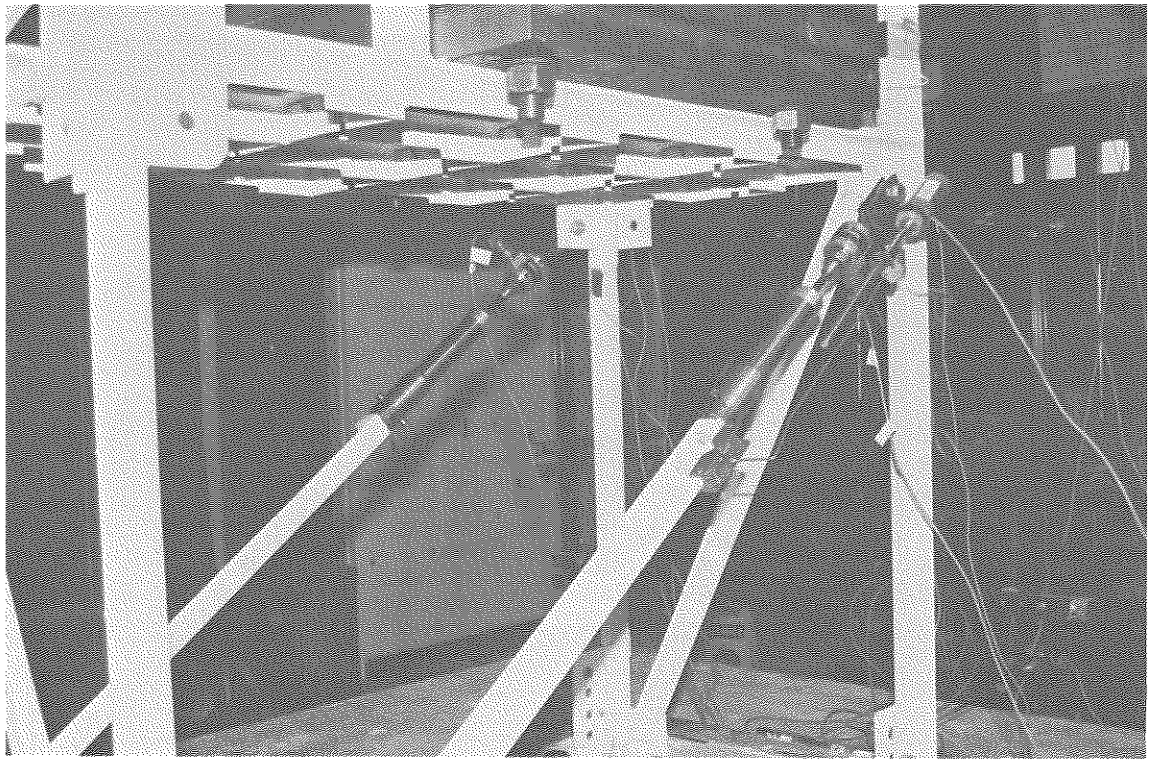

FIGURE 3-7 **Close-up View of Two Dampers in the Model Structure at the First Story**

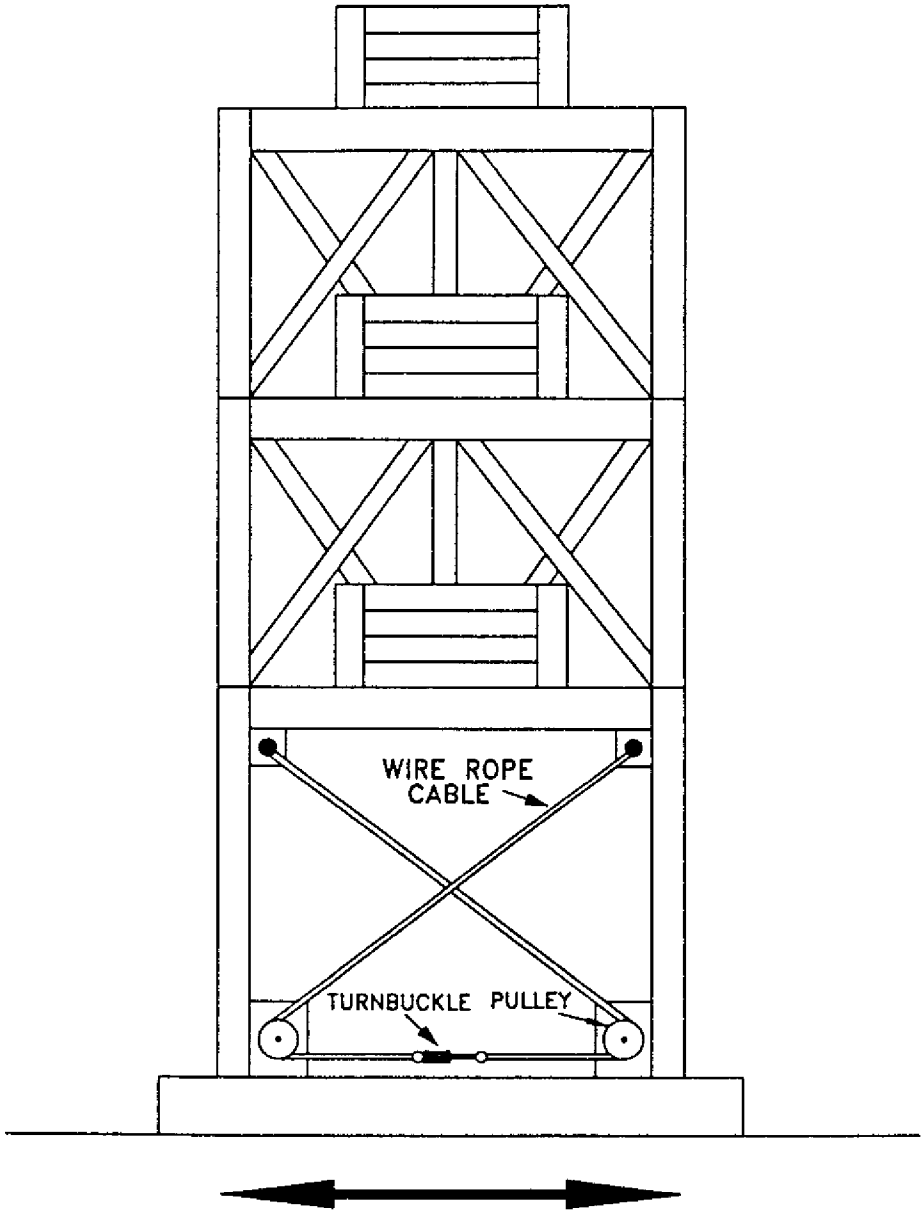

FIGURE 3-8 **Schematic of Structure with Wire Rope Cables**

In the three-story configuration, the bracing of the top two stories was removed. A view of the three-story structure with six dampers is shown in Figure 3-9. Note the presence of the stiffener plates at the top and bottom of each first story column (compare with Figure 3-6 wherein the stiffener plates have not been attached). The structure was identified at small amplitude of motion to have a fundamental frequency of 2 Hz and a corresponding damping ratio equal to 1.74 percent of critical. Tests were conducted without and with dampers.

3.2 Test Program

A total of 66 earthquake simulation tests were performed on the model structure. The earthquake signals and their characteristics are listed in Table 3-I. Each record was compressed in time by a factor of 2 to satisfy the similitude requirements of the quarter length scale model. Figures 3-10 to 3-14 show recorded time histories of the table motion in tests with input being the earthquake signals of Table 3-I. The acceleration and displacement records were directly measured, whereas the velocity record was obtained by numerical differentiation of the displacement record. It may be observed that the peak ground motion was reproduced well, but not exactly, by the table generated motion.

