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MEXICAN STRONG MOTION DATABASE. AN INTEGRATED SYSTEM TO COMPILE ACCELEROGRAPH DATA FROM THE PAST 35 YEARS

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ABSTRACT

Strong motion instrumentation in Mexico goes back to 1960 when the first accelerograph was installed. In the past 35 years, this network has grown to 430 recording stations and has produced over 7200 three-component accelerograms from close to 1000 earthquakes with magnitudes between 2.5 and 8.1. Most of this information has only been partially published and released by the research institutions which operate the networks and therefore, except by a reduced group of people, has been generally inaccessible to researchers, engineers and students. Along the years the network has been growing with many different types of accelerographs and recording media, thus producing data with a variety of formats which have made information interchange and processing difficult. As a joint effort of several research institutions, a project to create the Mexican Strong Motion Database started in 1992. Although this system is still under development, most of it is complete. It contains all information available regarding networks, stations, instruments, institutions, accelerograms and earthquakes gathered since 1960, which is compiled in a homogeneous and standardized database system. The objective of this system is to disseminate this information, national and worldwide through data catalogs, CDs and the Internet network. The structure of this database system and details of its contents is described in this paper.

KEYWORDS

Database; strong motion; Mexico; accelerograms; instrumentation; catalogs

STRONG MOTION INSTRUMENTATION IN MEXICO

35 years have passed since the first instrument to record strong ground shaking was installed in Mexico. After the destructive San Marcos earthquake (M=7.5), occurred in 1957, engineers recognized the need to measure the seismic waves generated by strong earthquakes and its effects on soils and especially on structures vulnerable to damage. At that time only high gain seismographs were available which always went off-scale during large events and were therefore not suitable for engineering purposes. In 1961 the first two accelerographs were installed in Mexico City, one downtown at the Alameda Central, and the other at the University campus.

The first records obtained during the Acapulco earthquakes of 1962 further motivated the deployment of more instruments in the city and other seismic regions of the country, particularly on large hydroelectric dams under construction at that time. Valuable data from direct measurements of several important earthquakes was gathered. This effort to improve and expand the observation network went on during the next three decades. Since 1960 over 450 strong motion accelerograph stations have been installed. Around 430 stations, most of them with digital recorders, are operating at present in several networks. These networks are located in Mexico City and neighboring states, along the subduction zone on the Pacific coast and also a network in the northwestern part of the country.

A map showing the location of all accelerograph stations in Mexico is given in Fig. 1. Quaas *et al.*, (1993b, 1995c) describes these accelerograph networks and instrument distribution in detail.

