STRONG MOTION EARTHQUAKE MEASUREMENTS IN EPICENTRAL REGIONS

D. E. Hudson[I]

SYNOPSIS

Only a few dozen of the more than 1000 strong motion accelerograms obtained throughout the world since the early 1930's have been recorded at distances from points of seismic energy release as small as the dimensions of the earthquake source. Uniformly processed data for such near-field measurements are summarized along with references on geological and seismological features of the events.

NEAR-FIELD ACCELEROGRAMS

Figure 1 shows to a common scale one horizontal component of each recorded near-field accelerogram, and Tables I and II give additional information (26). It will be noted that there are striking differences in the appearance of the records which suggests that the visual character of the accelerogram may be an important indicator of significant aspects of the earthquake which may be difficult to capture in a quantitative way through such parameters as peak values, duration, or spectral properties. No simple parameters or combination thereof seem to correlate very well with the general impression of the overall damage potential of the event.

EARTHQUAKE DATA

El Centro. The main energy release occurred during the first 25 sec and involved 4 separate events (44). The surface fault length was 65 km, with a maximum fault displacement of 5.7 m (41). With an average displacement of 1.25 m and an assumed rigidity of 3.3×10^{11} dyne/cm^2, a seismic moment of 1.4×10^{26} dyne cm is calculated (44,8,9). Stress drops are of the order of 200-350 bars for the separate events (47). The maximum energy release occurred within some 25 km of the accelerograph (44).

San Fernando. The accelerograph was located directly above the epicenter, within 5 km of the sources of major energy release. The special conditions at the recording site are described in detail in ref. 45. Source parameters are relatively well-defined (4,46,11,33,52): typical values are area 320 km^2, average fault displacement 1.5 m, seismic moment 1.5×10^{26} dyne cm, stress-drop 85 bars (46). Details of the overthrust faulting have been worked out by several methods with reasonable agreement (28,48).

Olympia. Depth slightly greater than usual for the region. Of 2 well-defined fault-plane solutions, one agrees with previous earthquake activity in the Pacific Northwest, the other with local geological evidence (38,5,35).

Helena. The second largest event of a major earthquake swarm in Montana lasting 6 months and culminating in a M $6\frac{1}{4}$ earthquake occurring before the accelerograph was installed. Instrument was probably within 3-8 km of energy release. No surface faulting was observed (15,37,19).

Parkfield. Surface aseismic fault slip motions along the San Andreas fault extended for some 33 km. Seismic energy release occurred over a buried fault length of 20 km at depths of 3-9 km, with an average dislocation amplitude of 1.2 m (49,3). Seismic moment calculations vary from 0.06×10^{25} (51,1) to 4.4×10^{25} dyne cm (49) and stress drop calculations from 0.1 (51)

[I]Professor of Mechanical Engineering and Applied Mechanics, California Institute of Technology.

to 10 bars (2). Although the accelerogram at stn. no. 2 was on the fault, it was 30 km from the epicenter, since faulting began at the opposite end.

San Francisco. On the main trace of the San Andreas fault with no evidence of surface fault breakage. Depth of the order of 10 km, and distances from energy release of about 15 km for Golden Gate Park (GGP) and 18 km for the State Bldg. (7, 25). Fault plane solutions agree with dip and strike of San Andreas as known from geologic evidence, but are not compatible with the usual right-lateral movement (43).

Lytle Creek. On the main trace of the San Andreas fault at a depth of about 8 km. The accelerograph was on the fault a distance of about 12 km from the epicenter. No seismological or geological studies relating to source mechanisms have been reported (13,32).

Port Hueneme. Perhaps the best example of a single-pulse event (24). Although accelerograph starting delays lost the initial portion of the record, the essential features are present. The instrument was about 8 km from the epicenter (7).

Stone Canyon. This event occurred 1-2 km SW of the main trace of the San Andreas fault at a depth of 5 ± 1 km. Because of its closeness to the Stone Canyon Geophysical Observatory it is an unusually well documented earthquake (14,34,17). The accelerograph was about 8 km from the epicenter whose location was determined to 1-2 km (50). No surface fault motion was reported. Calculations give seismic moment of about 4×10^{23} dyne cm, average fault displacement 15 cm, and stress drop = 44 bars (27). Strain measurements showed that the earthquake was accompanied by a 5×10^{-8} strain step followed by a post-earthquake creep episode of 2×10^{-7} in 1 hr (10). A pre-earthquake creep event was also reported (36). Geodetic measurements before and after the event revealed no anomalous effects (40).

Koyna. The best documented case of a reservoir-loading associated earthquake (12,21). Accelerograph was located at midheight of dam monolith and represents ground motion over frequency spectrum of main engineering interest (20,31). Depth of event, 8-12 km. The fractures apparently initiated about 15 km north of dam, and proceeded towards dam, with main energy release about 3 km south of dam (22). Fault plane solutions indicated nearly vertical fault, with variation in strike from various investigations from N32°W to N37°E, and ambiguity between dip-slip or strike-slip motions (23).

