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CORRELATION BETWEEN RECORDED BUILDING DATA AND NON-STRUCTURAL DAMAGE DURING THE LOMA PRIETA EARTHQUAKE

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ABSTRACT

A study of non-structural damage observed in the instrumented Santa Clara County Government Center building, during the Loma Prieta, California, earthquake of October 17, 1989, has been carried out, to correlate the recorded CSMIP response data with observed non-structural component damage. A methodology is presented to assess the performance and behavior of non-structural building components during earthquakes.

INTRODUCTION

Widespread non-structural component damage was observed and reported in a broad class of buildings during the Loma Prieta, California earthquake of October 17, 1989. Such damage was distributed over the San Francisco Bay Area, including the cities of Oakland and San Francisco as well as San Jose. The major consequences of the non-structural component damage are the severe economic impact posed by such damage as well as possible life-hazard in some cases. It is worth noting that as expected non-structural damage was observed mainly in modern multi-story buildings which otherwise behaved satisfactorily during the Loma Prieta, California Earthquake. The objective of the project is to analyze recorded SMIP data and study the correlation between available recorded data and non-structural component damage in instrumented buildings during the Loma Prieta earthquake of October 17, 1989.

INSTRUMENTED BUILDING CASE-STUDY SANTA CLARA COUNTY SERVICES BUILDING - SAN JOSE

After initial study it was decided to lead this research project with a case-study of the Santa Clara County Government Center Building located in downtown San Jose. This building has been the source of recorded data from two previous earthquakes in 1984 and 1986, and has been the subject of studies during these previous earthquakes. The overall view of this case-study building is presented in Figures 1 and 2.

DESCRIPTION OF BUILDING STRUCTURAL SYSTEM

This thirteen story building is essentially square in plan configuration. The structural system consists of moment-resisting frames at 26 ft. o.c. in both directions. Wings along the west and south sides of the building are used primarily for circulation, e.g., elevators and stairs as well as for mechanical systems. These wings are offset in plan and that is

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the only plan irregularity in the layout of the primary structural system. Furthermore, these wings extend one floor above the roof which is the main vertical irregularity in the building structural system. There is a non-structural irregularity on the southwest corner between the two wings discussed above. From the ground floor to the fifth floor there is a glass enclosed architectural space. The main foundation system consists of a solid mat foundation. The typical floor framing plan is presented in Figure 3. Typical moment-resisting-frame elevations are shown in Figures 4 and 5.

OBSERVED NON-STRUCTURAL DAMAGE

Non-structural building components are classified to include partitions, suspended ceilings, curtain walls, facades and cladding, and contents, e.g., filing cabinets, book shelves, computer equipment, office furniture, etc.

The non-structural damage observed in the Santa Clara County Government Center Building falls mainly in the category of contents damage including damage to interior space-enclosure partial-height partitions.

In general, valuable non-structural damage data gets lost soon after an earthquake due to the need and necessity to quickly repair such damage to bring building facilities back into operation. For this case-study, the Santa Clara County Government Center Building, a video tape documenting non-structural damage observed soon after the Loma Prieta earthquake, was obtained [5] for study and analysis.

A review of the video tape [5] of observed non-structural damage shows that there was substantial damage to contents in this building facility, mainly at the 7th, 9th, 10th and 11th floor levels.

A classification of non-structural components (contents) and corresponding observed damage and location is presented in Table 1.

RECORDED MOTIONS

The typical recorded and processed data obtained from the strong motion instruments in the Santa Clara County Services Building, as provided by the CSMIP program [4] is shown in Figure 6.

A typical floor acceleration response spectrum for the 7th floor (NW corner) based on CSMIP vol. 3 [4] data for this building is presented in Figure 7.

CORRELATION BETWEEN RECORDED DATA AND OBSERVED NON-STRUCTURAL DAMAGE

Non-structural component damage in buildings is characterized by both acceleration as well as inter-story drift effects. A study of the observed non-structural damage data recorded on video tape showed that in general, there was no damage observed below the fifth floor level. The majority of the non-structural component damage is concentrated at the 7th and 11th floor

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levels, with lesser damage observed at the 8th, 9th and 10th floor levels. Efforts are now under way to complete the correlation between floor responses (accelerations and displacements) and corresponding observed non-structural component damage. It is planned to develop a non-structural damage index as one means of quantifying the observed non-structural damage in relation to corresponding recorded response data (accelerations, displacements, etc.).