Figures 3-10 to 3-14 also show the response spectra of displacement and acceleration (exact, not pseudo-acceleration) of the table motions. The 5-percent damped acceleration spectra is compared to the spectra of the actual record to demonstrate the good reproduction of the motion of the table. The spectra at larger values of damping will be useful in analytical calculations to be presented later in this report.

A list of the earthquake simulation tests together with the structural system conditions is presented in Table 3-II. The

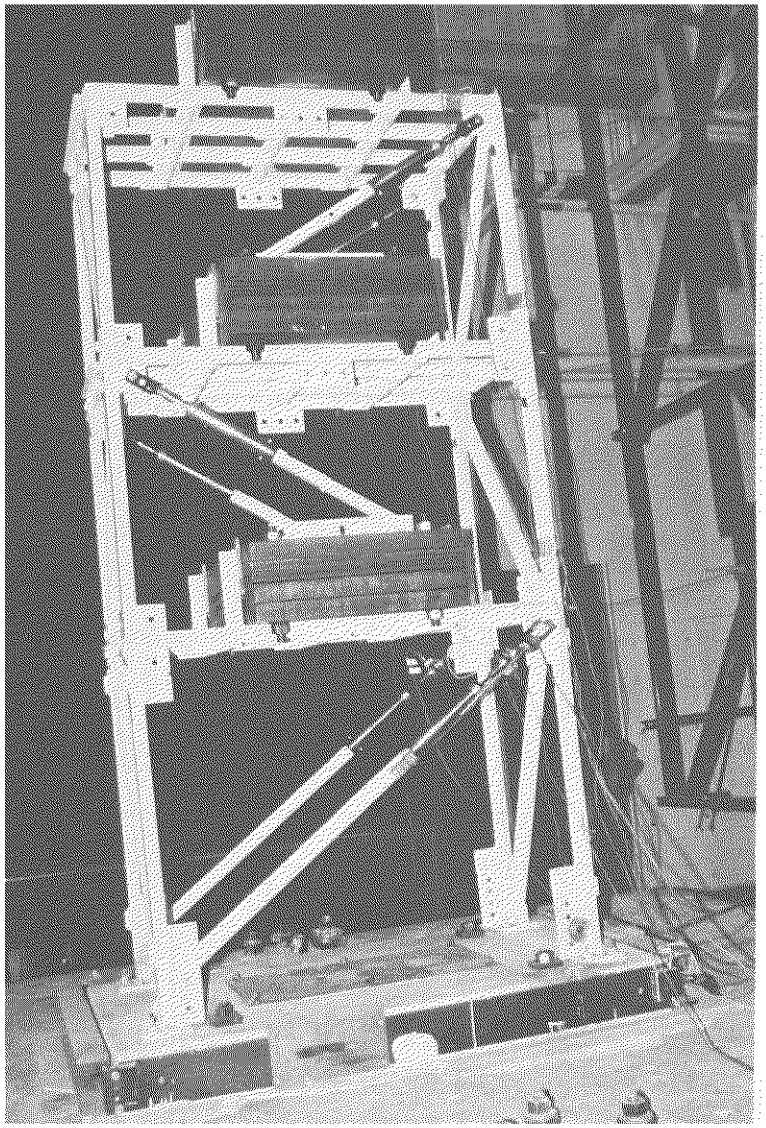

FIGURE 3-9 **View of 3-story Model Structure with Six Dampers**

TABLE 3-I Earthquake Motions Used in Test Program and Characteristics in Prototype Scale (1 in. = 25.4 mm)

NOTATION	RECORD	MAGNITUDE	PREDOMINANT FREQUENCY RANGE (Hz)	PEAK ACCELERATION (g's)	PEAK VELOCITY (in./sec)	PEAK DISPL. (in.)
El Centro S00E	Imperial Valley, May 18, 1940, component S00E	6.7	1-4	0.34	13.17	4.28
Taft N21E	Kern County, July 21, 1952, component N21E	7.2	0.5-5	0.16	6.19	2.64
Pacoima S74W	San Fernando, February 9, 1971, component S74W	6.4	0.25-2	1.08	22.73	4.26
Miyagi-Ken-Oki	Tohoku University, Sendai, Japan, June 12, 1978, component EW	7.4	0.5-5	0.16	5.55	2.00
Hachinohe	Tokachi-Oki earthquake, Japan, May 16, 1968, component NS	7.9	0.25-1.5	0.23	14.06	4.68

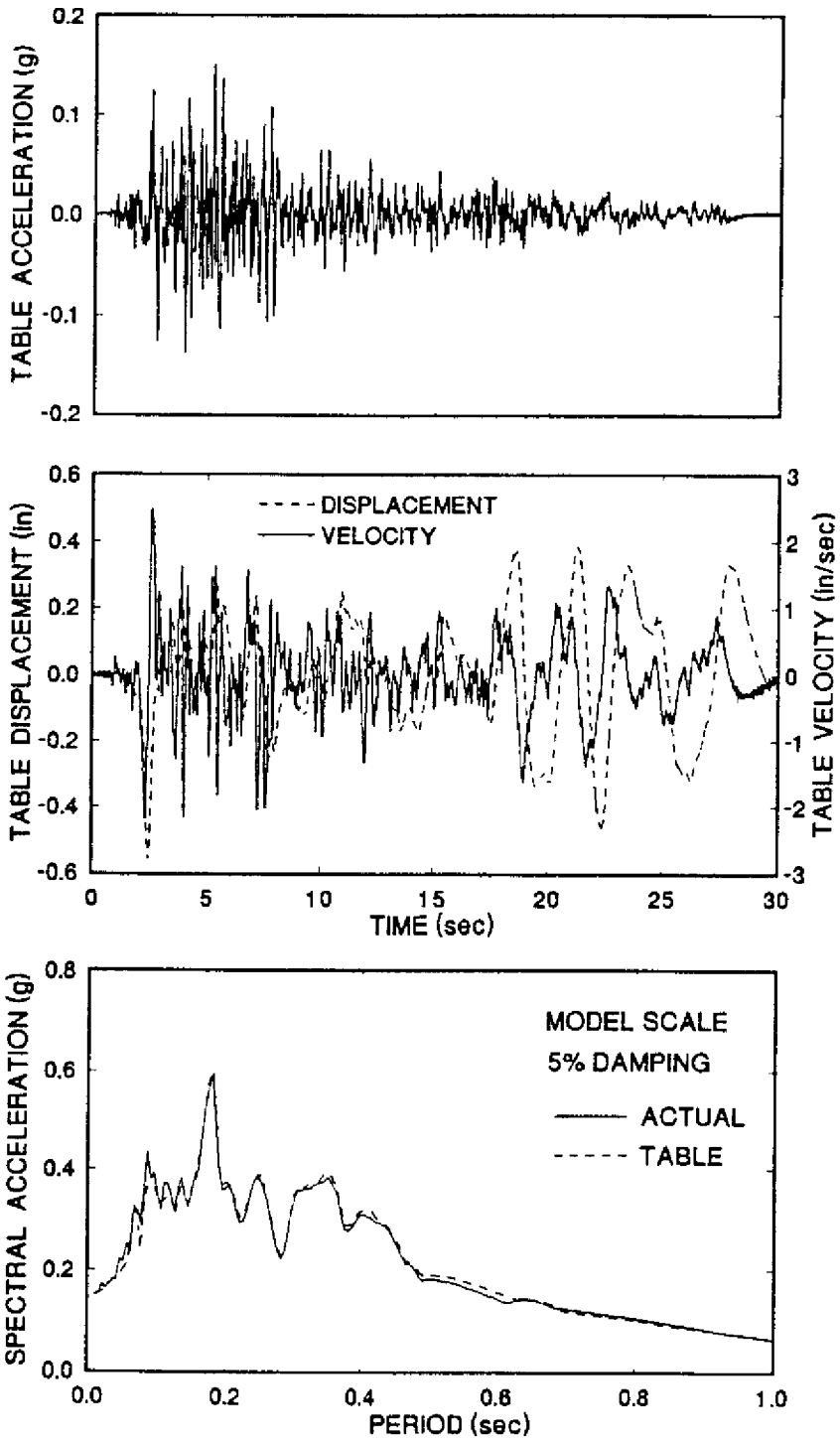

FIGURE 3-10 Time Histories of Displacement, Velocity and Acceleration and Spectral Acceleration and Displacement of Shaking Table Excited with Taft 100% Motion (1 in. = 25.4 mm)

