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FREE FIELD ACCELEROGRAMS IN PUEBLA CITY, MEXICO (1978-1994)

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ABSTRACT

The Accelerograph network of Puebla City (RACP) is integrated by 4 digital stations (DCA-333) in order to obtain the acceleration record of strong ground motions. Three of them belong to the Facultad de Ingeniería Civil y Tecnológicas de la BUAP, which are PBPP, UAPP and CAPP. The fourth station, named SXPU, is property of the Instituto de Ingeniería, UNAM. The criteria used for the location of these sites are supported on a preliminary zonation of the soils in Puebla City. This network covers approximately 50% of the urban zone and at the same time has permitted the acceleration recording of 16 earthquakes, 14 of them have an epicentral location in the Guerrero state coast, and two have it inner state. The main events are: October (24) 1980 and September (19) 1985. The records have shown that the earthquakes located near state could have deeper effects than those located at greater distances than 300 Km.

KEYWORDS

The Puebla City Accelerograph Network, strong motion, Seismotelemetric Network, Mexican Subduction Zone, accelerogram, seismic zonification.

INTRODUCTION

Through its history, the State of Puebla has shown vulnerability during the occurrence of seismic phenomena, and a large number have affected it (Figueroa, 1974). Some of them have reached important magnitudes, however the lack of instrumental recording in the past does not permit to know it accurately, on this way the values assigned are estimations based on the registered damages. The locations of the reported earthquakes show that Puebla City can be severely affected by events whose epicenter may be located in the state itself, as occurred on the 28 August 1973, or by earthquakes from the Mexican Subduction Zone, such as the April (7) 1845 quake, or more recently the events that occurred on September (19 and 21) 1985 and April (25) 1989, the last one reached an intensity of VI in Puebla City (Martínez and Javier, 1991).

For studying the seismic phenomena in the State of Puebla, the Instituto de Ingeniería (IdeI, UNAM), installed accelerographic stations in Ciudad Serdán, Izúcar de Matamoros and Puebla City. Valuable records have been obtained, in the last one, from some important earthquakes that have taken place in Mexico (González-Pomposo *et al.*, 1993). Considering the seismic risk in Puebla City and its social and economic impact in the country, some research has been carried out and as a result it has been set a preliminary seismic zonification of the state, which establishes Puebla City in zone 2 (defined as peniseismic); however, it is important to remind that the August 28, 1973 earthquake (m_b=7), generated VI and VIII intensities. Works also have been developed for analyzing the subsoil properties (Auvinet, 1976), and they have been useful tool for establishing a preliminary zonification. The results allowed, despite the great variability of the strata from one site to other, to define three zones: compressible, thermal depositions and tuffs.

Although the studies mentioned are important for investigating the seismicity and its possible effects on the structures, they will be insufficient if there are not acceleration records of the main strong ground motions that could occur and cause much human and material damage; because of this, is important to have seismic data for regulating the criteria of the seismic resistant construction codes.

By the exposed reasons and the fatal consequences that the September (19 and 21), 1985 earthquakes occasioned in Mexico City, it is clear the necessity of installing strong-motions networks in the main cities of the country. That is why the Civil Engineering School of the Universidad Autónoma de Puebla (UAP) installed the Puebla City Accelerograph Network (RACP) (Aviles *et al.*, 1989), which began to operate on November 1987 with three stations: Ciudad Universitaria (UAPP), Paseo Nicolás Bravo (PBPP), and Central de Abastos (CAPP); subsequently, for convenience of joining efforts with to the work that the IdeI has been developing it was decided to incorporate the Sismex Puebla Station (SXPU).

SITE DESCRIPTIONS

The criteria for installing the RACP stations were: to consider the existence of SXPU station, the preliminary zonification, and to have a better covering of the classified soil types. Figure 1 shows the final position in the urban zone and table 1 presents its geographical location. The four stations are of the type called "free field".