Summaries of the peak responses recorded at different levels in the Santa Clara County Government Center Building, during the 1989 Loma Prieta, California, earthquake as well as the 1984 Morgan Hill, California, earthquake are presented in Tables 2 and 3.

OBSERVATIONS/PRELIMINARY RESULTS/CONCLUSIONS

A comparison of peak recorded motions at different levels in the Santa Clara County Government Center Building during the 1989 Loma Prieta earthquake and the 1984 Morgan Hill earthquake shows that the peak recorded response floor accelerations and displacements during the 1989 Loma Prieta earthquake were almost twice those recorded during the 1984 Morgan Hill earthquake @ the 12th floor and roof levels and approximately 2.5 times @ the 7th floor level. According to damage data provided by Van Osdol [5], this building suffered non-structural component damage during the 1984 Morgan Hill earthquake and the 1986 Mt. Lewis earthquake also. Since that time certain levels of upgrading and retrofit of non-structural building components has been carried out, which helped reduce level of non-structural damage during the 1989 Loma Prieta earthquake. Work is now underway to carry out a seismic analysis of the building system using the computer program ETABS [1] to develop a better correlation between results of analysis, recorded data and observed non-structural component damage in the Santa Clara County Government Center Building.

ACKNOWLEDGEMENTS

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REFERENCES

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2. Reitherman, Robert, Personal Communication, 1991.
3. Shakal, A., Huang, M., et al., "CSMIP Strong-Motion Records and Processed Data from the 1984 Morgan Hill Earthquake," California Department of Conservation, Division of Mines and Geology, Office of Strong Motion Studies, OSMS 85-05.
4. Shakal, A., Huang, M., et al., "CSMIP Strong-Motion Records and Processed Data from the 1989 Loma Prieta Earthquake," California Department of Conservation, Division of Mines and Geology, Office of Strong Motion Studies, 1991.
5. Van Osdol, Wes., Personal Communication, 1991.

TABLE 1
CLASSIFICATION OF OBSERVED NON-STRUCTURAL DAMAGE

LEVEL	NON-STRUCTURAL COMPONENT	DESCRIPTION OF NON-STRUCTURAL DAMAGE												
		Topped Forward	Topped Backward	Opened	Moved Rel. to Original Position	Fell Down	Jumped Up	Torsion Component	Chipped	Scattered	Warped	In Plane Buckling		
7	File Cabinets	x	x	x	x									
7,11	Drawers in Desks			x	x	x								
7	Phone				x									
7,11	5+' Partitions	x	x		x	x								
7,11	6' Bookshelves	x	x		x	x								
7	Ceiling Plaster									x				
7	HP Computer	x			x					x				
7	Ceiling Molding				x	x								
7	Microfiche Files				x							x		
7	Desks				x									
7,11	Computer Screen		x		x					x				
7,11	Bookshelves				x									
7,11	General Supplies				x								x	
11	Laser Printer				x									

TABLE 1
CLASSIFICATION OF OBSERVED NON-STRUCTURAL DAMAGE
(Continued)

LEVEL	NON-STRUCTURAL COMPONENT	DESCRIPTION OF NON-STRUCTURAL DAMAGE													
		Topped Forward	Topped Backward	Opened	Moved Rel. to Original Position	Fell Down	Jumped Up	Torsion Component	Chipped	Scattered	Warped	In Plane Buckling			
11	Laser Ptr. Cart				x										
8, 10, 11	Plant Pots Broken				x	x									
11	Bookshelves on wall				x										
9	Microwave		x		x										
9	Bookshelves Standing														
10	Computer Sys. on wheels														
5, 7	Ceiling Moulding														
4	Ceiling Tile/Pipes														
4	Concrete Column														
4	Supporting Staircase														
4	Baseboard Molding														
7	Xerox Machine														
7	Air Conditioning vents														
7	Bookshelves Library	x													x

TABLE 2
Summary of Peak Recorded Motions/Damage Data by Levels
1989 Loma Prieta Earthquake