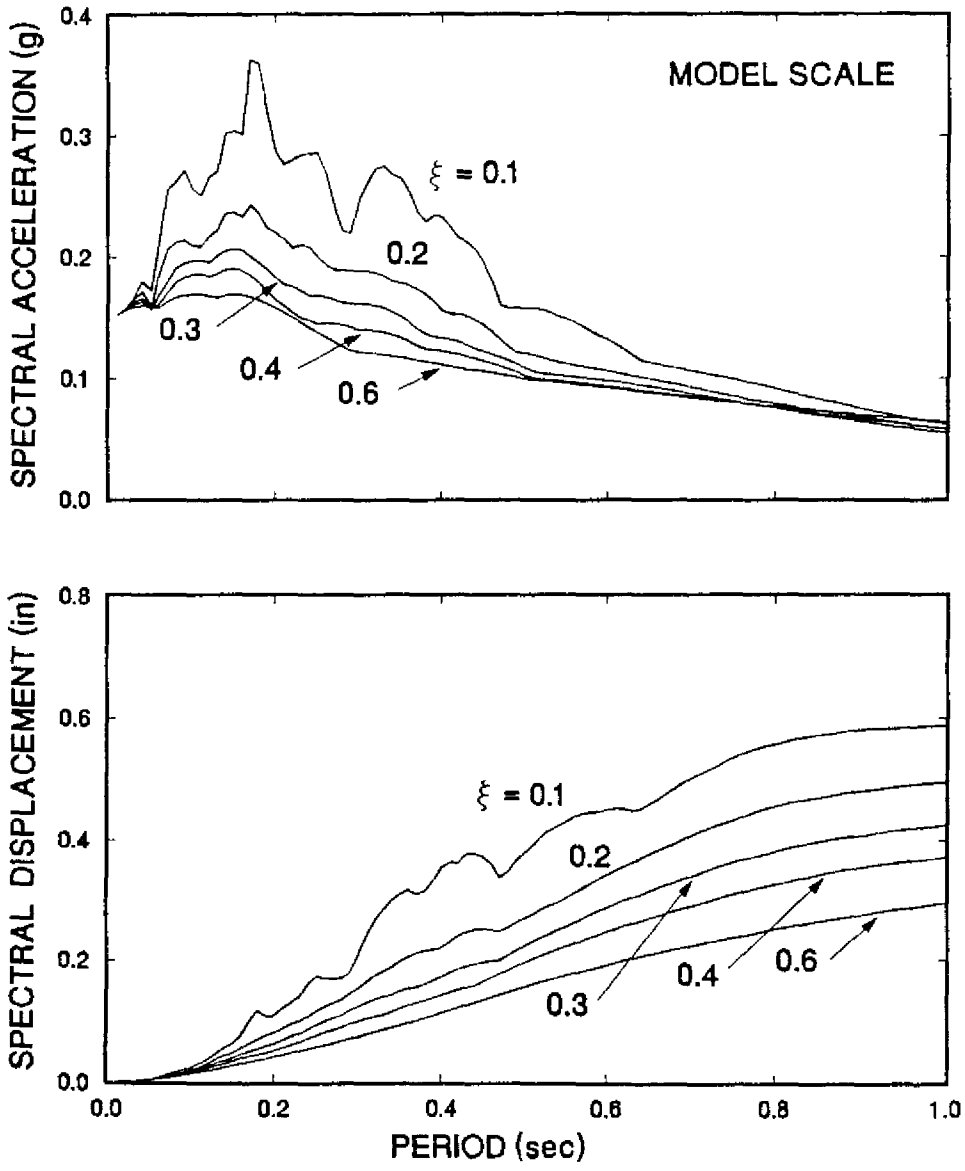

FIGURE 3-10 Continued

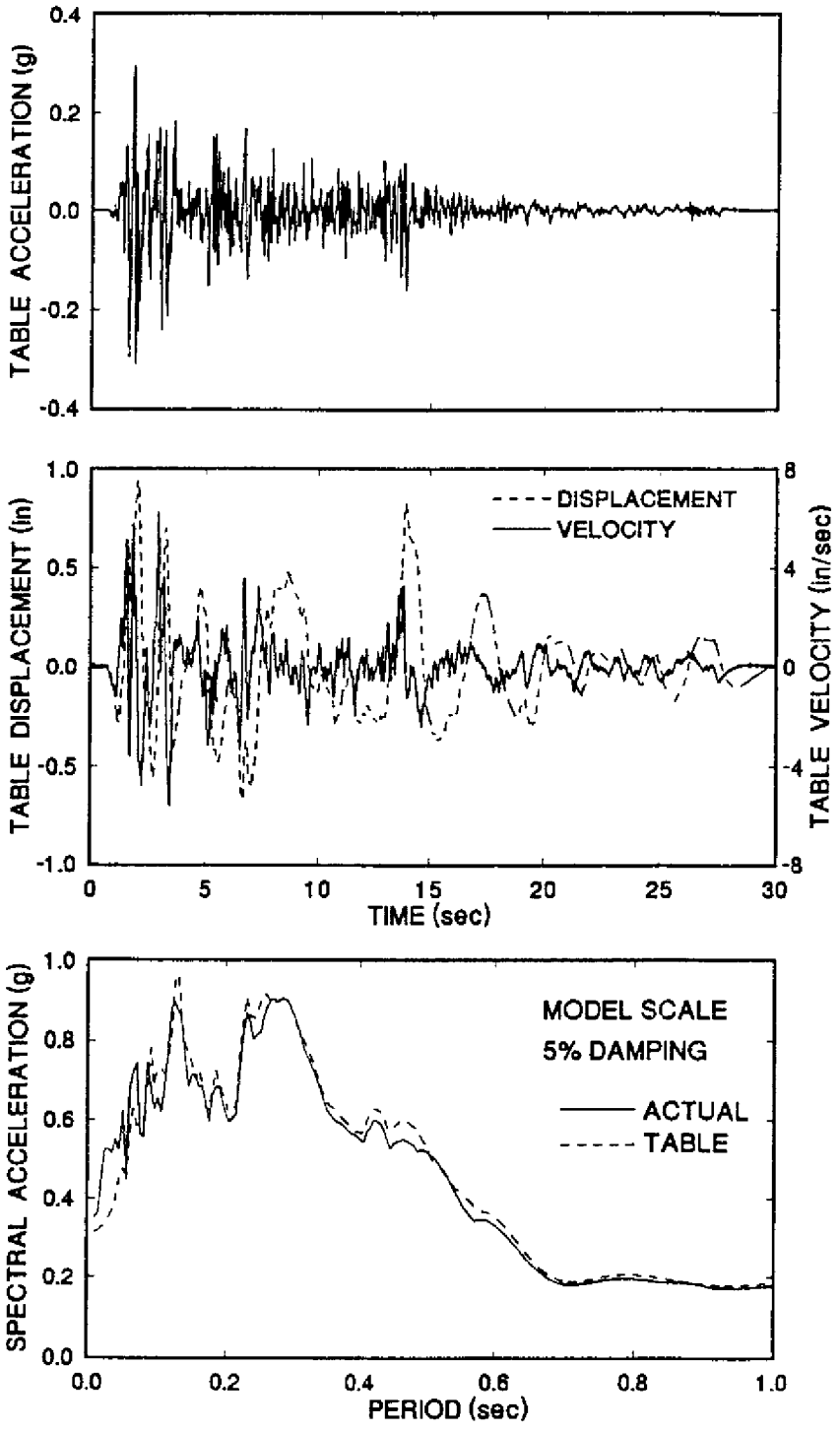

FIGURE 3-11 Time Histories of Displacement, Velocity and Acceleration and Spectral Acceleration and Displacement of Shaking Table Excited with El Centro 100% Motion (1 in. = 25.4 mm)

