Educational Facilities and Risk Management

NATURAL DISASTERS

OECD

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Programme on Educational Building

The Programme on Educational Building (PEB: P*rogramme pour la construction et l'équipement de l'éducation*) operates within the Organisation for Economic Co-operation and Development (OECD). PEB promotes the international exchange of ideas, information, research and experience in all aspects of educational building.

The overriding concerns of the Programme are to ensure that the maximum educational benefit is obtained from past and future investment in educational buildings and equipment, and that the building stock is planned and managed in the most efficient way.

The three main themes of the Programme's work are:

- improving the quality and suitability of educational facilities and thus contributing to the quality of education;
- ensuring that the best possible use is made of the very substantial sums of money which are spent on constructing, running and maintaining educational facilities;
- giving early warning of the impact on educational facilities of trends in education and in society as a whole.

Foreword

The OECD Programme on Educational Building (PEB), the Ministry of Education and Religious Affairs, Greece, and the School Building Organisation S.A., Greece, organised an international seminar in Thessaloniki, Greece, from 7 to 9 November 2001, devoted to natural disaster management and educational facilities. Together with government officials responsible for education and infrastructure, the seminar brought together architects, engineers and scientists to exchange views on the particular requirements of school buildings in the face of risk of natural disasters, and notably earthquakes.

The report focuses on the role that schools play in the community, a role that goes beyond just providing a place for teachers and students for a few hours each day. As community centres for social and cultural activities, sports meetings, etc. it is being increasingly recognised that special attention is needed in building new schools and retrofitting older ones so as to provide maximum protection to school users and physical infrastructure in the event of a natural disaster.

This publication not only raises the question of protecting schools physically, it underscores the need to introduce natural disaster response training and education.

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Introduction

by

Grace Kenny

On 7 and 8 November 2001, around 80 participants, from some dozen countries, met near Thessaloniki, Greece, to discuss the different situations and circumstances which may occur between educational facilities and natural disasters. The emphasis was on the implications and effects of earthquakes and other disasters and the appropriate design and use of educational buildings, both in their role as protection for their everyday users and in their role as emergency shelter for potential survivors.

Damage from disasters, particularly earthquakes, is not only physical, affecting buildings, their fittings, their contents and above all their occupants; it is also economic, cultural and psychological. The economic impact of natural disasters is all too apparent in developing countries, where floods and droughts can quickly destroy years of progress. The loss of archives (*e.g.* the library at Alexandria) and cultural artefacts can undermine a country's historical foundations, while research data and material may be impossible to replace. Equally, the psychological impact of disasters, and particularly earthquakes, can be devastating and long-lasting, especially for those unable to comprehend their cause, in particular the very young.

With the growth which has been seen in insured events, and with the increase in urban densities all over the world but above all in developing nations, the impact of disasters (both natural and man-made) on the built environment is striking. The probabilities and the scale of risks of natural disasters are becoming more and more something which needs to be reckoned with – to be assessed, to be monitored and to be guarded against.

Educational buildings

Distribution

Apart from dwellings, the most common type of building in any settlement is that used for the teaching and training of young people, namely nurseries, schools, colleges and universities. These buildings, by their very function, are evenly distributed across their catchments areas and are used, ideally at least, by the vast majority of populations at some time in their lives. In some cultures, schools are very much seen as the hub of local community life. The implication of this is that they are ideally placed as potential refuges in the case of a disaster. At the same time, however, it also means that if a disaster occurs, educational buildings and facilities are bound to be affected, and must therefore be the subject of particularly stringent regulations concerning design, construction and emergency procedures.

Occupants

In addition their occupants, being young and vulnerable, hold a special place in the public's consideration; any harm to them, and above all any harm which is preventable, is especially dreadful, and public authorities are only too aware of this. (The National Observatory for Safety in Schools and Higher Education Institutions in France was established for this reason.)