Level (1)	East-West Component				North-South Component				Non-Structural Damage Index*
	Peak acc. g.	Peak displ. in.	Peak spectral response @ T. sec.	Duration, sec., \geq 0.10 g *	Peak acc., g.	Peak displ. in.	Peak spectral response @ T. sec.	Duration sec., \geq 0.10 g *	
Lower	-0.091	-3.75			-0.106	-2.79			
2	-0.152	-6.1			-0.108	-4.53			
7	0.257	11.18	2.4		0.223	-10.91	2.4		
12	0.271	15.24	2.2		-0.261	-13.94			
Roof	0.334	14.53	2.2		-0.343	-14.57	2.4		

* under preparation

TABLE 3
Summary of Peak Recorded Motions/Damage Data by Levels
1984 Morgan Hill Earthquake

Level (1)	East-West Component				North-South Component				Non-Structural Damage Index*
	Peak acc. g.	Peak displ. in.	Peak spectral response @ T. sec.	Duration, sec., \geq 0.10 g *	Peak acc., g.	Peak displ. in.	Peak spectral response @ T. sec.	Duration sec., \geq 0.10 g *	
Lower	0.041	-1.04	2.2		-0.035	-1.26	3		
2	-0.057	1.53	2.2		0.049	-1.60	3		
7	-0.117	4.57	2.2		0.104	4.25	2.2		
12	0.160	6.97	2.2		0.168	-7.17	2.3		
Roof	0.174	7.56	2.2		0.169	-7.28	2.2		

* under preparation



Figure 1. Santa Clara County Government Center - San Jose
Overall View from South-West



Figure 2. Santa Clara County Government Center - San Jose
Overall View from the North-West