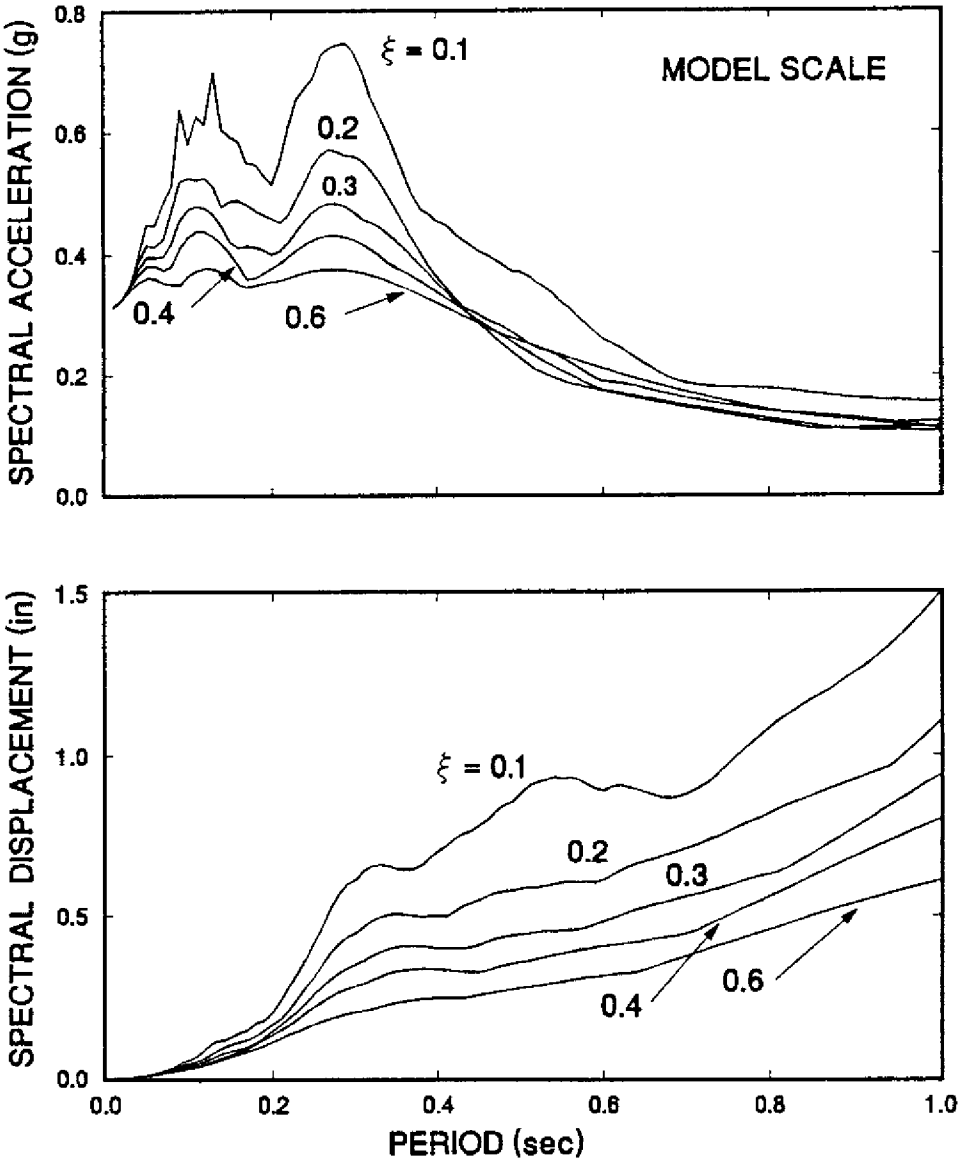

FIGURE 3-11 Continued

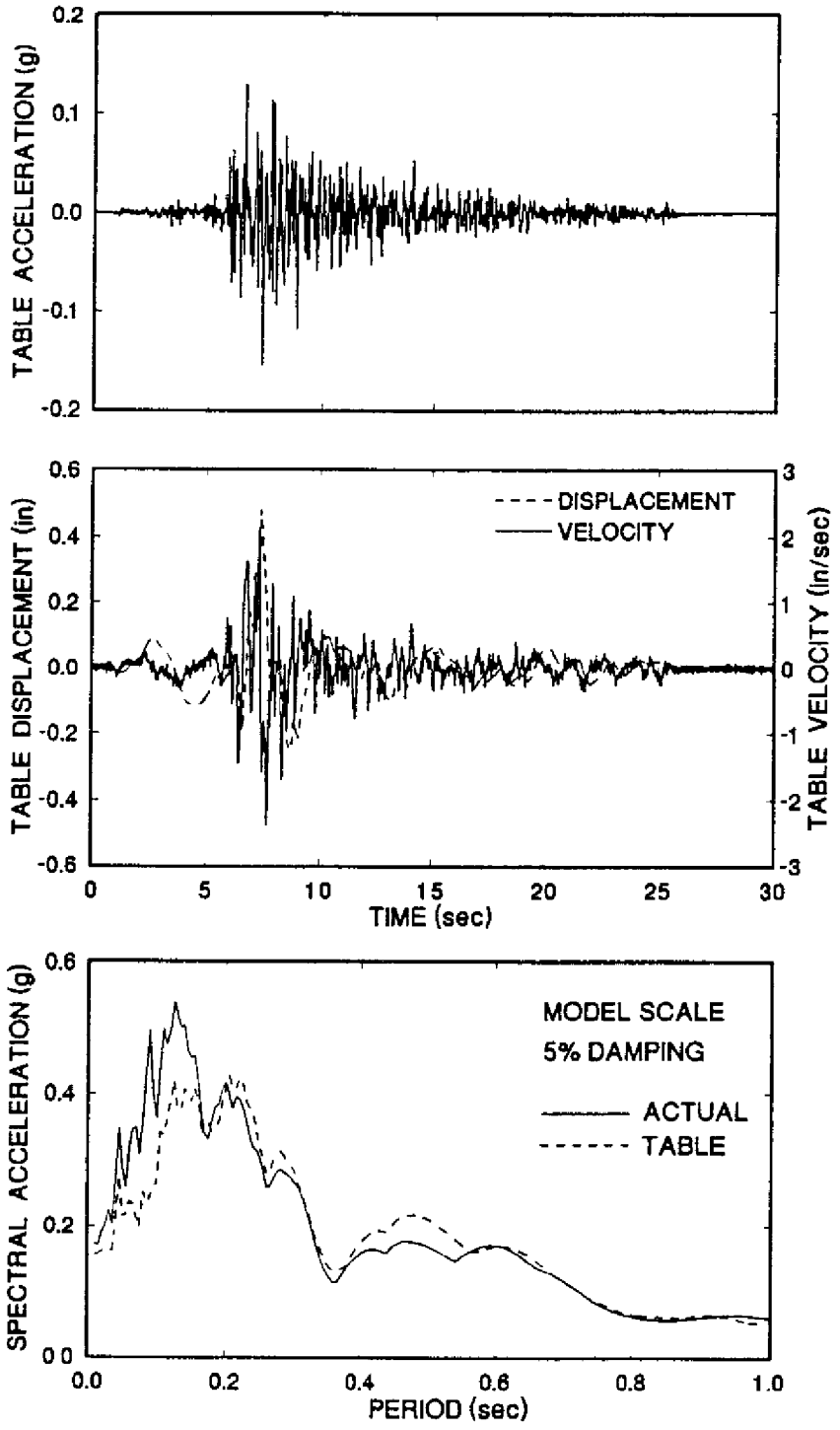

FIGURE 3-12 **Time Histories of Displacement, Velocity and Acceleration and Spectral Acceleration and Displacement of Shaking Table Excited with Miyagiken 100% Motion (1 in. = 25.4 mm)**