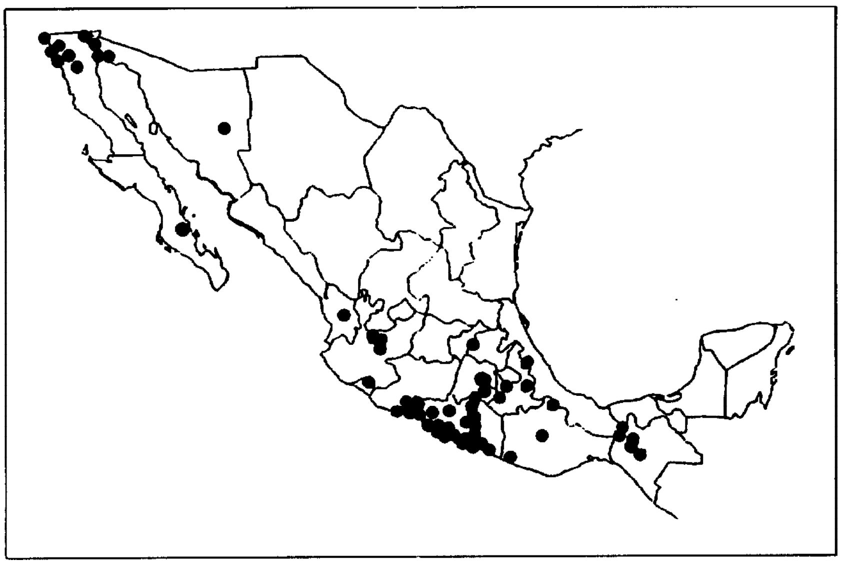


Fig. 1. Mexican accelerograph network

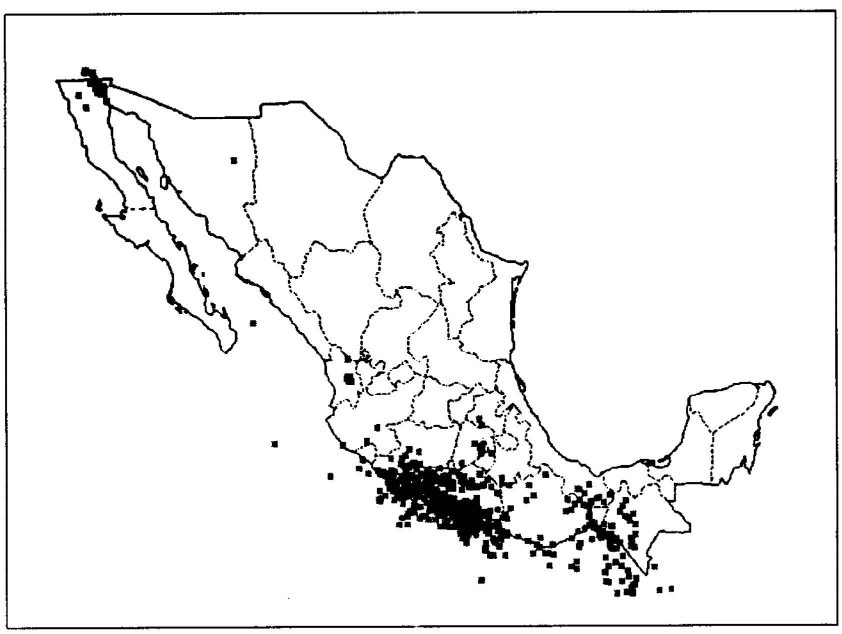
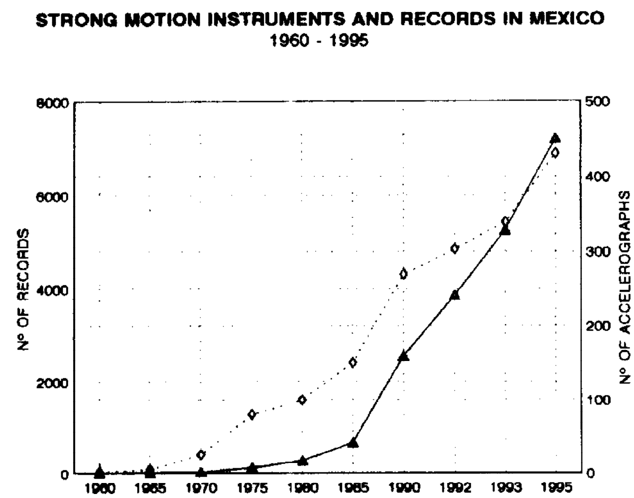


Fig. 2. Location of all earthquakes in Mexico between 1960 and 1994 which produced at least one strong motion record

Over a three and a half decade time span this network has been very productive generating over 7200 three-component accelerograms from around 1000 earthquakes (Quaas, 1995a). The magnitudes of these events are between 2.9 and 8.1. A map showing the distribution of these earthquakes in Mexico is given in Fig. 2.

The growth of the strong motion network in Mexico and the generation of records since 1960 is shown in Fig. 3. As can be seen the number of accelerograms is growing almost exponentially, in particular after 1985, year of the destructive Michoacan earthquakes. In 1985, only 110 stations were in operation, 438 at present. After that event also more institutions joined the effort to operate these networks and gather strong motion data.



	1960	1965	1970	1975	1980	1985	1990	1992	1993	1995
RECORDS ▲	0	9	22	118	273	669	2546	3858	5252	7200
INSTRUMENTS ◇	2	5	25	80	100	150	269	303	339	430

Fig. 3. Growth of the strong motion network and No. of accelerograms produced in the past 35 years

Besides the large network in Mexico City with 215 stations, one of the most important and productive networks operating in Mexico is the Guerrero Strong Motion Array (Anderson *et al.*, 1994) with 30 digital stations installed early in 1985 on rock along the Pacific coast, mainly in the state of Guerrero and some stations inland on a line towards Mexico City. Part of this network is located within the Guerrero seismic gap which has a high probability to produce a large earthquake in the near future. This network itself has produced over 1300 digital accelerograms from around 500 events, the most important being the September 19, 1985 earthquake (M=8.1) (Anderson *et al.*, 1986) and the Copala event from September 14, 1995 (M=7.2) (Anderson *et al.*, 1995).

