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INTER-UNIVERSITY STRONG MOTION ACCELEROMETER NETWORK IN MEXICO

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ABSTRACT

A consortium of Mexican universities was created in 1994 with the objective of developing construction regulations in different capital cities in Mexico with no local seismic design provisions. As a result of this association, an accelerometer network has been installed covering the different soil conditions of the metropolitan areas, in order to obtain valuable local seismological data. The operation of the accelerometric stations is supported by the active participation of local universities; local studies and experience are invaluable to determine locations where representative ground motion data can be obtained. Involvement of the local teams in the operation and signal processing of the data has shown to increase the efficiency of the accelerometer operation process, which is performed independently by each of the universities constituting the network. As a result, accelerometric records are now being obtained in populated areas where scarce information, if any, was available in the past despite the historical knowledge of seismic vulnerability. From these records, important information about local ground motion effects is obtained, and seismic risk studies are being currently developed. The enthusiastic involvement of local teams is an important result of the network, leading to a major step in promoting local seismic research, and deriving in an effective interest in the implementation of adequate local design criteria and construction codes.

KEYWORDS

Instrumentation; ground motion; records; Mexico; network; accelerometer; accelerograph.

INTRODUCTION

The September 19th, 1985 Mexican earthquake uncovered the need for seismic instrumentation in different populated Mexican cities located in areas with significant seismic hazard. At that time, only eleven ground motion recording stations were operating in Mexico City valley, from which only one was located in the most damaged area. After 1985, Mexico City authorities impulsed a project to increase seismic instrumentation in the city, with the technical support of Fundacion ICA and Fundacion Barros Sierra and the financial support of Mexican and international agencies. This effort led to an important accelerometer network of more than 100 stations concentrated in Mexico City valley (Quaas *et al.*, 1993).

The situation turned to be quite different in most other Mexican urban areas. As of September 1985, instrumentation in capital cities was limited to Puebla, Oaxaca, Tuxtla Gutierrez, Ensenada and Chilpancingo; each having only one strong motion recording station in their urban areas. After 1985, seven accelerometric stations were implemented in Guadalajara, three additional ones in Puebla, one in Morelia, and one in Cuernavaca. In contrast, the stations in Chilpancingo and Tuxtla Gutierrez were abandoned inoperative. From these data, it is apparent that the great instrumentation effort did not reach adequately most urban areas throughout the country, despite their historically known seismicity.

Consistently with the previous observations, and in contrast to the enormous efforts made during the last decade to understand local seismic effects in Mexico City valley, little interest has been focused in other populated areas with known historical seismicity. In order to improve the inadequate, if any, seismic regulations in these cities, several universities started to collaborate in the development of microzonation studies in 1990. These studies were based on local geodynamic characteristics, leading to qualitative estimates of seismicity distribution in those cities. The enthusiastic involvement of local research teams and practice engineers, led to seismic zonation proposals that were readily implemented in local codes (Iglesias *et al.*, 1996). To complement the qualitative results from the seismic zonations with quantitative data from real earthquakes, these universities joined efforts to provide the studied cities with adequate instrumentation. As a result, the inter-university strong motion accelerometer network (*Red Interuniversitaria de Instrumentacion Sismica; RIIS*) started to operate in 1994. This network is an outcome of the consortium created in 1994; *Grupo Interuniversitario de Ingenieria Sismica* (GIIS), dedicated to improve local seismic knowledge in their host cities (Iglesias *et al.*, 1996). Up to date, six universities constitute the RIIS network (Fig. 1), being Universidad Autónoma Metropolitana (UAM) at Mexico City; Universidad Autónoma de Guerrero (UAG) at Chilpancingo; Universidad Popular Autónoma del Estado de Puebla (UPAEP) at Puebla; Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) at Morelia; Universidad Autónoma del Estado de México (UAEM) at Toluca and Universidad Autónoma de Chiapas (UNACH) at Tuxtla Gutiérrez. Each of these institutions have two operating accelerometric stations in their cities to date, except for UAM, having 3, and UNACH, having 1.