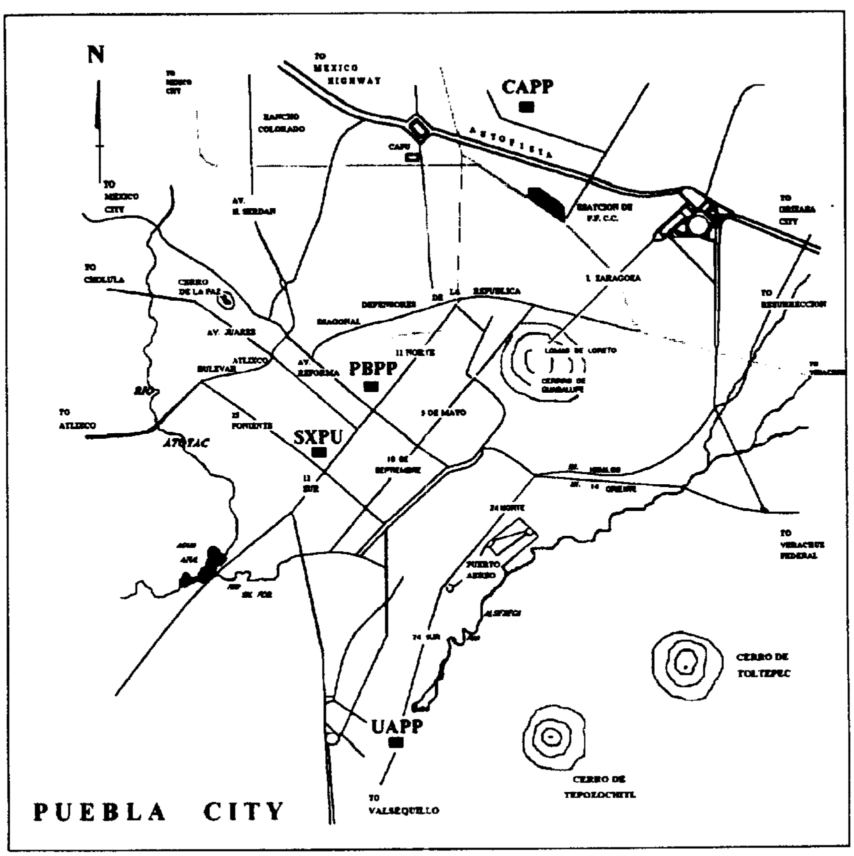

Fig. 1. Puebla City Accelerograph Network.

Table 1. Stations of the RACP

CODE	SITE NAME	LATITUDE (N) °	LONGITUDE (W) °	SOIL
UAPP	South Zone. Civil Engineering School	18.998	98.200	Low compressibility
PBPP	Center Zone. Paseo Nicolás Bravo Avenue	19.041	98.208	Middle compressibility
CAPP	North Zone. Central de abastos	19.089	98.188	Compressible
SXPU	South-West Zone. CFE offices	19.037	98.214	Non classified

The UAPP station is located southern city, in the facilities of the Civil Engineering School, over depositions classified as low compressibility soils. The PBPP and SXPU stations are in the central zone on medium compressibility soils; the first one is placed in Paseo Bravo, and the other is in Comisión Federal de Electricidad. Finally, the CAPP station is located northern city in the Central de Abastos on compressible soil. The proposed distribution, despite of having a general covering on a north-south line, is not sufficient due to the great variability of the subsoil between too near sites, and to the existence of specific areas such as the alluvial deposition, basaltic slags, basaltic rock, calcareous rock and artificial refills (Auvinet, 1976); hence, it would be convenient to select sites in such regions for future installation of instruments, not only "free field", but also borehole and over structures because that will allow the study of the seismic phenomenon since the moment that seismic waves propagate across the subsoil, arrive to the footing and are transmitted to the structure.

INSTRUMENTATION

The SXPU station was part of the Seismotelemetric Network (SISMEX) that the IdeI operates. The system is integrated by field-stations that contain seismometers, or accelerometers inside. The seismic signals detected are transmitted by telemetric linkages to the recording central point and were stored in magnetic tape; nowadays are plotted on paper. A servoaccelerometer Donner 4211 model, whose characteristics are summarized in table 2, was installed in SXPU. Later, it was considered convenient to transform this station in autonomous one, installing a DCA-310 digital instrument with SA-102 type external sensors, sampling rate of 100 and full scale range of +/- 1 G. On the other hand the UAP accelerographs are digital high resolution sets (model DCA-333) whose velocity of capture is 100 samples per second and full scale range of +/- 1 G (except for PBPP that has +/- 0.5 G).