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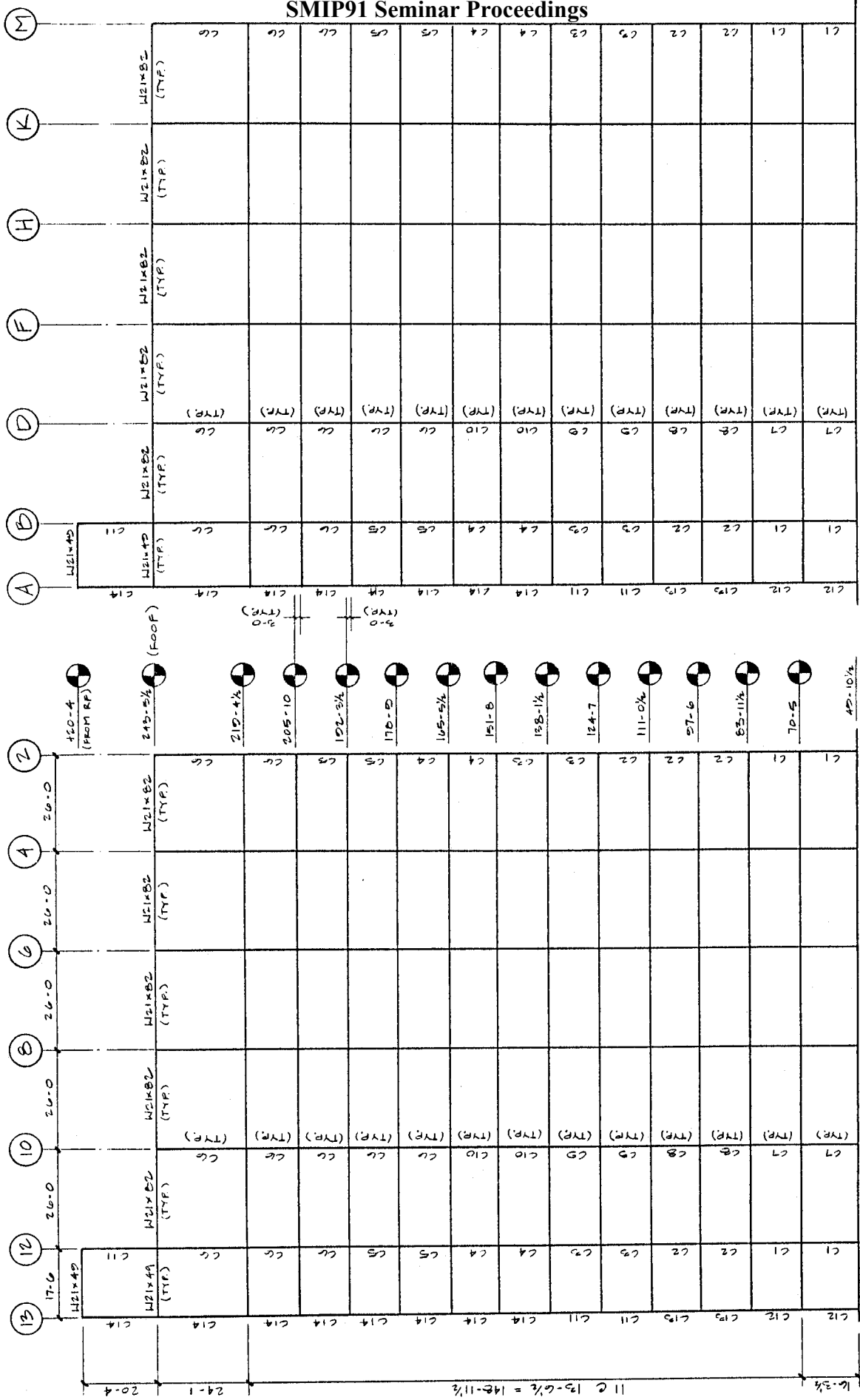
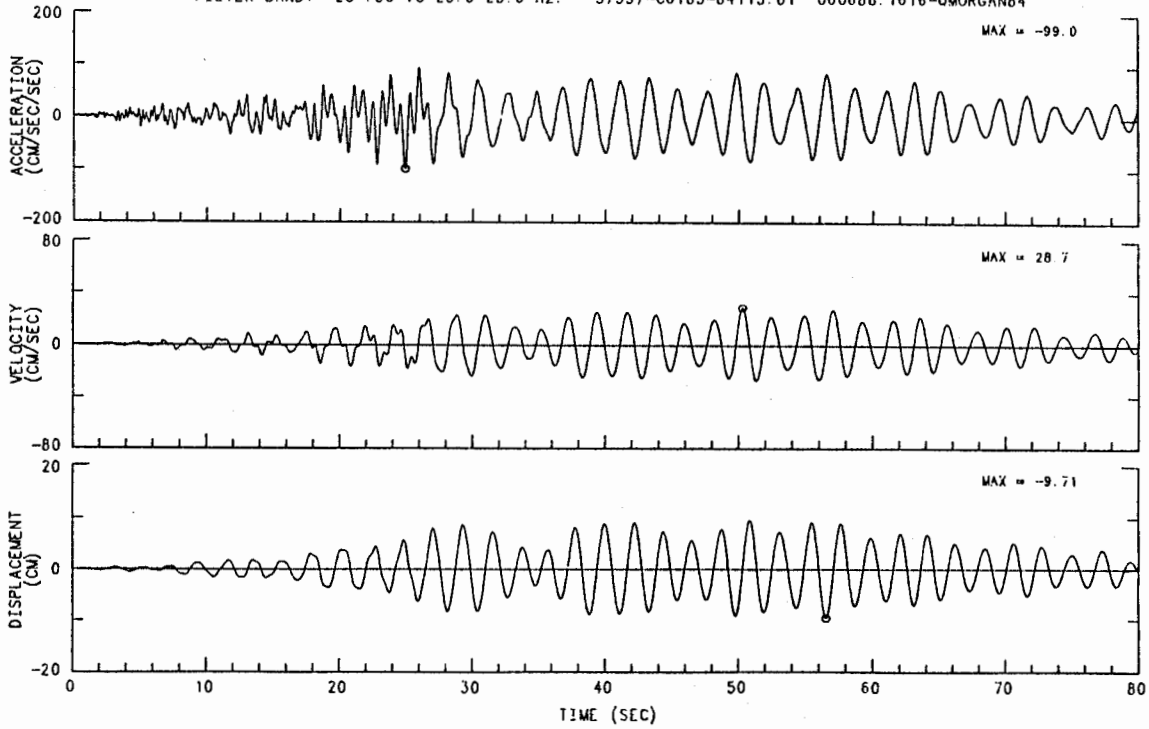


