REDUCTION IN FREE FIELD GROUND MOTION DUE TO THE PRESENCE OF STRUCTURES

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August 1980

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REDUCTION IN FREE FIELD GROUND MOTION DUE TO THE PRESENCE OF STRUCTURES

In the following tables are compiled a list of paired recordings demonstrating the effects of building size and foundation embedment on recorded earthquake motions. These effects are summarized in terms of the mean reduction in percent in the mean horizontal free field or ground-level recorded values as compared to nearby building or embedded recordings. A positive reduction means that free field/ground-level recordings were higher, and a negative reduction means they were lower than those recorded in nearby structures.

Tables 1 to 3 give results for peak horizontal accelerations, including brief descriptions of the recording stations. Table 1 compares free field accelerations with those recorded in nearby building basements. Table 2 compares free field accelerations with those recorded at ground level in nearby buildings without basements. Table 3 compares accelerations recorded at the ground level of buildings without basements with those recorded in nearby building basements.

The Imperial County Services Building is the only structure to record higher peak accelerations than its nearby free field station. However, there are several reasons to believe that this data is anomalous. First, there is an indication that the free field recording may be anomalously low compared to other nearby free field recordings. Second, the recorded motion in the building may have been complicated by the failure of the structure, which occurred before or just after the occurrence of the peak accelerations in the recording. Studies of this building are currently underway (e.g., Rojahn, Personal Communication, 1980).

The comparison between the El Centro Differential Array and El Centro Station 9 is an extrapolation since there is a relatively large (1.3 km) distance between these two stations. However, examination of recordings within the vicinity of these two stations shows no consistent attenuation over this distance range. Furthermore, soil and geologic conditions, including the depth of the water table, are very similar at these two stations. This suggests that the comparison offered by these stations is indeed valid.

Omitting data from the Imperial County Services Building, the mean reductions in free field horizontal accelerations due to the presence of structures and in ground-level building recordings due to embedment range up to 66 percent.

Mean reductions for 12 spectral ordinates ranging from 0.04 to 2.0 seconds for those records in Tables 1 to 3 for which 5-percent-damped pseudo-relative velocity (PSRV) spectra were available are presented in Tables 4A through 4H. Over the range of periods from 0.04 to about 0.2 seconds, the mean horizontal PSRV ordinates demonstrate reductions similar in magnitude to that observed for the peak accelerations. For periods longer than about 0.2 seconds, mean reductions tend to become smaller, approaching zero at around 1.0 to 2.0 seconds. These observations are consistent with those made by others, for example Crouse* (1978).

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* Crouse, C. B. (1978). "Prediction of Free Field Earthquake Ground Motions," from Proceedings of the ASCE Conference on Earthquake Engineering and Soil Dynamics.

TABLE I

REDUCTION IN FREE FIELD HORIZONTAL PEAK ACCELERATIONS
DUE TO THE PRESENCE OF EMBEDDED STRUCTURES*

Earthquake	Date	Magnitude (M_L)	Distance (km)	Station Location	Mean Reduction (%)
Kern County	07-21-52	7.2	107	Hollywood Storage Bldg.	22
Southern California	08-30-64	4.0	23	Hollywood Storage Bldg.	66
Lytle Creek	09-12-70	5.4	80	Hollywood Storage Bldg.	34
San Fernando	02-09-71	6.4	35	Hollywood Storage Bldg.	37
Lillis Ranch	08-03-75	4.9	18	Pleasant Valley Pump Plant	38
Ferndale	06-07-75	5.3	25	Humboldt Bay Power Plant	54
Imperial Valley	10-15-79	6.6	5	El Centro Station 9 El Centro Diff. Array	25

* Uncorrected accelerations from U.S. earthquakes.

TABLE 1A

RECORDING STATION DESCRIPTIONS

Description of Embedded Building	STATION NAME			
	Hollywood Storage Site (Building and Free Field)	Pleasant Valley Site (Building and Free Field)	Humboldt Bay Nuclear Power Plant (Free Field Storage Building and Reactor Caisson*	El Centro Differential Array (Free Field) and El Centro Station #9
Distance from Free Field Station	47m	400m	23m	1,310m
Site Geology	Alluvium, 130m	Alluvium	Pleistocene Hookton Formation (hard soil)	Alluvium > 300m
Number of Stories/Height Above Ground	14 stories	1 story	11m high	2 stories
Plan Dimensions	17m by 72m	--	37m by 14m	7m by 20m
Depth of Embedment of the Instrument	3m	5m	25m	7m

* The Reactor Caisson is an 18m diameter fuel containment structure located completely below the ground surface. Directly above this structure is the 37m long by 14m wide by 11m high refueling building. The storage building is a small 1-story non-embedded structure, considered to represent free field conditions.