Ironically, there is the feeling that the occupants of educational buildings spend the majority of their time in them. In fact this is debatable; in further education in the United Kingdom, for example, the funding council expects buildings to be available for 40 hours a week for 36 weeks a year: this is 16% of the year. And there is good evidence that this 16% is used for only around 40% of its potential. The buildings have students in them therefore, on average, for 7% of the time. During the seminar's presentations, it was striking to hear how often it was considered "lucky" that a disaster struck during the holidays or at a weekend.

Contents

As previously mentioned, the non-human contents of educational establishments can also be very valuable. Many older universities house collections of documents and objects which represent national treasures. Research institutions can also hold historical data that cannot be replicated or backed up electronically. At the same time, particular research institutes may be handling materials which are extremely dangerous, and the normal health and safety procedures which apply need to be reinforced in disaster-prone areas.

Partnerships

Perhaps unusually at an international conference, the participants' interests were unanimous – the protection and security of people and buildings. Apart from obvious geographical variations, cultural and national differences did not make themselves unduly felt. One underlying agreement was on the importance of partnerships, at all levels.

Design

At the level of design, a proper integration of the roles of architect, engineer and client is all important for the adequate strengthening of buildings. The engineer's part is particularly vital in the context of earthquake protection, while the architect should, among other things, consider providing simple buildings where potential subsequent damage is easy to detect and rectify. Inspection should be made as easy as possible in the event of a disaster. "Disguised" elements and, in Greece, half columns, were singled out as potential areas for hidden failure. Equally, the design and fitting of non-structural elements need to be considered and co-ordinated. A lot of injury in earthquakes and hurricanes is caused by falling light fittings and furniture, and by flying roofs.

The importance of the location of buildings and facilities should also not be forgotten, and meteorologists, geologists and environmental engineers can help to site buildings in optimum positions.

It may also be appropriate to bring in social scientists and disaster managers at some stages of the planning and design process in order to make sure that potential lifelines (water, heating, etc.) are adequate if the buildings are to be used as shelters.

Local

Where educational buildings are in use but are also considered as refuges after a disastrous event, there needs to be co-operation not just among their staff and pupils, together with parents and the surrounding community, but also with local fire, police, environmental and health services. Even if these co-operative arrangements necessarily operate at the local level, they may need to be organised and promoted nationally.

National

In the field of public buildings, there may be a "gap" between central design and funding, and local maintenance; this gap can be crucial when it comes to keeping buildings safe and secure, and some sort of agreed national intervention may be necessary.

In the event of a disaster, there is evidence that the presence of **nationally** accredited building inspectors, brought in as quickly as possible, is very reassuring to the victims.

International

Because of the international impact of natural disasters, and because developing countries are particularly vulnerable, international co-operation is essential, at both the prevention and the recovery stages, *e.g.* international networks (UN International Strategy for Disaster Reduction) and organisations. There are now in place large-scale programmes which aim to promote a "mitigation culture", such as the UNCRD's (United Nations Centre for Regional Development) Disaster Management Planning Programme (DMPP), initiated in 1985, within which there now exists the School Earthquake Safety Initiative (SESI). The DMPP's "research and training projects aim to support local governments, non-governmental organisations and academic institutions in creating **partnerships** for disaster management with communities in developing countries." Under this international rubric, the involvement of local people is encouraged, even so far as to include "capacity building" among local masons with a view to their retrofitting existing schools.

Another large scale international initiative, with an emphasis on the urban community, is RADIUS – Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters – which is being promoted by the UN/ISDR, the United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction. The initiative has been piloted in nine case-study cities, and a report has recently been published.

Training

An important element of all such initiatives and programmes is training, both for building designers and the builders themselves, but also for building users. Earthquake-prone countries must put greater emphasis than others on the appropriate training of architects and engineers, and specialists may be needed in the field of assessing and retrofitting existing buildings.

Preparedness

The odd thing about disaster training in schools is that we are preparing people for something which we hope will never happen, and we are preparing children, who may easily become alarmed by overly explicit material.