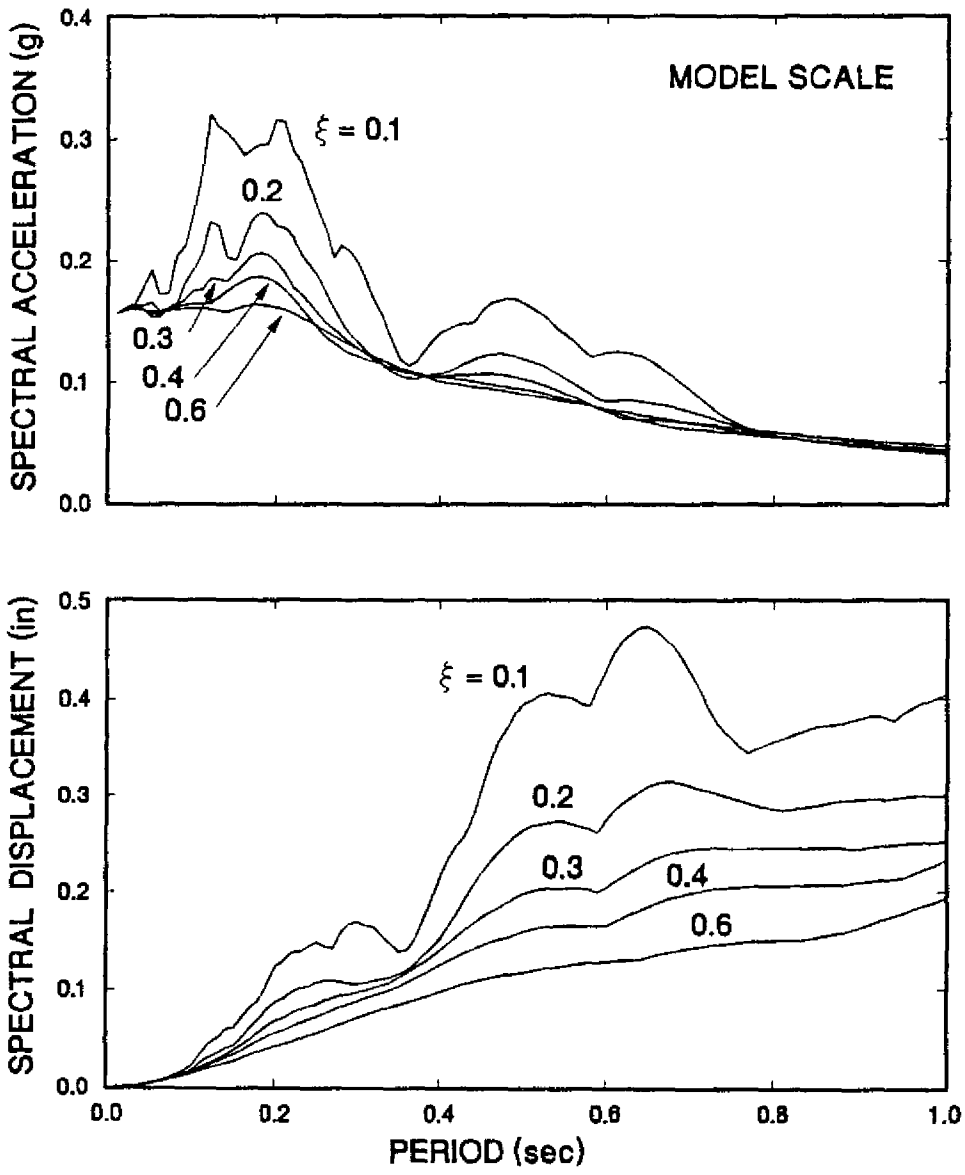

FIGURE 3-12 Continued

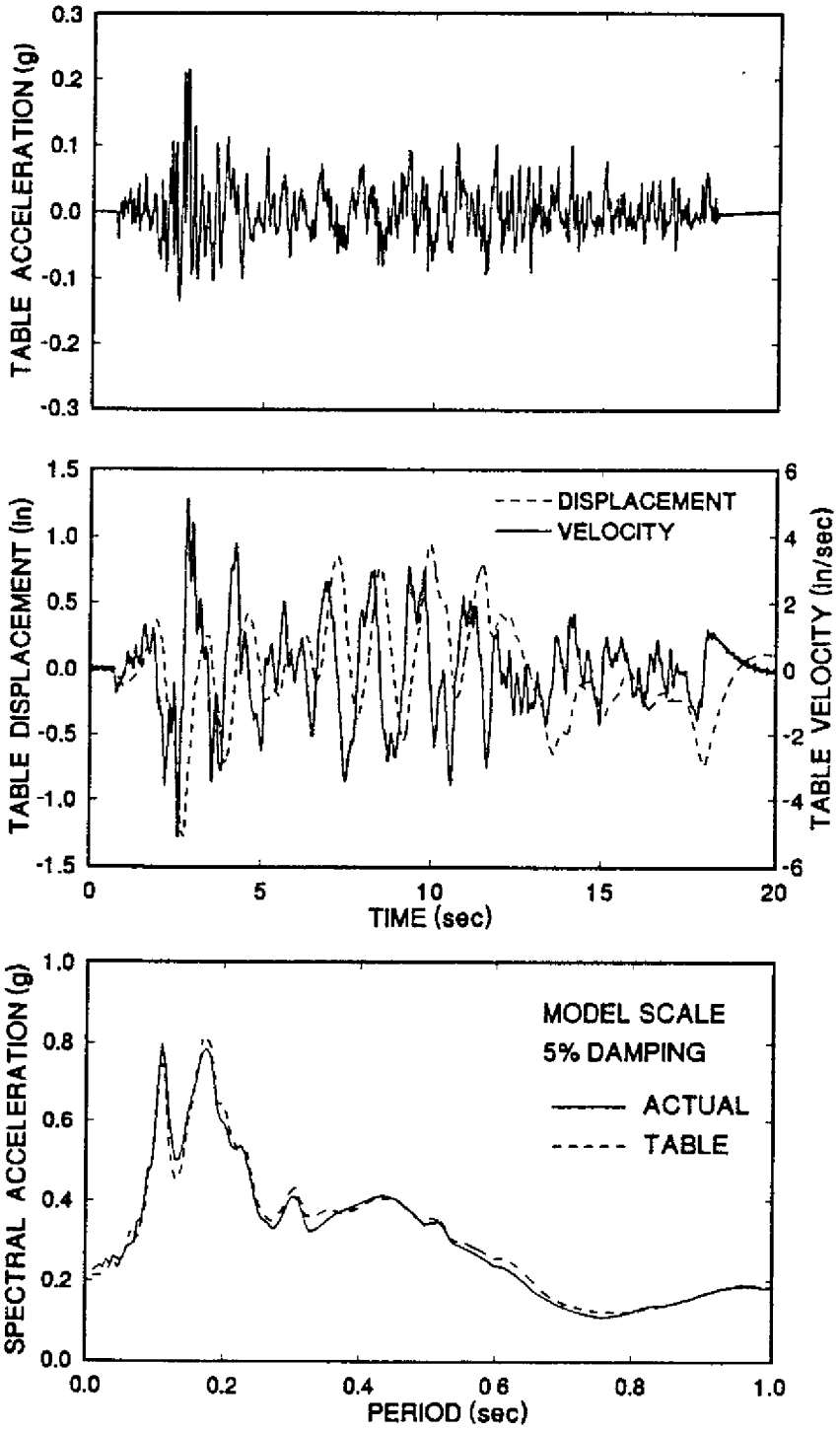

FIGURE 3-13 **Time Histories of Displacement, Velocity and Acceleration and Spectral Acceleration and Displacement of Shaking Table Excited with Hachinohe 100% Motion (1 in. = 25.4 mm)**

