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Main Shock Accelerograms of the Tabas, Iran, Earthquake of 16 September 1978

1978年9月16日イランTABAS地震の加速度記録

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Abstract

Five accelerograms (15 components) obtained during the main shock of the Tabas, Iran, earthquake of 16 September 1978 were corrected with respect to digitization errors to investigate the spectral features. The following information was summarized for each of the 15 components; (1) Acceleration time history, (2) Plot of absolute acceleration response spectrum, (3) Print-out of absolute acceleration, relative velocity and relative displacement response spectrum, (4) SI value, and (5) Duration of strong motion.

Introduction

The Tabas earthquake of September 16, 1978 of magnitude Ms=7.7 occurred in the Khorassan Province of east central Iran. The instrumental epicenter is reported at 33.210N, 57.350E with a focal depth 33km by USGS, and the center of serious damage zone located at about 40 km northwest from the above instrumental epicenter.

The main shock, which is the largest one so far recorded in Iran, destroyed over 15,000 housing units and 30 qanats*** in the epicentral region and completely demolished the Oasis Town of Tabas. Over 20,000 people were killed and thousands were injured. Large and small landslides and rockfalls occurred on steep slopes. The power generator (weighing more than 50 tons) and the tank containing 50,000 litres of diesel fuel at the time of earthquake, both of the Tabas Power Station, were shifted eastward by about 80 cm and 17 cm, respectively[1]. Maximum intensity of the earthquake was around X (MM scale) in Tabas and the region within a 20 km radius from Tabas, and in the area near a fresh fault which was assoiated with the event (Fig. 1).

The strong motion instrumentation network in the region within a 300 km radius from Tabas consisted of 20 strong motion recording stations where were installed 20 SMA1 accelerographs and one seismoscope. Several valuable records were obtained at 9 stations of the network, including Tabas station where the intensity was as high as X (MMI scale) during the main shock. Although the original time histories and the uncorrected digitized data were published by A. A. Moinfar and H. Adibnazari[2] in 1982, they have not been analyzed in detail so far to the authers' knowledge.

The acceleration response spectra, spectrum intensities SI and durations of the 15 components, all with maximum accelerations more than 20 gal, were analyzed, This paper briefly summarizes the results emphasis on the two strongest records.

Data Processing

Figure 1 shows the locations of the stations where the 5 accelerograms were recorded. The distances of the stations from Tabas are listed in Table 1. The accelerograms were digitized by SMAC reader SM-3 digitizer with time intervals of 0.02 seconds[2]. The mean of the digitized accelerations were calculated and the line passing through the mean value points was simply assumed as the tentative zero axis.

After plotting the time histories using the uncorrected digital data, it was found that there were a number of problems in the original data. Digitization of some accelerograms were apparently accomplished by deviding one record into several sections, but successive sections were so badly connected that the waveforms were extremely distorted. Some wavefor-

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***A series of subterranean wells used for irrigation specially in desert area.

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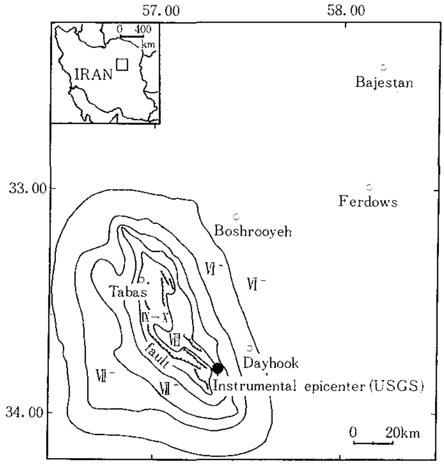

