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IDNDR Day October 13

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THE KHILARI EARTHQUAKE DISASTER

India has a long history of earthquakes but they are largely confined to the well-known Himalayan seismic belt on its northern border region. As recently as 19 November 1991, an earthquake of Richter magnitude 7.1 in that area caused at least 2,000 fatalities, a similar number of injuries and the loss of 18,000 buildings in the Chamoli-Uttarkashi area. In its epicentral area, landslides were triggered and a 30 metre deep crack was observed. Damage was reported from as far afield as New Delhi. Whilst most of India's larger earthquakes are in the north, central and southern areas have not been immune during the present century. The nearest previous large earthquake to Khilari occurred, with a magnitude of 6.5, near the Koyna dam in 1967, some 270km to the west. It caused approximately 180 deaths in an area of low population density and is thought to have been triggered by the recently impounded reservoir behind the dam.

The Khilari earthquake on 29 September 1993, with a Richter magnitude of 6.3, was a natural event caused by the strains which are constantly present in the Earth's crust even at great distances from plate boundaries such as the Himalayas. The build-up of strain to the point of fracture is, however, much slower within the plates and this itself results in the infrequent, large earthquakes often coming as a surprise to the authorities and the populace. Similar examples include the magnitude 5.1 (Richter) earthquake at a shallow depth under Newcastle, Australia, in 1989, which killed 12 people and the

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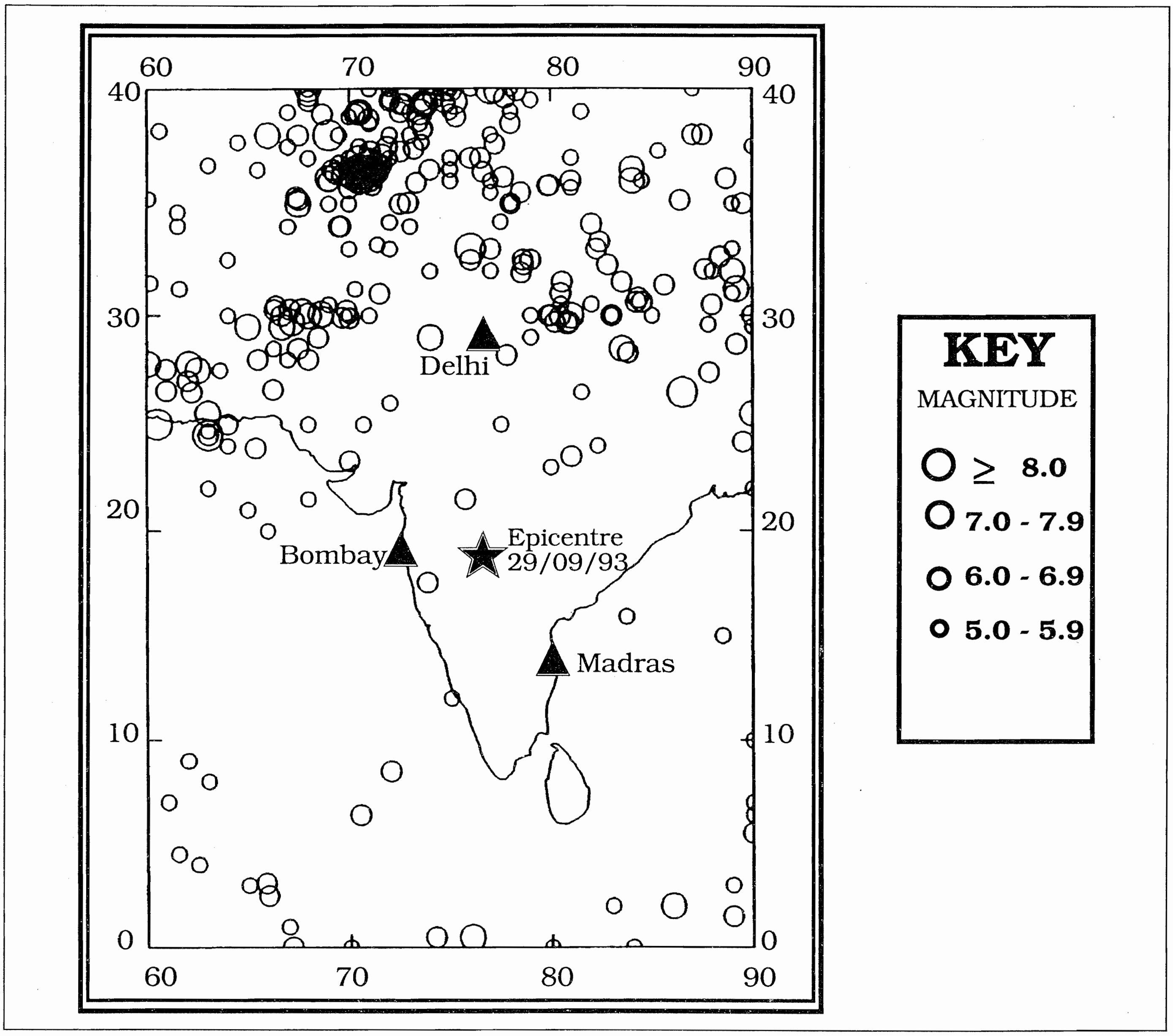


Above: Larger earthquakes in India during the 20th century (taken from the World Seismicity File of the British Geological Survey)

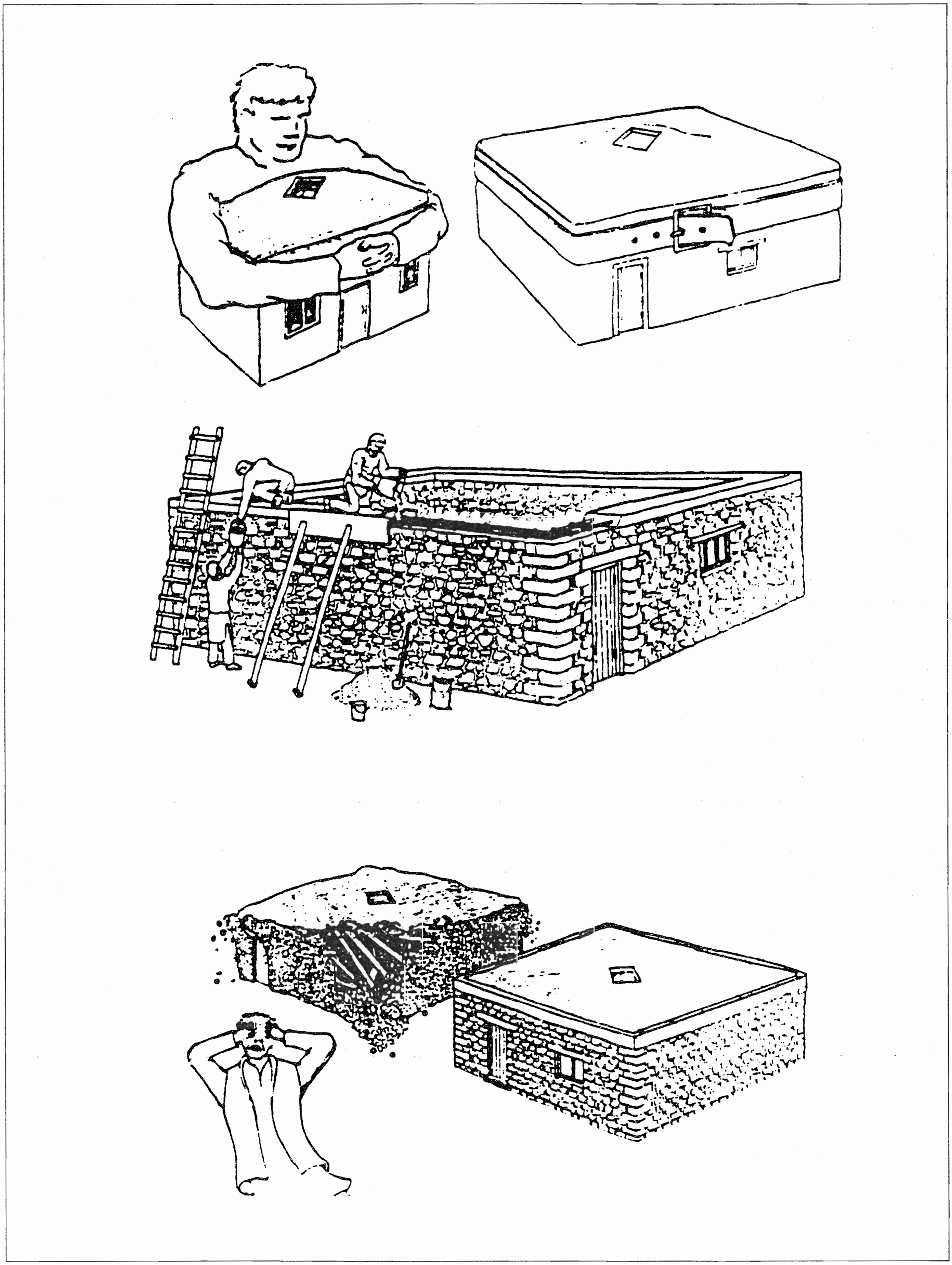
continued from page 1

magnitude 5.5 British earthquake in 1931. The latter occurred 100km offshore in the North Sea but damage was sustained to buildings widely down the east coast of England.

The tragedy of Khilari is that some 22,000 people have died and many more have been affected for the want of relatively simple house strengthening measures. This size of earthquake is common throughout the World, happening once a week on average, and in San Francisco or Tokyo, for example, there would have been minimal casualties and damage from it. The problem is one of resources, training and engineering for ordinary rural housing. Unfortunately, engineers do not win prizes for improving earthquake protection for such schemes; that is reserved for the likes of airports, bridges, dams and government edifices. But there exist techniques for tying walls together at the corners, securing roofs to the walls and providing further cohesion through the use of ring beams, wall ties and simple reinforcement. The introduction of lighter roofing materials can have a dramatic impact on the survivability of earthquakes. The reconstruction programme in Maharashtra will need to take such measures into account.

The mission of the **International Decade for Natural Disaster Reduction** is to help in such cases and to seek greater preparedness among other equally vulnerable communities by transferring existing knowledge and expertise, by training and by overcoming the cultural attitudes of both sophisticated engineers and local builders. There would be considerable impetus to this endeavour if national and world disaster relief agencies were to increase the proportion of their budgets invested in preparedness from the present 1% to 10% or 15%.

Chris Browitt
Global Seismology Research Group
British Geological Survey



Above: Conveying structural concepts for low cost housing. If builders are convinced of the benefit of a ring beam, their own building skills may be sufficient for them to build without detailed engineering instructions (source: the Overseas Development Administration (ODA) sponsored Building for Safety Project, Coburn et al, Intermediate Technology Publications)

UK LINKS TO GLOBAL ENDEAVOUR

Sir James Lighthill, ICSU Chairman Special Committee for IDNDR

INTRODUCTION

Although a mainly national contribution (such as a UK contribution) to the work of IDNDR can have very real value, a country like the UK may make even more important contributions to the International Decade where its nationals vigorously participate in major programmes that are organised on a truly international scale. This article highlights many kinds of global endeavour that can significantly contribute to reducing the human impact of natural disasters by improved forecasting and preparedness, and where UK nationals are playing leading roles. All of them are programmes which have been strongly supported by that ICSU Special Committee for IDNDR which I have the honour to chair.

Forecasting of, and preparedness against, any type of natural disaster demand dedicated inputs from outstanding scientists and engineers, working with gifted representatives of several other professions, and these needs are reflected in the membership of the ICSU Special Committee. The letters ICSU stand for ***International Council of Scientific Unions***; and indeed, four important scientific unions - in Mechanical and Geological Sciences, as well as in Geophysics and in Geography - are represented at high levels on the Committee, alongside both of the great global engineering bodies the World Federation of Engineering Organisations and Union des Association Techniques Internationales (WFEO and UATI). Moreover, the Committee is kept closely in touch with the practical problems of international collaboration on the ground to reduce the human impact of natural disasters through the presence on it both of the distinguished current Director of the UN Secretariat for IDNDR, Dr Olave Elo, and of his eminent predecessor Dr. Robert Hamilton.

From the outset, a vital role for the Committee was to concentrate, or focus, the IDNDR-related activites of global organisations in science and engineering on just a modest number of very carefully selected projects of high priority as judged by three conditions:

(i) that they are devoted to types of natural disaster where major improvements in forecasting and preparedness are urgently needed, and needed especially in developing countries;

(ii) that excellent new scientific and engineering programmes have good realistic chances of bringing about such necessary improvements during the Decade; and

(iii) that the work will be done in a close partnership between specialists from the developing countries that need help and professionals from other countries.

This article touches on just half a dozen programmes, on which international resources have been concentrated after this rigorous prioritisation process had been applied by the Committee; who felt obliged to exclude, by contrast, dozens of other projects. (For example, conditon (i) explains why the programmes include nothing on Tsunamis, since the existing Tsunami Warning System has reached high levels of effectiveness; condition (ii) explains the exclusion of any attempt to achieve short-term prediction of major earthquakes, which is simply not viewed as a realistic goal for this Decade - or even the next! - and condition (iii) explains the exclusion of tornadoes, as natural disasters whose incidence is almost entirely confined to developed countries). All six of these major international programmes have been explicitly endorsed as so-called *IDNDR Demonstration Projects* by the responsible body within the United Nations organisation.

TROPICAL CYCLONE DISASTERS

Out of the six programmes, several have benefited from dedicated initiatives by large numbers of UK nationals. The very nature of the phenomenon recognised by specialists all over the world as a Tropical Cyclone (although it has also local popular names like hurricane or typhoon) demands the most active international and interdisciplinary cooperation. It extends over huge distances of the order of 1000km; it affects many different tropical or near-tropial countries, both developing and developed; it depends on massive atmosphere-ocean interaction; it can be effectively countered only by substantial improvements in forecasting accuracy, so that the population under threat may come to rely on the forecasts and so adopt the "preparedness" measures recommended for their protection; while above all, the atmospheric processes to be forecast are in a close and intimate interaction with global atmospheric processes. Within the UK, the Meteorological Office at Bracknell has outstanding strengths in global weather prediction, offering a marvellous service in this respect to international airlines and to other customers all over the world; while complementary skills of a very high order are exhibited in the European Centre for medium-range weather forecasting at Reading. Scientists from these admirable bodies have combined with specialists in the sciences of the ocean and the atmosphere from the universities of Cambridge, London and Reading, and with scientists from Australia, China, France, Germany, India, Japan, Russia, USA and many developing countries, in the ICSU/WMO programme on Tropical Cyclone Disasters.

Indeed, out of the nine participants in the special ICSU Workshop (Vienna, August 1990) that gave the initial impetus for this programme - subsequently embraced by the World Meteorological Organisation as well as by the ICSU - four were from Britain, two from USA and one each from Australia, China and India. The book (with ten British contributors) "Tropical Cyclone Disasters", published by Peking University Press (ref 1), and being made affordably available in developing countries through big international grants, represents the first outcome of this programme. It includes the proceedings of a huge international meeting (Beijing, October 1992), carefully edited to give a coherent "state-of-the-art" picture of Tropical Cyclone Disasters and of associated forecasting and preparedness procedures, along with descriptions of advanced developments in these fields, as well as several key recommendations for improvement of these procedures, with special reference to the West Pacific and Indian Ocean regions. That meeting is being followed by another large scale meeting (Mexico, November 1993) with a rather greater focus of problems in and around the Caribbean.

DISASTER RESISTANT STRUCTURES

In order to maintain an even balance between the activities of scientists and engineers, an important international engineering project is described where both the initial impetus and a continued provision of central premises for it have been made by a most distinguished UK institution; no less than the Institution of Civil Engineers. This is the WFEO/UATI project on low-cost building design and construction for resistance against such natural disasters as earthquake or extreme winds; a project of vital importance to developing countries and one which the vast global experience of the members of the Institution of Civil Engineers fitted them admirably to initiate and maintain - always in close collaboration, of course, with colleagues overseas - and to link with those crucial quality-assurance considerations which call for rigorous measures to enforce building codes.

The structural project divides naturally into (a) problems of achieving good disaster resistance for engineered structures, where British experience links admirably with Japanese and with North American experience in both earthquake engineering and extreme-wind engineering, and (b) some quite different problems spreading knowledge on how to adapt non-engineered structures so that people within them can remain safe even when the structures collapse. Here the experience of Indian earthquake engineers is proving highly pertinent. Pulling together all these diverse threads has been proving a complex but rewarding exercise, and the Institution is to be warmly congratulated for having at the highest level firmly resolved to make this critically important contribution to IDNDR.

OTHER DECADE PROGRAMMES

Four more global programmes involve a substantial commitment of UK scientists and engineers. One of these (ref 2) involves geologists and geophysicists, concerned with forecasting extremely large explosive eruptions of volcanoes, alongside other specialists devoted to developing emergency plans for responding to such forecasts. British specialists, and also The British Council, contributed rather substantially to the important meeting on this subject "Large Explosive Eruptions" (Rome, May 93). Again, UK seismologists are helping with the Global Seismic Hazard Assessment Program, with objectives which are described elsewhere, including that of identifying all those regions where it is specially urgent to adopt earthquake-resistant design and construction of the types already mentioned. British geographers and social scientists, moreover, are deeply involved with colleagues from France and Germany and from many African countries in the work of IGU's Commission on Famine and Vulnerable Food Systems (ref.3).

Finally, the most interdisciplinary project of all - concerned with what has been called the Vulnerability of Megacities - involves yet again engineers from the Institution of Civil Engineers, operating in a close collaboration as confirmed at a recent meeting (Moscow, February 1993) with the excellent International Association of Engineering Geologists and with various earth-sciences Unions, on all those interacting problems which confer upon exceptionally large conurbations - especially in developing countries - various grave dangers that include an enhanced proneness to natural disasters.