TABLE 2

REDUCTION IN FREE FIELD HORIZONTAL PEAK ACCELERATIONS
DUE TO THE PRESENCE OF NON-EMBEDDED STRUCTURES

Earthquake	Date	Magnitude (M_L)	Distance (km)	Station Location	Mean Reduction (%)
Imperial Valley	10-15-79	6.6	7	Imperial County Services Building and Free Field	-21*
Average of Four After-shocks of the Tokachioki Earthquake of May 16, 1968 (Mag = 7.8)	8-19-68 to 8-25-68	< 6	50	Hacinohe Technical College and Free Field, Japan	50
Average of 20 Earth-quakes Near Inage, Japan	1971 to 1975	< 6	70 - 141	Apartment House and Free Field, Inage, Japan	33

* Additional studies have indicated that the free field instrument may be anomolously low. Also the recorded peak accelerations at the Imperial County Services Building may have been amplified by the failure of the structure since the horizontal peaks occurred after or just prior to failure.

TABLE 2A

RECORDING STATION DESCRIPTIONS

Description of Building	STATION NAME		
	Imperial County Services Building and Free Field	Hacinohe Technical College and Free Field	Apartment House and Free Field, Inage, Japan
Distance from Free Field Station	114 m	10 m to 50 m	19 m
Site Geology	Alluvium > 300 m	--	Silt, sand and clay to 24 m
Number of Stories	6½	6	7
Plan Dimensions	46 m by 28 m	3 wings: Each 80 m by 10 m separated by Hallways	60 m by 15 m
Depth of Embedment of the Instrument	Ground level	Ground level	Ground level

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TABLE 3

REDUCTION IN HORIZONTAL PEAK ACCELERATIONS
DUE TO THE EMBEDMENT OF STRUCTURES

Earthquake	Date	Magnitude (M_L)	Distance (km)	Station Location	Mean Reduction (%)
San Fernando	02-09-71	6.4	15	14724 Ventura Blvd., LA 15250 Ventura Blvd., LA	30
			19	1760 N. Orchid, LA 7080 Hollywood, LA	28
			20	6430 Sunset Blvd., LA 6464 Sunset Blvd., LA	30
			24	6200 Wilshire, LA 5900 Wilshire, LA	46
			39	3407 W. Sixth, LA 616 S. Normandie, LA 3470 Wilshire, LA 3411 Wilshire, LA 3550 Wilshire, LA	28
Southern California	01-01-76	4.2	9	Diemar Filter Plant	60

NOTE:

Other station pairs (one station in a building recording at ground level, the other recording at depth) exist in downtown Los Angeles. However, the effect of embedment in the central downtown area is complicated by the great density of large structures, the presence of underground transit tunnels, and complex geologic conditions.

TABLE 3A

RECORDING STATION DESCRIPTIONS

Station Name	Separation Between Stations	Site Geology	Number of Stories	Area of Building Beneath Surface	Depth of Embedment of the Instrument
14724 Ventura Blvd., LA	914 m	Alluvium	14	89 m^2	Ground level
15250 Ventura Blvd., LA		Alluvium	12	100 m^2	Basement
1760 N. Orchid, LA	450 m	Alluvium	23		Ground level
7080 Hollywood, LA		Alluvium	12		Basement
6430 Sunset Blvd., LA	100 m	Alluvium	15		Ground level
6464 Sunset Blvd., LA		Alluvium	12		Basement
6200 Wilshire, LA	500 m	Alluvium over asphaltic sands	17		Ground level
5900 Wilshire, LA		Alluvium over asphaltic sands	17		Basement
3407 W. Sixth, LA		Alluvium, Shale at 13 m	7	2,000 m^2	1½ m
3470 Wilshire, LA	536 m	Alluvium, Shale at 13 m	11	2,700 m^2	5 m
3411 Wilshire, LA	396 m	Alluvium, Shale at 10 m	31	8,500 m^2	18 m
616 S. Normandie, LA	416 m	Alluvium, Shale at 10 m	17	1,200 m^2	3 m
3550 Wilshire, LA	666 m	Alluvium, Shale at 33 m	21	2,300 m^2	7 m