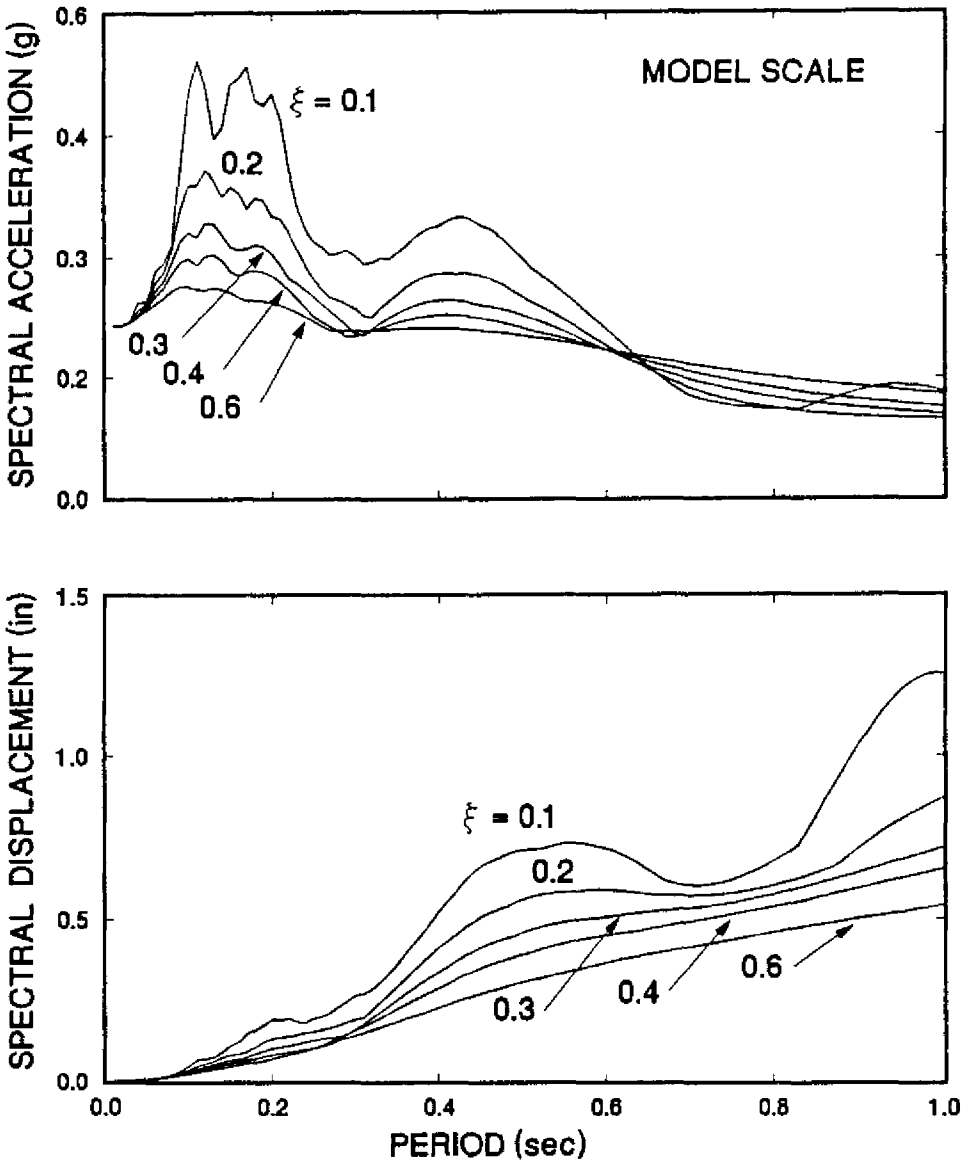

FIGURE 3-13 Continued

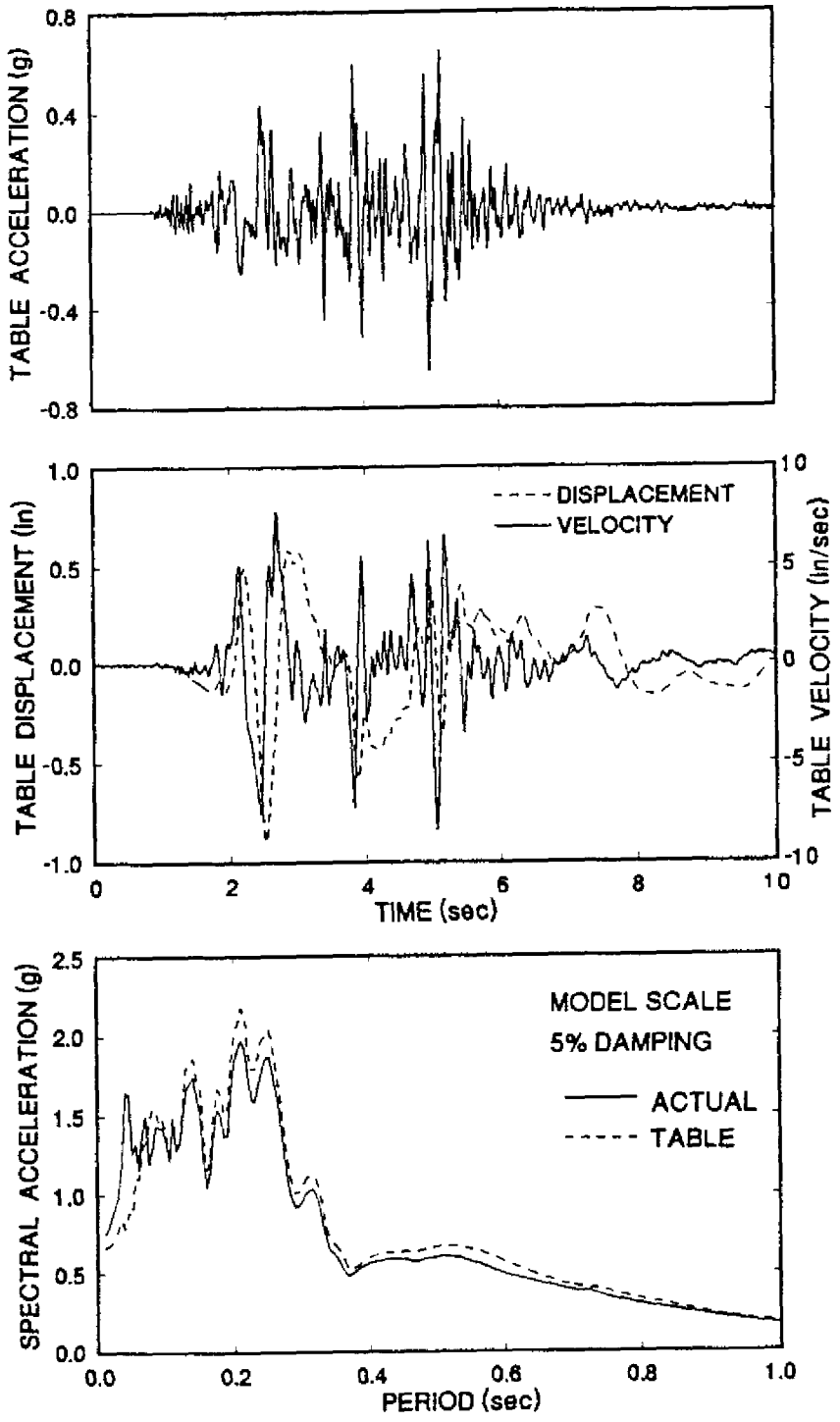

FIGURE 3-14 **Time Histories of Displacement, Velocity and Acceleration and Spectral Acceleration and Displacement of Shaking Table Excited with Pacoima 75% Motion (1 in. = 25.4 mm)**

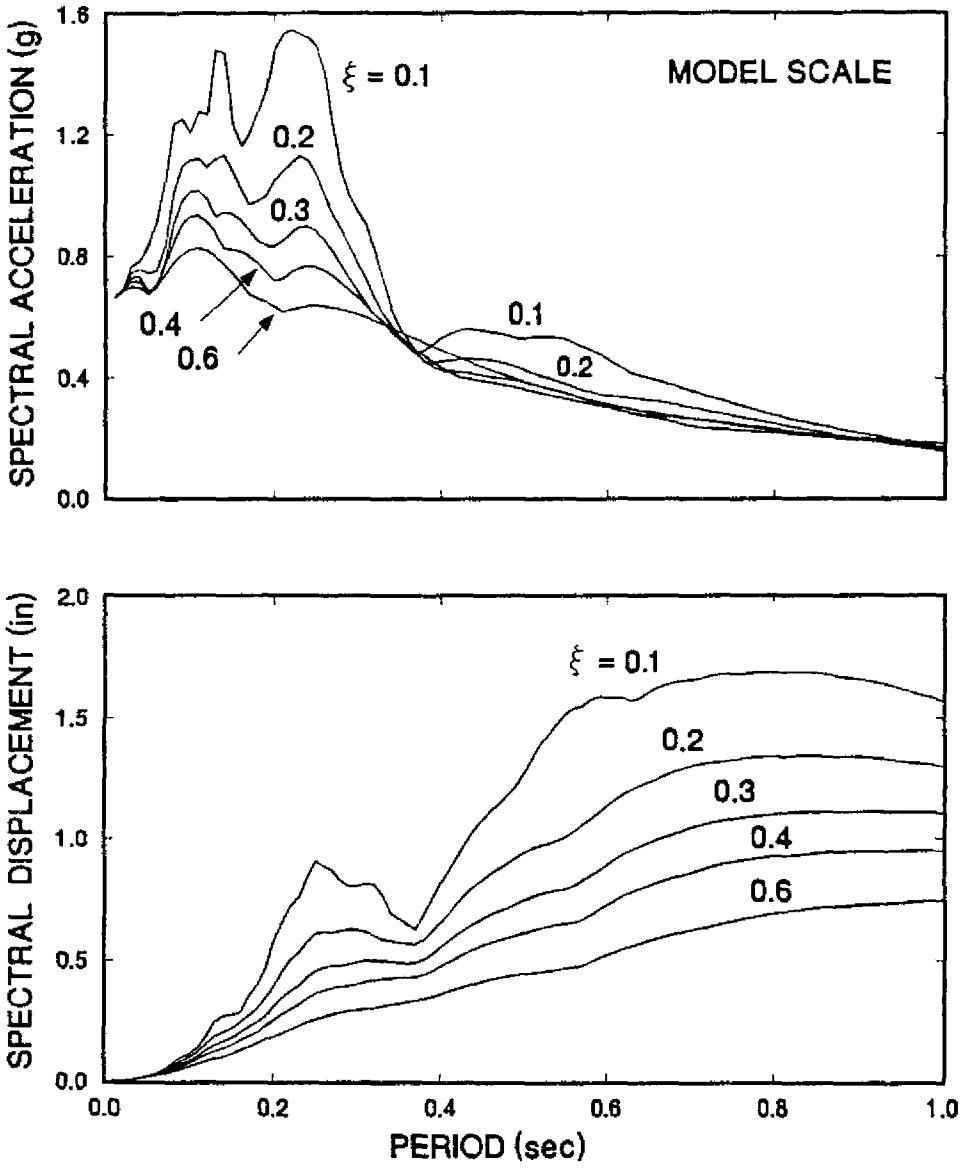

FIGURE 3-14 Continued

TABLE 3-II List of Earthquake Simulation Tests

TEST	STRUCTURE	DAMPERS	EXCITATION
1	1-story	0	El Centro 10%
2	1-story	0	El Centro 20%
3	1-story	0	El Centro 33.3%
4	1-story	0	Taft 33.3%
5	1-story	0	Taft 66.7%
6	1-story	0	Taft 100%
7	1-story	2	Taft 100%
8	1-story	2	Taft 100% (H&V)
9	1-story	2	El Centro 33.3%
10	1-story	2	El Centro 66.7%
11	1-story	2	El Centro 100%
12	1-story	2	Miyagiken 100%
13	1-story	2	Miyagiken 200%
14	1-story	2	Hachinohe 50%
15	1-story	2	Hachinohe 100%
16	1-story	4	El Centro 100%
17	1-story	4	Taft 100%
18	1-story	4	Miyagiken 200%
19	1-story	4	Hachinohe 100%
20	1-story	4	Taft 200%
21	1-story	4	Taft 300%
22	1-story	4	El Centro 150%
23	1-story	4	Miyagiken 320%
24	1-story	4	Hachinohe 150%
25	1-story	4	Pacoima Dam 50%
26	1-story	4	Pacoima Dam 75%
Stiffener Plates Added to Structure			
27	3-story	0	El Centro 33.3%
28	3-story	0	El Centro 50%
29	3-story	0	Taft 100%

H&V = Horizontal and Vertical Components

TABLE 3-II Continued

TEST	STRUCTURE	DAMPERS	EXCITATION
30	3-story	6	El Centro 50%