Fig. 1　Intensity distribution in epicentral area

Table 1　Summary of Five (15 Components) Accelero grams

No.	Station	Component	Distance from Tabas km	Maximum Acceleration gal	Duration of Strong Motion sec	SI Value cm/sec
1	Tabas	N 16 W U−D S 74 E	0	915.39 731.33 862.92	13.57 11.85 11.16	76.98 33.12 87.18
2	Boshrooyeh	N 11W U−D N 70E	60	83.04 76.53 102.78	9.84 10.57 9.80	14.95 8.43 13.84
3	Dayhook	N 10E U−D N 80 W	75	391.53 184.62 363.44	7.47 8.21 7.34	31.00 11.78 23.36
4	Ferdows	N 70 E U−D S 20 E	128	104.15 52.76 95.91	16.64 19.79 14.66	6.25 4.58 5.23
5	Bajestan	Horiz. 1 U−D Horiz. 2	160	65.88 23.79 87.85	11.49 15.51 13.00	3.71 2.02 4.57

ms were found clearly tilted that the zero line seemed to require angular rotations for certain section. Besides, when compared with the original time histories, there were several evidently erroneous readings of peak values in some of the data.

It was difficult to correct the distortion of zero line induced by sectional digitization without having more detailed information on the positions of the connection points of successive sections. Therefore, only the main portion of accelerogram was used for records No. 2, No. 3 and No. 5. The new zero line was assumed as $a+bt$, and coefficients a and b were determined so that the RMS value of acceleration was minimized. Evidently erroneous peak values were replaced by the mean value of two adjacent points. Finally, all the records were filtered by a high pass filter defined by the following equation

$$A(T)=\begin{cases} 0 & f\leqq f_{LL} \\ \dfrac{1}{2}\left(1-\cos\dfrac{f-f_{LL}}{f_{LU}-f_{LL}}\pi\right) & f_{LL}<f<f_{LU} \\ 1 & f\geqq f_{LU} \end{cases} \tag{1}$$

where $A(T)$ is the frequency response function of the filter, f is the frequency, f_{LU} is the cut-off frequency (0.1Hz) and f_{LL} is the roll-off frequency (0.06 Hz).

After the correction according to the above-mentioned method, the duration of strong motion defined by Zhou and Xie[3] was calculated by

$$T=2\sqrt{\frac{\int_0^{t_r}(t-T_c)^2a^2(t)dt}{\int_0^{t_r}a^2(t)dt}} \tag{2}$$

where $a(t)$ is acceleration, t_r is the total duration of record, and T_c is the center of power.

The spectral intensity value proposed by G. W. Housner[4] was also computed by

$$SI=\frac{1}{2.4}\int_{0.1}^{2.5}S_v(T_0,h=0.2)dT_0 \tag{3}$$

where S_v is the relative velocity response spectrum, T_0 is natural period and h is damping factor. Both the duration T and SI value are listed in Table 1.

Acceleration Time Histories, and Plots & Print-Outs of Response Spectra

The plots and print-outs of each record and its results of analysis were arranged in the following order:

(1) Acceleration time histories of the three components,

(2) Absolute acceleration response spectra of the three components with damping factors of 0.02, 0.05, 0.1 and 0.2,

(3) Print-outs of absolute acceleration, relative velocity and relative displacement response spectra of the three components.

Figure 2(a) and (b) show the corrected accelerograms and their acceleration response spectra for the ground motion in Tabas. The peak ground accelerations in the two horizontal directions are 915 gal and 863 gal, which are definitly among the strongest shakings ever recorded. Figure 2(b) indicates that horizontal response accelerations of simple structures with their periods shorter than about 1 sec are generally greater than 1 g (≒1000 gal) for damping factors