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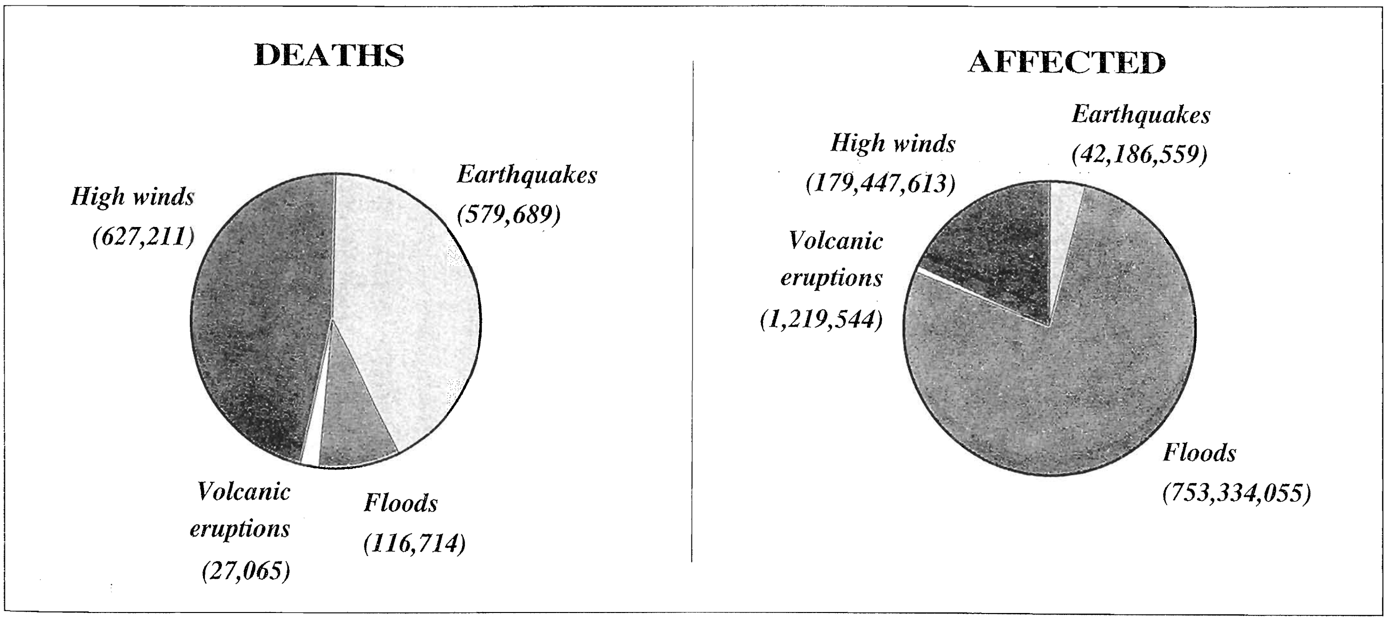
Below: Total deaths and population affected by type of disaster (1966 - 1990)



NATURAL DISASTERS - PROTECTING VULNERABLE COMMUNITIES: PROACTIVE OR REACTIVE ?

T D Pike, formerly Chief Engineering Adviser, Overseas Development Administration

INTRODUCTION

This article looks at the role of outside agencies in attempting to prevent or reduce human suffering as a result of natural events. The title is in itself something of a misnomer, suggesting as it does alternative ways of addressing the problem. In practice, of course, we must combine these approaches into a coherent programme. I shall be looking at the problem entirely in the context of the developing world, and thus concentrating on the types of event which are most frequent and dangerous in those countries. Unfortunately, many of the regions which are most at risk from natural events do contain developing countries where the necessary infrastructure is both fragile and embryonic. Under this I include not only the physical infrastructure, but also the mechanisms of government which must control the necessary activities.

THE REACTIVE APPROACH

Under this heading I consider actions taken both before and after the events, if they address remedial rather than preventative measures.

Before the Event

The most obvious need is the formulation of some sort of contingency plan to identify priority needs and design systems to deal with expected events. Such a plan must address a number of inter-related problems.

i) Clearly it is necessary to be able to maintain control of vital services after the disaster event. Design of the necessary team, identification of the individuals required, and training of that team are all valuable contingency actions which are not always adequately addressed in the developing world.

ii) Associated with that command structure will be the emergency infrastructure necessary to enable it to function. Secure accommodation with adequate communications and power are vital. Stores of materials and equipment can be strategically located, and other potentially useful equipment such as contractors' construction plant can be identified and given specific contingent duties and responsibilities.

iii) Training and public awareness programmes also have an important role to play. The hurricane preparedness programmes in the Caribbean are an example of this, as is the earthquake-preparedness training given in schools in New Zealand, for example.

iv) Links with potentially useful organisations outside the country are also important, and can greatly reduce the response time in emergencies and improve the appropriateness of the response. Organisations such as the ODA have recently devoted a great deal of attention to this point, since there was considerable evidence of duplication, delay, and wasted effort in the work of many relief agencies.

After the Event

i) The strategic contingency plan will have identified the most critical areas for protection and rehabilitation in the event of disaster. Obviously the main fabric of infrastructure must be made operational as soon as possible. Airports, power stations, telecommunications and water supplies are vital. Hospitals and food stores must also have high priority.

ii) Outside assistance can clearly give most immediate assistance in the form of food, medicines, and shelter, together with teams of skilled personnel able to undertake particular tasks, e.g. surgical teams, search and rescue groups. But, as described above, these inputs can only be really effective if properly co-ordinated , and this is where advance planning at both ends of the supply chain can pay dividends.

iii) Once the immediate effects have been dealt with, the much more difficult (and expensive) rehabilitation stage of the relief effort will come into effect. Again, co-ordination is crucial. All too often in the past we have seen well-meaning but ill-judged inputs which at best provide poor value for money, and at worst aggravate the situation. However, such co-ordination can be difficult to achieve, since responsibility for the work will normally have reverted to the line departments, from any central emergency control group. When one department is given the lead, as sometimes happens, it is not unusual to find a bias entering the work, due to that department's particular interests. For example, improvements to flood defences may be undertaken by an engineering department with little regard for agricultural needs.

THE PROACTIVE APPROACH

Thus far we have been considering actions to deal with a disaster situation as it evolves. Naturally we would prefer to avoid the occurrence altogether or, if this is not possible, to restrict its physical impact. Here the engineer and architect, have a particular responsibility. But other specialists can also assist, by tackling the environment within which the engineer must operate. In this context, one must consider the impact of:-

i) Population Growth

The fundamental difficulty facing the developing world is undoubtedly its burgeoning population. No other single factor has such an influence upon all aspects of a nation's ability to improve its lot. Quite apart from the steadily increasing burden which such growth imposes upon limited available resources, there are often distortions in the distribution of that demographic growth which greatly increase the risk from natural disasters. Here I am thinking of such factors as urban growth, and the spread of dense populations into exposed flood plains, similar coastal areas, or unstable hill-sides. All of these produce degrees of risk which could, in theory, be greatly reduced by adequate physical planning. In more general terms of course, desertification and deforestation are similar results of over population which give rise to natural disasters.

ii) The Legal Framework

In many developing countries there is inadequate legislation to empower government to limit risk from disaster. Such deficiencies range from land tenure to building codes, but the problem is the same. Unless government puts the necessary laws in place, little can be done to enforce prudent practices.

iii) Education

I have already referred to the need for training and public awareness. This requires an ingrained attitude to risk management which is not apparent in all societies. Cultural practices, often the result of religious impact, may seriously affect society's attitude to disaster and risk avoidance. This must be tackled with sensitivity, but the education system does offer the opportunity to introduce new attitudes.

iv) The role of the Professional

As I have attempted to suggest above, many factors will shape a nation's ability to cope with natural disaster. Within that framework it is clear that professionals in a wide range of disciplines can contribute significantly to the process. Each must identify the duty, and the potential contribution which he or she can make. But it is perhaps the engineers who bear the major responsibility for identifying the risks and proposing the solutions. This is particularly true when the solutions have financial implications, as they usually do. In such circumstances it is up to the engineers, architects, physical planners, etc. to effectively make the case for necessary investments. Not an easy task, especially in today's climate of financial stringency. But it must be here that the process of preventing human misery begins. Vested interests will inevitably react against such sensible preventative measures, but we have too many awful examples of the results of poor design, sub-standard construction, excessive cost-cutting and selfish disregard for the safety of others, to be able to live with our consciences if we fail to make our voice heard. And with care and ingenuity, the cost of reduced risk may not be that great.

Simple design practices can often significantly improve the strength of structures. This was amply demonstrated in San Francisco and Armenia. Sensible zoning can greatly reduce the numbers of people at risk.

CONCLUSION

Although we have greatly improved our ability to respond to natural disaster in the developing world, we have perhaps paid too much attention to reacting to situations, even in such matters as contingency planning.

Perhaps it is now time for professionals in a wide range of disciplines to focus their attention more closely on the means by which they can collectively produce an "enabling environment" within which developing world societies will be able to plan their development in such a way as to greatly reduce, or even prevent, significant natural disaster.

Right: Search and rescue operation on a collapsed six storey reinforced concrete apartment building (Kalamata earthquake, Greece, 1986)

THE HAZARDS FORUM: OBJECTIVES AND PROGRESS

Professor Sir Bernard Crossland, Past Chairman of the Hazards Forum

INTRODUCTION

The President of the Institution of Civil Engineers, A C Patterson CBE FEng, in his Presidential Address on the 1st November 1988 expressed the opinion that it was timely for professional engineers in Britain to be more visible in expressing their concern in the public interest for those matters relating to hazards and disasters that had an engineering content.

This initiative attracted wide interest and support. Exploratory discussions ensued involving members of the Institutions of Civil, Chemical, Electrical and Mechanical Engineers which resulted in a discussion meeting held on the 20th July 1989 when a proposal to set up a Hazards Forum was discussed. As a consequence of this discussion, the Hazards Forum was launched at a meeting on the 13th December 1989 with membership made up of:

Engineering Members - being those corporate bodies having a formal link with the engineering profession

Associate Members - being those corporate bodies of a discipline other than engineering who wish to participate in the work of the Forum

Affiliated Members - being those corporate bodies whose individual members practise in one or more specialities concerning hazards or related matters.

Currently the Hazards Forum has fourteen members, six associate members and three affiliated members who subscribe to its support.

MISSION

"The Hazards Forum exists to provide a national focal point in which engineering features in the mitigation and reduction of both man-made and natural hazards disasters."

The numerous inquiries which have been set-up to investigate major disasters during recent decades such as Flixborough, Herald of Free Enterprise, Hillsborough Football Stadium, King's Cross Underground Fire, Clapham Junction and Piper Alpha have demonstrated the importance of the recognition by management and engineers of their responsibility for the safety of the workforce and the protection of the public. This recognition applies not only to man-made disasters but also to natural disasters such as the Towyn Flood, where Departments of State and Local Government need to understand the potential for natural disasters and precautions which should be taken to reduce their severity, as well as planning relief to minimise the severity of the consequences. Engineers should be aware of the much greater risk of major natural disasters in earthquake zones and areas subject to tidal surges, cyclones and major flooding, and their responsibility as part of the world community to help in reducing the severity of such disasters in close consultation with the local population.

The recognition of the obligation of all chartered engineers to safeguard at all times the public interest in matters of health and safety led to the setting up of the Hazards Forum by many of the professional engineering institutions and some scientific bodies. The objective of the Hazards Forum is to provide a focus for engineers to consider the various aspects of preventing or ameliorating natural and man-made disasters, to co-ordinate initiatives aimed at greater safety in these areas, to make professional engineers more aware of their moral, professional and legal responsibility for health and safety and to serve as a platform for a more detailed discussion of the many scientific and sociological aspects of safety as well as cost benefit analysis.

The Forum recognises the expertise in these matters of all the institutions and other bodies in its membership. It aims to encourage these institutions to organise lectures, seminars or conferences for the broader community represented by the Forum. For example, the Institution of Chemical Engineers has been a leader in plant safety, particularly in the chemical and petrochemical industries, while the Institution of Electrical Engineers has been concerned with the analysis of safety critical systems involving computers, and the Institution of Structural Engineers has examined the safety problems associated with large crowds. However these areas of expertise are of great interest to other professional bodies in membership of the Forum. The role of the Forum is to recognise these common interests and to encourage a wider dissemination of information and ideas.

There are some specific areas which the Forum recognises and promotes itself. For example it believes that all undergraduate courses should contain a short awareness course on engineers' responsibility for safety, which it would like to see as a mandatory requirement. It has produced a syllabus which can be moulded to suit the particular engineering discipline. Currently it is trying to find financial support to produce the lecture material, and a range of associate case studies. The whole area of societal risk or the risk society may be prepared to accept is a matter of great debate and much concern to practising engineers. Consequently the Forum is promoting a discussion on societal risk involving engineers and sociologists. It is the role of the Forum to recognise these areas of common concern and to take action to increase the awareness of engineers.

ACTIVITIES TO DATE

The activities covered so far have been public lectures, seminars and conferences organised by the Forum or by one of the member bodies at the instigation of the Forum, and publication lectures:

Lectures:

Sir Frederick Warner - Major Man-Made Hazards over the last 2 Decades and the ensuing Inquiries.

Prof R W Severn and Dr A Patterson - Earthquakes (with particular reference to the Armenian Earthquake)

Sir Bernard Crossland - The King's Cross Disaster and subsequent Inquiry.

M Winney - The San Francisco Earthquake

Dr P A Bennett - Sofware in Safety-related Systems

Prof. R Farmer - Probabilistic Risk Analysis

J Whittle, J S Hopkins, Dr M W Horner and Prof P O Wolf - Floods and Gales

Dr J Brownscombe, F Low, K Riddell and Dr R Bailey - River Flood Hazards

R Green - The Impact of Psychological Factors on Engineering

Dr C Baker, Dr J C R Hunt, M J Prior and Dr T A Wyatt - Wind and Wind Pressures

A C Barnell and Dr T J Evans - Interactive Safety Training

Dr A A Wells - The Clapham Junction Rail Collision - General and Engineering Aspects

Prof F Lees - Piper Alpha: The Disaster, the Inquiry and the Lessons

R S Dobson - Tsunamis

Dr P A Bennett - Safety Critical System-So What...?

Seminars and Conferences:

Earthquakes - their impact on the community (half day)

Earthquakes, Hurricanes and Floods (one day international seminar)

Social and Economic Impact of Floods (half day)

Bangladesh (one day)

Engineers' Response to Disaster Preparedness (one day)

The Successful Management for Safety (two day international conference)

Publications:

Avoiding Disasters, Vols. 1, 2 & 3 - Papers and abstracts of the meetings held.

Annual Reports for 1990, 1991 and 1992.

Newsletter - Short notes of meetings, notice of forthcoming meetings organised by the Forum or member institutions and book reviews. It is published quarterly.

An Engineers' Responsibility for Safety - a proposal for an undergraduate awareness course.

CONCLUDING REMARKS

The Hazards Forum is well and truly launched and it has had the effect of increasing the awareness of its member bodies of their members awareness and responsibility for safety. A major problem is that of communication with the membership of the member bodies, so that they are aware of the activities of the Forum. Currently the Forum is seeking funds from trusts, the insurance industry and the manufacturing and transport companies to sponsor a major named lecture, and to support the development of teaching and case study material for the proposed awareness course.

MEMBERSHIP OF THE HAZARDS FORUM

Engineering Members

Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Electrical Engineers
Institution of Gas Engineers
Institution of Incorporated Executive Engineers
Institution of Mechanical Engineers
Institution of Mining Engineers
Institution of Nuclear Engineers
Institution of Railway Signal Engineers
Institution of Energy
Institution of Marine Engineers
Institution of Quality Assurance
Royal Aeronautical Society
Royal Academy of Engineering

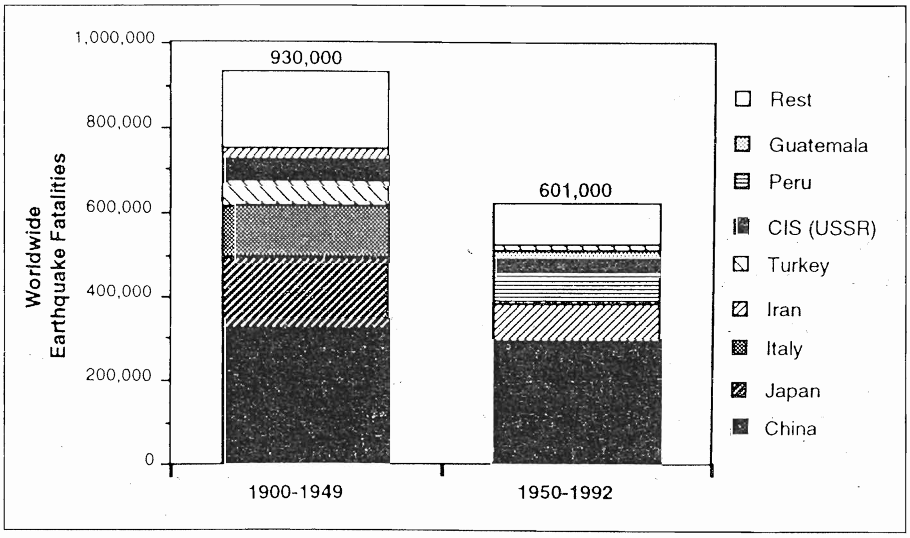
Affiliated Members

British Hydrological Society
Institute of Fire Safety
Institute of Hydrology

Associate Members

Institute of Physics
Royal Meteorological Society
Royal Society of Chemistry
Society of Chemical Industry
University of Aberdeen
The Meteorological Office

Below: Worldwide earthquake fatalities during the two halves of the 20th century and the countries that suffered most loss of life (after Pomonis, Coburn and Spence)



MEGACITIES AND BUILDING FOR SAFETY

S N Mustow, President-Elect, Institution of Civil Engineers

This article introduces the work being undertaken for IDNDR by the Institution of Civil Engineers, under the aegis of the World Federation of Engineering Organisations (WFEO) and the Union des Associations Techniques Internationales (UATI).

As international Non-Governmental Organisations (NGOs), WFEO and UATI are ideally placed to supplement the work of National Committees with a programme of international projects. The projects, approved by the United Nations' Scientific & Technical Committee, are:

A: Urban developments and their vulnerability to natural disasters, with particular reference to megacities.
B: Design and construction of buildings and structures to withstand natural disasters.
C: Roving seminars.
D: Cyclonic disasters in the Bay of Bengal.
E: Case studies eg. Lake Nyos (West Africa).

Projects C, D and E are being progressed through UATI, based in Paris. Projects A and B are being carried out at the Institution of Civil Engineers, by groups of selected experts, at the invitation of WFEO and UATI. Interaction and exchange of ideas and information between the two projects will be significant, although their objectives differ.