Warning systems must be reliable and accepted, and appropriate. We are all used to fire drills which we do not know whether to take seriously or not. One of the major problems in the recent storms in France (December 1999) was the fact that the weather warnings were not taken seriously enough; in addition, some of the local forecasts were simply inaccurate, predicting winds of up to 130 km an hour, whereas gusts of up to 170 or even 200 km an hour were recorded.

In Mexico, however, regional seismic charts have been drawn up, and the Centre for Instrumentation and Seismic Recording has developed a Seismic Alert System (SAS). The system has 12 seismic sensor stations on the coast of Guerrero that can anticipate and track the effects of a major event developing there. Also, since 1993 the Ministry of Education requires all schools in the metropolitan area of Mexico City to be tuned to AM or FM radio stations, enabling evacuation procedures to be launched as soon as the alarm activates.

If good action plans are in place, they can be put into effect very quickly. In Greece on 7 September 1999, the Attica basin was struck by an earthquake measuring 5.9 on the Richter scale; during the night of 7 to 8 September an operational programme was elaborated, and on 8 September, teams of civil engineers of the national School Building Organisation were visiting, inspecting and checking 634 buildings in the 20 municipalities of the epicentral area. Schools were able to reopen on 20 September.

Specificity

The training for school users needs to be specific to the type of danger to be expected; this may seem obvious, but there have been cases where children have been trained in evacuation procedures when remaining in the building might have been safer (in the case of external chemical leakages for example).

Acceptance

Again, training must be accepted as normal, and in a sense routine; this both lessens the feeling of alarm and improves levels of achievement. In Mexico, earthquake drills are carried out every two months. In France, emergency plans now have to be prepared and submitted to senior officials every year; this has been imposed on schools by the national government, a fact which underlines both the importance which is now being given to disaster management in schools and the clout which can be engendered by powerful and prestigious bodies (in this case the state).

On occasion, the impetus for improving training and preparedness comes from unions involved in education (France). The acceptance of this type of preparedness training shifts the emphasis of programmes from reaction to prevention.

Materials

All the programmes and campaigns mentioned, and others, make use of extremely imaginative teaching materials, including documents, CDs, videos and even models of buildings. See for example the adventures and games of "Nee-Naw and his Friends" from Portugal, a CD-ROM developed by the Civil Protection Service of the City of Lisbon, "Go in, Stay in, Tune in" produced by the United Kingdom National Steering Committee on Warning and Informing the Public during Emergencies, and "Safety Skills for Life" produced by the Streetwise Safety Centre in Dorset, also in the United Kingdom. These latter will form part of the European Commission's "Learning Protection through Playing" strategy. See also the work done for the *Scuola Sicura* in Italy. For fuller details of these programmes and materials, see the last section of this chapter.

The most recent "Science Year" in the United Kingdom kicked off on 7 September 2001 with the Giant Jump, when over 1 million children in nearly 5 000 schools all jumped at exactly the same time, to see whether there would be a measurable impact on the UK's earthquake detection system. Local traces were detected, but the overall results are still being investigated.

Standards, regulations and procedures

Risk assessment

All programmes of prevention and strengthening begin with some form of risk assessment; this must start with a visual inspection of buildings, and it will then be accompanied by standardised but appropriate formulae to cover such elements as age, type of construction, location and environmental conditions. Programmes such as RADIUS produce software to help in this process, and inspection cycles are now becoming more common and more regular (in Japan and in Greece for example).

Inhibition or support

There is a view that construction standards may inhibit good design. On the other hand if standards are constantly challenged and reviewed by researchers and users, they must be a good thing, and a check on shoddy building.

Execution

However, as with much else, there may well be a gap between the establishment of appropriate standards and their proper implementation "on the ground". Any set of building codes must be backed up by a rigorous policing system, capable of imposing penalties.

On the other hand, they must not be set so rigidly that 75% of school buildings would need to be closed if they were imposed, as has been suggested.

Central versus local

There may be tension between standards which have been established by national bodies, to cover all types of buildings and eventualities, and the conditions which may be found locally. A particular problem may be that national school safety standards may not be able to take local geographic conditions into account, and they may not adequately consider the snow-ball effect of several weather conditions and multiple hazards coming into play at the same time (*e.g.* wind and rain).