Figure 4. Santa Clara County Government Center - San Jose Typical North-South Moment-Resisting-Frame Elevations

Figure 5. Santa Clara County Government Center - San Jose Typical East-West Moment-Resisting-Frame Elevations

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MORGAN HILL EARTHQUAKE APRIL 24, 1984 13:15 PST
SAN JOSE - SANTA CLARA CO. BLDG. CHN 12: 90 DEG (7TH FLOOR, NORTHWEST CORNER)
INSTRUMENT-CORRECTED AND BANDPASS-FILTERED ACCELERATION, VELOCITY AND DISPLACEMENT
FILTER BAND: 20-30 TO 23.0-25.0 HZ. 57357-C0185-84115.01 060688.1616-QMORGAN84



SANTA CRUZ MTNS (LOMA PRIETA) EARTHQUAKE OCTOBER 17, 1989 17:04 PDT
SAN JOSE - 13-STORY GOVT. OFFICE BLDG. CHN 12: 90 DEG (7TH FLOOR, NW CORNER)
INSTRUMENT-CORRECTED AND BANDPASS-FILTERED ACCELERATION, VELOCITY AND DISPLACEMENT
FILTER BAND: 0.12-0.24 TO 23.0-25.0 HZ. 57357-C0185-89291.03 032191.1634-QL89A357A

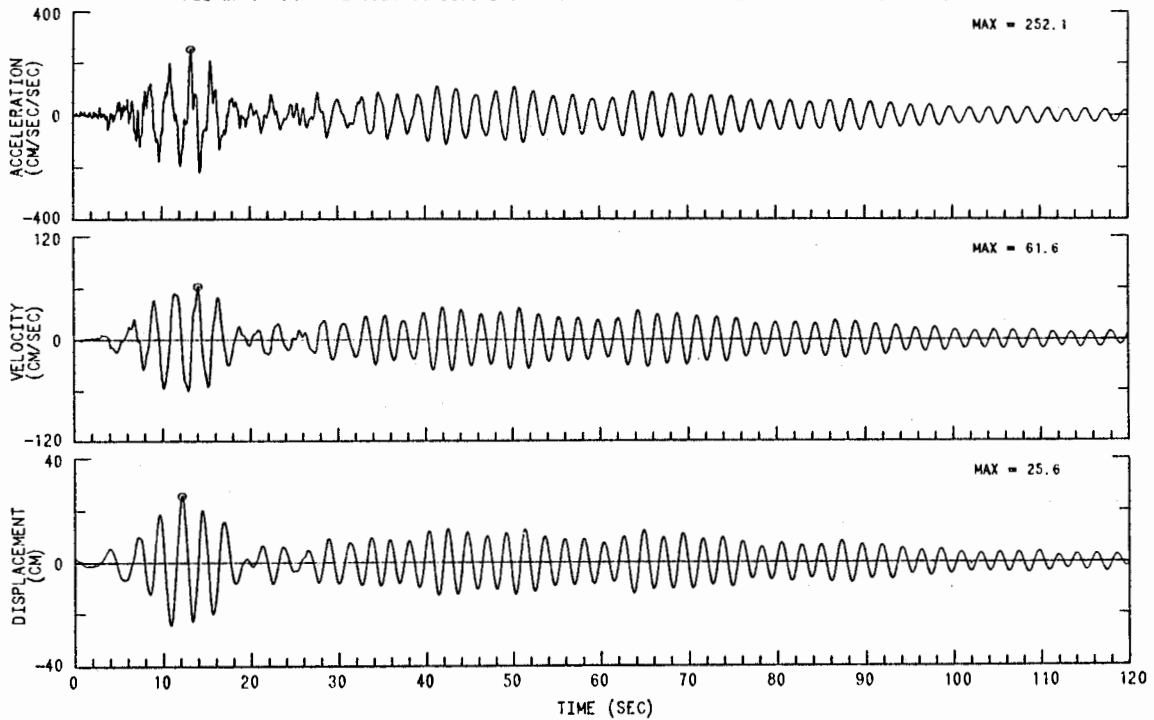


Figure 6
Source: Ref. [3], [4]

SANTA CRUZ MTNS (LOMA PRIETA) EARTHQUAKE OCTOBER 17, 1989 17:04 PDT
 SAN JOSE - 13-STORY GOVT. OFFICE BLDG.