THE STRONG MOTION DATABASE SYSTEM

The operation of such an extended network and the processing of this huge amount of data has been carried out independently by many institutions and people. Along the years the network has been growing with many different types of accelerographs and recording media, consequently producing data with different formats which have made information interchange and processing difficult.

Most of this impressive amount of information has only been partially published and released by the research institutions which operate the networks and therefore, except by a reduced group of people, has been generally inaccessible to researchers, engineers and students.

With the objective to organize and disseminate this scattered information about strong motion instruments and records available in Mexico, in 1992 several of the main research institutions which operate accelerograph networks and process data, agreed to initiate a coordinated effort to create the Mexican Strong Motion Database.

The first step was to make an inventory of what was available in the country regarding instrumentation and strong motion data and also contact the institutions and people involved. Then a computer program was designed to capture and concentrate this information. This task took several years of intense work and interaction between many people and organizations until finally an interactive database system was developed. Its general block diagram is shown in Fig. 4.

The system was developed for a PC platform using a Clipper compiler working under MS-DOS (Medina and Quaas 1993). PCs were chosen for the simple reason that everyone now has this computer and can easily run the software without too many hardware constrains. This makes the system universal and handy, particularly for the process of gathering data from so many different sources.

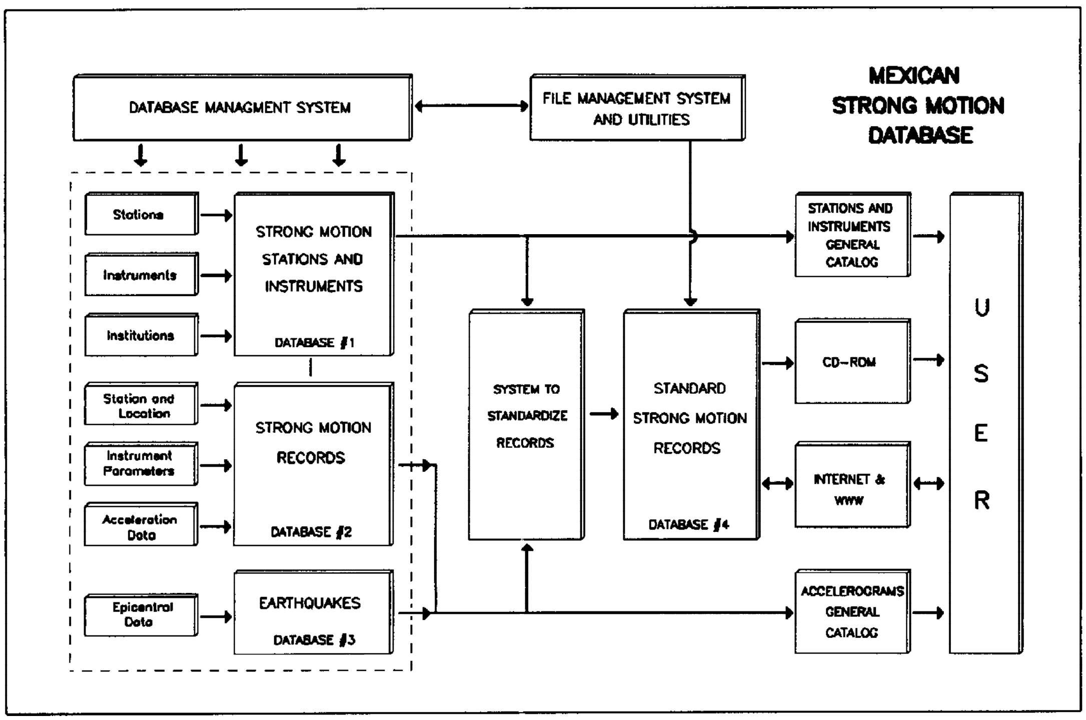


Fig. 4. General block diagram of the Mexican Strong Motion Database System

As can bee seen from this diagram, the information was structured in four subdatabases:

- Database #1: for information regarding strong motion networks, stations and instrumentation
- Database #2: for information about the accelerograms
- Database #3: for information about the recorded earthquakes
- Database #4: for all the strong motion records processed and translated into a standard format

The first database is essentially an inventory of the available strong motion instrumentation in the country. It has detailed information of more than 450 accelerograph stations so far operated, including station location, site description, specifications of its instrumentation, date of installation operating status, and data about the responsible institution and persons in charge.