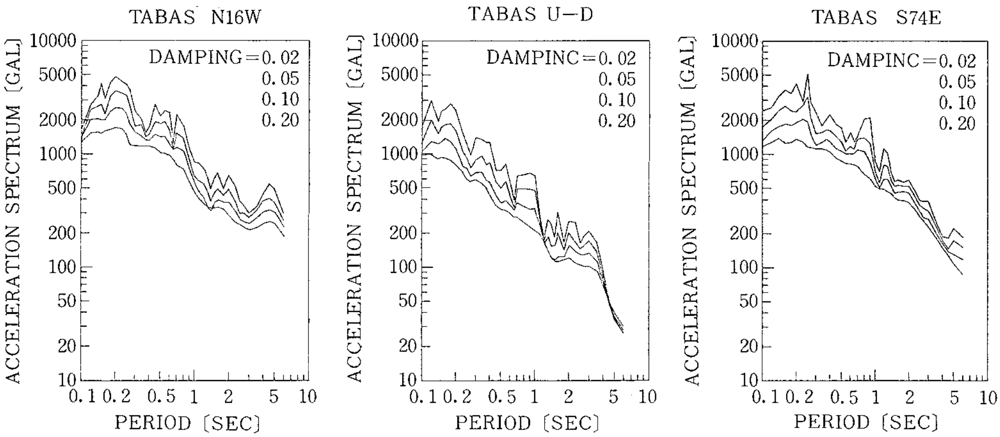

Fig. 2(b)　Acceleration response spectra of the record in Tabas

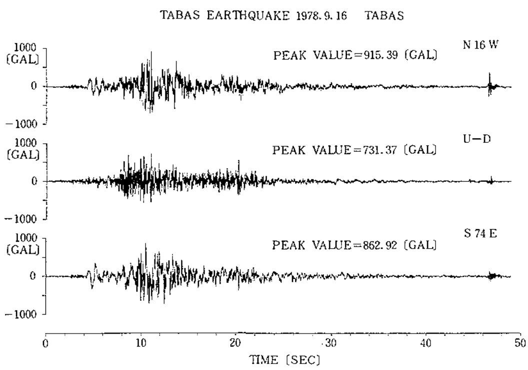

Fig. 2(a)　Corrected acceleration time histories of the record in Tabas

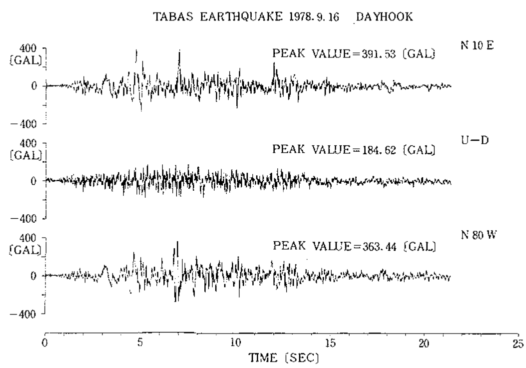

Fig. 3(a)　Corrected acceleration time histories of the record in Dayhook

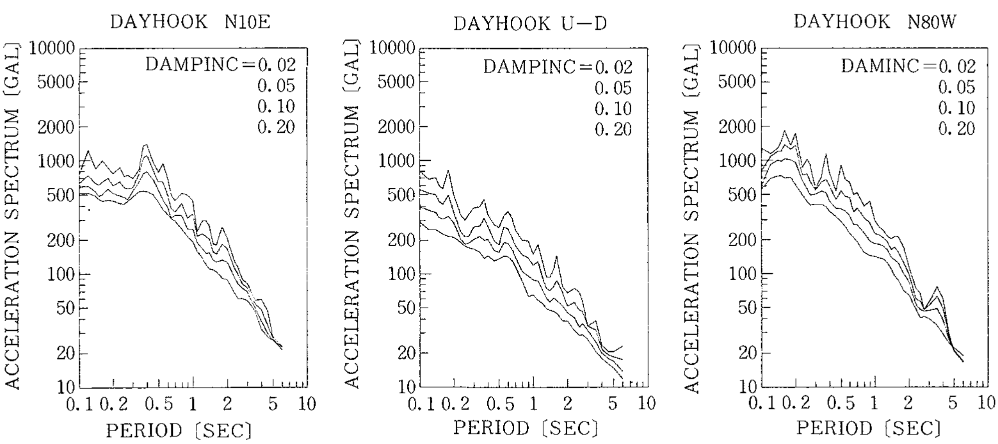

Fig. 3(b)　Acceleration response spectra of the record in Dayhook

Table 2　Digital values of acceleration, velocity and displacement response spectra for the Tabas N16W record