CHAN 12: 90 DEG (STA CHN: 12) LOCATION: 7TH FLOOR, NW CORNER

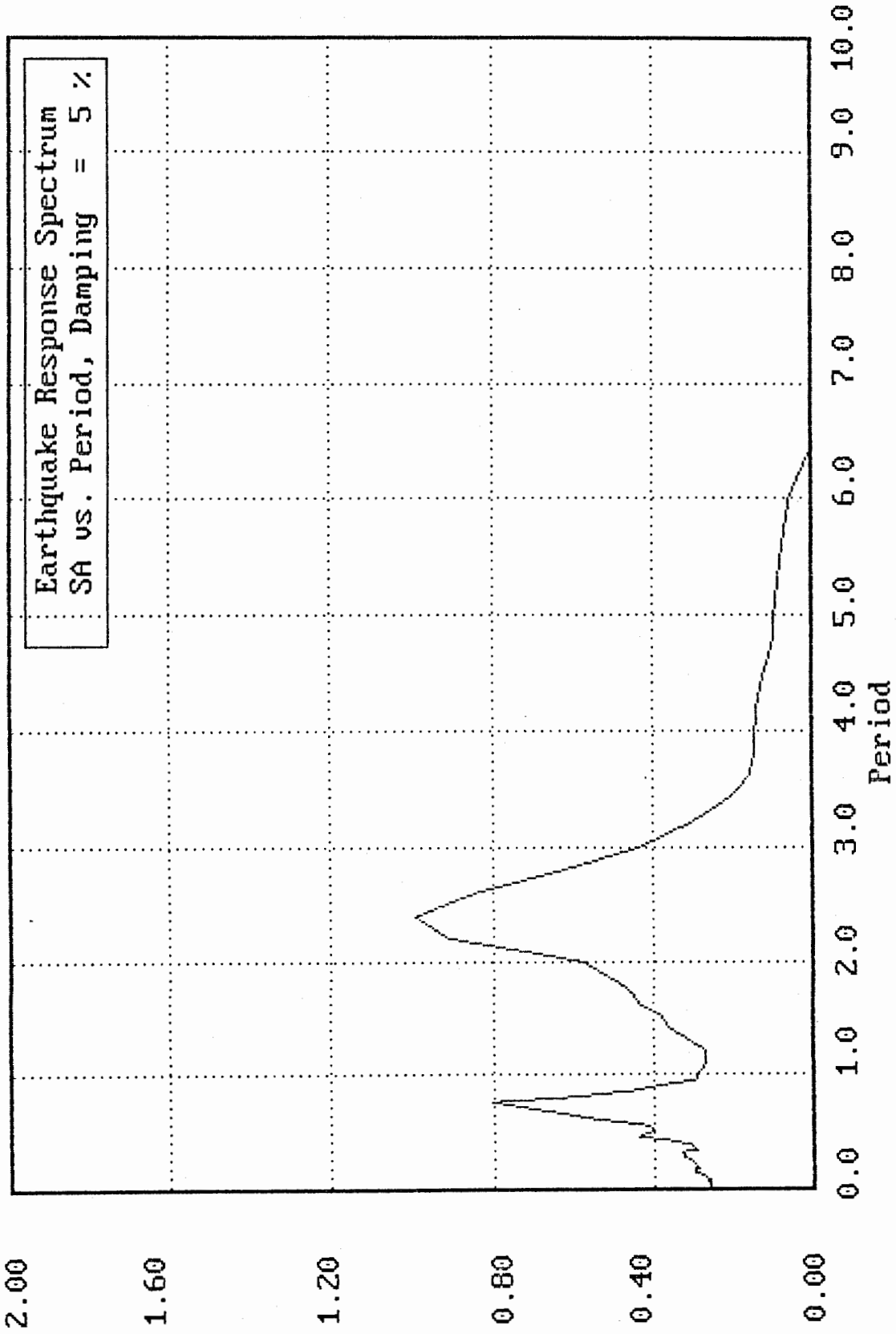


Figure 7