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NATIONAL CIVIL PROTECTION SYSTEM

RESEARCH ACTIVITY AT CENAPRED ON STRONG-MOTION SEISMOLOGY FOR DISASTER PREVENTION (ABSTRACTS)

DEPARTMENT OF RESEARCH

DEPARTMENT OF INSTRUMENTATION

NATIONAL CENTER FOR DISASTER PREVENTION
MEXICO

PRESENTATION

The Government of Japan through the Japan International Cooperation Agency (JICA) and the Government of Mexico through the National Center for Disaster Prevention (CENAPRED) signed a technical cooperation agreement, among whose objectives are the development of cooperative research and the dissemination of its results to institutions and people interested in prevention of earthquake disasters.

The Research Department and the Instrumentation Department at CENAPRED carry out studies on the characteristics of natural phenomena and human activities that are potential sources of disaster, as well as of the technologies and actions aimed at reducing its consequences.

Results of the earthquake engineering studies and the disaster prevention studies with important merits constitute the present collection of abstracts prepared in the last years under the Japan-Mexico cooperative research efforts.

The series of publications "Cuadernos de Investigación (Research Reports)", "Informes Técnicos (Technical Reports)" and the "Publicaciones Específicas (Specific Publications)" like this can be obtained through the Dissemination Department of CENAPRED.

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EDITORIAL COMMITTEE

FOREWORD

Disaster prevention due to earthquakes is a complex and multi-disciplinary task involving engineers and architects, as well as civil defense officers, social scientists, communication specialists and psychologists, among others. From civil engineering point of view, in a case of a country like Mexico, two main contributions to disaster prevention can be summarized as the development and dissemination of techniques aimed at:

1) estimation of seismic actions that structures are likely to face during a given time period;
2) construction of structures capable of resisting such seismic actions.

It is known that the amount of loads induced to a structure during an earthquake is largely controlled by the size of motions exerted by the foundation ground. Thus, the first and indispensable step towards estimating the size of the seismic loading is to understand the nature of ground motions at the site where the structure is -or will be- constructed. Once this has been achieved, the next step is to understand the relation among ground motion, structural characteristics and structural response. This amounts to being able to compute the internal stresses generated in the members of a structure when it is subjected to an earthquake of known characteristics. Finally, one should be able to know how to design and construct a structure so it can be able to resist the internal stresses posed by an earthquake with a risk level either optimal or tolerable to society

Strong-motion seismology is the discipline which applies seismological knowledge for civil engineering purposes. As many other engineering disciplines, strong-motion seismology uses a theoretical scientific background but heavily relies on observational data. Both aspects are essential in understanding the nature of ground motions, and it is only with the input of both types of knowledge that results useful for disaster prevention can be obtained.

In the last years, the strong-motion group at CENAPRED has carried out activities covering the three main items of disaster prevention research, namely, theoretical investigation, observational work, and development of engineering application. For methodological reasons, the study of earthquakes has been divided into several categories. First, it is important to construct models of the seismic source, that is, the area where an earthquake is originated, also known as the rupture zone. The characteristics of the motion generated by the seism are initially determined by the details of the rupture process; thus, it is of great interest to analyze strong-motion recordings obtained at close distances from the source, in order to constrain or improve theoretical models of the rupture phenomena. With the help of a well-known Japanese expert, studies of this kind have been performed, specifically oriented to the subduction earthquakes originated in the Pacific Coast of Mexico.

But the nature of the seismic waves that arrive to a site is not fully determined by what takes place in the source. The waves are -sometimes dramatically- modified by the geological characteristics of rocks and soil that they find in their way. In particular, sedimentary basins, as the one underlying Mexico City, produce changes in the seismic waves that make them very hazardous for human settlements. The study of this fact requires, again, theory and field measurements, including determination of properties of soil and rocks, as well as observation of ground motion during earthquakes. Being this problem of great importance to Mexico, large efforts have been devoted to it.

In the frame of the Japan-Mexico cooperation program, theoretical models of the behavior of sedimentary basins have been constructed and tested versus the observed data. Also, several projects have been devoted to the investigation of the properties of subsoil, mainly in the Valley of Mexico, but also at other locations, and different techniques for this purpose have been tested. It is important to note that our models, and hence our capacity to predict ground motion during earthquakes, are only as good as the data we possess of the subsoil. For this reason, much importance has been dedicated to investigating properties of soil and rocks in the vicinity of important cities. As a result of both theoretical and observational work, we have now a clearer picture of the problem, and we have been able to disclose some puzzles posed by previous earthquakes. In particular, as it will be discussed later, our present knowledge of the soil in Valley of Mexico allows us to make predictions of ground motion with great detail.

Once the seismic source and the characteristics of the soil are reasonably understood, the next step is to estimate the motions that could take place at sites of interest if an earthquake of known magnitude succeeds at a given location. In the last years, various techniques have been developed or improved on this subject. The estimations can be performed at different levels of detail. We have developed new tools to predict motions of response spectra and, more recently, techniques to produce artificial accelerograms resulting from a postulated event. These artificial accelerograms can be of great help in designing structures since, for the vast majority of engineering application, they suffice to describe the ground motion with a single accelerogram. In these activities, we have benefited from the experience of Japanese experts.