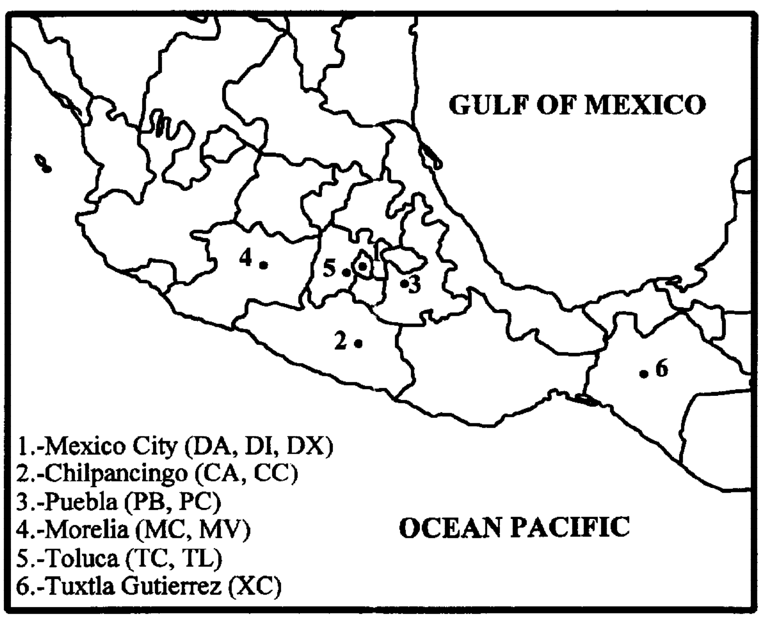

Fig. 1. Cities and stations comprising the RIIS.

RIIS DESCRIPTION

Despite of the need for local strong motion data in urban areas, technical and economic support is not easily obtainable. This circumstance leads to a thorough evaluation of the most efficient locations to obtain representative data, in order to optimize available resources. Therefore, accelerometric stations in the involved cities can not be efficiently installed until seismic zonation studies have been performed. These studies provide guidelines to select locations which are representative of the different dynamic soil characteristics of the urban areas. Following this approach, one station on firm soil and other station at medium soft soil have been located in most cities covered by RIIS; Chilpancingo, Puebla, Morelia and Toluca. Additionally, RIIS operates 3 stations in the Mexico City valley and only one in Tuxtla Gutierrez, in this case due to the relatively homogeneous characteristics of the soil (Alonso *et al.*, 1996).

One of the most important considerations for implementing the accelerometric network is the active participation of local universities in the process. First of all, local teams detect the proper sites where the stations are to be located in order to obtain representative ground motion data and to minimize the number of required accelerometers. The criteria for the selection of these locations are based on microtremor studies throughout the populated areas and the local geological and boring data available, accounting for previous existing stations, if any, to optimize resources. Typically, two stations per city are installed; one is placed on firm soil and the other on the softest detected soil, or where local experience indicates potential ground motion amplifications. Once the stations are installed, technical capacitation is given to the local teams so they can independently operate the accelerometers and process the signals, thus elaborating local ground motion reports. In the case of a major event recorded in several cities, a conjunct report is published with all the data recorded in the different cities. Needless to say, the enthusiastic involvement in the operation and signal processing of the local teams is considered to be an important result of the network, leading to a major step in promoting local seismic research.

STATION CHARACTERISTICS

Differences in technical background and human resources among the RIIS universities makes it fundamental to homogenize at its maximum the characteristics of both the station and the equipment. Currently, SSA-2 Kinemetrics solid state accelerometers are used in all stations. They have proved to be reliable and economic instruments, sampling 12 bit data at a 200 samples per second rate. Electrical power is supplied through an underground line. An external battery back-up system was provided to account for unexpected power breakdowns.