Table 2. Recording system characteristics.

EQUIPMENT	SISMEX	DCA-310	DCA-333
RECORDING SYSTEM	Magnetic Tape	Digital cassette	Digital Cassette
DAMPING	0.60 to 0.70 from the critical	0.70 from the critical	0.70 from the critical
NATURAL FREQUENCY	25 Hz	30 Hz	30 Hz
SCALE	± 1.00 G, ± 0.10 G and ± 0.01 G	± 1.00 G	± 0.50 G and 1.00 G
PRE-EVENT MEMORY	—	2.56 s	4 s
POST-EVENT MEMORY	—	15 s	15 s
TOTAL-RECORD TIME	---	15 minutes	15 minutes
SAMPLING RATE	Continuous	100 sps/channel	100 sps/channel
A/D CONVERTER	12 bits	12 bits	12 bits
DYNAMIC RANGE	80 dB	72 dB	72 dB
THRESHOLD TRIGGERING	Electromechanical	Adjustable by programming	Adjustable by programming
TIME REFERENCE	WWVB	Internal clock, 1×10^{-6} and external time	Internal clock, 1×10^{-6} and external time
POWER	± 12 VDC, charger and automotive battery	± 12 VDC, charger and automotive battery	± 12 VDC, charger and automotive battery

All the instruments have triaxial sensor systems placed in orthogonal position and are oriented north-south, west-east and vertical directions. They are provided with an automatic trigger mechanism, by this the instrument begins the record of some event when his programmed activation threshold has been reached. That feature depends on the soil conditions where the equipment is settled, and the level of civil activity that is developed in the site. For setting a definitive value is necessary to make an adjust iterative process in order to get an optimum one that allows to obtain seismic records of earthquakes of a wide range, avoiding the saturation risk of the storage memory by recording events no-related with the seismic activity.

The programmed shoot threshold is 8 Gal in SXPU, 10 Gal in UAPP and CAPP stations, while in PBPP is 5 Gal. As an additional characteristic, it can be mentioned that these instruments have a pre-event memory (2.5 s for DCA-310 and 4 s for DCA-333) that allows to record the arrival of the seismic signal, besides they have an acquisition system on magnetic tape with recording time of 15 minutes.

ACCELEROGRAPH RECORDS

Getting accelerograph records is one of the most important factors for developing a Design Spectrum in areas that are located on seismic zone. This fact has more significance in an important human settlement as Puebla City. Nowadays fifty one acceleration records have been obtained from the RACP. Figure 2 shows in a same vertical-horizontal scale the main acceleration components for the recorded earthquakes.