TABAS N16W　SAMPLING INTERVAL = 0.02 (SEC), TIME LENGTH = 49.00 (SEC), MAX. INPUT ACC. = 915.39 (GAL)

	DAMPING = 0.02			DAMPING = 0.05			DAMPING = 0.10			DAMPING = 0.20		
PER.	SA	SV	SD	SA	SV	SD	SA	SV	SD	SA	SV	SD
0.10	1644.05	20.98	0.41	1425.35	18.51	0.36	1405.52	16.58	0.36	1278.93	13.51	0.32
0.12	2673.93	40.54	0.97	2434.39	37.12	0.86	2014.90	30.54	0.68	1525.87	22.00	0.52
0.14	3228.62	70.39	1.58	2609.25	48.02	1.25	2040.59	34.03	0.96	1553.35	24.78	0.72
0.15	4107.29	84.71	2.35	2690.27	52.06	1.54	1992.92	36.73	1.13	1511.96	26.30	0.82
0.16	3042.51	67.32	1.98	2210.48	48.02	1.46	2005.46	38.37	1.24	1585.88	29.40	0.95
0.18	4228.71	107.37	3.49	3202.55	76.66	2.64	2371.41	56.42	1.92	1638.80	37.68	1.27
0.20	4711.87	137.00	4.75	3563.56	100.19	3.57	2552.83	71.92	2.49	1711.48	48.12	1.60
0.23	4275.01	147.72	5.77	3397.24	119.67	4.61	2515.05	90.56	3.39	1656.23	57.29	2.06
0.25	4046.46	153.33	6.40	3243.08	126.07	5.13	2266.29	90.89	3.61	1464.35	55.96	2.13
0.27	3612.78	151.89	6.68	2600.10	117.88	4.76	1814.89	86.51	3.33	1206.63	55.90	2.10
0.30	2375.17	110.41	5.45	1728.13	84.69	3.99	1553.64	70.22	3.50	1182.87	54.90	2.44
0.34	2023.67	122.26	5.88	1782.19	106.56	5.20	1438.32	86.51	4.07	1171.58	64.70	3.18
0.37	1516.65	102.24	5.26	1418.68	101.15	4.91	1338.25	90.49	4.57	1181.55	69.47	3.76
0.40	1718.13	99.83	6.95	1467.13	100.32	5.96	1319.46	93.29	5.27	1169.04	71.91	4.30
0.45	2692.18	188.79	13.86	1903.87	136.82	9.67	1494.02	104.59	7.54	1136.49	73.21	5.28
0.50	2144.00	186.33	13.54	1822.66	157.59	11.48	1409.49	118.87	8.73	1027.08	89.74	6.05
0.55	2359.52	188.03	18.00	1902.63	159.54	14.44	1422.03	133.29	10.66	1009.67	99.01	7.20
0.60	2288.03	236.14	20.83	1578.85	169.70	14.23	1221.59	135.72	10.89	966.30	99.80	8.07
0.65	1263.72	133.17	13.53	1100.54	137.76	11.73	1092.23	121.50	11.41	889.94	95.13	8.64
0.70	2225.96	229.93	27.63	1527.04	150.00	18.93	1143.32	116.46	14.01	795.40	88.48	9.36
0.80	1754.93	230.85	28.40	1374.89	164.52	22.15	1057.23	124.07	16.81	731.23	88.15	10.99
0.90	1112.93	149.89	22.82	923.78	126.33	18.85	732.04	103.21	14.85	564.77	76.28	10.69
1.00	842.35	126.37	21.33	652.93	105.25	16.48	554.49	84.89	13.90	455.93	72.25	11.05
1.10	827.30	152.14	25.36	579.07	98.94	17.64	462.42	78.41	13.96	401.12	65.65	11.79
1.20	742.73	147.42	27.06	551.80	103.81	20.01	411.80	77.57	14.64	364.32	62.27	12.69
1.30	630.33	129.85	26.98	473.58	95.86	20.16	336.70	71.49	14.11	340.72	64.33	13.84
1.40	495.91	118.68	24.62	385.10	89.56	19.02	315.20	73.16	15.41	333.11	66.80	15.64
1.50	609.17	151.20	34.71	449.39	112.20	25.55	374.29	88.38	21.01	336.45	69.61	18.00
1.60	681.47	166.83	44.18	495.05	119.91	31.96	395.53	91.59	25.07	338.00	70.08	20.36
1.80	498.18	142.35	40.86	430.05	120.50	35.06	377.01	104.74	30.19	323.28	76.12	24.14
2.00	651.31	216.23	65.97	491.71	169.62	49.52	377.94	124.84	37.47	283.90	83.55	26.99
2.30	521.14	190.79	69.79	378.64	145.06	50.46	305.58	118.70	39.94	249.39	97.81	31.06
2.50	383.20	166.70	60.63	298.22	152.67	46.91	264.53	134.64	41.33	235.82	109.67	35.39
2.70	354.48	178.36	65.38	303.08	162.00	55.69	251.63	142.53	45.29	224.92	116.76	39.35
3.00	303.37	147.29	69.08	274.34	146.05	62.12	243.17	139.18	53.54	212.82	121.35	44.84
3.50	344.57	176.71	106.80	315.65	153.35	97.37	275.71	139.72	83.43	223.17	122.31	62.11
4.00	439.80	277.05	178.10	382.54	232.09	154.14	308.54	194.63	122.37	241.72	154.73	90.88
4.50	540.77	388.91	277.18	406.05	317.88	207.26	318.69	261.36	158.53	254.30	190.45	118.14
5.00	496.10	411.06	313.83	377.60	320.31	237.77	305.92	263.81	188.97	243.48	195.59	138.21
6.00	298.74	316.20	272.14	260.04	273.14	235.46	226.84	242.85	201.90	188.25	195.79	152.30

