The Rôle of Science in Protecting Man against Earthquake Disaster

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Seismologists all over the world have been studying earthquakes to get a better understanding of this natural phenomena, especially since the turn of this century. But the greatest advances were achieved during the last decade. All available modern methods and techniques are being employed in solving problems related to earthquakes which could in the end, help to protect man against it. By gathering large amount of data through systematic observation and by analysis, evaluation and interpretation of them we have come to a state of knowledge whereas we can plan, design and build structures that would resist and survive large and destructive earthquakes. An excellent case of history is provided by the recent San Fernando earthquake of the Los Angeles area. The damage done by this shock is far too small when we compare it with the amount of damage observed by some other recent earthquakes of similar magnitude that occurred elsewhere.

In many areas the intensity and acceleration of a strong earthquake are determined through visual inspection of the damage. For a sound engineering practice much better data are needed which can only be obtained by suitable strong motion instruments. In many countries including many in Europe, there are very few of those instruments in use. Establishing a well planned network of strong motion instruments might be considered one of the items of an international project to be taken up by CCMS. Whenever I speak about the question of earthquake resistant buildings, I always think of the problem of designing simple small houses that could withstand earthquake forces. These types of houses are needed in rural areas of most of the earthquake prone countries. Building materials could be selected or manufactured according to the supplies available in a given region. This conference could emphasize these problems and encourage research on the international scale.

As a result of the advanced level of our knowledge today, the seismologists have been seriously considering to predict earthquakes. There are already news of some successful prediction and research programs are in progress.

Earthquakes have occurred where no such events were known before. Such observations could be correlated sometimes with the injection of large amounts of water deep underground and in other cases with the detonation of atomic bombs or with filling with water of large dams. All these observations of man-made earthquakes lead seismologists to think that perhaps the energy stored within rocks could be released by controlled amount in areas of large destructive shocks and thus prevent the loss of life and property. This type of effort could eventually make the control of earthquake a possibility.

All these results of the scientific endeavour well known to seismologists particularly to Californian seismologists are excellent examples of how findings of pure and applied scientific research can be channelled into practical forms and thus science can be put in service for man's protection against natural disasters.

What I have tried to say up to this point summarizes very briefly what can and should be done to minimize the hazards of earthquake disaster. In many earthquake zones of the world the protection measures are far from adequate and when an area is striken by a severe shock, the whole scientific achievements are just phoney stories to the person involved. He wants immediate rescue shelter, food and a helping hand. I can not find words to express the importance of an alert emergency organization. During some recent earthquakes in many parts of the world we have observed that shortcoming of emergency measures have increased the death toll. It is our task to see to it that earthquake countries be better prepared to meet the challenge of disasters of that kind in the future. I hope that some practical and useful resolutions on this humanitarian aspect of earthquake may come out of this conference.

In Turkey we have had a destructive earthquake every two years or so since 1939. During this period tens of thousands of people lost their life. In this period of intense seismic activity geologists, seismologists, civil engineers and government officials have learned a great deal and become really interested. This interest was exhibited during the Gediz earthquake of March 1970 which was studied by so many geologists, seismologists and particularly engineers.

Before conclusion, I like to mention the effort of UNESCO to support the seismological development in many countries through which more efficient data were collected and acquired knowledge was disseminated to countries which need it.

SAFETY AND SURVIVAL IN AN EARTHQUAKE

SECURITE ET SURVIE AU COURS D'UN TREMBLEMENT DE TERRE

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THE SAN FERNANDO EARTHQUAKE OF 9TH FEBRUARY, 1971

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The Los Angeles region, which was hard hit on its Northern fringes by the moderate earthquake of 9th February, 1971 (Richter magnitude 6.6), is a region in which much attention has been given to the earthquake hazard. Even then, this natural violence of the earth directly affected more than 400,000 people in the city of San Fernando and surroundings by damaging or destroying homes and public facilities and utilities - with a cost of 64 lives and perhaps as much as a billion dollars. Collapse of a portion of the Van Norman Dam led to the evacuation of 80,000 inhabitants living below the dam for several days while water was drained from the reservoir to avert imminent rupture of the dam and a catastrophe unprecedented in this country.

The ground quaked early in the morning (about six a.m. local time) while highways were relatively free of traffic and before most workers had occupied offices in public buildings, and this minimized loss of life. Some of the earthquake losses can and will be restored in the near future; others, such as transportation disruption, severe damage to public utilities and facilities, and serious lowering of water-storage capacity, will take longer; and some losses can never be regained. These effects will force stricter earthquake preparedness measures in the Los Angeles area - and, we may hope, in other areas as well - as it is now clear that better preparation could have been made.