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TABLE 4A

KERN COUNTY EARTHQUAKE

07-21-52

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	Hollywood Storage Bldg. (Basement)		Hollywood Storage PE Lot (Ground)		Mean Reduction (%)
	S00°W	N90°E	S00°W	N90°E	
0.04	0.136	0.109	0.146	0.103	1.6
0.05	0.171	0.136	0.183	0.130	1.9
0.065	0.239	0.194	0.245	0.190	0.5
0.08	0.290	0.223	0.313	0.228	5.2
0.10	0.345	0.334	0.381	0.329	4.4
0.13	0.533	0.423	0.680	0.556	22.7
0.20	1.27	1.05	1.49	1.32	17.4
0.30	2.52	2.54	2.70	2.59	4.3
0.40	3.69	2.39	3.44	2.73	1.5
0.75	5.34	5.16	5.28	4.86	-3.4
1.0	7.15	6.26	7.16	6.31	0.4
2.0	4.91	5.31	4.71	5.22	-2.8

Uncorrected PGA Mean Reduction = 22%

Distance = 107 km.

TABLE 4B

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	Hollywood Storage PE Lot (Ground)		Hollywood Storage Bldg. (Basement)		Mean Reduction (%)
	S00°W	N90°E	S00°W	N90°E	
0.04	0.435	0.525	0.272	0.371	33.0
0.05	0.608	0.713	0.349	0.469	38.1
0.065	0.987	1.01	0.496	0.648	42.7
0.08	2.15	1.69	0.786	0.867	57.0
0.10	3.08	3.11	1.25	1.33	58.3
0.13	3.63	4.61	1.75	1.90	55.7
0.20	4.98	7.41	3.42	4.42	36.7
0.30	6.76	9.75	6.21	8.30	12.1
0.40	7.37	11.0	5.81	10.4	11.8
0.75	7.34	9.92	7.24	9.61	2.4
1.0	9.60	15.2	9.35	14.9	2.2
2.0	13.4	9.64	13.8	9.43	-0.8

Uncorrected PGA Mean Reduction = 37%

Distance = 35 km.

TABLE 4C

IMPERIAL VALLEY EARTHQUAKE

10-15-79

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	Imperial Co. Svcs Bldg. Free Field (Ground)		Imperial Co. Svcs Bldg., (Ground)		Mean Reduction (%)
	002°	092°	North	East	
0.04	1.34	1.53	1.79	2.03	-24.9
0.05	1.74	1.90	2.42	2.61	-38.2
0.065	2.75	2.56	3.42	3.47	-22.9
0.08	3.31	3.76	5.44	4.22	-26.8
0.10	7.02	5.04	8.38	6.16	-20.6
0.13	8.51	6.76	13.8	9.14	-50.2
0.20	17.7	16.0	25.6	13.6	-16.3
0.30	19.0	18.8	38.5	37.7	-50.4
0.40	22.8	27.0	55.1	46.8	-51.1
0.75	43.4	62.2	58.3	37.3	9.5
1.0	65.9	55.4	79.5	59.5	-12.7
2.0	57.7	72.8	61.7	78.4	-6.9

Uncorrected PGA Mean Reduction = -21%

Distance = 7 km.

TABLE 4D

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	14724 Ventura Blvd., LA, (Ground)		15250 Ventura Blvd., LA, (Basement)		Mean Reduction (%)
	S00°W	N90°E	S00°W	N90°E	
0.04	0.509	0.643	0.557	0.368	19.7
0.05	0.792	0.825	0.722	0.479	25.7
0.065	1.44	1.15	0.961	0.646	38.0
0.08	1.74	1.67	1.56	0.903	27.8
0.10	2.34	2.97	1.91	1.42	37.3
0.13	4.44	4.77	3.52	2.31	37.7
0.20	7.70	7.61	8.33	4.23	18.0
0.30	8.10	19.0	10.8	7.50	32.5
0.40	9.44	18.2	16.5	13.7	-8.5
0.75	8.72	11.1	10.3	6.33	16.1
1.0	7.59	9.24	10.3	10.4	-18.7
2.0	15.0	18.6	24.8	23.0	-19.7

Uncorrected PGA Mean Reduction = 30%

Distance = 15 km.