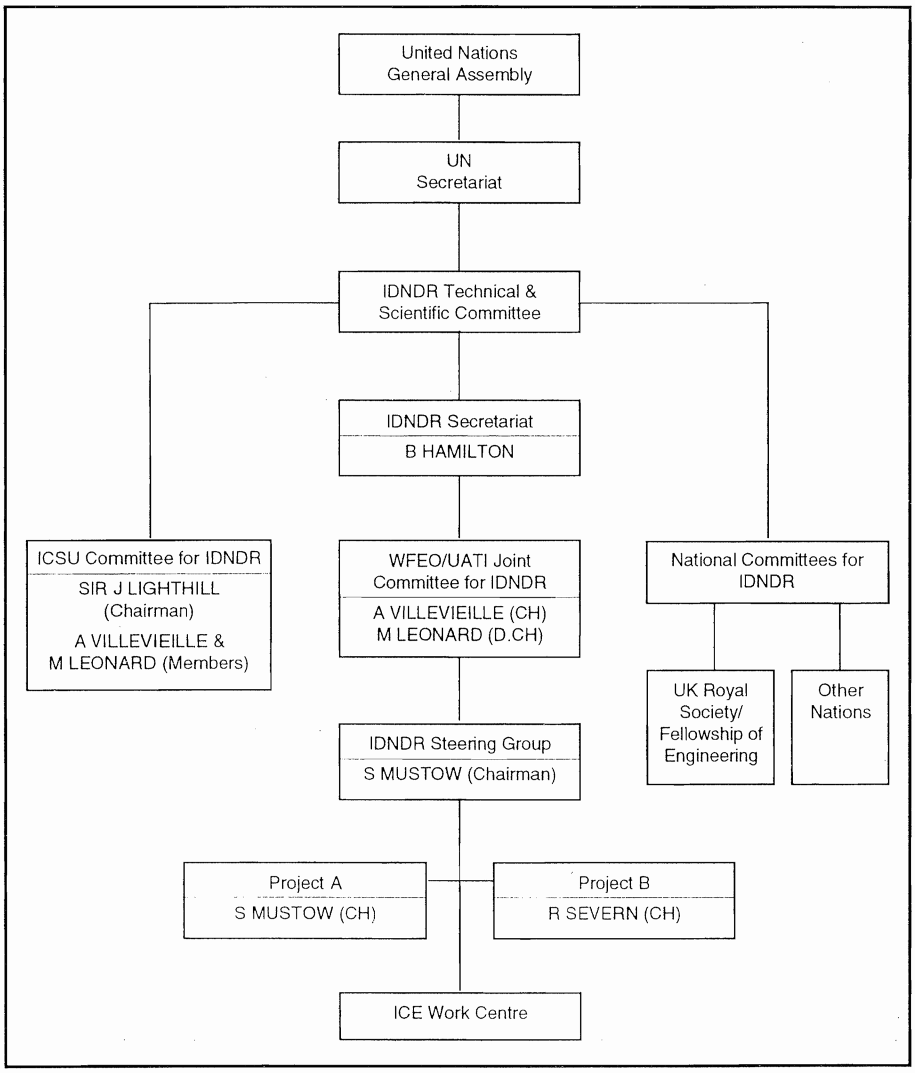
The ICE is proud to be involved in this endeavour, in which it has received substantial assistance from the Overseas Development Administration of the UK.

The organisation chart above displays the lines of responsibility.

THE MEGACITIES OF THE DEVELOPING WORLD

Project A: Urban developments and their vulnerability to natural disasters with particular reference to megacities

One of the greatest challenges facing the world today is the population explosion. In the cities of the developing world, where natural increases are compounded by high levels of migration, the challenge is especially acute.



Above: IDNDR Megacities project responsibility and communication chart

In the developed world, urban populations are stabilising. By comparison, in the developing world growth is such that the number of 'megacities' (urban conurbations with populations of 8 million or more) has risen from 5 in 1970 to 14 in 1990, and is forecast to reach 20 by the year 2000. The number of smaller but still substantial cities, of between 2.5 and 8 million, will rise from the current total of 49 to 67 by 2000.

Many of these are situated in areas which are susceptible to natural hazards such as floods, windstorms, earthquakes and sea surges. The risk to life, property, infrastructure and the economy will be, within a densely populated area, correspondingly greater.

Within the cycle of disaster management, attention is most commonly focused on post-disaster response and rehabilitation. The Institution considers that preparation and pre-disaster planning are far more effective in the long-term; it is in these areas that the contribution of civil engineers is invaluable.

Therefore, the motivation for Project A can be summarised as follows:

"To reduce the vulnerability of urban developments, particularly megacities, to the effects of natural hazards by increasing awareness of the risks, by skilled engineering of buildings, structures and infrastructure, and by delineating the contributions of administrators, planners, social scientists, health care providers and other professionals."

To achieve this objective, the project will produce a practical manual, of maximum utility to national and municipal governments. The manual will define procedures for assessing risk, establishing codes of practice, and implementing mitigation measures; in order that disaster mitigation becomes integral to the planning and implementation of new development. It is hoped that this manual will be a useful tool and stimulus, encouraging municipalities to bid for and improve resources for preparedness and to implement measures for disaster mitigation before disaster occurs.

The Project team is adopting a multi-disciplinary approach to these complex problems; however, it is appropriate that the work is led by civil engineers, the profession that creates the infrastructure that provides the veins and sinews of municipalities. The vulnerability of a megacity lies in its buildings, structures and lifelines. Many solutions to the risks of natural hazards affecting megacities lie with civil engineers.

Three megacities in the developing world have been selected for detailed study, in order to focus the project and to identify specific areas of vulnerability and responses. These are Karachi (Pakistan), Jakarta (Indonesia), and Metro Manila (the Philippines). Initial visits to these cities by the Steering Group Chairman and Project Leader, in June of this year, confirmed that the aims and objectives of the Project were understood and welcomed. Further site visits will take place in January 1994.

The initial visits identified many ways by which the vulnerability of megacities to natural hazards could be reduced, at international, national and regional levels.

For example, there is a need for a comprehensive internationally accepted methodology for disaster mitigation, which can then be applied to the specific circumstances of the individual nation.

At the national level, the main requirement is for a disaster management strategy, which can be used as the basis of funding applications to international agencies. Making budget allocations, enhancing public awareness and reviewing progress in disaster mitigation are also important tasks. At regional or municipal level there is a need for accurate scientific data, to assess a city's vulnerability and to establish priorities for disaster mitigation. Many actions are required, from a range of people and organisations.

The manual will include comprehensive recommendations, together with a methodology showing how the recommendations can be implemented.

BUILDING FOR SAFETY

Project B: Design and construction of buildings and structures to withstand disasters

The Project B team comprises experts in structural dynamics and earthquake engineering, under the Chairmanship of Professor Roy Severn of Bristol University, a Past President of the Institution. The project focuses on practices within the construction industry, addressing themes such as the implementation of building codes and standards, and quality assurance.

By undertaking seven interrelated studies that focus on imperfectly engineered reinforced concrete structures, the Project aims to identify factors affecting their ability to withstand disasters. The scope of the Project is limited to hazards that directly impact on structures, primarily earthquake and windstorm.

Each study covers specific aspects of the theme, centred upon a particular location. They can be described as follows:

Sub-Project 1: Low Cost Reinforced Concrete Housing in Urban Locations in the Philippines

This study aims to establish the perceived problems in ensuring the resistance to earthquakes and extreme winds of low cost housing, focusing on the Luzon area, four years after its damage by earthquake.

Sub-Project 2: Development of Liquefaction Resistant Bridge Design

To raise interest in the problems created by liquefaction, and to generate potential solutions, an International Ideas Competition is being run with a prize provided by sponsors.

Sub-Project 3: Earthquake Preparedness and Seismic Design Practice in Egypt

A destructive earthquake hit Cairo on 12 October 1992, highlighting the shortcomings of emergency management and deficiencies in design and construction practices. The study of the effects of this earthquake, leading to identification of post-earthquake priorities, will be applicable to other countries in the Middle East and 'developing' regions of the world.

Sub-Project 4: Wind Effects in the West Indies

This sub-project concerns losses from hurricanes in Jamaica. Following significant damage from recent major hurricanes and storms, efforts were made to improve education and design practices, in order to reduce the scope for damage in the future. This process was instrumental in reducing the damage to Jamaica in the most recent hurricane to hit the island; it could therefore provide lessons of benefit to other regions, and help to direct the resources of the IDNDR working groups.

Sub-Project 5: Reassessment of the Erzincan Earthquake Case Study, Turkey

This sub-project will begin with a critical analysis of the document entitled "Case Study of Erzincan Earthquake of 13th March 1992", and of papers presented at the Istanbul Conference on Erzincan, held during March 1993. These will be used as background sources in preparing a report on structural damage to reinforced concrete and its implications for existing codes.

Sub-Project 6: Application of Earthquake Protection Measures in the Construction of Reinforced Concrete Structures in Greece

Recent earthquakes have triggered a substantial revision of codes and regulations, aiming to reduce future vulnerability. This sub-project will focus on houseowners and developers using reinforced concrete construction; it will assess the ways in which they learn about safe building techniques, their definitions of acceptable risk, and their choice and implementation of preventive measures.

Sub-Project 7: Seismic Hazard Auditing of Buildings in Colombia

The purpose of this sub-project is to evaluate the susceptibility to earthquake induced failure of various classes of structures (common dwellings, engineered buildings, hospitals, etc.) in the Colombian city of

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UK CONTRIBUTIONS TO THE IDNDR: MEDICAL ASPECTS

Dr Peter J Baxter MD FRCP, University of Cambridge

For years the attitude of health professionals in the developed countries to disasters has been governed by numerous myths which have only recently started to become dispelled. The IDNDR, with its emphasis on fostering research and the application of science and technology should lead to a more enlightened approach. It is important that the IDNDR does not create a false aura of its own that high technology by itself will achieve the goal of disaster reduction and the saving of lives. Disaster prevention requires a much greater understanding of the hazards and risks of natural disasters, together with the factors that increase the vulnerability of populations. To understand the numerous health impacts in different types of disasters will require a multi-disciplinary effort involving a range of scientists and health professionals in disaster preparedness.

Health professionals in developed countries are at last beginning to appreciate that the following widely held axioms are untrue:

- *A disaster is the overwhelming of normal functioning, e.g. in a hospital.* A true disaster constitutes a qualitative, not just a quantitative, difference in that demand cannot be adequately met by the society affected without help from outside areas or countries. The hospitals and health facilities may be nearly totally destroyed. The hallmark of a disaster is chaos.

- *A large influx of health care workers will be needed in the post impact phase of a disaster.* They may not be - some disasters may cause large numbers of deaths but leave very few casualties. Generally the role of medicine in reducing deaths and injuries in disasters is very limited and the only way of making a major impact in the future will be by enhanced pre-disaster planning and emergency preparedness.

- *Sophisticated medical supplies and field hospitals and vaccination programmes are needed after disasters.* They are not - but there may well be a demand for reconstructive or orthopaedic surgery for years later, long after the publicity is over.

- *Medical teams from developed countries are needed in disasters in developing countries.* Most lives will be saved by prompt actions within the first few hours of the impact by survivors and any intact local emergency services, certainly before 24-48 hours have elapsed. By the time foreign teams arrive the hospital attendance rate may have fallen back to normal levels. Local communities need to be trained in first aid and rescue.

- *Relief supplies should be despatched to disaster areas as rapidly as possible.* Actually it is better to delay the sending of aid until a proper assessment of need has been made.

- *Different types of natural disaster have little in common and as each disaster is unique there is not much point in making specific disaster plans.* In fact all disasters have a common framework as far as planning and response are concerned and the management of casualties has many common features.

The main health objectives of disaster management include:

- prevention or reduction of mortality due to the impact, to a delay in rescue and to lack of appropriate care

- provision of care for casualties such as immediate post-impact trauma, burns, and psychological problems

- management of adverse climatic and environmental conditions (exposure, lack of food, and drinking water)

- prevention of short-term and long-term disaster morbidity, e.g. outbreaks of communicable diseases due to disruption of sanitation, living in temporary shelters, overcrowding and communal feeding; epidemics such as malaria due to interruption of control measures; rise in morbidity and mortality due to disruption of health care systems; mental and emotional problems

- ensuring restoration of normal health by preventing long-term malnutrition due to disruption of food supplies and agriculture

- re-establishing health services

A one-day Workshop entitled "*Medicine in the IDNDR: Research,*

MEGACITIES

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Buenaventura. It will centre around the application of a hierarchical model for hazard auditing, currently being developed at Bristol University.

Results from the seven sub-projects will be consolidated into a final report, which is intended to benefit both the formal and informal sectors of the construction industry in the developing world.

CONCLUSION

In May 1994, it is intended that an interim report will be presented on both Projects at the UN Scientific & Technical Committee Conference in Yokohama. This report will include recommendations for action, and targets for the year 2000, which cover the field of disaster mitigation.

Full reports of both Projects are due for completion by the end of 1994, and publication early in 1995.

It is hoped that these projects will make a valuable contribution to the IDNDR programme and help to relieve the suffering and economic damage caused by natural disasters. In particular, it is intended to provide a framework within which international funding agencies can direct resources for the development of disaster mitigation plans. The problems are vast and the effort required is huge, but by applying the engineer's methodical and logical approach, we hope that much can be achieved by the end of the decade .

Preparedness and Response for Sudden Impact Disasters in the 1990s" was held at The Royal Society on 19 April 1993. Some of the objectives for completion in the IDNDR in the UK which emerged from the Workshop included:

- improving ways of rapidly deploying appropriately trained UK health-related personnel in disasters
- developing skills of UK professionals in disaster assessment and epidemiological surveillance
- widening medical involvement to include community preparedness for a disaster, including sociological aspects, preferably develop a major project in a developing country along these lines
- establishing a multi-disciplinary scientific team capable of rapid deployment to study building types and deaths and injuries in earthquakes, and possibly in volcanic and other types of disaster
- stimulating the development of disaster medicine and epidemiology in the post-graduate training and research of physicians and surgeons
- developing cross-speciality links between the fields of health care, sociology and anthropology, engineering, geosciences, meteorology, etc., to devise new multi-disciplinary projects in disaster reduction.

The UK is fortunate in having a large pool of enthusiastic and highly trained health care professionals who would be willing to become involved in disaster activities. A major educational initiative is needed to overcome the myths about disasters and to clarify the aims of disaster management. At the same time new ways need to be devised to channel the interests of those who wish to gain experience in disaster reduction.

IDNDR CONFERENCE: PROTECTING VULNERABLE COMMUNITIES

A United Kingdom contribution to the International Decade for Natural Disaster Reduction

The preceding articles present an overview of the United Kingdom's contributions to the International Decade of Natural Disaster Reduction (IDNDR). The articles are extended abstracts of papers to be presented at the Wednesday afternoon session of the Conference at the Institution of Civil Engineers.

The IDNDR Conference **Protecting Vulnerable Communities** to be held on 13th - 15th October at The Royal Society, London, will bring together scientists, planners and engineers to highlight and discuss how their knowledge can be applied to reducing the effects of natural disasters such as tornadoes, floods, earthquakes and volcanoes. The Conference is supported by The Royal Society, The Royal Academy of Engineering and the Society for Earthquake and Civil Engineering Dynamics.

The Society for Earthquake and Civil Engineering Dynamics (SECED) has played a leading role in the organisation of the Conference. Half of the Organising Committee are SECED members.

A special thanks goes to the Organising Committee and Conference Sponsors for bringing together UK and overseas organisations to make this contribution a truly international event.

The Organising Committee comprises **Dr Robin Adams**, International Seismological Centre; **Dr Chris Browitt**, British Geological Survey; **Dr Ian Davis**, Managing Director, International Development and Emergency Relief Consultants Ltd; **Dr Peter Merriman** (Chairman), British Nuclear Fuels plc; **David Oakley**, Consultant, Disaster Preparedness; and **Professor Brian Wilkinson**, Director of the Institute of Hydrology. Drs Adams, Browitt and Merriman are SECED Committee members.

The Conference Sponsors are British Nuclear Fuels plc, British Geological Survey, The Royal Society, The Royal Academy of Engineering, The Insititution of Civil Engineers and the Overseas Development Administration.


Dr Robin Adams


Dr Chris Browitt


Dr Ian Davis


Dr Peter Merriman (Chairman)


David Oakley


Professor Brian Wilkinson

RECENT NOTABLE EARTHQUAKES (1980 - 1993)

A world review by the British Geological Survey

The British Geological Survey records and reports data from earthquakes in all parts of the World. Clearly, the most significant events for most British organisations are those which occur in and around the British Isles or on the nearby Continent. More distant events, however, are important too: whether they are the target for rapid humanitarian aid (at British export sites) or the source of data for the further understanding of seismic hazard, earthquake processes or the structure of the Earth. Of particular interest are the relatively small earthquakes, with Richter magnitudes less than 6.0, which nevertheless prove to be seriously damaging: casting light on the possible rare event which could occur in the UK.

In human terms, the most notable earthquakes are those which cause serious casualties and significant damage, rather than simply the strongest in terms of energy or Richter magnitude (M_s). Ten or more earthquakes with magnitudes over 7.0 occur every year, but often with epicentres in remote or oceanic areas where they prove to be of little consquence for humanity; whereas earthquakes with magnitudes not much more than 5.0 can prove to be devasting when they occur close to a major conurbation. When a major earthquake strikes a highly populated area, the consequences can be disastrous.

In the following we summarise the notable World earthquakes since 1980 from a British viewpoint. Their significance is primarily in human terms and only secondarily in terms of magnitude. Magnitudes quoted are normally Surface Wave Magnitude (M_s) which is the most appropriate measure of large, shallow, earthquakes. Other magnitude formulations (m_b, M_L) are occasionally quoted where they are more appropriate because of greater depth or smaller size.

The 1980s began with two major world earthquakes in the autumn of 1980. The magnitude 7.3M_s Algerian earthquake of 10 October 1980 claimed the lives of 3,500 people and caused extensive damage in the El Asnam area. Just a few weeks later, on 23 November, southern Italy was struck by a magnitude 6.8M_s event which caused the death of 3,000 people and extensive damage around the Naples area. El Asnam was built on ruins which had resulted from a past major earthquake and the seismic hazard was well known. Poor quality building standards and maintenance contributed significantly to the damage that resulted from the Italian earthquake.

A little reported magnitude 6.7M_s earthquake, on 11 June 1981, resulted in the deaths of over 3,000 people and much destruction in the Kerman region of southern Iran. Another event in the same general area on 28 July 1981 killed 1,500 people and caused further extensive damage.

An area with relatively little previous history of earthquakes, the Western Arabian Peninsula, was struck on 13 December 1982 by a magnitude 6.0M_s event which resulted in the deaths of 2,800 people and destroyed about 300 villages in Yemen.

The major earthquakes of 1983 were generally away from populated areas. However, a magnitude 6.9M_s event resulted in the deaths of 1,342 people in the Erzurum and Kars provinces of eastern Turkey on 30 October of that year. Fifty villages were destroyed by this earthquake and 25,000 people were left homeless. Another area with a modest past experience of earthquakes, Guinea in West Africa, suffered extensive damage and the deaths of 443 people as the result of a magnitude 6.2M_s earthquake on 22 December 1983.