In Italy, for example, the conditions in the northern half of the country are very different from those in the south. In Mexico, the country has been divided into different earthquake zones.

Currently several organisations (see the last section of this chapter) are working on an acceptable European-wide standard, Eurocode 8. "Eurocode 8 (EC8) is one of the new Eurocodes that will eventually replace the many different design codes used in the European countries and will help to standardise design methods throughout Europe. Eurocode deals with the design of all types of structure to withstand seismic loading" (EERC – *Earthquake Engineering Research Centre*, United Kingdom).

Improvements

Standards need constant revision as technologies change, and indeed as conditions change (increasing urbanisation, even climate change). In Greece for instance, the building codes relevant to earthquakes have been revised in 1959, 1985, 1995 and 2000.

Finance and legislation

Prevention

The range of resources for carrying out strengthening and prevention programmes is extremely wide. In some villages which are involved in UN projects, the local inhabitants have even resorted to fund-raising in order to protect their own schools. In Greece, a substantial programme of assessment and improvement is under way, with considerable help from European Union funds. In Japan, there is now an arrangement in place whereby, according to the state of school buildings, the government will subsidise up to half the cost of seismic reinforcement for public schools, and up to a third of the cost for private schools. This is in recognition of the importance and impact of damage to public buildings and of the fact that, on the whole, such costs cannot be borne locally.

Maintenance, which is usually the responsibility of local authorities, is another area where proper funding is essential if safety and security are to be kept up to acceptable standards.

Recovery

Similar arrangements are in place when it comes to recovery and repair. In Japan, restoration of disaster is subsidised when there is "severe destruction" (designated by Cabinet order), on the scale of two thirds of the cost for public schools and one half of the cost for private schools.

There are also *ad hoc* or established disaster funds (such as the National Fund for Natural Disasters set up in 1996 in Mexico), and the involvement of private foundations and benevolent individuals. Iceland uses a system of semi-mandatory private insurance.

One of the crucial decisions to be made when buildings are damaged is whether to repair or to demolish, and there are many and various formulae upon which this decision can be made. In Greece, if a building has survived for more than half its lifespan, the cost of repair must be less than half that of new building if it is to be repaired. And if it is newer, up to 80% may be allowed. However, listed buildings do not come under this criterion, and indeed local political and cultural pressures can result in schools being repaired when the formulae would decree otherwise. The Field Act (USA, 1933) recommends up to 70% while Iceland and Spain bear only 50%.

Special legislation

When a disaster hits, rapid intervention and repair are of the essence. In Greece, where earthquakes are fairly common, and as after the 1999 earthquake, the Ministry of National Economy can allow for exceptional procedures and funding in times of emergency, by-passing normal arrangements. The law also allows special dispensations in order for building licences to be obtained, land to be acquired and contracts to be let. Such legal constraints, which require certain time rules to be followed, were a particular obstacle during the recent repair work in France, not to mention the potential conflicts between different expert professions and disagreements over liability. There needs to be a disinterested, overarching third party to resolve such conflicts.

Time-scale

Even if programmes of assessment and strengthening may appear very costly in the first instance, after the first round the costs should fall very quickly. It has been estimated that such costs will be recovered within 15 years. This is another reason why it may be worth-while for international bodies to fund the first stages of such projects – to kick start them – in order to pass the future funding on to national and local authorities. Again, the importance of proper maintenance must be stressed.

Research and support

Technical

Earthquakes and similar disasters are not an area where full-scale and real time academic technical research is possible. However, that is not to say that laboratory-based research is impossible. There are several such research centres, and some are listed in the references section. Such research is the more valuable the more its methods as well as its results are challenged and improved. Such research, however, must interact with the experience of practitioners and building users if it is to be incorporated into improved standards.