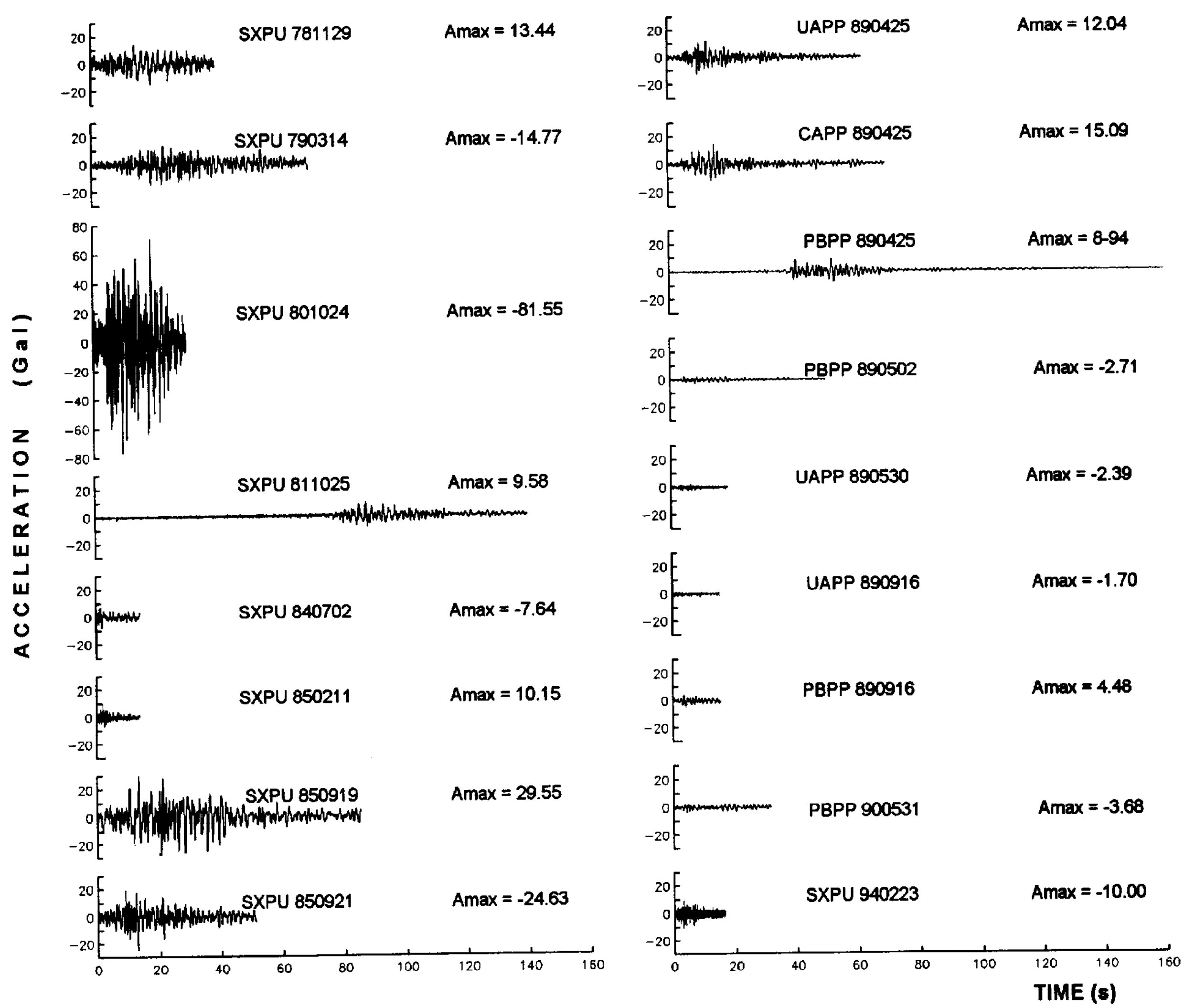

Fig. 2. Accelerograms obtained by the RACP.

From 1978 to 1994, valuable accelerograms were gotten of several earthquakes that have occurred in Mexico and the most important are: November (29) 1978, March (14) 1979, October (24) 1980, October (25) 1981, September (19 and 21) 1985, and April (25) 1989. Some features of them like: time (GMT), epicentral coordinates, and magnitude are listed on table 3.

Table 3. Events recorded by the RACP

NUMBER	DATE YYMMDDE	TIME HR:MN:SEC	NORTH LATITUDE (°)	WEST LONGITUDE (°)	MAGNITUDE Mc	Ms	Msz
1	7811291	19:52:48	16.010	96.591	6.5	6.4	7.7
2	7811292	20:04:47	16.160	96.746	—	5.3	—
3	7811293	20:49:49	16.185	96.630	—	5.7	—
4	7903141	11:07:16	17.813	101.276	6.5	6.5	7.6
5	8010241	14:53:35	18.211	98.240	6.5	6.4	—
6	8110251	03:35:36	17.647	102.779	—	5.3	—
7	840702A	04:50:44	16.804	98.441	—	5.9	6.0
8	850211A	00:13:54	16.644	94.968	5.0	5.2	—
9	850919A	13:17:47	18.190	102.533	8.1	6.8	8.1
10	850921A	01:37:13	17.802	101.647	7.5	6.3	7.6
11	890425A	14:29:00	16.773	99.328	6.5	6.2	6.8
12	890502A	09:30:15	16.747	99.343	5.1	5.4	4.9
13	890530A	13:50:56	17.401	94.645	5.0	5.2	—
14	890916A	23:20:56	16.231	94.000	5.5	5.9	—
15	900531A	07:35:27	17.260	100.707	5.5	5.8	5.9
16	940223A	14:13:49	18.096	97.144	5.3	5.4	—

The epicenter locations (Fig. 3) shows that almost all are along the Mexican Subduction Zone; nevertheless, the 5 and 16 events are found on the State of Puebla and become and example of the seismic hazard in the area. Although only two events are shown, it does not mean that the seismic activity is low.