Managua. The accelerograph was located within 5 km of main shock (30,42). Surface fault motions were reported for 4 separate faults with the following lengths and maximum displacements: 1.6 km, 2.2 cm; 5.1 km, 26.6 cm; 5.9 km, 38 cm; 2.7 km, 2.0 cm (39). Fault plane solutions indicate left-lateral strike-slip N45°E at dip of 74-82°SE (6).

Ancona. The major shock associated with a remarkable earthquake swarm beginning near Ancona, Italy in Jan. 1972 and continuing through the summer (16, 18). The accelerograph was about 5-6 km from epicenter. Focal depth, 4-9 km. No well-defined fault plane, and no consistent fault plane solutions for even the larger, well-located shocks of the swarm (29).

CONCLUSIONS

An examination of all references for the earthquakes for which near-field accelerograms exist reveals a disappointing lack of detailed information. Only for the San Fernando earthquake, and perhaps to a lesser extent for the El Centro and the Parkfield events, are there enough data to make it possible to carry out meaningful source mechanism studies. This emphasizes the tentative nature of much of our strong motion earthquake knowledge

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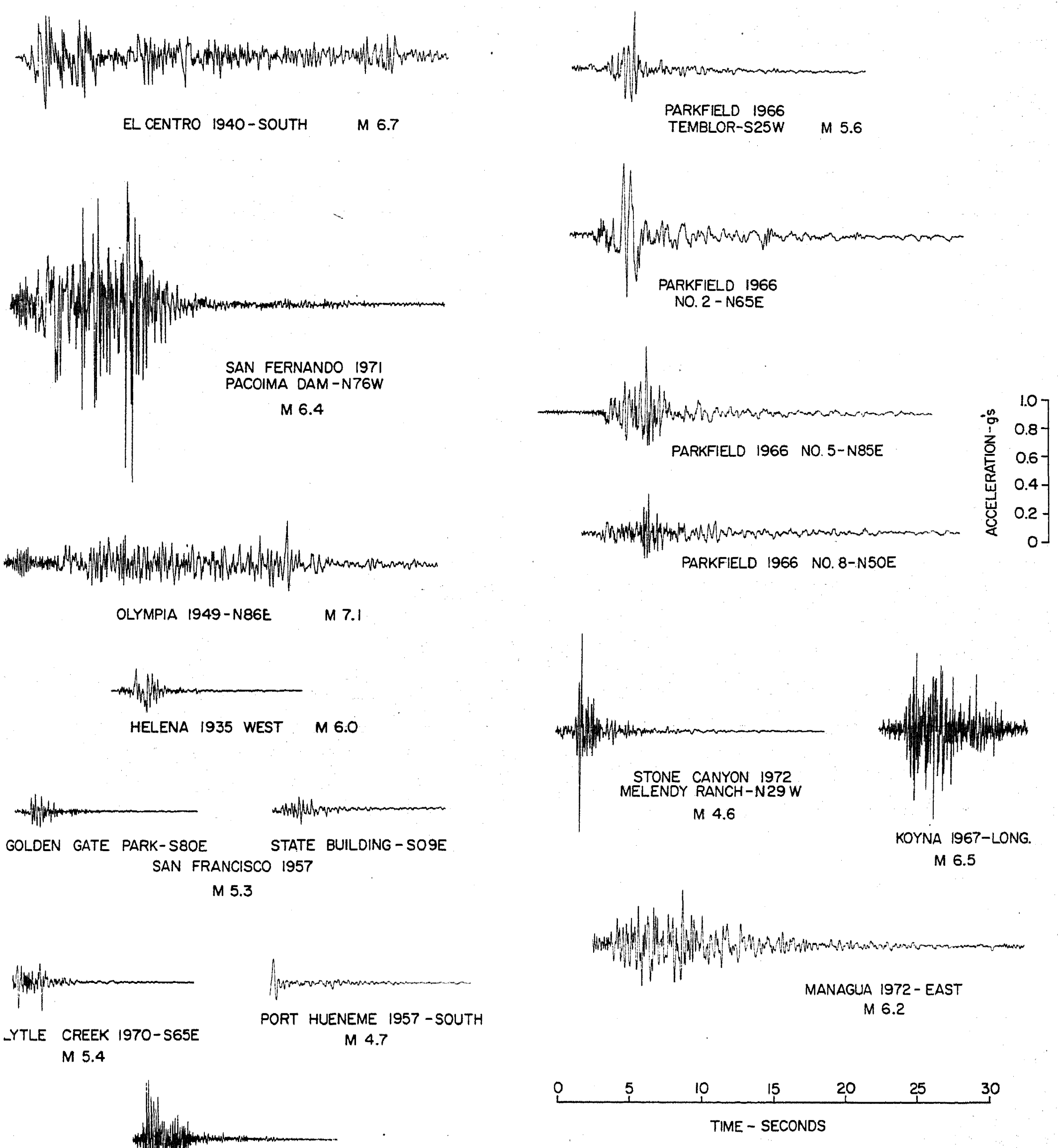