31	3-story	6	El Centro 100%
32	3-story	6	El Centro 150%
33	3-story	6	Taft 100%
34	3-story	6	Taft 200%
35	3-story	6	Taft 300%
36	3-story	6	Hachinohe 100%
37	3-story	6	Miyagiken 200%
38	3-story	6	Pacoima Dam 50%
39	3-story	6	Pacoima Dam 50% (H&V)
40	3-story	6	El Centro 100% (H&V)
41	3-story	6	Taft 200% (H&V)
42	3-story	2	El Centro 50%
43	3-story	2	El Centro 75%
44	3-story	2	Taft 100%
45	3-story	2	Taft 200%
46	3-story	4	El Centro 50%
47	3-story	4	El Centro 100%
48	3-story	4	Taft 100%
49	3-story	4	Taft 200%
50	1-story	0	El Centro 33.3%
51	1-story	0	Taft 100%
52	1-story *	0	El Centro 33.3%
53	1-story *	0	Taft 100%
54	1-story	2	El Centro 33.3%
55	1-story	2	El Centro 66.7%
56	1-story	2	Taft 100%
57	1-story	2	Taft 200%
58	1-story	2	Hachinohe 100%
59	1-story	2	Hachinohe 150%

H&V = Horizontal and Vertical Components
* = Wire Rope Cable System Attached

TABLE 3-II Continued

TEST	STRUCTURE	DAMPERS	EXCITATION
60	1-story	4	El Centro 33.3%
61	1-story	4	El Centro 66.7%
62	1-story	4	El Centro 100%
63	1-story	4	Taft 100%
64	1-story	4	Taft 200%
65	1-story	4	Taft 300%
66	1-story	4	Hachinohe 150%

excitation is identified with a percentage figure which represents a scaling factor on the acceleration, velocity and displacement of the actual record. For example, the figure 200% denotes a motion scaled up by a factor of two in comparison to the actual record.