An adequate design of an accelerometric station with its accessory equipment can influence the ground motion records reliability. Although RIIS permanent stations are thought to record free field movement at ground level, it is necessary to install the equipment inside a protective enclosure. Soil structure interaction effects from this enclosure will modify up to a certain extent the ground motion signal. This phenomenon is particularly significant in stations located on soils with low shear wave propagation velocities (Bycroft, 1978). Theoretical and ambient vibration experimental studies indicate substantial differences between recorded signals in typical accelerometric stations and the free field ground motion signal (Chavez *et al.*, 1989). To minimize these effects, it is convenient that stations have the smallest size possible to locate the equipment. Additionally, the station has to be firmly anchored to the soil and the accelerometer centered on the base, which should not significantly arise from the ground level (Crouse *et al.*, 1984). From these guidelines, a standard reinforced concrete base was designed for the RIIS stations, based on security and safety criteria and an experimental study of ambient and forced vibration recordings that was carried out to study soil-structure interaction effects in three prototypes (Ramirez, 1993). Final base characteristics are shown in Fig. 2.

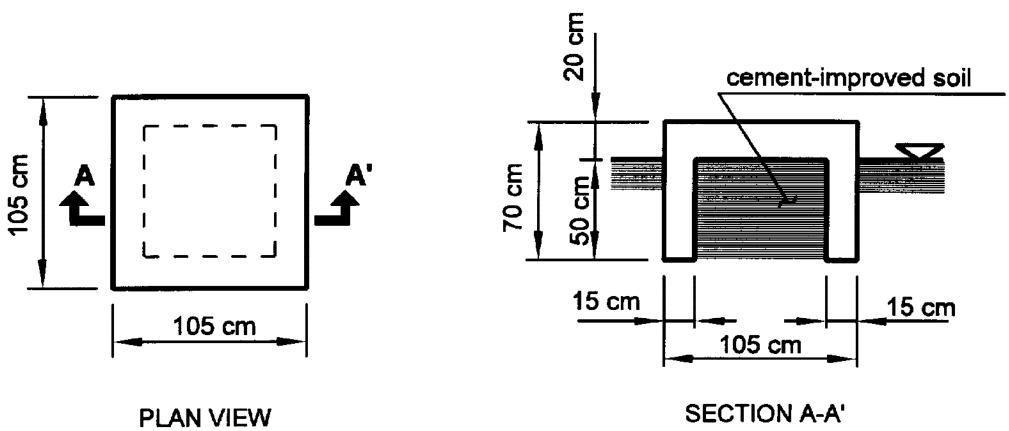

Fig. 2. General base characteristics for the stations operated by RIIS

In order to protect the equipment from external agents, a 50 cm height metallic box anchored to the base was design. A double layer cover was deemed necessary to avoid abrupt temperature changes inside the box.

OPERATION

In order to ensure the adequate operation of the network, it is necessary to program a schedule of periodical visits to supervise the integrity and operativity of the equipment, to retrieve recorded events and clear the memory for future ones. Triggering thresholds are adjusted to the local conditions in each case, to ensure proper functioning under ground motion events and avoiding accidental ambient noise triggering that could saturate internal memory. This supervision and maintenance process is carried out independently by local university teams for the stations located in their host cities.

In case of a significant seismic event, each university elaborates a preliminary report the following day, evaluating the need for checking structural damage in the university facilities. The procedure is based on studies that approximately relate peak ground motion acceleration to structural strength (Aguilar,1990). This evaluation is of key importance in universities hazard reduction programs. Following this, each local team elaborates a more detailed report including the results of the data processing. Finally, in the case of events simultaneously recorded in different cities, all information is gathered in a conjunct report.

RESULTS

Since its implementation in 1994, five conjunct reports have been published to date (Sordo *et al.* 1994, 1995, 1996 a, b; Alonso *et al.*, 1996). In many cases, RIIS has proved to fill an important gap in local seismic knowledge in the cities where accelerometric stations were implemented. Two significant examples are described next.

Chilpancingo City.