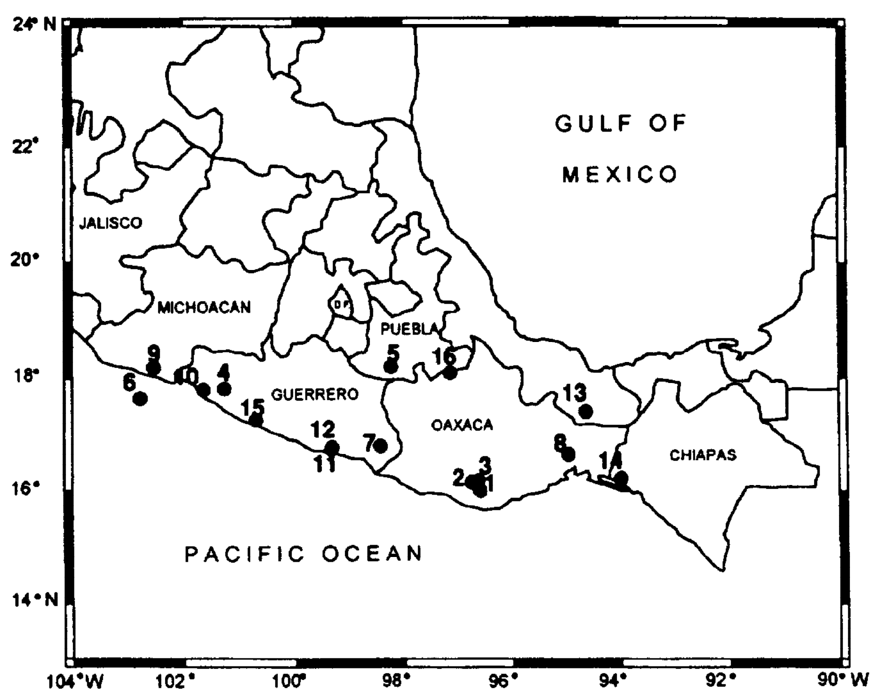

Fig. 3. Epicenters of the events recorded by the RACP.

Table 4 includes a list of earthquakes registered by the Puebla Seismological Network (González-Pomposo *et al.*, 1995), from December 1985 to June 1991. The list presents just the events that were located in the state region and which magnitude was in excess of 4.5. The acceleration records that are comprised in this paper were codified and transferred to an compatible IBM PC using a reduction data system developed at the IdeI. Base line correction, velocities, displacements, Fourier spectrum amplitudes and the response spectra were computed using the TERRE programs (Mena, 1986).

Table 4. Events located in the State of Puebla

EVENT	DATE YYMMDD	ORIGIN TIME HR:MN:SEC	GEOGRAPHICAL COORDINATES		DEPTH	MAGNITUDE
			LATITUDE (°)	LONGITUDE (°)	(Km)	
1	860220	20:54:48.1	17.91	96.06	40	4.9
2	860418	05:29:19.3	18.35	99.50	62	4.6
3	860509	01:00:36.8	19.63	98.57	0	4.6
4	870127	03:51:33.6	18.08	98.41	31	4.6
5	870612	18:39:46.4	18.05	99.01	40	4.5
6	870814	09:40:24.0	18.14	96.43	86	4.7
7	880331	07:34:34.3	18.78	97.38	20	4.8
8	880326	23:58:20.5	17.93	97.52	62	4.5
9	891118	15:42:57.0	17.86	98.62	15	4.7
10	891102	07:35:39.1	18.72	98.32	15	4.8
11	900326	13:26:20.7	18.33	97.47	8	5.7

RESULTS

The October 24, 1980 Huajuapan Earthquake (m_b=6.5), whose epicenter was located in the State of Puebla at 150 Km from Puebla City (Table 3), has generated the major intensity values. It was recorded in the SXPU station and Fig. 4 shows the most important 30 seconds of the accelerogram, which maximum acceleration was 81.6 Gal. Integrating process was done using the proposal of Iwan *et al.*, (1985).The peak velocity and displacement were 10 cm/s and 3.2 cm respectively. The second main event that has produced large intensity in Puebla City was the September 19, 1985 Earthquake (Ms=8.1) (Table 3) which maximum acceleration was 30 Gal. Even though this event was bigger than the October (24) 1980, the energy difference ($\log E = 11.8 + 1.5 M$) between them is 8.87×10^{23} ergs, the effect of the October Earthquake in the State of Puebla was more intense, due to the close distance between earthquake epicenter and Puebla City.