In a similar manner, the second database is related to the strong motion data so far produced. Over 7200 accelerograms have been analyzed and carefully cataloged together with data of the earthquake and instrument which produced each records. Among the data compiled for each record are: institution, station code and name, record identification code, date and time of the record, time accuracy, length, maximum acceleration for each channel, type and serial number of the instrument and comments about its quality and availability.

Database #3 was created to handle information about close to 1000 earthquakes. For each event it has the following data: event code, date and time of occurrence, epicenter location and depth, magnitude and the source which provided this data.

Finally database #4 is the main part of the system. It eventually will have the 7200 or more acceleration files each converted from its original format into a new standard strong motion format. This homogeneous platform has been designed to facilitate dissemination and processing of the information. Each file in this standard format contains extensive data about the recording instrument, station, institution, time, epicenter data of the earthquake, data about the record itself and finally, the numerical data of up to 12 acceleration components.

The first three databases are controlled by a relational database management system specifically designed to capture data, store it, sort it and also allow it to be displayed, printed and edited.

As a separate process, but part of the whole system, several especial programs were written to transform the original acceleration files from its native formats into the standard format (García and Cruz, 1996). It has to be considered that in the past three decades about 15 different accelerographs types have been used, producing data in different formats . Because of the large number of accelerograms of this database, this part of the process has been the most difficult one to handle.

Associated to the standard acceleration database a file management system and several utilities have also been developed. The file manager program interacts with the database management system and its main function is to organize and administrate this complex structure of files. The utilities allow the edition, seeking and sorting of files, inspection of records, numerical and graphic display and assist the manager to route the data to the distribution media.

Three basic communication links to the user are available:

a) Printed catalogs with information about the network and its instrumentation, summary and description of accelerograms and earthquakes.
b) CDs with standard accelerogram files.
c) Internet network and a home page with all information on the World Wide Web.

STANDARD STRONG MOTION FILE FORMAT

This file is a text file with standard ASCII characters only. As a text file it can easily be viewed and modified with almost any text editor and can also efficiently be compressed to save space and facilitate transportation. It has been demonstrated that, in most cases, compressed ASCII files are slightly larger than the original binary files. This standard format was chosen for its universality and simple handling. As will be seen, it is self-explanatory and no additional information is needed to use and interpret its data. A detailed description of the standard acceleration file is given in Quaas *et al*., (1996). The general structure of this file is shown in Fig. 5. It is basically divided into a header block and a data block. A brief description of each block follows.

Title: Identification of the responsible institution, its name, address, etc.

Filename: Name of the file, format version, date and time of its creation and a reference to the general accelerogram catalog (record number and page) (Quaas *et al.,* 1995a)

Recording station and instrument: It includes a description of the station, name, code, address and location (coordinates), altitude, type of soil and institution in charge of its operation. Regarding the instrument, following parameters are specified: model, serial number, No. of channels, orientation, sampling rate, full scale range, natural frequency, damping, sampling interval, trigger threshold for each channel, pre-event memory and post-event time.

Data about the earthquake: This block includes date and origin time (GMT) of the event, magnitudes, epicentral location, focal depth and the source which provided this information.

Data about the accelerogram: Time of the first sample (GMT) and its accuracy, record duration, No. of samples, maximum acceleration (in gals) and the sample at which it occurred for each channel, decimation factor and specification of FORTRAN-type data format used for the numerical values.

Comments: This part of the header allows for some comments about the accelerogram data like quality, processing methods and additional information relevant to the record or the earthquake.

Acceleration data: This is the main part of the file. It holds the numerical acceleration values of up to 12 data channels. These 12 series are organized in a multi column structure, each with a fixed 10 character field and a data format specified in the header (like 3F10.2, which specifies three 10 character long real numbers, 7 characters for the integer part and 2 decimals).