Due to its particular situation near the pacific coast of Guerrero, this capital city has suffered the effects of severe ground motions in the past (Figueroa, 1972; Rosenblueth, 1960). However, the single accelerometric station that was located in the soft soil deposits of the city valley, operated by the Instituto de Ingenieria-UNAM (Quaas *et al.*, 1993), was abandoned inoperative. RIIS installed two accelerometers in this city, as two different soil conditions were encountered in the urban area after the corresponding seismic zonation study (Gama and Whitney, 1996). The first one was located on the soft soil deposits of the Chilpancingo valley (RIIS-CC station), where strong motion amplifications were suspected to occur. The other was located in one of the surrounding hills were the metropolitan area is growing (RIIS-CA station) and where topographic effects need to be studied in detail. Since the implementation of the RIIS-CA and RIIS-CC stations in 1994, more than 20 records have been obtained. Figure 3 illustrates the E-W accelerogram components obtained from the December 10th, 1994 earthquake for these stations, together with an accelerogram from a station (CENAPRED-CHIL) located at rock site 10 km from Chilpancingo City, provided by Centro Nacional de Prevencion de Desastres. Comparison of the records illustrate the strong amplifications occurring in both areas of Chilpancingo City. All information recorded to date, together with future ground motion records, will provide key data to properly assess seismic vulnerability in this capital state. Studies on this regard are been currently carried out by GIIS research teams.

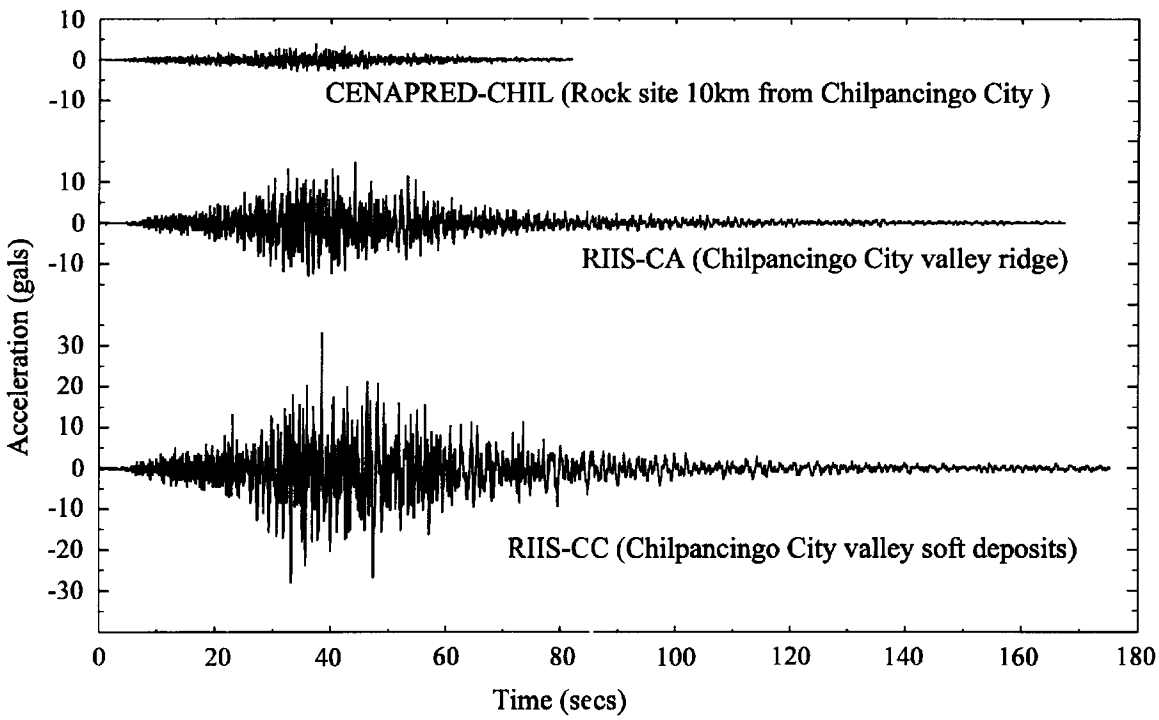

Fig. 3. Amplification effects in Chilpancingo valley, as detected by the RIIS stations.

<u>Tuxtla Gutierrez.</u>

Tuxtla Gutierrez is located about 150 km from the Pacific Coast of Chiapas, where the North American plate is subducted by the easternmost Cocos plate section and the Caribbean plate. Additionally, several major local strike-slip fault zones contribute to the seismic vulnerability of this capital city. In spite of this situation, the single accelerograph that was installed in Tuxtla Gutierrez in 1970 by Instituto de Ingenieria-UNAM (Quass *et al.*, 1993) was recently abandoned inoperative, despite the valuable information that this station had provided in the past. In 1994, RIIS installed one accelerometric station (RIIS-XC) in the urban area; a second station was not deemed necessary due to the homogeneity of the soil conditions (Alonso et al, 1995). Since its installation, two ground motion records have been obtained. The most relevant is the one obtained during the October 20th, 1995 ground motion that severely damaged the city and surrounding villages. Unprecedented peak ground motion accelerations of nearly half gravity were recorded by the RIIS-XC station, as shown in Fig. 4.