Results from the theoretical and observational work previously described have been used to perform a detailed seismic risk assessment of Mexico City. A computer system has been established which allows estimation of levels of hazard and risk that Mexico City would face should an earthquake of prescribed characteristics occur in the Pacific Coast of Mexico. This system constitutes a practical tool for urban planning, seismic code drafting and disaster management activities. This system and an important instrumental development are the bases of a computer system which will provide Mexico City's authorities estimations of the intensities experienced in this city a few minutes after an earthquake is initiated. A system of this kind will be a valuable tool in guiding the reconnaissance and eventual rescue activities. Moreover, it will certainly help disaster management from the political point of view. Also, theoretical work has been carried out in search of reasonable microzoning techniques for urban areas and the theoretical bases of a new conceptual approach of geographical information systems oriented to disaster reduction. In order to better understand the vulnerability of constructions in Mexico, a factor of great impact has been developed in earthquake risk estimation; investigations have been carried out concerning the behavior of existing buildings in Mexico City. These analyses have shed some light on certain vulnerability items and, also of great importance, on some possible improvements of existing building codes.

As mentioned before, theoretical work is of little use if it is not constrained by observed data. In this sense, the strong-motion observation network donated by the Japanese Government in the frame of the five-year agreement has been used extensively. These recording instruments, operated at high-level standards, have been extremely useful in all the activities previously outlined. We have obtained valuable data from ground-surface accelerograms, bore-hole logs, building instruments and portable broadband seismographs.

In this report we summarize the activities carried out by different teams which have worked on the strong-motion field during the last years. Each chapter includes the abstracts of different papers presented in this field.

Chapter I starts with a state-of-the-art paper, which gives an overview of what was learned during the first years after the September 19, 1985 Michoacan earthquake. The paper includes some advances on the study of the source characteristics of Mexican earthquakes, their statistics of occurrence, regional tectonics and strong motion seismology. The chapter also includes two papers specifically devoted to the study of the earthquake source. The first one, by Prof. T. Mikumo, deals with a three-dimensional dynamic model of the rupture zone of earthquakes arising along the Mexican subduction zone. Relevant conclusions are obtained as to the importance of the distribution of stresses in defining the nature of the ground motions generated. The second paper, by M. Santoyo, deals with the solution of what is called *the inverse problem*; that is, the calculation of the seismic slip distribution in the rupture zone, given a set of strong-motion recordings. In this case, the April 25, 1989 Guerrero earthquake (M=6.9) is analyzed. As mentioned above, knowledge of the seismic source improves our capacity to predict ground motion of future earthquakes.

Chapter II deals with the seismic instrumentation programs of CENAPRED. First, a report is given on the operation of the strong-motion instrumentation network, which includes surface recorders in the attenuation line from the Pacific Coast to Mexico City, and surface, building and bore-hole recorders in Mexico City. The report describes the network and gives an overview of its operation during the last years; it contains the accelerograms collected so far, along with their initial processing. It is important to mention that the strong-motion network has provided one of the most important ingredients to scientific research: theory without constraints from observed data is seldom useful. The instrumentation program of CENAPRED includes not only strong-motion recording, but also broad-band seismic observation. These data provide important information about earthquake characteristics impossible to observe with strong-motion instruments. In the next paper of this chapter, a description is made of the equipment acquired through the Japanese donation and its utilization, past and future, within CENAPRED's research program. The third paper in Chapter II deals with a study of structural response performed using the accelerograms installed in a building located in the soft-soil area of the Valley of Mexico. It is shown how recorded earthquakes can be used in inferring characteristics of building response, such as natural vibration periods and distribution of shear forces along the height of the building during earthquakes. Important conclusions are derived in this respect, some of which can be used in refining the methods of analysis indicated in the current Mexico City Building Code so as to compute more realistic seismic design forces.