Feedback

Real progress can only be achieved through the proper recording and assessment of catastrophic events. Among others, the Administrative Committee for the Federal Programme of School Construction in Mexico has concentrated on this aspect; in Japan, particular studies were made of how different building materials (reinforced concrete) react to earthquakes. In the recent Californian events, studies were made of what caused the most injuries (falling furniture rather than structural elements), whereas in France, in the storms, flying roofs were more hazardous than walls or windows. An idiosyncratic example comes from Papua New Guinea (July 1998) (Tassios *qv*) where elderly residents recognised the relation between ground shaking and tsunami hazard, and told others to move inland, which they did.

As far back as 1929, experience in Iceland showed that "traditional" timber buildings were more robust than "masonry" and non-reinforced concrete, and this early realisation has been borne out increasingly since. The more recently established School Earthquake Safety Initiative (SESI) has reinforced these findings.

Action research

As awareness and networking have grown, it has been possible to test various combinations of approaches – construction, planning, proactive and reactive – in the field. This has been the great impetus behind the RADIUS project, where cities at risk have been offered the chance to set up and put into place assessment, prevention and management strategies. Their "year-after review" shows the results of these initiatives in eight case-study cities: three in Asia (Bandung, Tashkent and Zigong), three in Latin America (Antofagasta, Guayaquil and Tijuana), together with Addis Ababa and Izmir. It has been possible to test the application of the recommended procedures in real situations, with all the real-life constraints of local pressures and politics; it has not been easy.

Specialist units

What seems to be happening is that all the information (research, experience, feedback) which used to be gathered at the time of a catastrophic event, and which then often went unused, is now more systematically gathered, assessed and disseminated to and by specialist units. There are such organisations within individual countries, and they are generally public bodies, like the Earthquake Planning and Protection Organisation (EPPO) in Greece and the Disaster Prevention Unit in Japan, both of whom concentrate largely on educational and cultural buildings. Other such organisations are not necessarily made up of people who share a workplace, or even a country; increasingly they are more or less loosely constituted organisations which can call on the appropriate range of experts when these are needed. The various agencies of the UN are a prime example of this, and exchanges of information (feedback, experience) and expertise (professional research and studies) are becoming easier with the Web and the Internet.

Although these units may have a primarily technical bias, the importance of raising awareness of the issues involved can mean that the team will sometimes include psychiatrists and other social scientists, and even "celebrities", useful when the public needs to be "buttonholed" or when money needs to be found. The essence of these units is that they are teams, virtual or real, which can be co-ordinated by quite small secretariats, in order to try to foresee and to react to potentially catastrophic public events. Moveover "global" teams can help motivate and organise local teams.

Conclusion

As ever, there is an enormous amount of extremely good work going on in the field of school building design and use and the impact on these of different types of disaster, natural or otherwise.

The growth of specialist teams and organisations underlines the importance that the public and politicians attach to these events. It is clear that as urbanisation increases, as climate change becomes possible (with dire effects particularly for developing countries) and as the globalisation of information becomes a reality, disasters and their impact can no longer be left to the best efforts of communities and regions. Overarching organisations, either national or international, are the only ones with the necessary funding and influence to support and, if necessary, to impose acceptable criteria for construction, maintenance and recovery.

On the other hand, in the field of educational buildings in particular, with their vulnerable occupants, it is argued that the psychological aspects of awareness training and recovery from disaster must be paramount. Of course, they are important; however, without the very real progress which is being made in technical standards and in their implementation and monitoring, many more buildings would be damaged or destroyed and, inevitably and unfortunately, any psychological implications would have no chance to come into play.