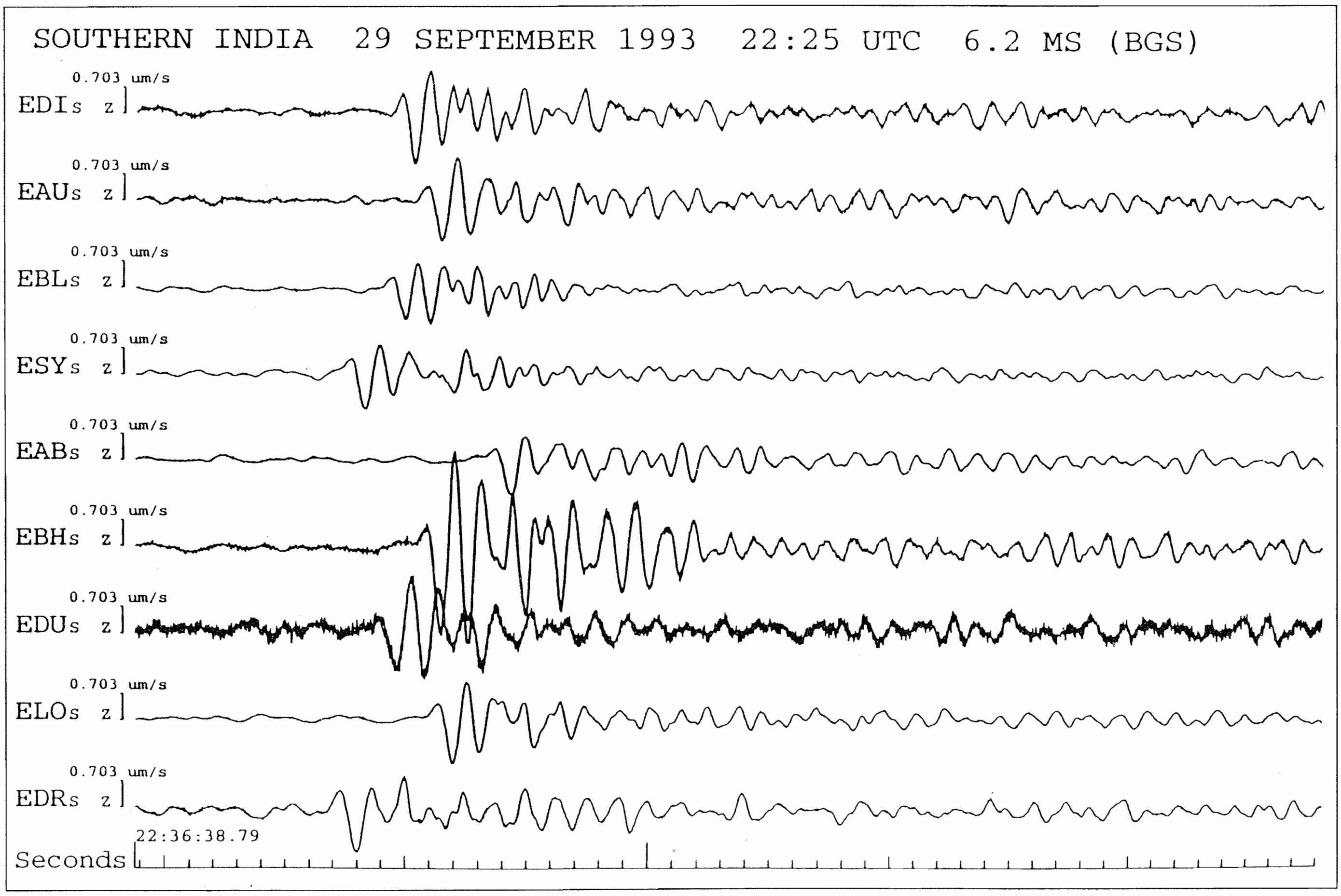
The year of 1984 was relatively uneventful, as regards earthquakes, worldwide. The British Isles, however, experienced its largest earthquake since 1931 as a magnitude 5.4ML event struck the Lleyn Peninsula of North Wales, causing minor damage in the epicentral area. The earthquake was felt throughout most of Wales, eastern Ireland, England and southern Scotland.

The first 'great' earthquake (magnitude $> 8.0M_s$) of the decade struck Mexico on 19 September 1985. This magnitude 8.1M_s earthquake resulted in the devastation of parts of Mexico City and the deaths of at least 9,500 people even though the epicentre was on the coast almost 400 kilometres away. The nature of the lake bed sediments, on which large parts of Mexico City are built, and the presence of many high-rise buildings, resulted in strong amplification effects with buildings between 8 and 18 stories high being the worst affected. A major aftershock, on 21 September, caused further casualties and damage in the Mexico City area.

Southern Greece was struck by a magnitude 5.9M_s earthquake which killed 20 people and resulted in damage to about 1500 buildings in the Kalamai area on 13 September 1986. The El Salvador earthquake of 10 October 1986 was, however, the most remarkable of the year. This event, with a magnitude of only 5.4M_s resulted in the deaths of over 1,000 people and caused severe damage in the San Salvador area. A shallow focal depth, the proximity of the epicentre to a highly populated area and possibly poor building standards, contributed to the exceptional devastation generated by this 'moderate' earthquake. It is worthy of note that the Dogger Bank earthquake 60 miles off the east coast of England in 1931 had a magnitude of 5.5M_s and, despite its distance, caused damage to property widely down that coast.

A 'great' earthquake occurred in the Kermadec Islands region on 20 October 1986. This magnitude 8.2M_s event knocked objects off shelves on Raoul Island and was felt at Napier and Wellington, New Zealand; however, little other damage was caused and the tsunami generated was small. This was the largest world earthquake since 4 February 1965 when an event of the same magnitute struck the Aleutian Islands.

Landslides and extensive damage occurred as a result of a magnitude 6.9M_s earthquake in the Colombia-Ecuador border region on 6 March 1987. Approximately 1,000 people were killed by this earthquake. Damage to an oil pipeline led to considerable economic disruption: an instance of how modern society can



Above: Seismograms of the earthquake in Southern India on 29 September 1993, recorded by the British Geological Survey seisometers in Edinburgh.

be vulnerable to earthquakes in new ways.

Early 1988 saw the surprising occurrence of three earthquakes in excess of magnitude $6.0M_s$ in an area of northern Australia where only microseismicity had been recorded previously: all on 22 January. The biggest event, with a magnitude of $6.7M_s$, caused damage in the small town of Tennant Creek and was felt over two-thirds of Australia. A 32km fault rupture could be traced at the surface. Happily, no casualities resulted from these earthquakes; however, events later in the year were to prove far more deadly. First, a magnitude $6.6M_s$ earthquake, on 20 August 1988, resulted in 1,000 deaths and extensive damage in northern Bihar, India. Then, on 6 November, 730 people were killed by a magnitude $7.3M_s$ event on the Burma-China border which caused severe damage in the Lacang-Menglian area of China. However, the Armenian earthquake of 7 December 1988, magnitude $6.8M_s$, proved to be by far the most deadly of the year, killing 25,000 people, injuring 13,000 and leaving 500,000 homeless. A shallow depth of focus, an epicentre near to population centres and poor building design and construction in a known seismic zone, all contributed to the scale of the disaster.

The most deadly earthquake of 1989 proved to be the Tajik event of 22 January with the loss of 274 lives. A mudslide generated by this magnitude $5.3M_s$ earthquake was repsonsible for the destruction of two villages resulting in most of the casualties.

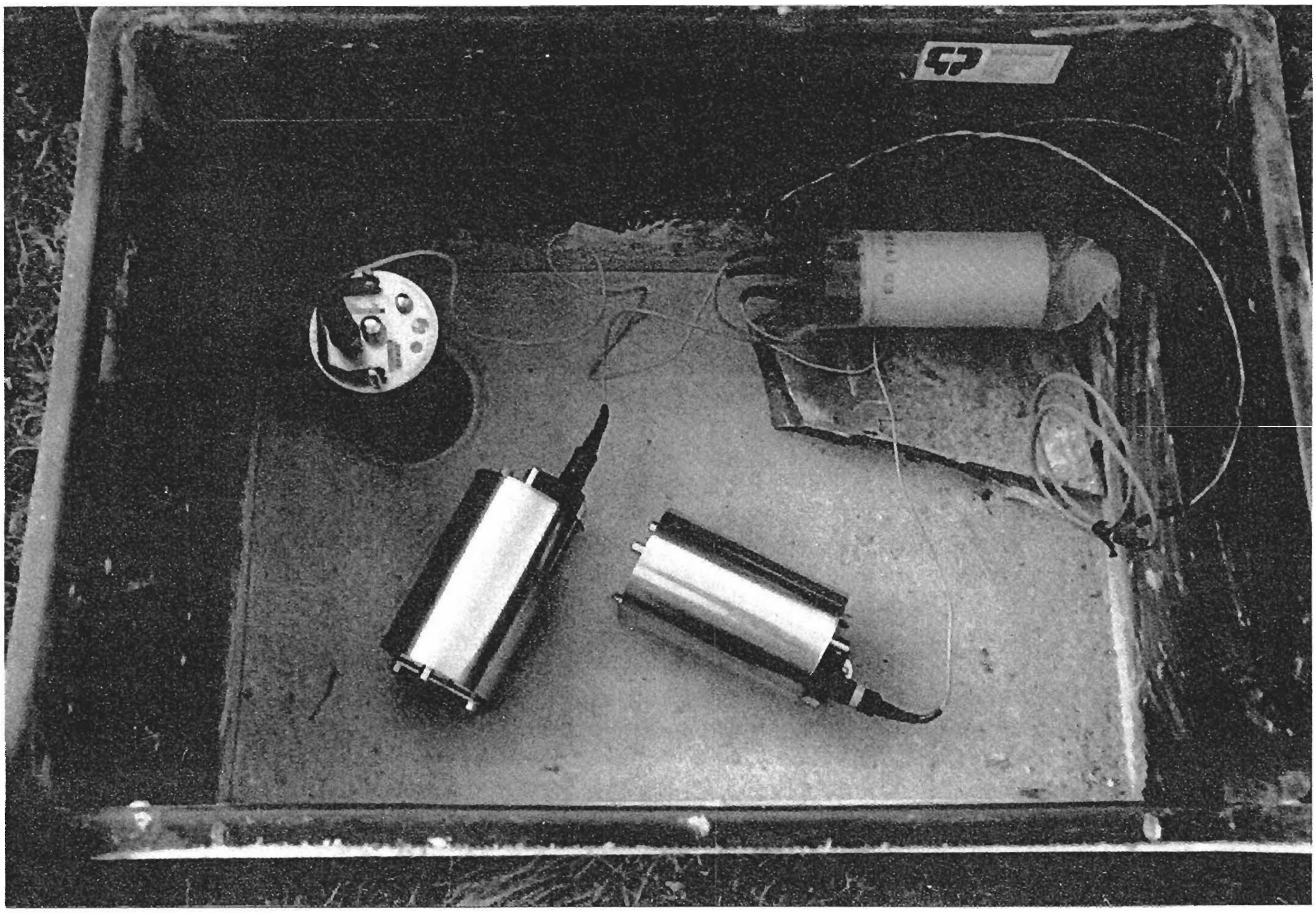
The third 'great' earthquake of the decade occurred on 23 May 1989 with a location in the MacQuarie Islands region, south of New Zealand. This magnitude $8.2\ M_s$ event was felt on a few remote islands and very slightly on South Island, New Zealand, but no damage was reported, and the British press, at least, took no interest despite its size.

California was also struck by an earthquake during 1989. The Loma Prieta earthquake of 18 October 1989 had a magnitude of $7.1M_s$ and resulted in the deaths of 62 people. The San Francisco Bay area was particularly badly affected by damage, especially where land-fill and Bay muds resulted in amplification effects. An estimated $5.6 billion damage was caused. Nevertheless, the relatively low death toll, when compared for instance with the Armenian earthquake, bears witness to the benefit of well enforced building codes.

The town of Newcastle, eastern Australia, an area with a seismic hazard not dissimilar to that of the United Kingdom, experienced a magnitude $5.4m_b$ earthquake on 27 December resulting in the deaths of 12 people and causing severe damage in the town.

The United Kingdom experienced its second 'large' earthquake in the period with a magnitude over $5.0M_L$ on 2 April 1990. With a magnitude of $5.1M_L$ and an epicentre near to the town of Bishop's Castle on the Shropshire-Wales border, this event caused minor damage in Shrewsbury, Wrexham and Welshpool as well as in the epicentre area. It was felt throughout most of England and Wales.

The year of 1990, moreover, proved



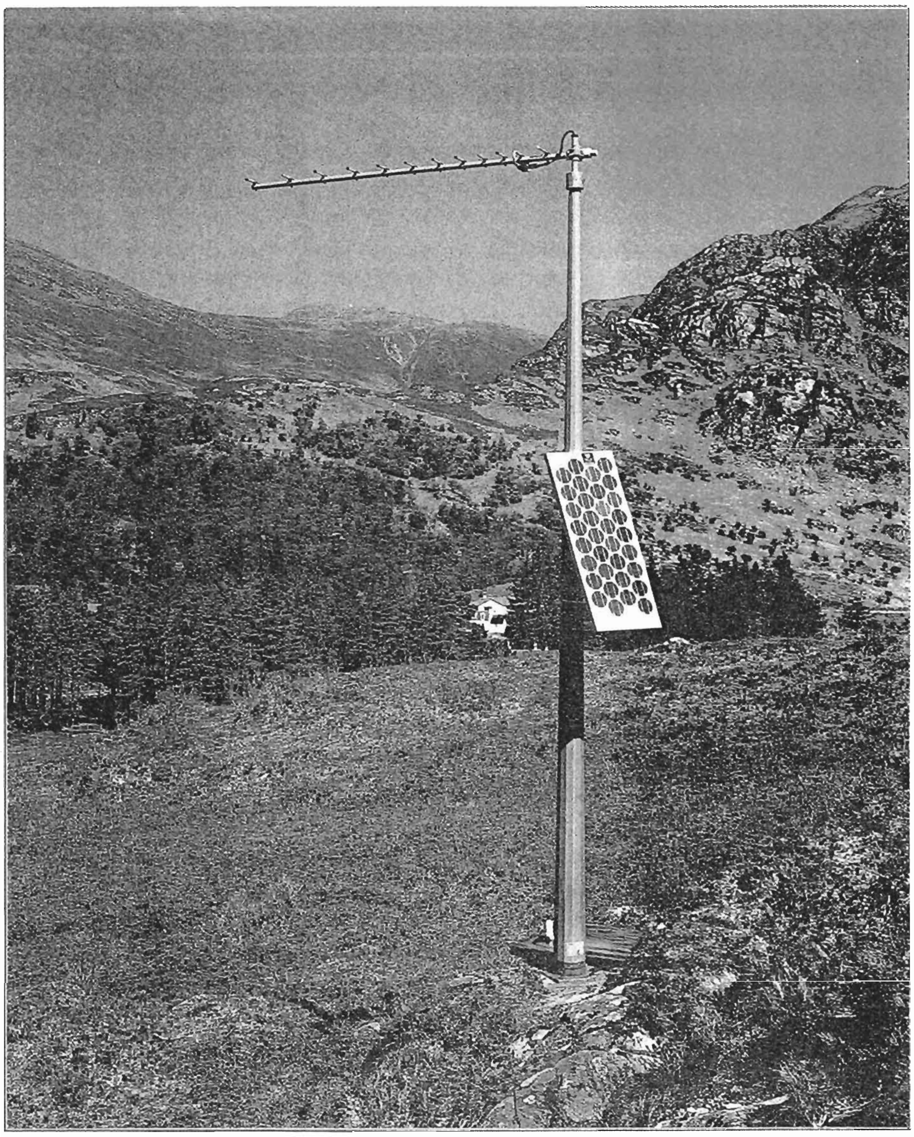
Above: A typical British Geological Survey three component seismometer pit

to be an exceptionally deadly year worldwide in terms of earthquakes, with the magnitude 7.7 M_s, Iran earthquake of 20 June which killed between 40,000 and 50,000 people. This was the largest death-toll since the 1976 Tangshan, China, earthquake. In addition to the deaths, 60,000 were injured and 400,000 were made homeless. Nearly all the buildings were destroyed in the towns of Rudbar and Manjil. The earthquake was felt throughout much of northwestern Iran and Azerbaijan. A further 1,621 people died in the Philippines when a magnitude 7.8M_s earthquake occurred on the island of Luzon, causing severe damage, landslides and liquification. A relatively small earthquake, 5.4m_b, caused the deaths of 19 people in Sicily on 13 December 1990. It also injured 200 people, made 2,500 homeless and caused severe damage in the Carlentini area.

A number of large earthquakes resulted in casualites and deaths in 1991, but not on the scale of those of 1990. The Hindu Kush, northern Peru, Costa Rica and the western Caucasus were all affected by large damaging earthquakes which caused fatalities. Earthquakes accompanied the volcanic eruption of Mount Pinatubo in the Philippines in June in which 137 people died. The largest number of casualties occurred in Northern India on 19 October 1991 when a magnitude 7.1M_s event killed 2,000 people and destroyed 18,000 buildings. A particularly small event (4.6m_b) caused the death of 10 people in Yemen on 22 November.

Twenty-three earthquakes with magnitudes over 7.0M_s occurred during 1992, by far the largest annual number of such events since before 1980. A number of these were in populated areas and caused casualties and damage. Again, however, some smaller events proved also to be damaging due to their location near to heavily populated areas. The first event to cause significant casualties was the magitude 6.8M_s Erzincan earthquake in eastern Turkey on 13 March. Severe damage and landslides occurred and 498 people were killed. On 13 April a magnitude 5.2M_s earthquake caused significant damage at Roermond, Netherlands, and Heinsberg, Germany. One person died of a heart attack in Bonn and twenty people were injured. The earthquake was felt slightly in parts of England.

California suffered several major earthquakes during 1992, the largest, with a magnitude of 7.6M_s, caused 3 deaths and injury to 400 people. Damage was substantial in Landers and the Yucca valley. This, the largest Californian earthquake since 1952, occurred in a relatively sparsely populated area which limited the consequences. Nevertheless, the damage was estimated at $92 million. Kyrgyzstan was struck by a magnitude 7.4M_s earthquake on 19 August killing



Right: Typical British Geological Survey remote, solar-powered earthquake monitoring station

75 people and causing severe damage over a wide area. A 7.2M_s earthquake near the coast of Nicaragua on 2 September proved to be damaging because of the tsunami it generated. Over 116 people were killed and many houses and fishing boats were destroyed on the west coast of Nicaragua.

The Cairo area of Egypt was struck by a magnitude 5.2M_s earthquake on 12 October 1992. Despite its relatively small magnitude, 541 people were killed, 6,500 were injured and 8,300 buildings were damaged or destroyed. This 'moderate' earthquake, with an epicentre near a major conurbation, proved again that even a relatively low seismic risk should not be ignored. The most disastrous earthquake of 1992 proved to be the Flores Island event of 12 December. Over 2,200 people were killed by the combined effects of the earthquake and the tsunami it caused. Most of the town of Maumere was destroyed.