TABLE 4E

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	1760 N. Orchid, LA, (Ground)		7080 Hollywood Blvd., LA, (Basement)		Mean Reduction (%)
	South	East	South	East	
0.04	0.310	0.424	0.205	0.258	36.9
0.05	0.450	0.527	0.277	0.330	37.9
0.065	0.554	0.746	0.397	0.468	33.5
0.08	0.824	1.35	0.631	0.649	41.1
0.10	1.28	1.49	0.773	1.14	30.9
0.13	2.09	3.38	1.67	1.39	44.1
0.20	5.80	6.30	2.95	1.82	60.6
0.30	4.87	6.40	4.87	5.25	10.2
0.40	3.96	11.7	4.34	7.30	25.7
0.75	3.90	6.19	4.81	4.73	5.5
1.0	4.31	9.60	4.52	7.99	10.1
2.0	5.05	6.62	5.35	5.91	3.5

Uncorrected PGA Mean Reduction = 28%

Distance = 19 km.

TABLE 4F

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	6430 Sunset Blvd., LA, (Ground)		6464 Sunset Blvd., LA, (Basement)		Mean Reduction (%)
	South	East	South	East	
0.04	0.477	0.461	0.307	0.287	36.7
0.05	0.577	0.588	0.402	0.379	33.0
0.065	0.897	0.828	0.569	0.631	30.4
0.08	1.28	1.17	0.834	0.853	31.1
0.10	2.24	2.32	1.11	1.06	52.4
0.13	3.12	2.96	1.59	2.30	36.0
0.20	7.55	4.62	3.89	5.08	26.3
0.30	7.55	7.97	6.05	4.85	29.8
0.40	10.0	9.54	6.43	5.98	36.5
0.75	7.30	8.37	8.59	7.86	-4.7
1.0	10.4	17.2	13.5	10.6	12.7
2.0	12.0	9.32	8.47	12.2	3.0

Uncorrected PGA Mean Reduction = 30%

Distance = 20 km.

TABLE 4G

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	6200 Wilshire Blvd., LA, (Ground)		5900 Wilshire Blvd., LA, ("B" Parking Lot)		Mean Reduction (%)
	N82°W	N08°E	N83°W	S07°W	
0.04	0.324	0.312	0.171	0.239	35.5
0.05	0.409	0.406	0.222	0.297	36.3
0.065	0.521	0.629	0.291	0.391	40.7
0.08	0.828	0.919	0.356	0.504	50.8
0.10	1.01	1.50	0.475	0.640	55.6
0.13	1.52	3.12	0.759	0.815	66.1
0.20	3.48	3.94	2.12	1.59	50.0
0.30	5.04	6.94	2.38	3.98	46.9
0.40	7.23	9.76	3.77	6.17	41.5
0.75	9.07	6.45	8.11	10.4	-16.2
1.0	9.02	7.51	12.0	9.28	-22.3
2.0	11.2	8.86	14.1	12.7	-25.1

Uncorrected PGA Mean Reduction = 46%

Distance = 24 km.

TABLE 4H

SAN FERNANDO EARTHQUAKE

02-09-71

Pseudo Relative Velocity Spectrum (in/sec)
Damping = 5%

T (sec)	Los Angeles										Mean Reduction (%)
	3407 W. Sixth St. (Ground)		616 S. Normandie (Basement)		3470 Wilshire (Basement)		3411 Wilshire (Basement)		3550 Wilshire (Basement)		
	South	West	South	West	South	West	South	West	South	West	
0.04	0.400	0.438	0.282	0.282	0.343	0.294	0.279	0.321	0.408	0.329	24.3
0.05	0.522	0.623	0.364	0.360	0.438	0.370	0.363	0.426	0.543	0.440	27.9
0.065	0.762	1.09	0.540	0.513	0.578	0.527	0.521	0.675	0.717	0.645	36.3
0.08	1.21	2.09	0.859	0.766	1.02	0.707	0.849	0.899	0.966	0.752	48.3
0.10	2.45	2.34	1.40	1.12	1.13	1.00	1.38	2.09	1.50	1.14	58.2
0.13	3.19	4.31	2.76	1.99	2.42	1.76	3.42	3.25	3.19	1.77	31.5
0.20	5.30	3.86	2.70	3.66	4.38	3.03	3.60	3.76	3.81	4.09	20.8
0.30	10.3	6.18	5.83	7.78	8.15	6.88	4.36	3.11	8.83	6.54	21.9
0.40	11.1	4.95	6.69	6.86	8.56	6.94	3.74	3.60	9.75	6.78	17.6
0.75	11.1	7.30	8.32	5.62	11.9	7.33	6.85	4.61	8.87	8.00	16.4
1.0	16.0	12.4	13.4	10.2	17.2	9.31	14.4	6.69	12.9	10.6	16.6
2.0	11.0	7.36	11.1	8.49	11.7	10.8	10.2	8.54	11.4	11.9	-12.7

Uncorrected PGA Mean Reduction = 28%

Distance = 39 km.

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