The particular location of this shock was not previously suspect any more than the heart of Los Angeles, where the damage would have been more catastrophic. Earthquakes of this size are not uncommon: more than 100 occur yearly around the world, but this one struck the edge of a great metropolis. It is certain that earthquakes of this size - and larger - will rock other places in the United States, rural and urban, in the future.

Earth scientists and earthquake engineers have been deeply concerned about their generally limited understanding of the hazards of earthquakes and by the consequent limited understanding by public officials responsible for the safety of millions. During the past few years, several reports have been written that both provide background knowledge and recommend action toward the mitigation of earthquake effects. The recommendations made in the reports listed in Appendix C are as valid today as when they were written. What seems needed now is to learn from the San Fernando Earthquake how best to prepare for and cope with the effects of future disasters of this kind.

1. SIGNIFICANCE OF PERMANENT GROUND DISPLACEMENT

Disruptions of the ground surface by faulting and other closely associated permanent deformations of rock and soil were much more important causes of structural failure during this earthquake than in any previous United States earthquake. This emphasizes once again the hazards associated with urbanization of active fault zones. On the other hand, many of the faults that broke during this earthquake were not generally shown on geologic maps published prior to the event, and none had been considered particularly active. The need for making structures safe is obvious. At the same time, more intensive geological, geophysical, and geodetic studies of earthquake-prone regions of the country must be made. Were there unrecognized geological clues that might have revealed that this area, and these faults, were particularly hazardous? Are there other geologically similar areas in which comparable earthquakes might occur? Merely asking such questions points up the necessity for interdisciplinary efforts by engineers, seismologists, and geologists in land-use planning for earthquake-prone regions.

2. MEASUREMENT OF STRONG GROUND SHAKING

An unprecendented description of the ground motions and the resulting building responses was provided by more than 200 stron-motion accelerographs. This National Oceanic and Atmospheric Administration network operated well during the earthquake. Among the records were several obtained on dams. One instrument, in the epicentral region, showed the highest acceleration ever measured during an earthquake; it indicated in detail the time sequence of the main shock and many of the major aftershocks. These measurements will form the basis for a re-evaluation of earthquake-resistant design. The accelerograph records obtained in about 30 large modern buildings will permit many significant studies of the design of earthquake-resistant structures. The success of this network, and the potential value of such data for the protection of the public, leads us to recommend strongly that the currently very inadequate strong-motion-accelerograph coverage should include numerous building structures and ground sites in all urban areas in seismic regions and important engineering structures such as dams and nuclear power plants.

In addition, greater effort and appropriate instrumentation should be devoted to studies of the effects of topography and the character of geologic material on the distribution and amplitude of strong ground motion.

3. SIGNIFICANCE OF THE STRIKING LOCAL GROUND MOTIONS

This earthquake demonstrated that local ground motion is not a simple function of the size of the shock. This magnitude 6.6 earthquake was associated (mainly in a restricted region some ten miles long and five miles wide along the Valley edge) with a severity of ground motion that was probably close to the maximum generated by any earthquake. An earthquake of greater magnitude would involve strong ground motion over a greater area consistent with longer fault breakage, and a greater duration of shaking.

The surface expression of the faulting and its character at depth as determined by seismological studies, showed that the crustal materials beneath the San Gabriel Mountains were uplifted and thrust toward the Northern margin of the Valley by six feet or more. In the Upper San Fernando Valley and in Sylmar, buildings were called upon to withstand exremely strong ground motions. In this local region, the motion consisted of both severe shaking and a heave upward and toward the South (perhaps in several episodes). The strong-motion accelerometer at Pacoima Dam, on solid rock, showed ground motions 50 to 75 percent of the earth's natural gravitational acceleration (with a few peaks equal to gravity) lasting approximately 12 seconds overall. The dam is less than two miles from the Sylmar Veterans Hospital, which sustained severe damage and loss of life.

4. BUILDING CODE REVISION

This earthquake has provided the first really comprehensive practical test of United States earthquake codes in and close to an epicentral region. Modern structures designed according to the earthquake requirements of the building code performed well in the regions of moderately strong ground shaking (peak accelerations of 10 to 20 percent g). In the region of very strong ground motion, however, some modern buildings were severely damaged. A few that collapsed would have caused many additional deaths had they been occupied at this early hour. If the duration of strong ground shaking had been appreciably longer than ten seconds, as it would be in a great earthquake, some of the severely damaged structures would almost certainly have collapsed. It is clear that existing building codes do not provide adequate damage-control features. Such codes should be revised.