Until the end of August 1993, the most damaging earthquake of the year was the Hokkaido, Japan, event of 12 July. This magnitude 7.6M_s earthquake caused the death of at least 200 people and severe damage in south-west Hokkaido both as a result of the earthquake and of the related fires, landslides and tsunami. A 'moderate' event (5.2M_s) near Khartoum in Sudan on 1 August caused the deaths of 2 people and some damage. The first event to reach magnitude 8.0M_s since 1989 occurred on 8 August 1993 south of the Mariana Islands. There were no fatalities but 40 people were injured and there was considerable damage on the island of Guam. Port facilities were heavily damaged.

In central southern India, villages in Maharashtra were destroyed by an earthquake on 29 September 1993, at 22.25UTC. Richter magnitudes were assigned as 6.2 (British Geological Survey) and 6.3 (US Geological Survey) making this a moderate earthquake. Worldwide, such events occur at a rate of one each week on average. The shallow depth of the earthquake, the lack of previous history of such events in the region and the vulnerability of local buildings all contributed to the ensuing disaster. Up to 25,000 fatalities are expected.

Since the start of 1980 until the end of September 1993 there have been four great earthquakes, with magnitudes over 8.0M_s, worldwide. This averages one per 3.4 years, which is low compared with the average for this century of about 1 per year. There was an annual average of about 11 'major' earthquakes with magnitudes between 7.0 and 7.9M_s compared with a long term average of 18 and there were about 102 'strong' events per annum as opposed to a long term average of 120 (6.0 - 6.9M_s). 'Moderate' events (5.0 to 5.9M_s) occurred on average about 1,560 times a year. The United Kingdom experienced 2 events over 5.0M_L, 3 between 4.0 and 4.9M_L and over 30 between 3.0 and 3.9M_L (2.4 per annum on average) in the same period. In the 13.7 year period, over 120,000 people have died in earthquakes worldwide, averaging 8,700 per year, a figure which could be significantly reduced if the understanding and technical knowledge available in the world were more effectively and widely applied.

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EARTHQUAKE IMPACT REDUCTION

by Chris Browitt, British Geological Survey

Introduction

In the past 20 years, losses from all natural disasters have been estimated at 3 million deaths, hundreds of billions of dollars and the disruption of the lives of 15% of the world's population. Earthquakes are the greatest contributor, accounting for over half of the deaths this century and the scale of individual events can be awesome. The Tangshan earthquake of 1976 killed up to 650,000 people. The estimated cost of the next great earthquake in Tokyo is $200 billion and in San Francisco is $50 billion despite their disaster mitigation programmes. In recent years, 90% of deaths from natural disasters have occurred in developing countries where vulnerability is increasing. World population has quadrupled this century and urbanisation has increased from 14% in 1900 to 45% at the present time with much of this expansion in vulnerable coastal areas. As a result, there has been a significant increase in disasters and losses owing to greater exposure to the hazards.

In the 1980's, geophysicists and engineers have been reminded of lessons to be learnt if we are to reduce the impact of earthquakes. In 1989, the Loma Prieta earthquake ($M_s = 7.1$) killed some 65 people, injured 3,000 and caused direct losses of $8.3 billion. The relatively small scale of these losses demonstrated a high level of preparedness in California in contrast to that in Armenia in 1988 where the smaller Spitak earthquake ($M_s = 6.8$) caused 25,000 deaths, 18,000 injuries and reconstruction costs of $16 billion. The Mexico earthquake of September 1985 (Ms = 8.1) resulted in at least 10,000 deaths in Mexico City, some 400km from the epicentre. Despite this ‘safe’ distance, a combination of the amplifying response of lake sediment foundations with high rise building rendered structures vulnerable. This experience needs to be transposed to newly urbanised regions in coastal or lakeside areas throughout the World where the same vulnerability exists at increasing numbers of localities. In less earthquake prone areas, large intraplate earthquakes can occur in regions with no previous history (e.g. Tennant Creek, Australia, 1988). Small earthquakes can cause damage and deaths; such as in Liege, Belgium, in 1983 ($M_b = 5.0$, $60 million) and in Newcastle, Australia in 1989 ($M_b = 5.4$, $1.1 billion, 11 deaths). In the UK in 1580, 2 lives were lost in London from an earthquake centred in the straits of Dover.

Earthquake protection can be improved by understanding the probability of the occurrence of strong earthquakes in different regions (the hazard) in order to focus available resources in those regions. The total risk from earthquakes also depends on the vulnerability of the buildings exposed to them including the vulnerability of the foundation soils and siting, both of which can have a marked affect on the way the seismic shock waves are transmitted to the building. Whilst the earthquake hazard cannot be reduced, the overall risk can be if measures are taken to reduce the vulnerability of the buildings and if people take certain precautions during the earthquake. The last requires a preparedness which can be acquired only through appropriate training programmes. The prospect exists of precise earthquake predictions which would lead to effective temporary evacuation but the science is in its infancy.

Hazard assessment

For the World as a whole, we already know where the biggest earthquakes are most likely to strike. However, in order to focus limited resources on to those areas of a country most at risk, it is necessary to understand the pattern of earthquake activity more precisely and to put a quantitative probability to the likelihood of occurrence of strong earthquakes. This is a seismic hazard assessment and it is a broad-brush way of predicting earthquakes although it cannot provide the exact time and magnitude of the next one.

In every populated region exposed to earthquake hazards, valuable information already exists. Some is in the World databases covering the past few decades of modern global monitoring, some in local historical records and some in the geology and tectonics of the region. To be useful in hazard assessment, all of this information must be the subject of a special study to extract, integrate and interpret it in order to calculate the hazard. This applies equally to the objective data on modern earthquakes in order to provide sufficiently accurate focal parameters as bulk processing of data on a global scale rarely gives the necessary accuracy or completeness for a local or regional assessment. A hazard study based on existing information can start immediately, give early, beneficial results and illuminate deficiencies to be tackled with new data acquisition.

Seismic monitoring

In order to refine the initial assessment of hazard, based on existing information, it is necessary to monitor seismic activity with modern instrumental networks of seismographs. They are needed to:

(i) Precisely locate the seismic activity of the region thereby identifying the presence and parameters of known and ‘hidden’ faults and providing information on seismogenic depth zones.

(ii) Rapidly obtain data on small earthquakes which can be used, through a scaling process, to simulate larger ones. In that analysis, many of the uncertainties of local site effects, resonances, attenuation, depth and focal mechanisms can be taken into account. In the longer-term, accurate information will be obtained on strong ground accelerations caused by large earthquakes.

(iii) Determine the characteristic source frequencies of any larger events which occur and model the attenuation characteristics of the region which strongly affect hazard calculations.

(iv) Determine stress directions from focal mechanisms.

(v) For felt earthquakes, provide a comparison between the instrumental and macroseismic (felt report) method of locating and sizing earthquakes. This affords a calibration of the historical, pre-instrumental, record on which the seismic hazard is also based.

Secondary hazards

Geological, geographical or geotechnical factors, not directly related to the earthquakes or their causes constitute secondary hazards which must be taken into account in the overall seismic hazard assessment. The Mexico earthquake in 1985 was a dramatic (and simple) example of how, given an exposure to earthquakes, the local geology can radically influence their impact on buildings, lifelines and the community. In this case, because of a (predictable) ground resonance in response to a distant large earthquake, almost all of the losses were restricted to buildings in the 6-20 storey category on a particular foundation soil. Elsewhere, the community was barely inconvenienced. In the more general case, the prediction of topographic effects, ground motion amplification, slope instability and liquefaction all need to be studied together with the planning and engineering actions to be taken in order to mitigate the effects of such problems. This whole area is one which has been neglected world-wide and which is pertinent to the objectives of the IDNDR. Much theory already exists and the need is to develop economical methods of application in representative regions, to test the predictions with observation and, through those case histories, to transpose the results to other, similar regions. A large part of the expanding World population is being accommodated in areas where the foundations are vulnerable.

Vulnerability

The great majority of casualties in an earthquake are caused by the collapse of buildings and much of the subsequent economic losses and disruption to the community result from these collapses and from the interruption of lifelines (transport systems, water supply, sewage etc.). Therefore, after assessing the likelihood of the occurrence of a strong earthquake, the next step is to assess its impact through a vulnerability study. That is to determine the probability that buildings and structures of any particular type will sustain damage at different levels of ground shaking. The vulnerability is a function of the strength of the building, its design and the materials with which it is constructed.

There are large uncertainties in the assessment of building vulnerability but it is a necessary first step if limited resources are to be targeted most effectively. It must be remembered that whilst we have increasing understanding of earthquake occurrence and the ways in which new buildings can be designed to withstand their impact, the greatest risk over the next few decades is to building stock already in existence. One of the most effective ways of furthering vulnerability assessment techniques is to study, in detail, the effects of contemporary earthquakes both in the region under consideration and in similar environments elsewhere (then importing the experience). This strategy also provides a test of any protection measures previously taken in the zone of strong ground shaking.

In the seismology and earthquake engineering communities, the terms risk and hazard have different meanings such that:

seismic risk = seismic hazard x vulnerability

If there are no people and no structures in an area of high hazard there is no risk because the vulnerability is zero.

Earthquake engineering for ordinary buildings

Large, engineered industrial buildings, hotels, power plants, dams etc. are generally built with seismic protection, even in developing countries, through the guidance and requirements of the funding agencies and engineers from the industrialised world. For ordinary buildings, where most casualties are caused and where the economy is hard-hit through the disruption of small businesses and infrastructures, it is essential to find the methods and educational programmes to permit:

(i) The building (and rebuilding after an earthquake) of houses which will better withstand the next one.

(ii) The retrofitting of existing vulnerable buildings, which form a vast stock in need of treatment before the next disaster.

In neither of these areas has there been much research nor of application of known methods in a way which leaves a community better able to look after itself for generations to come. It is not sufficient for agencies to move in with alien materials and an alien culture and often rebuild in the wrong place. At the most, such action might satisfy one generation at high cost.

Earthquake prediction

Whilst hazard assessment provides information on the probability of an earthquake occurring, which is a crude form of forecasting, efforts are being made to seek a way to predict where, when and how big an earthquake will be within time and space limits which are going to be useful in evacuating people, closing schools and factories, taking precautions with electricity, gas, oil and water supplies, and bring emergency services to full alert. This is proving to be very difficult. The only prediction of a significantly large earthquake was reported from Haicheng in China in 1975 (M = 7.3) when people were evacuated shortly before the event. The Chinese seismologists, however, failed to predict the Tangshan earthquake 18 months later in which over ½ million people lost their lives.

In some earthquake prone areas of the world, particularly along the simple, linear plate boundaries, gaps can be observed where there has not been a recent large earthquake. As the strain build up along the boundary is largely uniform, identification of these gaps is a way of predicting earthquakes which lies between the probabilistic hazard method and attempts at truly deterministic prediction ('where, when and how big').

Because of its apparently unique cyclical behaviour, a section of the San Andreas fault at Parkfield in

California is being studied in great detail because it is the most likely place to find precursory phenomena and to develop prediction techniques. Changes are being sought in the pattern of small earthquakes, in crustal deformation, water flow, electric and magnetic fields among others. In the 130 years since the great southern California earthquake of 1857 (which ruptured the San Andreas for hundreds of km to the south of Parkfield) a series of earthquakes with moderate magnitudes of about 6.2 have occurred on the Parkfield segment with a near-22 year regularity. The next one is just overdue. Whilst this is one of the most studied areas, earthquake prediction research is being conducted in several other parts of the World including Japan and Turkey. In the UK, the BGS is developing techniques to interpret the information imparted to shear waves as they pass through an earthquake preparation zone in which stress changes affect the cracks and fluid distribution in the rocks which are anisotropic to shear wave transmission.

Although research into deterministic earthquake prediction will have longer-term benefits, it is important to recognise that hazard and vulnerability assessments (including research into site effects) together with the development of techniques to cheaply improve the risk to existing buildings and lifelines, have a greater short-term impact. It may be of only marginal advantage to predict an earthquake in the Philippines, for example, if a large part of the population have their lives ruined economically through the loss of commercial buildings and because bridges and roads collapsed anyway.

Training and preparedness in the community

For communities in which new building construction and repairs and strengthening to old ones is done at a small-scale, local level, training programmes are needed to incorporate earthquake resistance. To succeed, such programmes need to be sensitive to existing custom, culture and materials and to the (often low) level of literacy and education of the recipients.

Regardless of whether engineering and planning measures have been taken, there are many things which can be done by individuals before, during and after an earthquake to reduce its consequences. They include such things as knowing how to shut off water, gas and electricity, having a torch on hand, keeping heavy objects off the tops of shelves, securing heavy items which may topple, learning first aid, holding earthquake drills. During the earthquake; if indoors, people should watch for falling objects, keep away from windows, mirrors and chimneys, don't automatically rush outside; if outside, they should stay in the open away from buildings and electrical cables. Immediately after the earthquake, they should check for fires, check and shut off utilities, do not use naked flames, avoid power cables, clean up spilled poisons or harmful materials, obtain emergency water supplies and check sewage lines. The injured need care appropriate to the severity of their injuries. Damaged buildings need to be avoided because of aftershocks and waterfront areas because of the threat of seismic sea waves (Tsunamis).

UK strengths

British earthquake seismologists were in the vanguard of the development of seismology in the last century and early in the twentieth century when Richard Oldham deduced the broad structure of the Earth's interior using records from the first global network of seismometer stations established by Milne with the backing of the British Association. Those strengths, on the world stage, continued for many years and, although fragmented more recently, the capabilities remain in existence in Institutions such as the British Geological Survey, Imperial College and the Universities of Durham, Cambridge, Edinburgh, Leeds and East Anglia. Earthquake engineering expertise has been expanding and becoming more cohesive in recent years with the British construction industry adopting new techniques in its overseas markets. In the research area, the engineering has been boosted by a 5-year programme supported by SERC during which a number of institutions have become established as centres of excellence in complementary areas. They include Bristol, Cambridge, Glasgow and Nottingham Universities and Imperial and University Colleges, London. The British engineering industry is geared towards civil engineering works worldwide including many of the most seismically active regions of the planet.

Under the Institution of Civil Engineers, the Society for Earthquakes and Civil Engineering Dynamics (SECED) has provided a forum for bringing together experts in the seismological and engineering fields. Its 'Directory of Practitioners' provides a more detailed register of the UK capabilities in the field. Cambridge Architectural Research is one of the UK leaders in the problems of vulnerability and community protection. Many of those practitioners contribute to the UK's Earthquake Engineering Field Investigation Team (EEFIT) which strives to learn from the effects of significant earthquakes, worldwide, and to disseminate that knowledge through the seismological and engineering community.

Summary

In order to reduce the impact of earthquakes the first steps need to:

(i) Identify faults or zones likely to produce earthquakes

(ii) Estimate the probability of a damaging earthquake in, say, a 30-year period

(iii) Predict the expected level and duration of shaking at sites of interest for the expected earthquake allowing for amplification effects of local geology

(iv) Identify sites where the ground is likely to fail through faulting, liquefaction or landslide

(v) Assess the vulnerability of existing structures and protect against collapse

(vi) Pinpoint weak links in lifelines: transportation, water, electricity, sewers, telephones

(vii) Raise the level of community awareness to the earthquake threat and the protection measures which can be taken.

EEFIT : THE FIRST DECADE

by Robin Spence, Scott Steedman and Adrian Chandler

The UK Earthquake Engineering Field Investigation Team (EEFIT) was formed officially in 1982. Its origins can be traced back to the Campania/ Basilicata (Italy) earthquake of 1980. This was one of a number of damaging earthquakes occurring in the European arena during the late 1970's and early 1980's; these also included events at El Asnam (Algeria) and Corinth (Greece). Earth scientists were carrying out post-earthquake studies and developing their understanding of faulting mechanisms, and aid agencies were involved in the emergency, with their activities also increasingly of interest to academics. UK earthquake engineers and engineering seismologists were also carrying out field investigations, most notably Professor Nicholas Ambraseys of Imperial College, London. However, with the increasing involvement of UK engineers in earthquake resistant design of buildings, civil engineering structures and industrial facilities, there was an apparent need for a new organisation to facilitate multi-disciplinary field studies after major earthquakes.

In 1981, a group which had previously worked together on the International Karakoram Project in Northern Pakistan (Spence, Nash, Hughes, Coburn, Taylor, Ledbetter, d'Souza) obtained follow-on funding to carry out a field investigation to Southern Italy after the 1980 Campania/Basilicata earthquake. Because of the time needed to organise and finance the investigation, it took place finally three months after the earthquake, at a time when many of the most seriously damaged structures had been demolished, and severe winter weather had added to the damage of the rest. The team's members had little experience of earthquake engineering, and none at all of the problems of conducting field work in a foreign country in a disaster zone. In spite of these drawbacks, much was learned about structural damage and its relationship to ground motion, geotechnics, and building construction standards. This was achieved, not least through the contacts with other disciplines - geophysicists, geographers, sociologists, architects - who were also working there.

It became clear that if the lessons of further post-earthquake field investigations were not to be lost, it would be essential to form a team of people ready to move quickly into the disaster zone, with some prior planning and preparation so that they could be effective. It was also apparent that the team should be a multi-disciplinary one, including engineering seismologists, structural and geotechnical engineers, architects and sociologists, and that it should combine interested academics and persons from the construction industry. Finally, and most importantly, this would involve identifying sources of finance for such investigations *in advance of the earthquake.*

It was these conclusions which led in 1982 to the formation of EEFIT, initially consisting of the Campania team, plus Edmund Booth who had recently taken over from David Dowrick as Ove Arup and Partners' earthquake engineering specialist. The project was from the outset strongly supported by a group of experienced advisors including Bryan Skipp and Nicholas Ambraseys, and by organisations such as SECED, the Institution of Civil Engineers (ICE) and the Institution of Structural Engineers (IStructE). EEFIT was also backed by the Science and Engineering Research Council (SERC), who although refusing to consider an up-front grant, agreed to the swift and sympathetic consideration of a post-earthquake application for travel funds. This procedure has been adopted successfully in many subsequent field investigations.

The first EEFIT Objectives and Methods statement was written during 1982 in the form of a grant application to SERC. It gave as the objectives of field investigations:

1. To evaluate the performance of both engineered and non-engineered building structures, civil engineering structures and associated slopes and soil structures.

2. To report to UK and local engineers on the levels and types of damage, the relationship between damage and known or inferred ground motion, and other effects of the earthquake.