EARTHQUAKE GROUND ACCELERATIONS IN EPICENTRAL REGIONS

Figure 1

TABLE I

MAXIMUM GROUND MOTIONS FROM NEAR-FIELD EARTHQUAKE MEASUREMENTS

Earthquake	Peak Acceleration (g's)			Peak Velocity (cm/sec)			Peak Displacement (cm)		
	H1[I]	H2[I]	V[I]	H1	H2	V	H1	H2	V
EL CENTRO, 1940	0.36	0.22	0.28	33.4	36.9	10.8	10.9	19.8	5.6
SAN FERNANDO, 1971	1.24	1.25	0.72	113.2	57.7	58.3	37.7	10.8	19.3
OLYMPIA, 1949	0.16	0.31	0.10	21.4	17.0	6.8	8.5	10.4	4.0
HELENA, 1935	0.14	0.16	0.10	7.3	13.3	9.5	1.4	3.7	2.8
PARKFIELD, 1966 (T)	0.28	0.41	0.16	14.5	22.5	4.4	4.7	5.5	1.4
PARKFIELD NO. 2	0.51	—	0.35	77.9	—	14.1	26.3	—	4.3
PARKFIELD NO. 5	0.40	0.47	0.18	22.5	25.4	6.8	5.2	7.1	3.4
PARKFIELD NO. 8	0.28	0.28	0.14	10.8	11.8	4.5	4.4	3.9	2.1
SAN FRAN., 1957, GGP	0.11	0.12	0.05	4.9	4.6	1.2	2.3	0.8	0.7
SAN FRAN. STATE	0.10	0.07	0.05	5.1	4.0	2.3	1.1	0.9	0.6
LYTLE CREEK, 1970	0.15	0.20	0.08	8.7	9.6	3.1	2.1	1.0	1.4
PORT HUENEME, 1957	0.17	0.09	0.03	17.9	8.9	1.9	4.0	2.6	0.5
STONE CANYON, 1972	0.56	0.71	0.20	18.5	19.5	4.8	0.3	0.6	0.3
KOYNA, 1967	0.63	0.49	0.34	30.0	25.2	34.6	10.1	19.4	24.1
MANAGUA, 1972	0.33	0.38	0.33	30.0	37.7	17.5	6.2	14.9	8.7
ANCONA, 1972	0.61	0.45	0.30	9.4	9.4	4.0	0.7	0.7	0.2

[I] H1, H2 = Horizontal; V = Vertical

TABLE II

GROUND MOTION PARAMETERS FROM NEAR-FIELD EARTHQUAKE MEASUREMENTS

Earthquake	Magnitude	Max. M. M. Intensity	Peak Ground Velocity (cm/sec)[I]	Max. Response Velocity (cm/sec)[II]	Acceleration Duration (sec)[III]	$\left[\int a^2 dt\right]_{max}$ (m²/sec³)[IV]
EL CENTRO	6.7	X	35	56	25	21
SAN FERNANDO	6.4	X-XI	85	150	7	109
OLYMPIA	7.1	VIII	19	32	22	13
HELENA	6.0	VIII	10	16	2	1
PARKFIELD, T.	5.6	VII	19	39	5	5
PARKFIELD NO. 2	5.6	VII	78	114	7	12[V]
PARKFIELD NO. 5	5.6	VII	24	48	7	10
PARKFIELD NO. 8	5.6	VII	11	19	13	5
SAN FRAN. GGP	5.3	VII	5	9	3	6
SAN FRAN. STATE	5.3	VII	5	10	6	6
LYTLE CREEK	5.4	VII	9	19	3	2
PORT HUENEME	4.7	VI	13	16	9	1
STONE CANYON	4.6	VI	19	37	2	10
KOYNA	6.5	VIII+	28	37	5	19
MANAGUA	6.2	IX	34	53	10	24
ANCONA	4.9	VIII+	9	21	3	7

[I] Average of two horizontal components.

[II] $(SV)_{max}$ at 10% damping. Average two horizontal components.

[III] Time to $\left[\int a^2 dt\right]_{max}$ minus first and last 5%. Average two horizontal components.

[IV] $\int_0^T (a_{H1}^2 + a_{H2}^2)\,dt$.

[V] One component only.

DISCUSSION

R. Guzman (U.S.A.)

The discussor thinks, there are a few records missing from your figures such as the Holiday Inn records and perhaps others from the 1971 San Fernando Earthquake.

Author's Closure

With regard to the question of Mr. Guzman, we wish to state that the only accelerogram from the San Fernando Earthquake which is believed to be within distances from points of major energy release of the order of the source dimensions is the Pacoima Dam record. Although the ground motions at Holiday Inn were very severe, the site was probably outside the near-field region so defined. Such definitions are of course arbitrary, and for some of the earthquakes included the exact source dimensions and locations are uncertain. It is to be hoped that more exact information on source regions will be collected for future earthquakes of importance.