Chapter III is the longest of the present report, since it deals with one of the most important items of the seismic problem in Mexico City, namely the amplifications due to the nature of the local geology, known as *site effects*. The first paper deals with a gravity survey performed in order to obtain geophysical information about the basement below Mexico City. It is currently believed that part of the amplification of the seismic waves in the Valley of Mexico is due to the effects of the deeper geological structure; so its knowledge becomes important in understanding the phenomena involved. The second paper also deals with investigation of deep structure, this time by using seismic refraction techniques, from which information about the mechanical properties of the underlying soil is obtained and correlated with those coming from other sources. The third paper illustrates the use of microtremor measurements in determining, in a rapid and economical way, key parameters useful to assess the importance of site effects. It is important to highlight that this technique has been extensively tested and has been proven very useful in Mexico City. Next, a paper is presented on a new technique to measure P- and S-wave velocities on the top layers of the soil. The technique was applied in several sites in Colima and at one point in the Valley of Mexico. It is known that a very important part of the nature of the motions recorded in Mexico City can be attributed to the characteristics of the most surficial soil layers; therefore, information about these characteristics is essential to predict motions correctly during future events. Results from the application of this technique complement those already obtained by other means. The fifth paper in the chapter presents an analysis of seismic data which shows that even the so-called hard sites in the Valley of Mexico suffer wave amplifications, with respect to what would be expected in sites at comparable epicentral distances. The cause of this amplification is not known clearly yet; however, it is suggested that regional geology plays an important role. If so, geophysical investigation of deeper structure below Mexico City is needed to understand this observed effect. The next two papers deal with the interpretation of recordings obtained by bore-hole instruments. First, a statistical technique is presented, which helps to separate contributions to the recorded motions of Love and SH waves. For our purposes, it is important to know the greatness of the contribution of Love waves to estimate the errors involved in the prediction of soil response using simple one-dimensional (1D) models that account only for shear (SH) waves. An analysis of this kind is presented in the following paper, in which it is shown that, as a first approximation, the soil response in the Valley of Mexico can be modeled with 1D models of the propagation of SH waves, provided that the input at the base of the deposits is known. Paper 8 gives a summary of particular aspects of ground motions in Mexico City, such as the evolutionary nature of their frequency and duration. Concerning the latter, paper 9 contains a feasible and simple explanation as to why strong motions in Mexico City last so long. It is stated that motions in the soft soil are so long because the incident wavefield itself has a long duration, mainly due to multiple reflections of the seismic waves in their way from the coast to Mexico City (roughly 300 km). The last paper in the chapter is a numerical model of wave propagation in sedimentary basins; it provides a theoretical framework from which observations can be interpreted.

Chapter IV presents three techniques of practical use to estimate future ground motions. The first one deals with a new method, based on Bayesian statistics, to construct semiempirical attenuation relations, that is, relations between magnitude, epicentral distance, and some measures of the seismic intensity. The technique allows for an efficient use of both empirical and theoretical information. The second paper is an application of a method previously developed by Prof. K. Irikura to produce artificial ground motions, in this case generated by a postulated earthquake in the Guerrero area, using the recordings of small events as empirical Green's functions. It was found that, if enough knowledge on the earthquake source is available, the predicted motions are in good agreement with the observed ones. In the most general case, that is, when detailed knowledge on the source is neither available nor easily reduced to a few variables, the technique presented in paper 4.3 can be useful. With this approach, empirical Green's functions are also used, in a summation scheme that forces the recording of a small earthquake to scale, in the whole frequency range, as predicted by the Brune's theoretical source model. This paper presents successful comparisons between observed and artificial accelerograms and estimates the motions that could be expected in a hypothetical magnitude 8.2 earthquake in the Coast of Guerrero.

Chapter V presents research activities oriented to seismic zoning and risk assessment The first paper reports results obtained for Mexico City using a geographical information system which stores information on distribution of constructions throughout the city, and ground motions and damages expected as a consequence of the occurrence of a postulated earthquake. This system includes much of the knowledge that has been gained in recent years about seismic response of the Valley of Mexico during earthquakes and of structural vulnerability. It constitutes a valuable and practical tool for microzoning, land-use planning and disaster management. In the second paper, a new approach is presented to compute and analyze hazards and risks using techniques of geographical information systems, based on object-oriented programming. With this approach, each element under risk is considered an object which can be operated with other objects according to preestablished rules. Under this philosophy, construction and computational management of large areas subject to risks are simplified greatly. An application of this approach is presented in the following work, in this case for the 300,000 inhabitants of Colima City, for which maps of seismic damages and ground motions can be constructed for several likely earthquake scenarios. The final paper in this chapter presents a numerical technique, based on genetic algorithms, to solve the problem caused by the lack of a practical tool to solve optimal microzoning numerically. The problem was theoretically formulated and solved an year ago, but its application had been delayed. With this approach, the boundaries of seismic zones can be found so as to minimize either the total estimated cost of seismic resistant designing (that is, the construction cost plus the expected losses) or only the construction cost. The recently developed algorithm will be applied to Mexico City next year.

Finally, Chapter VI includes two papers related to the strong-motion database. In view of the existence of numerous accelerographic stations which record ground motions continuously, handling and management of these large amounts of information have become complex. In fact, if the recorded motions are not properly organized and easily accessed by researchers, their utility is greatly diminished. In the first paper of the chapter, the architecture of the strong-motion database of CENAPRED is described. It includes 293 three-component accelerometric recordings obtained from 40 different earthquakes occurred since 1990. This system, originally written for a personal computer environment, has been the basis for the development of the National Database of Strong-Motion Recordings, which will include information not only from CENAPRED stations, but also from all the major accelerometric networks in the country. Some ideas for the development of this database are presented in the last paper of the chapter.

We hope that this collection of abstracts of research papers will provide a general and clear view of the research works carried out at CENAPRED in the last years as well as of its current and potential applications to earthquake disaster prevention.