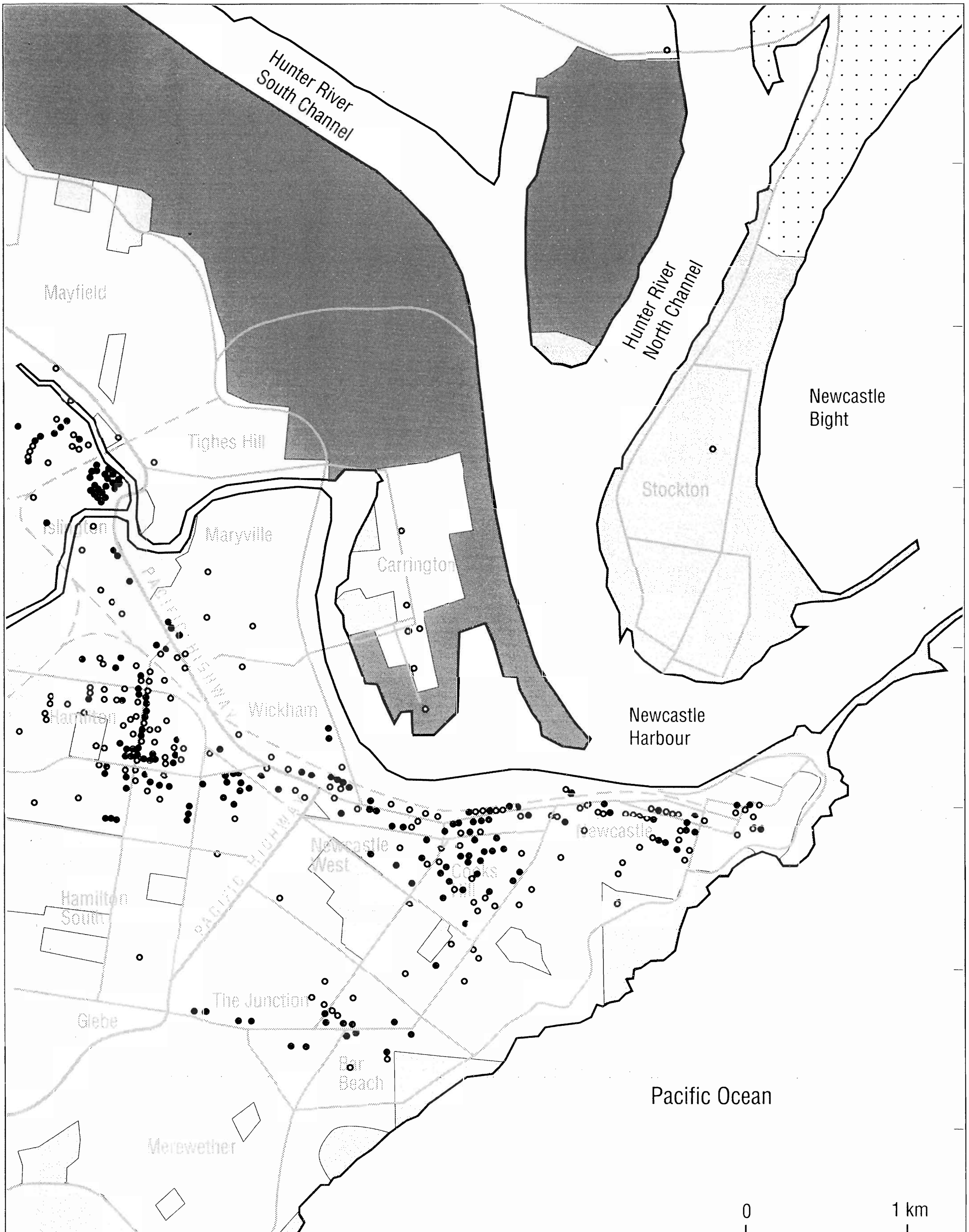
3. To identify suitable projects for more detailed long-term analysis in collaboration with local engineers.

These have remained the principal aims to EEFIT.

In late 1983, a relatively small earthquake took place in Liege, Belgium, killing two people and causing extensive damage to old masonry buildings. Because of the lack of damage to modern engineered structures, a full EEFIT field investigation was not considered justified. However, Edmund Booth visited the area 9 days later on behalf of EEFIT, and wrote the first EEFIT report. In 1983 and 1984, EEFIT members (Hughes and Coburn) also conducted field investigations and prepared reports on the earthquakes in the Erzurum/Kars region of Eastern Turkey, and the Dhamar region of North Yemen, both of which affected largely rural areas.

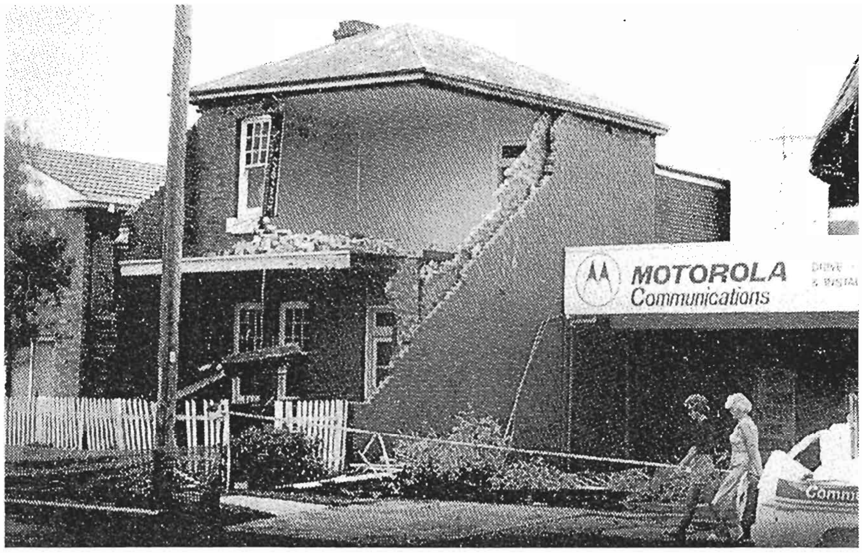
Hence it was not until March 1985 that the first full-scale EEFIT field investigation took place, in Chile. This visit demonstrated clearly the value of local contacts and interaction with other international teams, which added considerably to its success. The Chile earthquake report was the first to adopt the present format of EEFIT reports, and set the style for subsequent publications. Later the same year a team visited the aftermath of the Mexico earthquake disaster, and with experience in the field being gained rapidly, the group coordinated closely with other international teams, local experts and the British Council. Surveys were made along cross-sections through the city, a practice which is now standard wherever possible (see figure overleaf).

The Mexico earthquake excited considerable interest in the UK, and a pattern of debriefing afternoon meetings and more formal evening



Above: Systematic zonal surveys were used by EEFIT in Newcastle, Australia (1989) and elsewhere, in this case to locate structures with moderate or heavy damage (hollow and solid symbols respectively)

Right: Front and side collapse in modern unreinforced brick masonry, two storey dwelling in the 1989 $m_b = 5.4$ Newcastle earthquake, Australia



meetings at the IStructE and the ICE was developed. Joint meetings with SECED and Imperial College were established, and continue to be held annually, to present field reports of recent earthquakes.

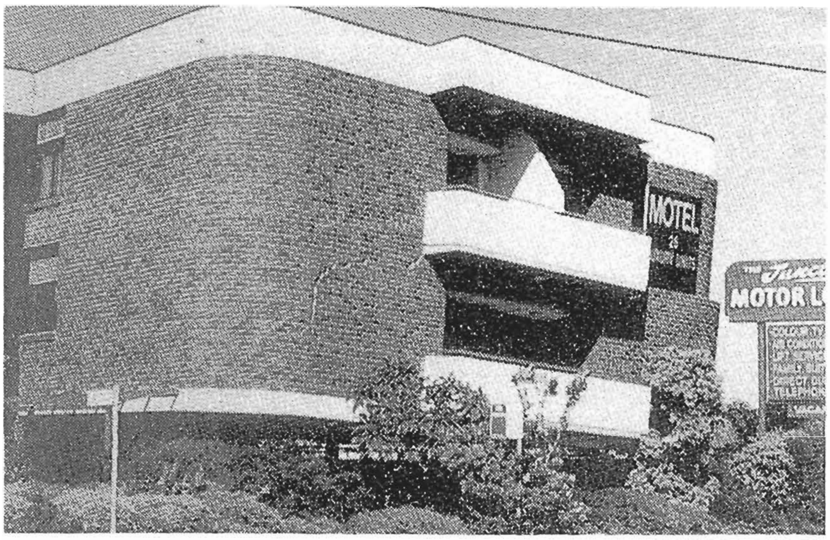
In 1986 a more formal structure for EEFIT emerged, with the publication of the Constitution and the establishment of a Committee (6 Members plus up to 3 Co-Opted Members) under the Chairmanship of Colin Taylor (University of Bristol), who took over the week-to-week management from Robin Spence. Arrangements were made with the IStructE who kindly agreed to host the Secretariat and provide a base for operations. The three classes of EEFIT Membership were then established, namely Full Members, Honorary Members (both for individuals), and Corporate Members. Membership is thereby open to persons and organisations interested in the advancement of earthquake engineering and related fields, as evidenced by their professional activities in these fields, or by other relevant activities.

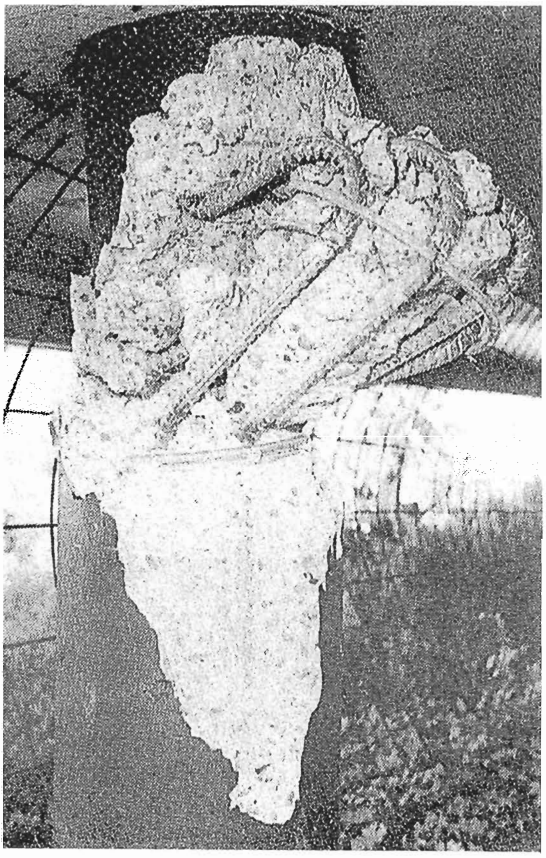
Decisions on whether to mount an EEFIT Field Investigation, and its subsequent monitoring, are the responsibility of the Field Investigations Committee, consisting of the Chairman and Vice-Chairman of the Management Committee and 3 other appointed members. In addition to deciding when to mobilise a Field Investigation Team, this Committee determines the size of the team, and selects the Base Co-ordinator in the UK, a Team Leader and Team Members. The Field Investigations Committee informs all Corporate Members that a Team is being sent, so that they can provide members and funding if appropriate. Other EEFIT members are asked to contact the Field Investigations Committee if they wish to be considered for the Team, or can offer assistance in other ways. Following the Team's return, the Field Investigations Committee organises a debriefing meeting (open to all), and supervises the dissemination of information resulting from the Field Investigation, including the final report.

EEFIT's busiest period to date began in 1988, when Stephen Ledbetter, who had led the San Salvador team in 1986, became Chairman and was quickly faced with the task of organising the team to visit California following the Loma Prieta earthquake of October 1989. The Loma Prieta earthquake investigation saw the largest EEFIT team yet assembled, with 11 members travelling from the UK and 2 others joining separately. This proved quite a management challenge, but an excellent opportunity to broaden the base of UK engineers with field experience. All team members contributed to the Report, which unfortunately proved very time consuming to assemble and was published finally only this year. This ambitious effort pointed clearly to the need for reports to be produced by a limited number of authors (perhaps four, at most), and possibly for stricter control of the size of field teams.

The EEFIT Chairmanship was taken over by Scott Steedman in 1990, following Stephen Ledbetter's move to the Directorship of the Cladding Research Centre at the University of Bath. This change took place in the midst of a wave of activity as individuals and teams travelled to and from the Newcastle, Australia earthquake (in December 1989), and the Manjil (Iran), Romanian, Luzon (Philippines) and Sicilian events which all took place in 1990. Reports for each of these events have been published or are in the final stages of preparation. The Newcastle earthquake provided data which has greatly assisted the evaluation of seismic risk to building stock with similar forms of construction in the UK.

With the continuing strong support of the IStructE and SECED, and the growing number of interesting and high quality reports, it became clear during 1991 that a more organised and professional approach was required to the marketing of EEFIT reports. Instead of individuals producing reports simply under the name of EEFIT, it was agreed that production and printing of reports would be controlled centrally by the IStructE, and therefore copies of all existing EEFIT reports were collected and are now held at the IStructE for archiving and distribution. The reports (and now slide sets) produced by EEFIT are now published by EEFIT and distributed through the IStructE, and this has greatly helped rationalise the business base of the organisation. Also in 1991, the Objectives and Methods statement was brought up to date, to reflect the practice and growing interests of EEFIT members, both individual and corporate. A revised Constitution is also presently in the final stages of preparation, and better reflects the





Above and right: Combination of a soft first storey and a highly asymmetric stiffness layout led to shear failure and crushing at the top of a row of exterior reinforced concrete columns at the Junction Motel, Newcastle, Australia (1989). This building was demolished immediately after the earthquake

present-day activities of the organisation.

Beginning in 1991, discussions were opened with the French and German earthquake field investigation teams, and this has lead to a successful collaboration with regular exchanges of information on earthquakes and invitations to form joint teams where appropriate. In 1992, for example, Edmund Booth joined the French team to visit the Erzincan earthquake in Turkey, linking up in the field with the main EEFIT team who arrived a few days later. The Erzincan report is an excellent example of the thorough, informative and well-presented style of publication that is now standard.

The start of 1992 saw significant changes of personnel in the Management Committee of EEFIT. Regrettably, demanding commitments in his new position at Sir Alexander Gibb & Partners necessitated Scott Steedman to leave the Committee, although he retains his interest and involvement with EEFIT for a further year by serving on the Committee as immediate past Chairman. His invaluable experience of, not to mention boundless enthusiasm for, all aspects of earthquake field investigations is a valuable resource, much appreciated by his colleagues on the Committee. Similar qualities were also brought to the Committee over a period of several years by Jack Pappin (since June 1993 of Ove Arup and Partners, Hong Kong) who also resigned in March 1993 from his capacity as EEFIT Vice-Chairman. Both of these long-standing members will be sorely missed, and it is to be hoped that their links with EEFIT will be maintained, albeit in a different form, despite their change of professional circumstances.

The present Chairman is Adrian Chandler (Reader in Earthquake Engineering at University College London), and Gavin Trott (R.T. James and Partners) serves as Vice-Chairman. Three additions have been made to the Committee membership, these being Tony Blakeborough (University of Bristol), Alan Hoy (EQE International) and Ziggi Lubkowski (Ove Arup and Partners, London). All three new members bring to the Committee new ideas and a fresh approach, which will stimulate EEFIT's progress into the second decade of its operation. The remaining Committee members are Ian Morris (British Nuclear Fuels), John Bethell (Nuclear Electric), Richard Hughes (Ove Arup and Partners, London) and Robin Spence (Cambridge University), who each bring to EEFIT their individual contribution of expertise and experience. The balanced blend and strength-in-depth of the present Committee augers well for the future of EEFIT, which despite the lack of major, damaging earthquakes in the past 18 months has had no lack of activity on an administrative level. The consolidation and broadening of the membership base of EEFIT, both individual and corporate, is an on-going priority.

EEFIT Reports remain the principal source of information following a field investigation; a total of 10 reports are currently available, with one in preparation. The sale prices range from £12 to £30 for EEFIT members, with supplements for non-members *(contact IStructE at 11 Upper Belgrave Street, London SW1X 8BH, Tel. 071-235 4535, for further details, along with information on the sale or hire of slide sets).* EEFIT regards its members as its lifeblood, and welcomes the ideas and participation in its activities which continues to flow from this source. The organisation is in a healthy state, awaiting with anticipation its next field investigation, and looks positively towards its second decade of operation.

COLLAPSE OF RC BUILDINGS IN EARTHQUAKES: IMPLICATIONS FOR THE SEISMIC SAFETY OF MEGACITIES

by Antonios Pomonis

INTRODUCTION

Reinforced concrete (RC) is today the most popular building material worldwide for buildings more than three storeys, especially in areas of seismic risk. However experience of several recent earthquakes has given cause for concern about the safety of RC buildings in areas where the anti-seismic codes are inadequate or not properly enforced . In Southern Italy and Alergia (1980), Greece (1981 and 1986), Mexico (1985), San Salvador (1986), Armenia (1988), Philippines (1990), Eastern Turkey and Egypt (1992) many multi-storey buildings collapsed because they were not designed to resist the shaking which they experienced. As a result the loss of life due to the collapse of RC buildings is rapidly increasing. Since 1977 more than 20,000 people are known to have died in collapsed RC buildings. This amounts to at least 17% of the total earthquake death toll of the last 15 years (121,000 people).

The causes of collapse of RC buildings although well known among earthquake engineers are not yet fully understood by developers, builders, owners and local authorities. Reinforced concrete structures under earthquake loading can behave surprisingly poorly if the anti-seismic design guidelines are not put into practice properly. Rapid urbanization, construction boom, high demand and inadequate code enforcement have led to the mushrooming of sub-standard and seismically unsound RC structures in many earthquake prone parts of the world. Megacities with a significant seismic hazard like Istanbul, Teheran, Naples, Athens, Caracas, Manila and so on have now a large number of vulnerable RC structures.

Disaster management in such areas must be given proper attention to this issue because the collapse of multi-storey RC structures is potentially very lethal and search and rescue operations can be very slow and frustratingly unsuccessful. It is very important for the responsible authorities to have a reasonable estimate of the likely numbers of buildings that might be affected, but also they should be well informed on issues related to the safety of the occupants, the likelihood of loss of life, the nature of injuries and the organization of search and rescue.

This article addresses some of these issues which were investigated by the Martin Centre for Architectural and Urban Studies, University of Cambridge, Department of Architecture, as part of a SERC research project entitled *"Human Casualties in Building Collapse".*

CAUSES OF COLLAPSE IN REINFORCED CONCRETE BUILDINGS

Experience gained so far from previous earthquakes has identified particularly vulnerable features in the design of RC buildings that may contribute to their collapse. These are separated in:

- Inferior materials and workmanship
- Layout irregularities in plan and elevation
- Mass eccentricities in plan and elevation
- Structural irregularities in plan and elevation
- Inadequate reinforcement detailing
- Non-structural effects
- Indirect efects

All these are of particular importance to cast in-situ RC frame structures with or without shear walls as well as RC buildings with flat slabs (without beams). However many of the issues addressed here are equally valid for prefabricated structures as well. A brief discussion on each of the aspects is given as follows.