5. BACK-UP EMERGENCY SERVICES

In earthquake-prone regions, service organizations such as the police and fire departments, and medical services will be put under heavy stress following an earthquake of significant size. The San Fernando Earthquake affected an area of only moderate size. It is necessary, therefore, to examine the organization and distribution of emergency services in the light of the fact that a major earthquake would affect a much larger area. Moreover, much of the loss of life and damage to property associated with an earthquake are attributable to after-effects such as fire, flood, or seismic sea waves.

The opportunity should be seized to make a careful evaluation of the performance of emergency services following the San Fernando Earthquake and to determine the kinds and extent of back-up required to prepare for a much larger event. Such a study, preferably involving federal, state, and other organizations, would provide guidelines for other earthquake-prone regions of high population density as well.

6. RAPID RECONNAISSANCE STUDIES

The vital need for rapid reconnaissance studies immediately following a damaging earthquake is once again emphasized by the experience of the San Fernando Earthquake. For example, the entire Northern part of the San Fernando Valley should have been systematically photographed from the air at very large scale (one inch equal to several hundred feet) on the morning of the earthquake in order, as quickly as possible, to locate sites of severe damage and to delimit the overall extent of such damage, as well as to identify visible surface expression of the faulting. But apparently no agency had the responsibility to initiate such an effort. It is clear, therefore, that an agency should be designated to assume the responsibility to initiate rapid reconnaissance studies of this type following future major earthquakes, and that adequate funding should be provided.

7. PROTECTION OF CRITICAL PUBLIC BUILDINGS

A striking consequence of the earthquake was the fact that four hospitals in the San Fernando area were damaged so severely that they were no longer operational just when they were most needed. Certain critical structures should be designed so that they will remain functional even after experiencing the most severe ground shaking. Included are hospitals, schools, and other high-occupancy buildings, as well as buildings housing police and fire departments and other agencies relied upon to cope with disasters. Basic utilities that must be depended upon to mitigate a disaster must also receive an extra measure of protection. Ordinary building codes cannot be depended upon to provide this extra protection, and special damage-control provisions should be mandatory to ensure such additional safety in high-risk areas.

8. EARTHQUAKE SAFETY OF DAMS

The near failure of the lower Van Norman Dam endangered the lives of tens of thousands of people. Such risks are clearly unacceptable. An improved program for bringing older dams in earthquake-prone areas up to the best modern safety standards is imperative, and these best standards should themselves be constantly reviewed. Many existing dams in all parts of the country have not been disigned to resist significant earthquake forces; these structures should be thoroughly examined and measures should be taken to reduce such hazards. Additional basic research into the behaviour of dams and soil structures during earthquakes will be required for the implementation of such a program. The fact that the Van Norman Dam did not quite fail totally should not be a source of comfort.

9. EARTHQUAKE HAZARD OF OLD STRUCTURES

During the San Fernando Earthquake, many old, weak buildings in the regions of strong and moderately strong shaking suffered severe damage, and the major loss of life occurred in one old building, the Sylmar Veterans Hospital, designed befor e the adoption of modern building codes. There are many thousands of such old buildings in California that will collapse if subjected to strong ground shaking. Programs should be undertaken to render such buildings safe, or to raze them, over a reasonable period of time.

A successful effort to improve or eliminate old structures has been underway for some time in the city of Long Beach, and in the city of Los Angeles especially hazardous parapet walls have been removed from several thousand buildings or have been strengthened. This earthquake dramatically demonstrated the value of such procedures. A much more extensive program to eliminate the major hazard of old buildings is strongly recommended. Urban renewal programs can provide a suitable opportunity for such improvements in California and in other earthquake-prone areas.

10. SAFETY OF BRIDGES AND FREEWAY OVERPASSES

A number of freeway overpass bridges collapsed during the San Fernando Earthquake, causing some deaths and resulting in significant local disruption of traffic. In an earthquake of greater extent, such interruption of transportation could greatly magnify the disastrous effects of the earthquake. Freeway bridges and important highway bridges should be disigned for adequate safety against collapse. Present standard code requirements for earthquake design of highway bridges in high-risk areas are grossly inadequate and should be revised.

