millikan Library.	C. I. T. (Pasadena)	RC		9
6.	Valley Presbyterian Hospital.	15107 Vanowen.	RC	1	7
7.	Farmers Insurance.	4680 Wilshire.	RC	1	7
8.	Holiday Inn.	8244 Orion.	RC	0	7
9.	Holiday Inn.	1640 Marengo.	RC	0	7
10.	Bank of California.	15250 Ventura.	RC	0	12

Table 1. (Continued)

Seismographs				Largest Acceleration			
				Bottom		Top	
Number	Epicentral Distance (km)	Component	Predominant Period, T (sec)	Position	gal	Position	gal
1.	39	U-D		Bsmt	60	12th	103
		S00W	1.28		108		194
		N90E	1.05		88		251
2.	28	U-D		Bsmt	100	R	197
		S81E	2.73		140		221
		S09W	3.41		129		215
3.	28	U-D		1st	97	P	159
		S12W	1.08		243		368
		N78W	1.14		197		250
4.	39	U-D		Bsmt	73	10th	150
		N90E	1.10		156		346
		S00W	1.32		147		223
5.	37	U-D		Bsmt	91	10th-R	119
		N90E	1.03		182		341
		N00E	0.65		198		306
6.	24	U-D		Bsmt	106	8th-R	159
		S00W	1.05		114		372
		S90W	0.87		103		311
7.	38	U-D		Bsmt	65	6th	136
		N15E	0.42		115		238
		N75W	0.61		82		279
8.	20	U-D		1st	168	8th-R	212
		N00W	1.52		250		375
		S90W	1.32		132		314
9.	42	U-D		1st	75	8th-R	103
		N38W	1.03		118		230
		S52W	1.45		130		412
10.	28	U-D		Bsmt	95	R	141
		N11E	1.86		221		283
		N79W	2.93		146		195