In Fig. 4 are shown the accelerations, velocities and displacements of the April 25, 1989 Earthquake (Ms = 6.8) of PBPP, CAPP and UAPP stations as well. It is important to mention that in PBPP station were recorded 200 seconds of the event, being this the longest gotten in Puebla City, even though his maximum acceleration was just 9 Gal. In CAPP, where the layers are classified as compressible, were obtained 15 Gal and finally in UAPP were gotten 13 Gal. According to the soil classification presented in table 1, it would have been expected bigger acceleration in PBPP than in UAPP. By this, it would be convenient to make soil mechanic tests for each site in order to have more accuracy about the subsoil properties.

Regarding to Fourier spectrum amplitude was made an arrangement of the events that have generated the largest amplitudes (Fig. 5). In SXPU are presented four of the main earthquakes that have occurred in Mexico, the most energetic is indicated with flat line, and belongs to October (24) 1980; whose biggest amplitudes are from 0.7 to 2.0 Hz. In UAPP, on low compressibility soil, the frequency range associated to the maximum amplitudes is between 0.7 and 2.0 Hz. While in CAPP and PBPP, that have more compressible soils, the range is from 0.5 to 1.0 Hz, lower than the first one.

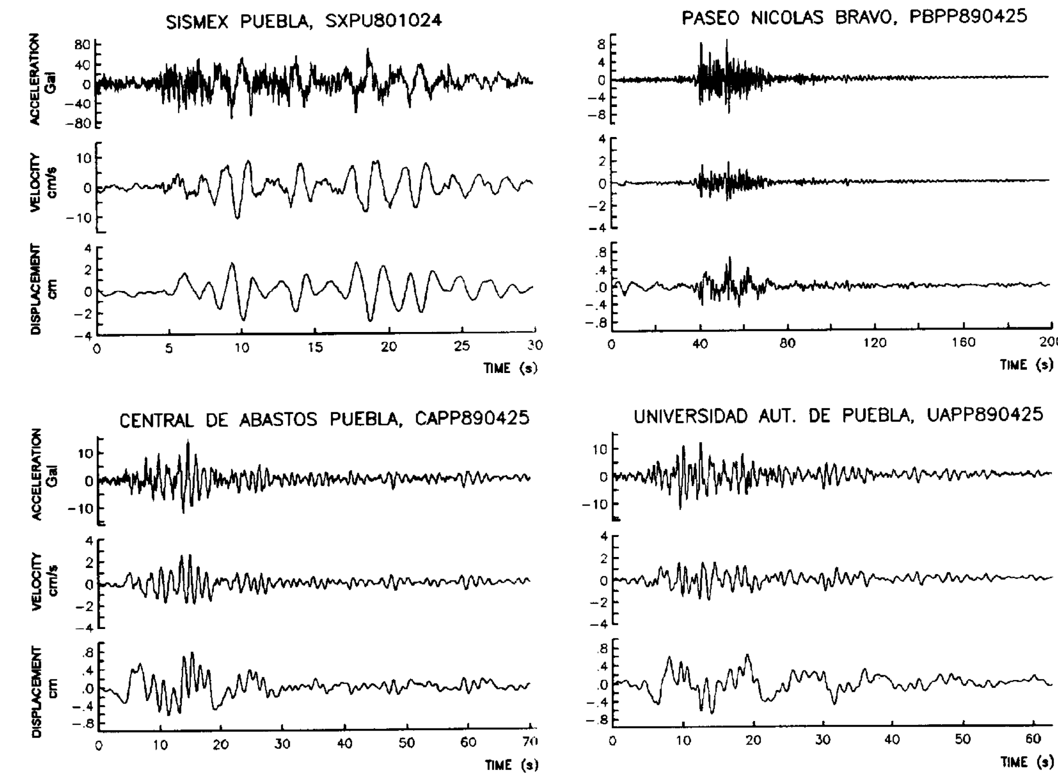

Fig. 4. Acceleration, Velocity and Displacement in the stations SXPU, PBPP, CAPP and UAPP.