Inferior Materials and Workmanship

Reinforced concrete is a safe material for building in earthquake areas only if it is constructed to a high standard. Experience shows that many of the failures of individual reinforced concrete buildings in past earthquakes have been the result not of design failings, but of failure to implement the design. Some of the most commonly disregarded issues are:

- The quality, cleanliness and size of the aggregates
- On-site storage of aggregates and protection from contamination
- On-site protection of cement from damp
- The strength and quality of formwork and its supporting framework
- On-site storage of reinforcement and protection before casting
- The bending of reinforcing bars on site and their protection before casting
- The quality, strength and workability of concrete
- The procedures for casting concrete
- The minimum compressive strength in seismic areas should be 20 MPa
- Inadequate casting procedures in relation to climatic conditions
- Protection of the frame from moisture loss after the removal of the formwork

Layout Irregularities in Plan and Elevation

It is best if the overall building layout is simple and symmetrical. Buildings with the following attributes are more vulnerable during earthquakes, because their irregularities generate increased torsional loads.

- "L", "T", "U", "E", "H", "P", "Y" plans that are not separated with seismic joints
- Long and thin plan shapes without separating seismic joints.
- Plans with many re-entrant corners
- Buildings with stepped sections (terraces) or large unsupported overhangs
- Buildings with cantilevered top in both directions (reverse pendulum)

Mass Eccentricities in Plan and Elevation

It is best that the centres of rigidity and mass are not far from each other because otherwise the eccentricity will generate torsional moments that might overload the structure. This can be achieved by making sure that the stiffer and heavier parts of an RC structure are evenly distributed in plan and elevation. Buildings with the following attributes are more vulnerable:

- Buildings with a lift shaft or staircases, close to a corner
- Unevenly distributed frames and shear walls
- RC frames with in-fill masonry, situated in street corners, with the walls facing the streets having many openings, while the other perimeter walls are filled
- Heavy roof appendages like large water tanks, elevator rooms, communication equipment or other heavy loads that can cause severe stresses if not taken into account during the design stage

Structural Irregularities in Plan and Elevation

RC structures should have as much as possible a uniform rigidity distribution in each storey and between successive floors. The structure should have redundancy in the case of failure, meaning that if one element fails others should be able to complement it so that a full collapse is avoided. Columns and beams should have similar strength because a ductile mode of failure, like bending of beams is preferable to a column failure. Flat slab buildings should have strong columns or alternatively lighter waffle slabs can be used to reduce the weight. The foundations should be either continuous or, in case of individual footings, they should have strong tie beams. The following attributes create vulnerable buildings:

- Frames with columns not in straight line
- Frames with unevenly spread columns or shear walls
- Vertically discontinuous frames, or frames with sudden changes in cross-section
- Extensions or modifications to the frame without proper connections
- Frames much stronger in one orthogonal direction (lack of redundancy)
- Column-beam joints that are not central
- Beams much stiffer than the columns
- Frames with too many non-orthogonal beam-column intersections
- Separate casting of beams and columns
- Flat slab buildings with slender columns without capitals or haunches
- Unlevelled foundations on steep slopes.
- Frames with too many different column and beam sizes
- Soft storey structures with ground floor as open space or as a shop area with few partition and external masonry walls

Inadequate Reinforcement Detailing

Even if all the above guidelines are followed the good performance of an RC structure in an earthquake will not be achieved if the reinforcement details are not up to the required standard. Columns, beams and slabs should have longitudinal and transverse reinforcement properly spaced, spliced, anchored and with dimensions and minimum cover according to the code requirements. The most important guidelines that are often neglected in damaged structures are:

- Use of plain instead of deformed bars for longitudinal reinforcement
- Lack of sufficient transverse reinforcement either in spacing or diameter and inferior detailing
- Discontinuous reinforcement in columns
- Congested reinforcement in joints and insufficient dispersal of concrete
- Insufficient reinforcement in slabs

Non-Structural Effects

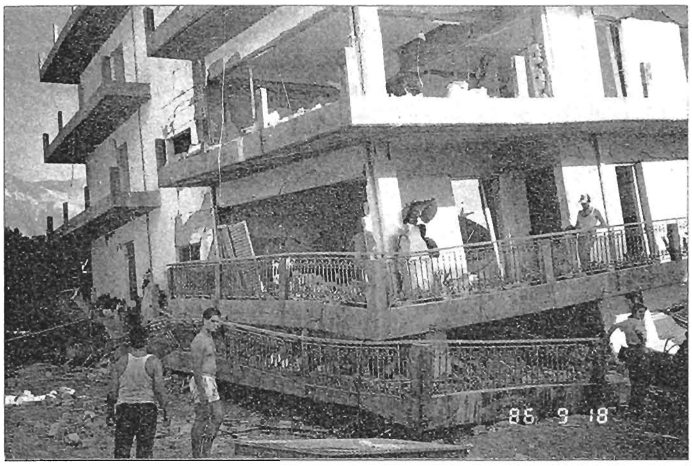
An important factor that is often neglected in the design of RC frames is the contribution of in-fill masonry to the structural behaviour during lateral loading. In flexible structures, that deform during earthquake loading, the in-fill panel is undergoing significant shear forces. If it is not connected to the frame, shear failure or even out-of-plane collapse may occur. Such a failure may result in a localized soft-storey effect with further consequences if the shaking is strong and long in duration. The most important guidelines that are often neglected in structures damaged due to unsatisfactory relationship between frame and infill panel are:

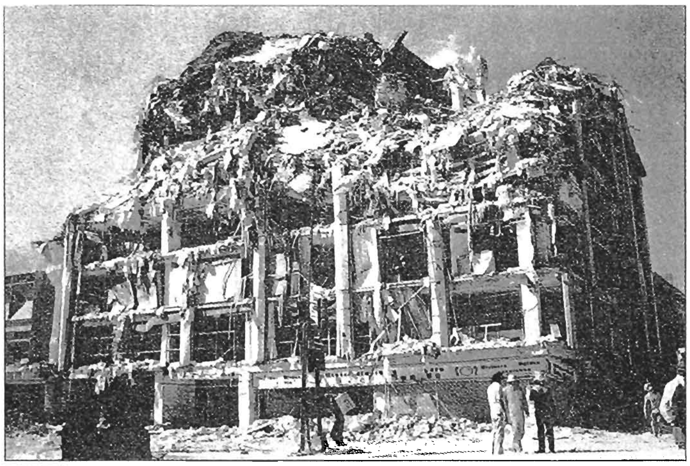
- Infill walls that are not arranged uniformly (irregular position of openings in plan or elevation)
- Use of heavy masonry units or weak mortar (perforated units are adequate)
- Use of different types of masonry in a single building
- Infill panels without any horizontal or vertical reinforcement
- Creation of short columns due to walls with openings extending to the column
- Short column effect in buildings with wide spans (>10m) that have normal storey heights (2.7-3.3m) due to low height to width ratio

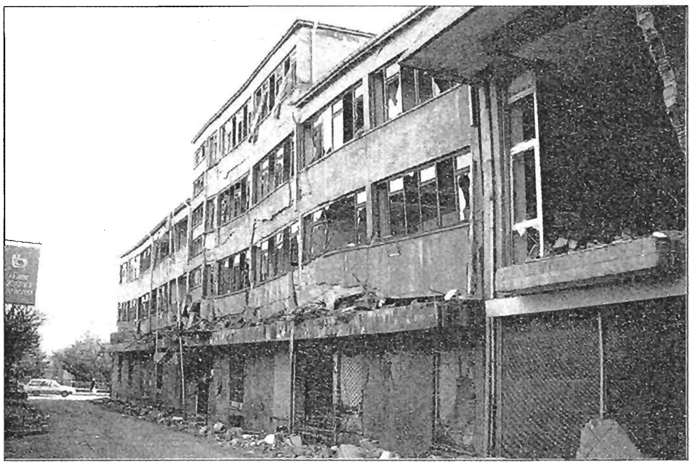
Indirect Effects

The indirect effects can be simply divided in two groups, namely those that happen as a result of ground shaking and those that may happen as a result of other secondary hazards triggered by ground shaking. The soil character of a building's location is one of the most important factors, contributing to damage or collapse of RC buildings. Buildings have to be constructed bearing in mind the dynamic characteristics of the underlying soil, the distance from possible earthquake sources and the type of earthquakes expected from each source (fault mechanism, depth, etc.). Large motion amplification can occur in soft soils, when long period waves propagate through them. The most important guidelines that are often neglected in damaged structures are:

- Structures with long natural period located in zones prone to long period wave amplification
- Structures built in areas susceptible to soil liquefaction
- Pounding between adjacent buildings or between parts of large structures due to difference in structural and dynamic characteristics and lack of adequate seismic joints. This can be







Top left: Example of collapse starting from the ground floor (Kalamata, 1986)

Top Right: Example of top-down collapse. This building was originally 11 stories high. The bottom 3 floors and part of the 4th floor are still standing (Mexico City, 1985)

Bottom Left: Example of mid-storey collapse (Erzincan, 1992)

Bottom Right: Example of pounding between adjacent structures (Mexico City, 1985)

particularly harmful if the floor levels between the buildings are not aligned, because the rigid RC floors will buffet each other's vertical structure

- Excessive gravity loads have been identified as a cause for RC collapses, even without the contribution of earthquake loads. In Athens a 3-storey RC building collapsed several years ago, because its roof was used as marble workshop
- Collapse of RC structures may occur, due to any other secondary effects triggered by ground shaking, like tsunami, landslide, flooding or fire

COLLAPSE TYPOLOGIES OF RC STRUCTURES

There are mainly six collapse typologies, that will be briefly discussed here:

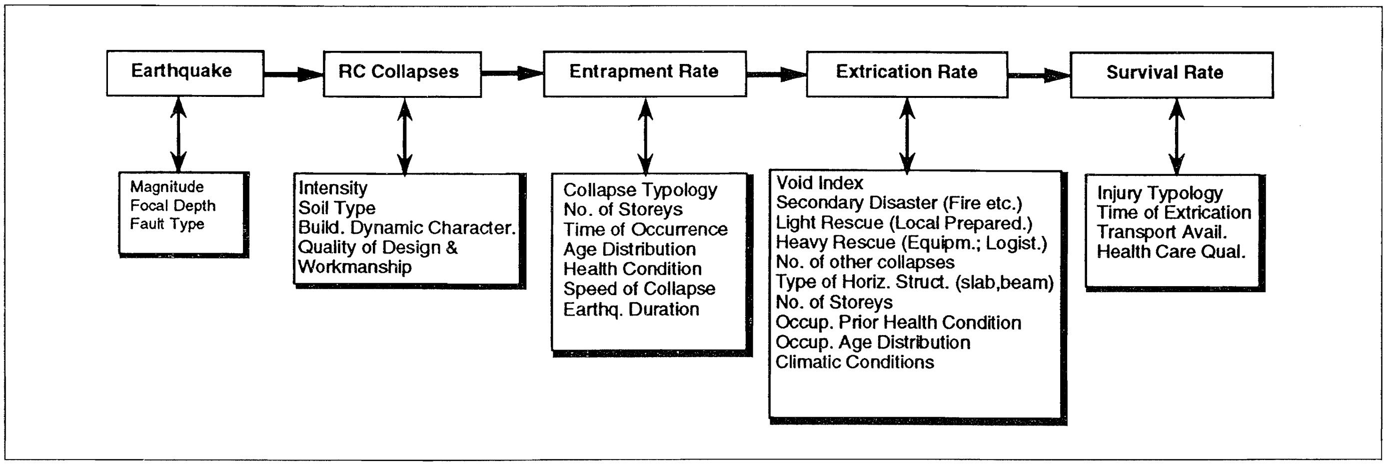
(a) Collapse starting from the bottom of the structure
(b) Collapse starting from the top of the structure
(c) Mid storey collapse
(d) Collapse due to pounding with adjacent strucutres
(e) Collapse due to combination of irregularities with torsion
(f) Collapse due to foundation failure or soil liquefaction

(a) Collapse starting from the bottom of the structure

This is commonly associated with problems in the vertical structure like; soft storey, short columns or inadequate strong beam-weak column design. The extent of collapse after the failure of the ground floor depends on the quality of design, number of storeys, duration and strength of ground shaking and availability of structural redundancy. In the best cases all the storeys above the ground floor simply fall down by one level but escape from further collapse due to sufficient redundancy or short duration of shaking. In the worst cases all the floors collapse, piling up and leaving very little void space for the survival of entrapped occupants (the so-called pancake collapse).

(b) Collapse starting from the top of the structure

This is associated with buildings with heavy flat slabs and slender columns; buildings with diminishing column section in higher storeys; defective splicing of column longitudinal reinforcement; or due to the collapse of infill masonry at top levels. It has been observed more often in multi-storey structures in the 1977 Romania and 1985 Mexico earthquakes notable for the long period amplification effects. The failure is progressive, starting



Above: Factors affecting human casualities in the RC collapse

either from the top floor and expanding downwards or at a mid-storey and expanding in both direcitons.

(c) Mid-storey collapse

This is commonly associated with short column effects or excessive dead loads in a particular floor. It can also occur in buildings that have a very stiff basement with RC shear walls and flexible superstructure. The failure is usually not very brittle and the rest of the structure escapes complete collapse.

(d) Collapse due to pounding

This usually happens between adjacent buildings with different dynamic characteristics not separated by seismic joints. The damage is more severe if the floor levels are not aligned in which case the rigid horizontal diaphragms can hit the neighbouring building's columns. In case of long duration shaking with repeated cycles partial or complete collapse may occur. Very often only a mid-storey might collapse but in more extreme cases many more floors might collapse often starting from the top.

(e) Collapse due to combination of irregularities with torsion

Buildings with several structural irregularities are of course more vulnerable and a combination of reasons might cause their collapse. For example a structure with a soft first storey and mass eccentricities might lose its ground floor and then in combination with the torsional loads resulting from the eccentricities a more brittle failure may occur, causing the structure to collapse and twist or overturn due to the action of torsional loads. Twisting and overturning are the most common patterns of collapse associated with torsional loads.

(f) Collapse due to foundation failure or soil liquefaction

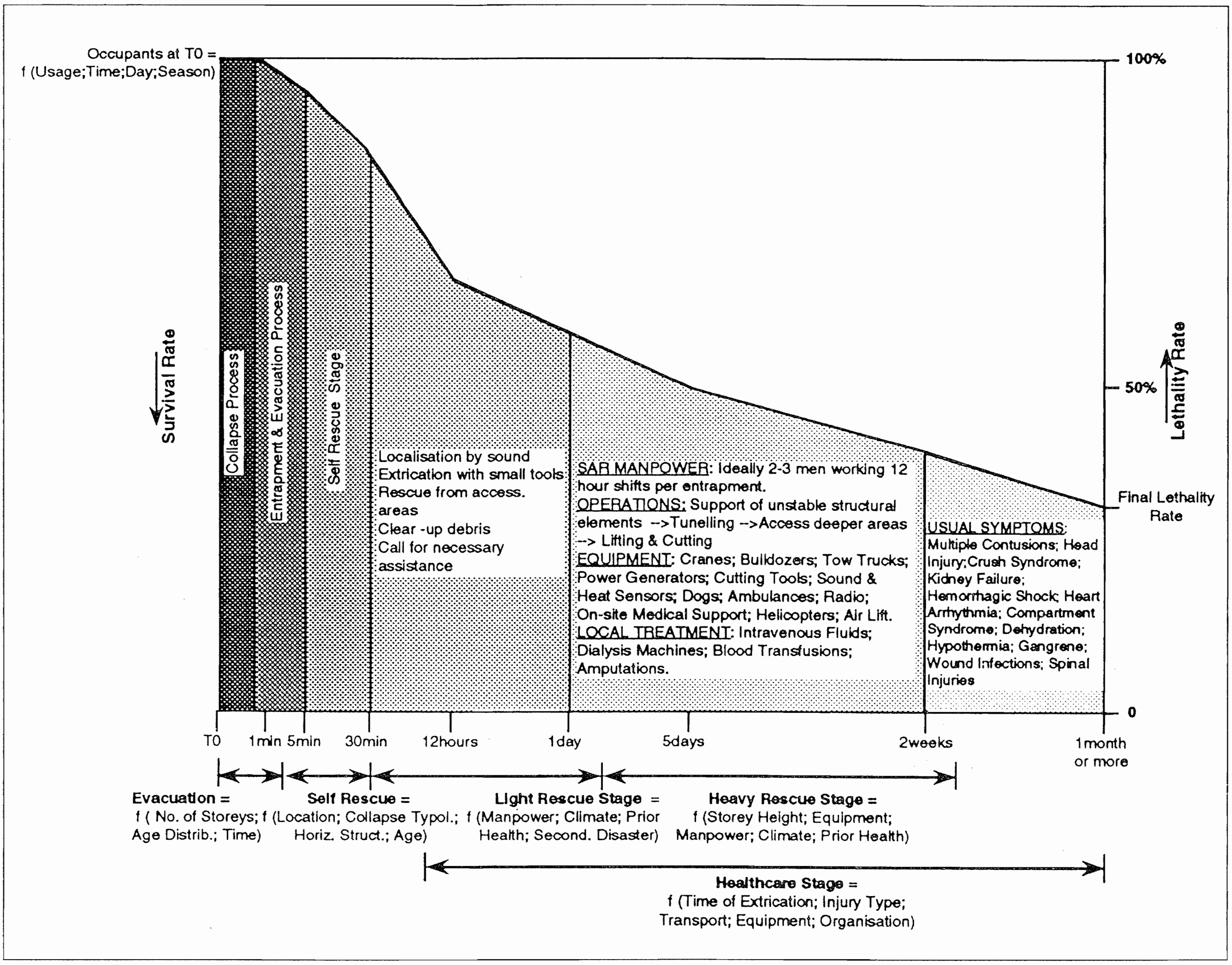
This is a less common failure but by no means unusual. In extreme cases buildings might overturn and collapse completely while in less severe cases they might simply sink into the ground or lean over without loosing their structural integrity (buildings with shear walls are more likely to suffer complete collapse).

IMPLICATIONS FOR OCCUPANTS AND SEARCH AND RESCUE OPERATIONS

Extremely few reports have been published or research carried out, regarding the lethality of collapse of RC buildings. As much information as possible must be gathered from particular building collapses even in non-earthquake circumstances in order to obtain a clearer picture of the parameters that influence the loss of life.