11. SAFENESS OF SCHOOL BUILDINGS

It is noteworthy that school buildings in the region of strong shaking designed and constructed since enactment of the Field Act of the California State Legislature did not suffer structural damage that would have been dangerous to the occupants had the schools been in session. This demonstrated that one and two-story school buildings can indeed be made safe by practicable code requirements, permitting them to withstand very strong shaking combined with appreciable ground deformation beneath the structure.

Older school buildings, which did not meet the requirements of the Field Act, suffered potentially hazardous damage as a result of moderately strong ground shaking. The lesson is clear that such hazardous school buildings must be eliminated or strengthened. Appropriate authorities in all seismic regions of the country should take this lesson to heart.

12. STUDY OF DAMAGED URBAN DWELLINGS

This earthquake throws an almost unique light on seismic hazard in a modern urban environment. Extensive damage to small homes and small-business structures occurred in zones where severe shaking was accompanied by permanent ground displacement associated with the faulting. Therefore, much crucial information can be gained by an immediate dwelling-by-dwelling study of earthquake damage. Such a study should be conducted by appropriate federal, state, and local agencies, with a view toward developing sounder guidelines for building construction, particularly of one and two-story buildings.

13. EARTHQUAKE INSURANCE FOR HOUSES AND SMALL BUSINESSES

Because recognized geological evidence of active faulting was lacking in this particular area, the people who lost their homes and businesses in the Sylmar-San Fernando areas could have had no warning of the special hazards to which they were exposed. Permanent displacement of the ground caused by surface faulting, landslides, and consolidation and slumping of soils were responsible for much damage to structures. In many places, deformation of the ground beneath a structure greatly magnified the damaging effect of the ground shaking.

Such innocent victims of earthquakes should be protected by insurance, or the authorities must be prepared to consider better relief measures than those now used. The cost of repairing such unforeseeable damage should be shared by all who live in disaster-prone regions. A form of earthquake insurance that will be much more widely used should be developed, with Federal Government back-up if necessary.

14. PRESERVATION OF VITAL SUPPORT SYSTEMS

Damage to the Sylmar Converter Station, a key link in a system for transmission of elctric power into the Los Angeles area, will keep this system inoperable for about a year while replacement parts are manufactured. This demonstrates in a dramatic way the increasing vulnerability to earthquakes of our society's vital support systems. Networks for the distribution of electrical power, water, and gas, for disposal of sewage, and for transportation of food and other essentials continue to grow in size and complexity as the numbers of people dependent upon them reach into the multimillions.

The collapse of several highway overpasses during the earthquake had a limited effect on transportation, but such destruction could be more widespread in a larger earthquake, perhaps compounding transportation difficulties to disaster proportions.

A major unit of the water supply system, the Van Norman reservoir, was virtually eliminated without seriously disrupting distribution of water. Compounding of such effects in a larger earthquake is clear cause for concern.

For the crucial systems vital to millions of people, design of individual components is not adequate in the face of the known earthquake hazard. Continuing efforts must be exerted to build into the system sufficient redundancy to ensure against complete failure in the event of a major earthquake.

15. THE PROBLEM OF SEISMIC ZONING

The unexpected occurrence of an earthquake in this location and the concentration of the most severe damage in zones of ground breakage forcefully illustrate both the importance and the difficulty of responsible and practicable seismic zoning. No evidence from previously completed geological or seismological studies had been generally interpreted as indicating that the region affected was a more likely place for a damaging earthquake than many other parts of the Southern California seismic region.

This experience points out once again that the short-term local seismic history is not in itself an adequate base for estimating earthquake risk. Until we gain a better understanding of earthquake processes and probabilities, due regard for public safety demands that seismic hazard be considered high throughout wide areas, and seismic zoning maps must reflect this. Many agencies and groups are working constructively on the problem of recognizing seismic hazards, but this effort is so important that it deserves more support.

16. LAND USE AND GEOLOGIC HAZARDS

More than ever before, local communities are seeking guidance concerning environmental hazards of all types that should be taken into account in planning for the use of land to be developed. Permits for construction of residential and commercial buildings in areas subject to earthquakes, landslides, and flooding, for example, should only be issued on the basis of a meaningful evaluation of the potential risks and only after the purchaser is aware of all the known facts.

State and local government needs support in the form of well-conceived regulations in order to resist political and economic pressures to develop land in ways that are unwise in terms of environmental hazards.