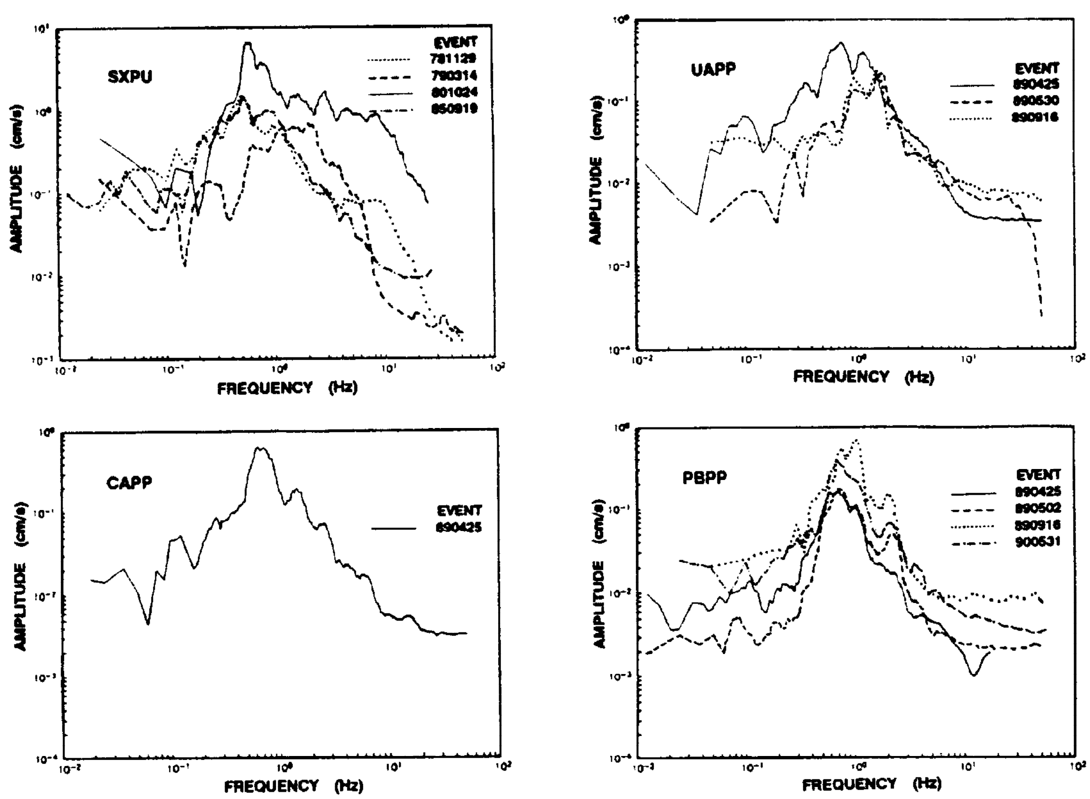

Fig. 5. Fourier spectrums.

CONCLUSIONS

The establishment of the RACP by the Benemérita Universidad Autónoma de Puebla in cooperation with the Instituto de Ingeniería UNAM, for monitoring strong ground motion, has allowed the record of 16 earthquakes. The Puebla Accelerograph Networks will produce important data, in particular if the epicentral source is near of the State of Puebla. The data will be essential for interpreting the seismic hazard in Puebla City.

Although a high percentage of the seismic activity in the country is generated along the Mexican subduction zone, and that is why a lot of accelerograph station are located there (Alcántara *et al.*, 1990) it is considered that the major seismic risk for Puebla City comes from earthquakes that can be generated in the boundaries of Oaxaca, Guerrero and Puebla states, as was shown by the October (24) 1980 event, which produced an amplitude 2.8 times bigger than the September (19) 1985 Earthquake.

Owing to the great variability of the subsoil conditions in Puebla City, it is necessary to extent the accelerograph array to other sites, in order to have better covering of the different soil types. This last and the record of future strong ground motions will allow a better zoning about the subsoil seismic response.

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