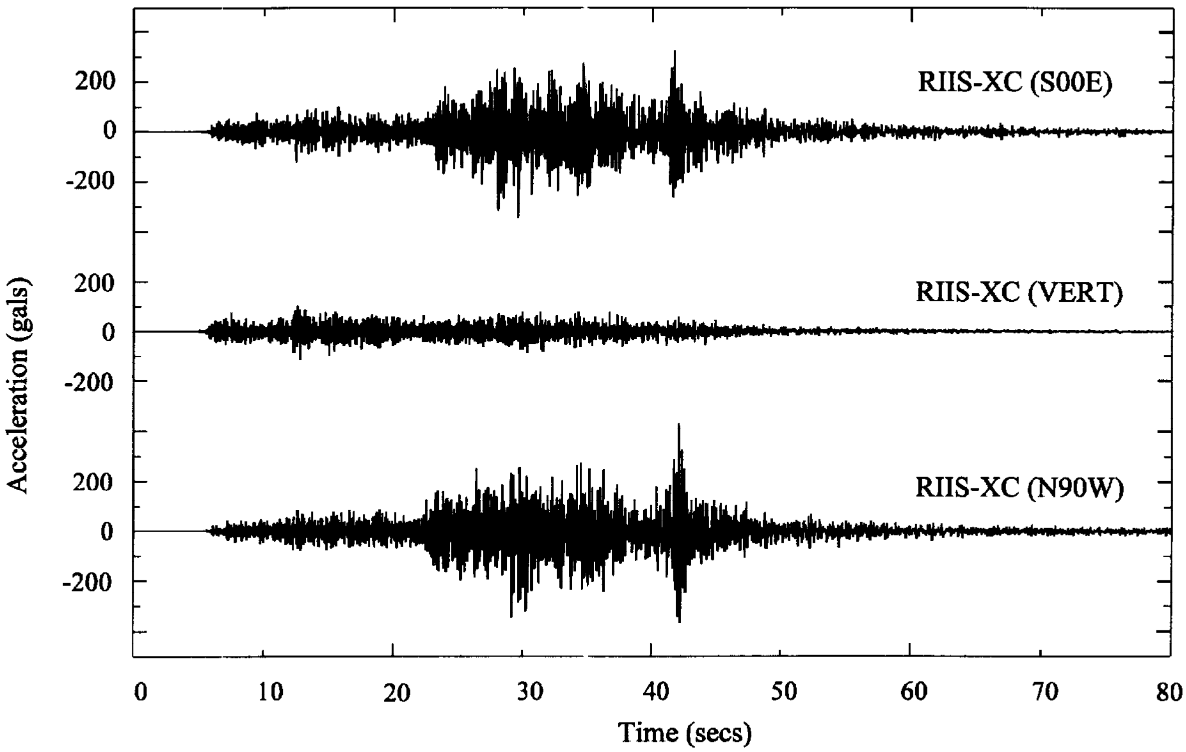

Fig. 4. Ground motion recorded at RIIS-XC during the October 20th, 1995 earthquake, with epicenter located 40km south-west from Tuxtla Gutierrez and magnitude Mb==6.3, according to the USGS.

CONCLUSIONS

The interuniversity accelerometric network (RIIS) described in this paper has led to a major step in promoting local concern and research in the study of ground motion effects in cities were scarce seismic studies were available. The enthusiastic participation of local research teams has shown to increase the efficiency of the accelerometer operation process. which is performed independently by each of the universities constituting the network. Local studies and experience are invaluable in determining locations where representative ground motion data can be obtained. Accelerometric records are now being obtained in populated areas where scarce information, if any, was available in the past, despite the historical knowledge of local seismic vulnerability. From these records, important new information about local ground motion effects is being obtained. This will allow to improve the building codes in the studied cities.

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