17. STUDY OF THE SOUTHERN SECTOR OF THE SAN ANDREAS FAULT

The redistribution of crustal stresses caused by the San Fernando Earthquake cannot help but have some effect on the nearby segments of the San Andreas Fault, which has long been considered a source for much larger earthquakes. Because of this changed situation, the San Andreas Fault in this temporarily "locked" segment is a particularly critical area to study and to monitor, especially in view of its proximity to the largest metropolitan center in the Western United States. (The closest point on the San Andreas Fault to the center of Los Angeles in less than half again as far as was the epicenter of the San Fernando Earthquake). It is strongly recommended that additional research programs be started at once to study the Southern sector of the fault.

18. SEISMOLOGICAL STUDIES

The San Fernando Earthquake was the best monitored earthquake in United States history because of the high level of scientific preparedness in this area and the immediate response of earthquake researchers. Immediately available seismic data were imprtant in delineating the scope of the disaster, aided repair and reconstruction, and facilitated further scientific studies.

In the Los Angeles area, a telemetry-equipped seismic network that was in operation prior to the earthquake provided excellent records of pre and post-earthquake seismicity, but even this network could have been markedly improved in effectiveness by a greater number of telemetry-equipped stations and a more comprehensive seismic monitoring program. It is clear that, prior to the earthquake, seismological information even for this region was not as complete as it could have been, and indeed should have been, given the capabilities of present technology. Pre and post-earthquake geodetic observations should be an intrinsic part of such monitoring systems. Both seismologic and geodetic capabilities are urgently in need of upgrading in all earthquake-prone regions of the country.

The seismic data gathered during and following the earthquake provided the basis for locating the sources and determining the mechanics of the faulting at depth. Such studies, together with geologic and geodetic studies, will also yield important information about the earth deformation that occurred in association with this earthquake and its aftershocks. This will be important in assessing the seismic hazard elsewhere. The San Fernando Earthquake is a reminder that a vastly improved understanding of earth movements at all scales is needed.

TOWARD REDUCTION OF LOSSES FROM EARTHQUAKES

Conclusions from the Great Alaska Earthquake of 1964

Prepared by : The Committee on the Alaska Earthquake
Division of Earth Sciences
National Research Council

RECOMMENDATIONS ON EARTHQUAKE LOSS-REDUCTION

1. Studies should be undertaken to develop improved earthquake-resistant designs, and more accurate and reliable methods of structural analysis, for all types of structures and for a variety of ground conditions.

2. Improved regulatory systems for control of structural and nonstructural design and of construction in seismic areas are needed.

3. Periodic reappraisals should be made of major dams, reservoirs, storage tanks, and older buildings in seismic areas to identify existing hazardous structures and to reduce hazards to life and limb.

4. Increased effort should be devoted to collecting data on ground movements and associated physical-field changes both between and during major earthquakes.

5. Needed improvements in the tsunami-warning system include better recording, faster transmission, improved analysis of data, more knowledge of the generation and propagation of tsunamis, and greater understanding of the human response to such warnings.

6. Studies are needed to make earthquake forecasting and hazard evaluation practicable; not only the feasibility but also the socioeconomic implications of such forecasting need to be studied.

7. Earthquake-hazard maps should be made of all densely populated seismic areas.

8. Informing the threatened public of the nature of earthquake hazard and education on means of reducing risk are vital to effective measures of loss reduction and loss adjustment.

9. A comprehensive study should be undertaken concerning the problems involved in establishing a system of earthquake insurance that will be widely used and that will lead not only to loss adjustment but also to loss reduction.

10. Emergency funds and personnel should be available to collect and analyze data from major earthquakes wherever they may occur.

11. The mechanisms for funding earthquake research and data collection should be improved.

12. A federal task force should be established to recommend a comprehensive government program directed toward reduction of losses from hazards such as earthquakes; at the same time, individual states or regional authorities should give attention to appropriate mechanisms for coping with these hazards.

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The report of the Committee on the Alaska Earthquake is planned as an eight-volume series with the following title:

THE GREAT ALASKA EARTHQUAKE OF 1964

GEOLOGY

SEISMOLOGY AND GEODESY

HYDROLOGY

BIOLOGY

OCEANOGRAPHY AND COASTAL ENGINEERING

ENGINEERING

HUMAN ECOLOGY

SUMMARY AND RECOMMENDATIONS

By February 1969, only the volume on Hydrology (NAS 1603) had been published, and it is available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418. Publication of the remaining volumes is expected during the next three years.