A selection of relevant documents, programmes and organisations

Ecuador

Escuela Politécnica Nacional/GeoHazards International (1995), "The Quito, Ecuador School Earthquake Safety Project: Investing in Quito's Future" (bilingual English/Spanish), geohaz@pangea.stanford.edu

European Union

Learning Protection Through Playing strategy, Panagiotis.Alevantis@cec.eu.int; http://europa.eu.int/comm/environment/civil/index/htm

France

Observatoire national de la sécurité des établissements scolaires et d'enseignement supérieur, www.education.gouv.fr/syst/ons

Greece

Earthquake Planning and Protection Organisation (E.P.P.O.), "Earthquake – Knowledge Means Protection", grtypou@osk.gr

Iceland

Sigbjörnsson, R. *et al.* (2000), *Earthquakes in South Iceland on 17 and 21 June 2000*, Earthquake Engineering Research Centre, University of Iceland, Selfoss, ragnar.sigbjornsson@hi.is

Italy

La scuola sicura project, www.scuolasicura.org

Japan

Disaster Prevention Unit, Department of Facilities and Administration, Ministry of Education, Culture, Sports, Science and Technology (MEXT).

Improvement of seismic performance of reinforced concrete school buildings in Japan.

Seismic capacity upgrading program of existing reinforced concrete school buildings in Ota City, Tokyo, Japan, www.mext.go.jp

Mexico

Government of Chiapas, "Esta Contigo!", School Construction Committee, ccruz@cocoes.gob.mx

New Zealand

Department of Education, Buildings Division (1983), Earthquake and Emergency Precautions in Education Buildings.

OECD/PEB

Safety and Security in Educational Buildings, conclusions of a seminar in Semmering, Austria, May 1987.

Portugal

Lisbon's Civil Protection Service, Lisbon City Council, "Growing Up in Safety", project for awareness training in civil protection and safety; "Nee-Naw and his Friends", CD-ROM available from ipais@cm-lisboa.pt

Switzerland

Joint Committee on Structural Safety (combining six international organisations), www.iabse.ethz.ch

UNESCO

School Buildings and Natural Disasters, Educational buildings and equipment 4, 1982.

Protection of Educational Buildings against Earthquakes, Educational Building Report 13, 1987, www.unesco.org

United Kingdom

Department for Education and Skills (1991), *A School for Armenia*, Building Bulletin 74, www.dfes.gov.uk/schoolbuildings

Earthquake Engineering Research Centre, www.cen.bris.ac.uk/civil/research/eerc

Royal Society for the Prevention of Accidents, "Learning About Safety by Experiencing Risk", (LASER), www.rospa.co.uk/laser

Streetwise Safety Centre, "Safety Skills for Life", available from alison@streetwise.org.uk

The Giant Jump, www.scienceyear.com

The Society for Earthquake and Civil Engineering Dynamics (SECED) (British branch of both the International Association and the European Association of Earthquake Engineering, working on preparation of Eurocode 8), eunice.waddell@ice.org.uk

UK National Committee on Warning and Informing the Public during Emergencies, "Go in, Stay in, Tune in", available from david.moses@hertsscc.gov.uk

United Nations

UN Secretariat for the International Strategy for Disaster Reduction (ISDR), UN World Disaster Reduction Campaign 2001, www.unisdr.org

UN Initiative towards Earthquake Safe Cities, Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters (RADIUS), okazaki-k29n@mlit.go.jp

Year-Later Evaluation of the RADIUS Case-study Cities, tsunozaki@un.org

UN Centre for Regional Development

Disaster Management Planning Hyogo Office/GeoHazards International (2001), Global Earthquake Safety Initiative (GESI), pilot project, final report, October, shaw@hyogo.uncrd.or.jp

United States

APPA (2000), "Disaster Planning and Emergency Preparedness", Facilities Manager, Volume 16, Number 6, November/December 2000, www.appa.org

Decker, Robert H. (1997), *When a Crisis Hits, Will Your School be Ready*?, Corwin Press, order@corwin.sagepub.com

Federal Emergency Management Agency (FEMA) (1990), *Guidebook for Developing a School Earthquake Safety Program*, www.fema.gov

Multidisciplinary Centre for Earthquake Engineering Research, http://mceer.buffalo.edu

Chapter 1

Risk Assessment and Strengthening Educational Facilities Against Natural Hazards

by

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Economic, cultural and social significance

Building is the most ancient industry. Humans were created "dangerously naked and without an instinct to build nests". Thus Prometheus feared that they would rapidly perish. Then a miraculous correction of creation took place: according to the Ancients, the creators offered technology to human beings – and so they gathered in cities, protecting themselves against nature, and they prospered.