PER.=PERIOD (SEC), SA=ABSOLUTE ACC. (GAL), SV=RELATIVE VELOCITY (CM/SEC), SD=RELATIVE DISPLACEMENT (CM)

equal to or less than 0.1. Figure 3(a) and (b) are the similar graphs for the ground motion in Dayhook, the second strongest shaking recorded during the earthquake. Unfortunately, the site ground conditions at the recording stations are not given in Ref. (2). Table 2 shows a sample of the print-out of the digital values of response spectra for the strongest component, the N16W accelerogram in Tabas with a peak ground acceleration of 915 gal.

The complete results of the analyses on the abovementioned 5 records will be compiled elsewhere[5].

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References

1) M. Berberian, "Earthquake Faulting and Bedding Thrust Associated With the Tabas-Golshan (Iran) Earthquake of September 16, 1978", *BSSA, Vol. 69, 1979*

2) A. A. Moinfar and H. Adibnazari, "The Tabas Earthquake of 16th Sep. 1978", *Publication of the Building & Housing Research Center, July 1982*

3) Zhou Yongnian and Tsuneo Katayama, "Effects of Magnitude, Epicentral Distance and Site Conditions on the Duration of Strong Ground Motion", *"SEISAN-KENKYU" (Monthly Journal of Institute of Industrial Science, University of Tokyo), Vol. 37, No. 12, 1985*

4) G. W. Housner, "Vibration of Structures Induced by Seismic Waves", *Shock and Vibration Handbook by C. M. Harris & C. E. Crede, 1961*

5) Zhou Yongnian and Tsuneo Katayama, "The Tabas, Iran, Earthquake of 16 September 1978—Time Histories and Response spectra—", *Report 85-03 (09), Earthquake Disaster Mitigation Engineering, Institute of Industrial Science, University of Tokyo, (To appear)*