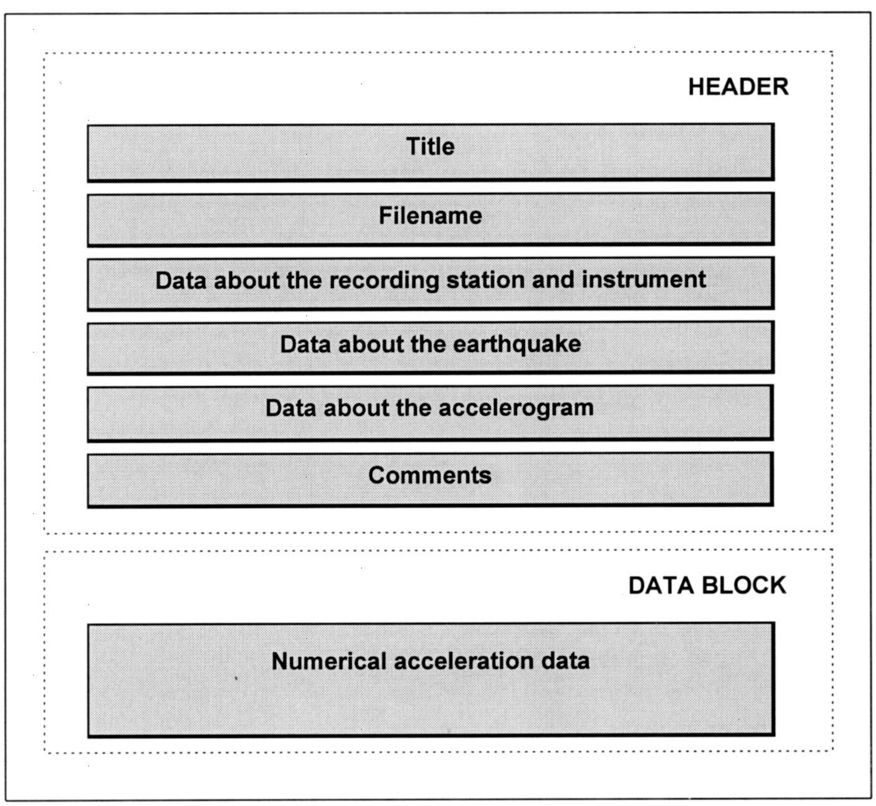


Fig. 5. Block diagram of the standard strong motion file

It should be mentioned that all main research institutions have agreed to support this standardization of accelerograms and decided to produce from now on its data in this new format. In addition several instrument manufacturers have in principle also agreed to develop especial utilities to generate directly files in this standard format.

RESULTS AND STATUS OF THE SYSTEM

In 1992 a committee was established to build the Mexican Strong Motion Database. Because of its complexity and amount of data involved it has been growing progressively and is still under development. Several important goals have already been achieved. Following is an update of the current state of the system.

In 1993 an extensive catalog with a detailed description of all strong motion networks, stations and instruments operated in Mexico from 1960 to 1992 was published (Quaas *et al.,* 1993b). It also includes the several institutions involved and a complete reference of all related publications written about strong motion instrumentation and networks. This catalog together with the database management system, completed the first part of the database.

During 1994 the work was focused to locate and capture all available strong motion records and information about the associated seismicity to establish the second and third database earlier described. This information, also in form of a catalog, was published in 1995 (Quaas *et al.*, 1995a). It contains detailed information and description of 5252 three-component accelerograms and 925 earthquakes recorded in Mexico from 1960 to 1993. Included are general statistics about the data, cross references to locate any record or event, and an extensive list of about 120 related publications which have been produced in the past 35 years in Mexico.

An especial publication with updated information regarding these two catalogs is in preparation and will cover data from 1993 to 1995.

As was pointed out, the main part of the system is the database with the standard accelerograms. Up to the date of this publication about 3480 accelerograms should have been converted into the standard format. This data covers all records from the years 1992, 1993, 1994 and part of 1995. From here the processing of records will go on backwards in time, continuing with the year 1991, 1990 and so on until 1961. This scheme was chosen considering that, from the user point of view, there was more interest in recent events than historical data.

With respect to the distribution media, very soon a CD-ROM will be available holding the accelerograms from this fist batch of records (1992-1995). In addition a home page on the World Wide Web is being prepared specifically for this database with all the information which will be accessible through Internet.

In summary, with the strong motion data base scientists and engineers in Mexico and other countries will have access to extensive information about a broad spectrum of accelerograms produced by a large variety of earthquakes together with data about networks and instruments. The opening of this new information window might stimulate researchers in fields of strong motion seismology and seismic engineering to allow a better understanding of the nature of earthquakes in Mexico and mitigate its effects.

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