In a separate study, a set of 12 RC buildings that have collapsed in Mexico, El Salvador, Greece and Armenia were examined in detail. Eight of these buildings were RC framed with infill masonry and 4 buildings were precast frames (in Armenia). The lethality amongst the entrapped occupants in the cast in-situ buildings ranged from 20 to 60% and a total of 52% of the estimated occupants were killed. By contrast a similar study on low-rise masonry buildings found that the lethality ranged from 5 to 18% except in some extreme cases in Iranian rural areas with earthen buildings (collapse of earthen buildings cause suffociation due to dust). Some useful information obtained so far may be summarised as follows:

- Entrapped people have been rescued alive even up to 10-14 days after an earthquake. Nevertheless, the survivability is rapidly decreasing after the first 24 hours
- The health condition of a victim prior to the collapse is one of the factors affecting survivability
- Search and rescue (SAR) for entrapped victims is most difficult in multi-storey structures that have suffered pancake collapse, due to the extreme weight of the floors. A large part of the volume of the building is lost, leaving very little void for the survival of entrapped occupants. In low-rise buildings sturdy pieces of furniture like electric appliances, armchairs and wooden tables can withstand the load of one or two floors above, thus forming air pockets where occupants may survive. It is obvious that SAR difficulty is proportional to the amount of collapsed floors
- Access in collapsed structures is usually gained from the top, which may be safer in case of aftershocks but is quite slow. The procedure is to gradually remove debris and concrete slabs by use of large cranes and slowly gain access to the interior of the collapsed structure. This process is very slow,



Above: Rescue stages, affecting factors and operations to minimise casualties in reinforced concrete building collapse

considering that the survivability of the entrapped victims decreases by the hour

- There is a severe lack of specialized equipment that could help speed up the process of dismantling safely a RC structure

The attributes of an advanced concrete cutting tool for use in SAR operations would be:

- portability and ease of use by a single person
- reliable power source (preferably from pneumatic compressor)
- highly abrasive with sufficient cutting speed

Attention must be paid that the sparks produced by a cutting tool should not come in contact with possible gas leaks. Low levels of noise and vibration must be produced in order not to hamper other aspects of the SAR operation. The machinery commonly used is heavy duty angle grinders of 200 to 300mm disc diameter, with an anti-vibration handle, weighing around 10 kilograms. Power on site is best provided by pneumatic compressors placed near the collapsed building so that little power is lost due to distance. Smaller grinders of 100mm may also be useful as auxiliary equipment to cut steel bars. High power drills are also useful to facilitate in the lifting of RC slabs by making loops.

The main problem in this operation is the slowness in cutting through concrete slabs and steel bars. Recent advances in the development of concrete cutters for bridges in motorway widening operations may have possible application in SAR operations. Diamond impregnated steel wires have been used to speed up operations. Expertise gained by demolition firms should also be very useful to advance the speed of SAR operations.

All these are summarised in the schematic diagrams shown in the above figures. The figures show the collapse of RC buildings involves 5 different stages that may overlap each other in time.

Some of the principal operations and factors involved to help minimize the amount of casualties are also shown. The usual symptoms of people rescued alive, gathered from several reports are more or less known and experience of the type of medical facilities necessary have been reported by disaster epidemiologists. It is evident that the task of minimizing the loss of life in future collapses of RC buildings, depends very much on the level of preparedness of the authorities in the affected regions. More inter-disciplinary research and development of a uniform way of documenting case studies in the future are extremely important in order to make information and experience useful for future actions.

EARTHQUAKE HAZARD AND RISK MITIGATION IN GHANA, WEST AFRICA

by D J Blundell and M Akoto

Intraplate earthquakes which occur in regions remote from the main global earthquake zones are amongst the most devastating since they are unexpected and strike communities that are most vulnerable because they are unprepared. Tragically, India experienced just such a disaster at 4 a.m. (local time) on 30 September 1993 from an earthquake of magnitude 6.2. Whereas a great deal of effort has been given, both scientifically and logistically, to reduce earthquake risk in the main earthquake zones, relatively little attention has been given to intraplate earthquakes. Ghana faces this hazard and is representative of the problems and solutions involved in reducing vulnerability within the context of a developing country. Help from the international community to support actions undertaken by Ghana could be of value, not only in preventing a potential disaster in Ghana, but in serving as a blueprint for action elsewhere. For this reason, IDNDR has formally recognised this as a National Project: NDR 620.

Earthquake Hazard in Ghana

Despite its situation of being far removed from the recognised global earthquake zones marking plate boundaries, Ghana has a well documented history of damaging earthquakes around magnitude 6, most recently in 1862, 1906 and 1939. These earthquakes were all located in SE Ghana in the general vicinity of the capital city, Accra, and caused a number of deaths and severe damage to buildings.

A seismic observatory operated for a while in the 1920's and recorded regular local tremors. Since 1973 continuous seismic recording has confirmed that local seismic activity is continuing at a rate consistent with the recurrence of magnitude 6 earthquakes every 50 years or so. The interval since the last major earthquake and the evidence of continuing activity gives grounds for concern that another major earthquake may occur near Accra in the not too distant future.

The seismicity is associated with active faulting, particularly near the intersection between the E-W trending coastal boundary fault and a NE-SW trending Akwapim Fault Zone, well defined by a number of active fault scarps with heights of around 300m. An excellent record exists of the effects of the 1939 earthquake including landslip, liquefaction, fissure and damage to buildings and major structures such as the Weija Dam, close to Accra, which resulted in flooding from the reservoir. The Weija Dam has been rebuilt at the same site.

The Community at Risk

In 1939, Accra was a relatively small city dominantly of single storey buildings built on hard rock foundations. Since that time, particularly since Independence in 1957, the city has grown and the industrial wealth of Ghana is heavily concentrated within its environs. High rise buildings have been built and the city has spread to the coastal flats where liquefaction of the unconsolidated sediments was reported following the 1939 earthquake. Foundation problems are exacerbated by the presence of swelling clays and laterites produced from deep weathering of hard rocks. Key buildings such as the main hospital of Accra (Korle-Bu) and many Government Departmental buildings are sited on the coastal flats.

Lake Volta was created in 1964 as a major reservoir through the construction of the earth-filled Akosombo Dam. This major civil engineering work is vital to the economy of Ghana, providing electricity and a good water supply for Accra and its environs. Its construction led to a further concentration of industry in the Accra area. The Akosombo Dam is situated near to the line of the Akwapim fault zone. Although its design is such that it can be confidently expected to withstand any foreseeable earthquake shaking, the generating plant and the 100km supply lines of water and electricity between Akosombo and Accra are more vulnerable.

The total population of Accra and its environs is around 1.5 million, representing about 12% of the population of Ghana.

Vulnerability

The high concentration of populace and industry within the environs of Accra, which also serves as the seat of Government and central administration, creates a vulnerability to the consequences of an earthquake. Site conditions are such that ground foundations are weak locally.

Understandably, the Government of Ghana does not have the financial resources to take expensive preventative measures to reduce vulnerability to what it regards as a natural hazard beyond its means to prevent. Earthquake activity is not a sufficiently common event in West Africa that it is high in public awareness as it would be in a major earthquake zone. But experience from other intra-plate earthquakes such as the devastating 5.9 magnitude earthquake that struck Agadir, Morocco on 29 February 1960 which killed 14,000 and, most recently, the tragedy in India, point to the very real risk of a disaster in these particular circumstances.

Measures in hand to reduce risk

A dedicated team of seismologists based in the Department of Geology, University of Ghana, Legon, in Accra, led by Mr M Akoto and supported by the Geological Survey of Ghana, has been monitoring seismicity continuously in the region since 1973, and has reported its observations of teleseisms regularly to the International Seismological Centre. This forms the Earthquake Hazards Minimisation Unit of the University, which aims to report its findings to a National Disaster Management Board. Seismic recording initially used a single vertical short-period seismometer attached to a smoked-drum recorder but since 1987 a telemetered network of 9 seismic stations with pen-drum recorders has been operating across SE Ghana in order to make more precise hypocentre and magnitude determinations.

Linked with the seismologists is Dr. K E N Tsidzi of the Geological Engineering Department, University of Science & Technology, Kumasi, who is experienced in earthquake engineering. Between them they have drawn up preliminary Geological Hazard maps to define hazard zonation as a basis for a Building Code which is being drawn up by a Government Committee. However, this Code has not been put into effect in a voluntary way by the major engineering contractors.

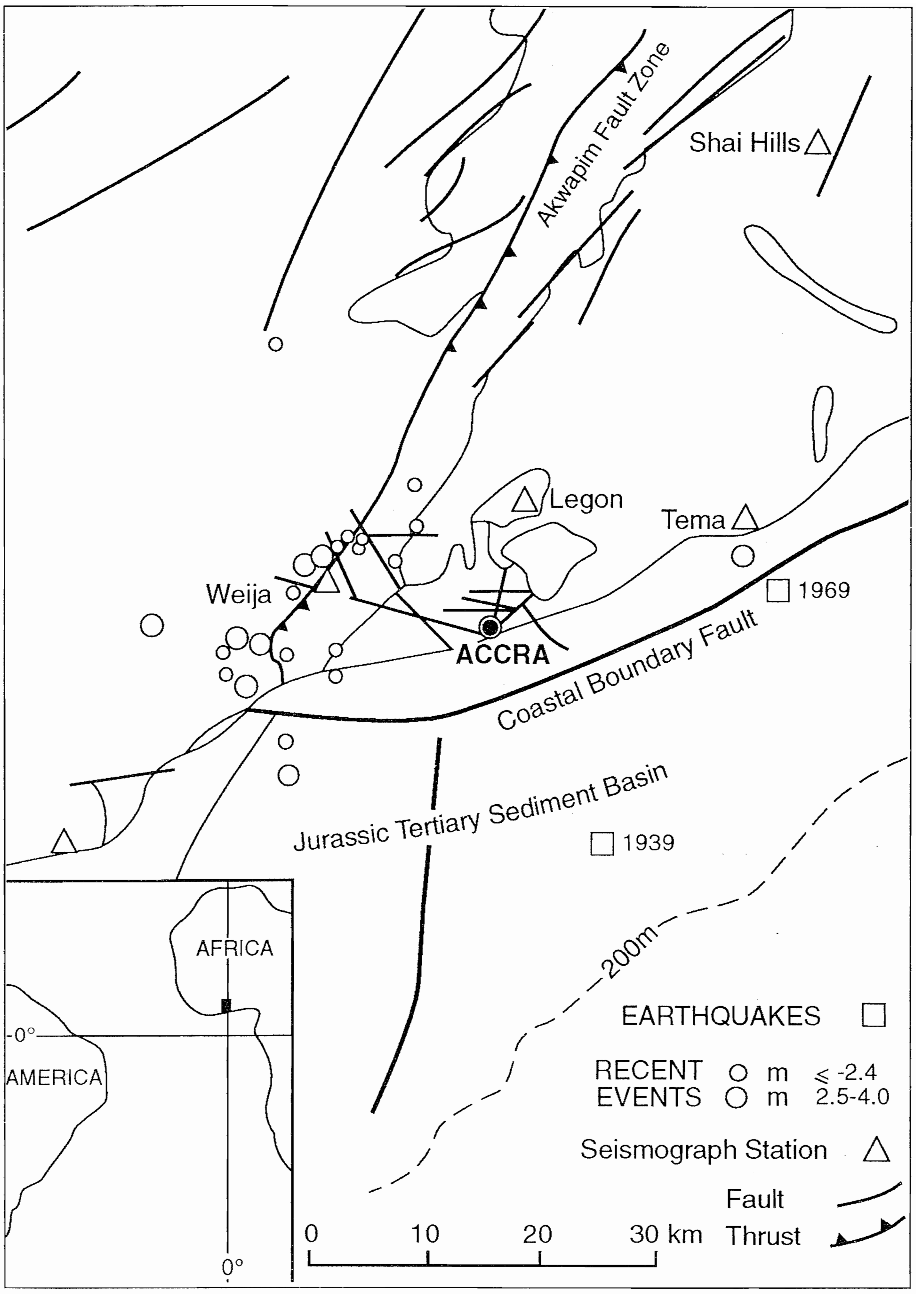
The Government of Ghana is making efforts to focus on all possible natural disasters in Ghana and in June 1992 sponsored a workshop to draw up a National Disaster Preparedness Plan. The next stage is to take reasonable and affordable measures to implement the plan.

Measures needed

As just explained, there exist a core of experienced and highly professional seismologists, engineering geologists and engineers in Ghana who, given appropriate support from the international community, have the ability to make a real and significant impact in saving the lives and livelihoods of their compatriots in the event of a major earthquake. There is a governmental infrastructure in place. What is needed is an initiative from the international community to give the right kind of support to those in Ghana who are trying to set things in train. This requires sensitivity, to avoid the perception of interference and to avoid being alarmist. It is necessary to raise awareness of the risk, first in government, then with the population at large. It would then be possible to put into effect a number of measures of *"earthquake preparedness planning"* designed to be appropriate to the level of risk and the economic and social environment pertaining in Ghana.

The seismologist, engineering geologists and engineers need help in the following areas:

(i) gaining Government credibility and support
(ii) maintaining and strengthening their database of seismic hazard
(iii) augmenting their analysis of the record of seismicity since 1973
(iv) assessment of ground conditions, particularly regarding possible amplification effects
(v) advising on possible strengthening of key buildings or structures to provide adequate earthquake resistance and on suitable designs
(vi) drawing up appropriate emergency procedures and organisation in the event of an earthquake which could be rehearsed from time to time
(vii) preparing a suitable educational programme both for those in authority and in public service and for schools and the general public.



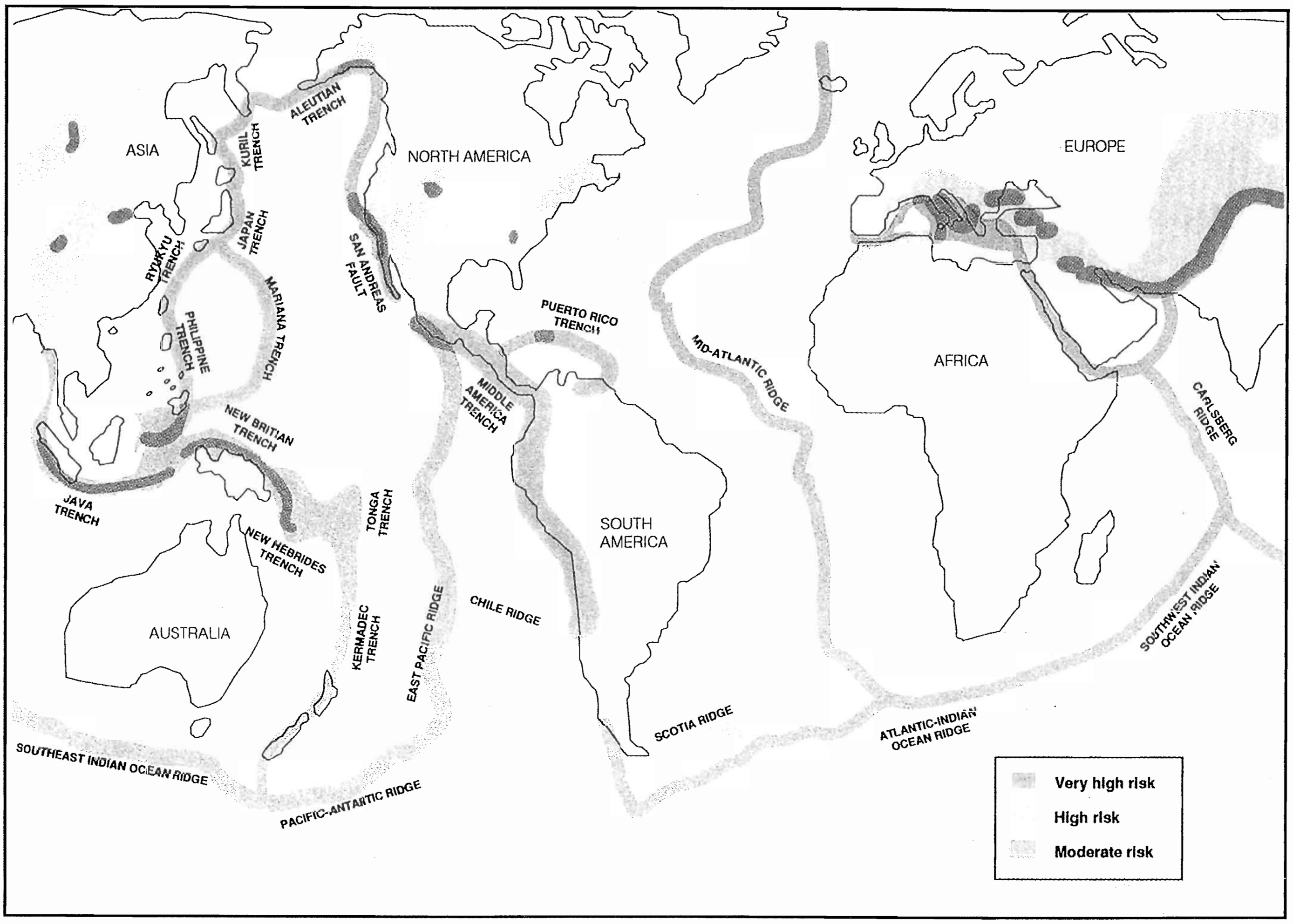
Why a demonstration project?

The situation in Ghana is far from unique and the practical application of earthquake risk mitigation here should be an example that can be applied many times over elsewhere.

There is a real and relatively imminent risk of an earthquake disaster in Ghana. This project could save many lives. An earthquake is the major sudden onset natural hazard in Ghana and so the project can realistically focus on a single hazard. The situation has all the classic ingredients for an earthquake disaster; a reasonably high level of seismic hazard, but not sufficient to register in government or public awareness; a concentration of industry and population in the area at risk; a clear vulnerability and lack of preparedness. Importantly, there is the nucleus of professional scientists and engineers who could take effective measures, given the international support that IDNDR can bring to bear. This project is needed urgently.

A TIME FOR ACTION FOR WORLD SEISMIC SAFETY

An undertaking of the International Association for Earthquake Engineering in support of the International Decade for Natural Disaster Reduction



Above: World seismic risk map roughly indicating the principal regions of the world. Because of its scale the map does not show many small regions with substantial seismic risk

Contents

SECED NEWSLETTER

The SECED Newsletter is published four times a year by the SOCIETY FOR EARTHQUAKE AND CIVIL ENGINEERING DYNAMICS. The Newsletter is issued in January, April, July and October and contributors are asked to submit articles as early as possible in the month preceding the date of publication. Manuscripts should be sent typed on one side of the paper only, and a copy on a PC compatible disk would be appreciated. Diagrams should be sharply defined and prepared in a form suitable for direct reproduction. Photographs should be high quality and black and white prints are preferred wherever possible. Diagrams and photographs are only returned to authors upon request. Articles should be sent to Nigel Hinings, Editor, SECED Newsletter, Allott & Lomax, Fairbairn House, Ashton Lane, Sale, Manchester, M33 1WP, United Kingdom (Tel. +44 (0)61 962 1214; Fax +44 (0)61 969 5131).

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SECED, The Society for Earthquake and Civil Engineering Dynamics is the British national section of the International and European Associations for Earthquake Engineering and is an affiliated society of the Institution of Civil Engineers. It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geological Society. The Society is also closely associated with EEFIT, the UK Earthquake Engineering Field Investigation Team. The objective of the Society is to promote cooperation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

For further information about SECED contact The Secretary, Institution of Civil Engineers, Great George Street, London SW1P 3AA, United Kingdom.

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