3.3 Instrumentation

A list of channels monitored and their corresponding descriptions are given in Table 3-III. A schematic of the structure showing the location of the instrumentation is presented in Figure 3-15. The acceleration of each floor was measured at both the east and west frame so that the effect of torsion could be evaluated. Note that the axial damper force (channels 17 through 20) was only measured for dampers used in the first story. In addition, the axial damper displacement (channel 21) was measured by a displacement transducer placed along the axis of a single damper at the first story. This displacement transducer measured relative displacement of one end of the damper with respect to the other end. All other displacement transducers measured displacements with respect to a non-moving frame.

The measured signals were filtered using a low pass filter with a cutoff frequency of 25 Hz in the D/A output and A/D input.

TABLE 3-III List of Channels (with reference to Figure 3-15)

CHANNEL	INSTRUMENT	NOTATION	RESPONSE MEASURED
1	ACCL	AFHE	Foundation Horiz. Accel. - East
2	ACCL	AFHW	Foundation Horiz. Accel. - West
3	ACCL	A1HE	1st Floor Horiz. Accel. - East
4	ACCL	A1HW	1st Floor Horiz. Accel. - West
5	ACCL	A2HE	2nd Floor Horiz. Accel. - East
6	ACCL	A2HW	2nd Floor Horiz. Accel. - West
7	ACCL	A3HE	3rd Floor Horiz. Accel. - East
8	ACCL	A3HW	3rd Floor Horiz. Accel. - West
9	LDT	DFHC	Foundation Horiz. Displ. - Center
10	LDT	D1HC	1st Floor Horiz. Displ. - Center
11	LDT	D2HC	2nd Floor Horiz. Displ. - Center
12	LDT	D3HC	3rd Floor Horiz. Displ. - Center
13	ACCL	AFAV	Foundation Average Horiz. Accel.
14	ACCL	A1AV	1st Floor Average Horiz. Accel.
15	ACCL	A2AV	2nd Floor Average Horiz. Accel.
16	ACCL	A3AV	3rd Floor Average Horiz. Accel.
17	LOAD CELL	LC01	Axial Force in Damper 1
18	LOAD CELL	LC02	Axial Force in Damper 2
19	LOAD CELL	LC03	Axial Force in Damper 3
20	LOAD CELL	LC04	Axial Force in Damper 4
21	LDT	DDSP	Axial Displ. of Damper 1
22 *	LVDT	DLAT	Table Horiz. Displ.
23 *	ACCL	ALAT	Table Horiz. Accel.
24 *	LVDT	DROL	Table Roll Displ.
25 *	ACCL	AROL	Table Roll Accel.

ACCL = Accelerometer
LDT = Linear Displacement Transducer
LVDT = Linear Variable Differential Transformer
* = Table Controls

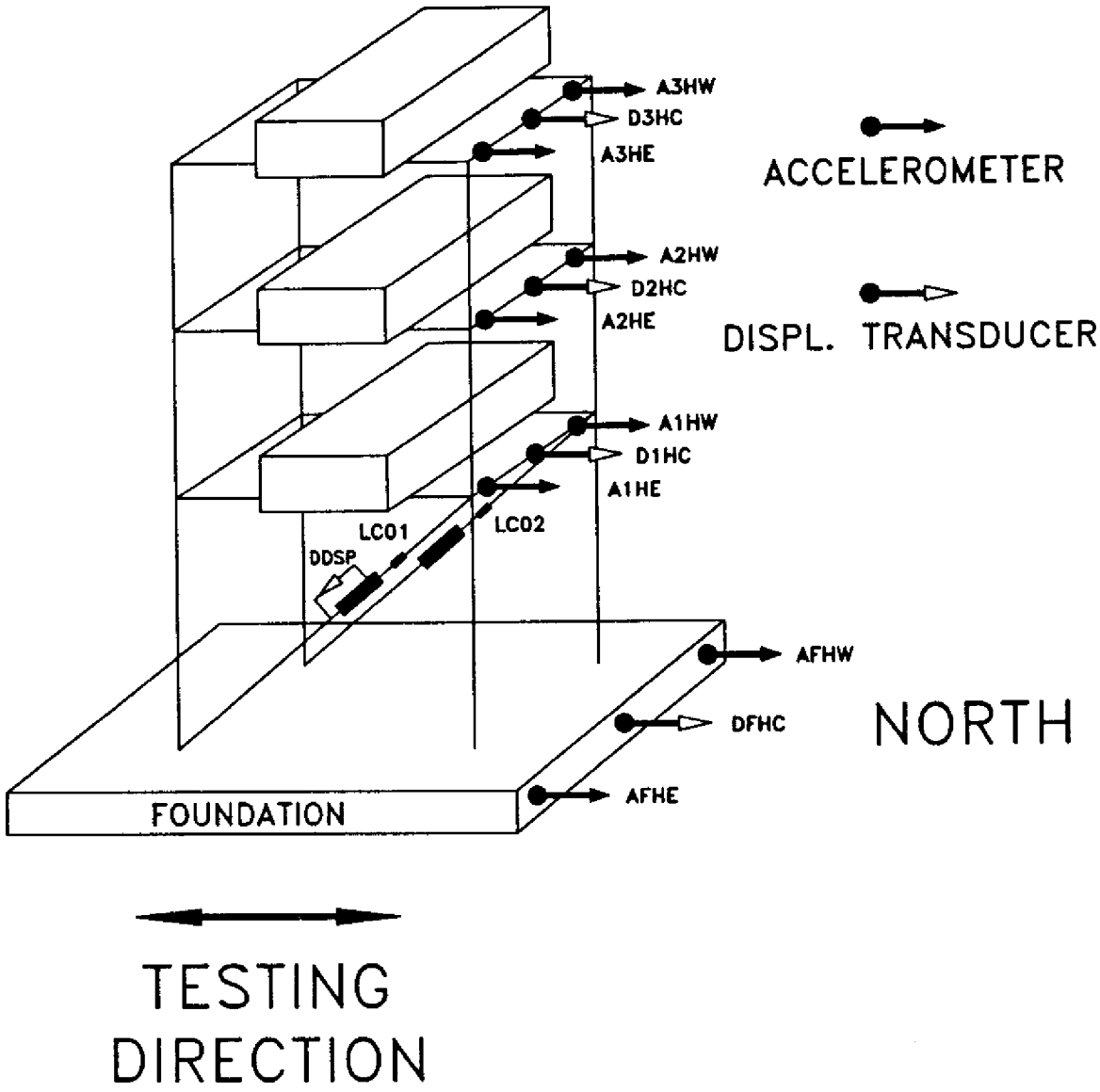

FIGURE 3-15 Instrumentation Diagram