Yet building is not only the most ancient industry; often it seems the most obsolete one too. It is slow to adapt to changing environmental circumstances and social conditions – doing little for the repute of architects and engineers.

People ask why we do not build structures, especially for the young, in other words schools, that can stand up to hurricanes, floods, landslides, forest fires, earthquakes or tsunamis. Our answer is "in fact, we do": look at the hundreds of thousands of successful school buildings that have resisted natural (and some man-made) hazards very well.

The riposte that then comes is "Yes, but what about the thousands of other cases, especially in developing countries, where dramatic failures occur?". Here the answer of the engineer would be that every structural design needs to presume some "maximum" expected intensity of a given hazard. And since we can only proceed on the basis of statistics for previous intensities, if only roughly, we have to select a maximum intensity with a "socially acceptable" small probability of being exceeded – which, as we know, *cannot* be equal to zero, because that would correspond to an infinite intensity (or, in other words, to an impossible structure).

How does a given society at a given point in time select an acceptable "failure probability" level? There is no explicit procedure. But the implicitly selected P_{f}_ value (probability of failure), based on long experience and on trial and error, is meant to optimise the total cost (direct investment, capital cost, plus costs that could be incurred if the "probable" hazard-intensity is exceeded), within the lifespan of the building to be designed. Quality assurance costs and maintenance costs enter the equation as well. The factors that affect the level of this "acceptable probability" are summarised in Table 1.

Theoretically, all components of the "generalised cost" are direct or indirect functions of the acceptable probability of failure P_f. Thus, for a given lifespan "t", and in given economic, state-of-knowledge and social conditions, the P_{f}_ value selected is the one which minimises generalised cost C_{gen}.

All factors affecting the safety level may be categorised as economic, state-of-knowledge or social, as shown in Table 1. It might seem strange that a concept

Table 1. **Social consensus regarding the safety level of buildings: natural and man-made hazards**

Social consensus	Factors	Social characteristics		
		Economic	*State-of-knowledge*	*Moral*
On "acceptable" failure probability	Hierarchy of values			●
	Average income	●		
On "quality assurance" of design, construction and supervision processes and on "maintenance"	State of the art		●	
	Level of education + professional skill		●	●
	Available resources	●		

such as "building safety level", which one would expect to be technical, can depend on so many economic, state-of-knowledge and social factors; but in fact it does.

It is precisely because of this complexity, and of the approximate nature of the statistical process I have mentioned, that our societies seem to be so frequently "surprised" by building failures when severe natural hazards occur.

In many cases, these failures are simply the price to be paid for our low-cost preferences in the past. In addition, "developing countries are much more vulnerable to losses from natural disasters than industrialised countries; they suffer more than 95% of all disaster-caused deaths, and economic losses 20 times more costly (as a percentage of gross domestic product) than those sustained in industrialised countries. By including hazard management in its regular operations, the World Bank aims to help countries plan for disasters and recovery, and reduce their severe vulnerability." This message from the World Bank (W. Anderson, NSF, June 2001) may assume much greater significance in the post-11 September 2001 period.

Because of these uncertain and highly diverse circumstances, annual losses of buildings (and more specifically of educational buildings) are very high across the globe – "embarrassing as it may be for professors and humiliating for theologians" (E.J. Barbier). The loss of life and material loss have tremendous economic and cultural consequences: direct economic damage (which has to be borne immediately by the current generation), educational damage (schooling has to be deferred), psychological damage (a considerable percentage of students are left with some kind of neurosis). Besides, when a school building is damaged or is unsafe, it cannot be used for temporary shelter during a crisis. Last but certainly not least, casualties and fatalities among the young are always felt much more heavily.

At this point, another component enters the equation: the older a school building is, the higher its risks may be, because of:

- the lower level of "know-how" and resources available in previous times;
- the structural deterioration which may have taken place during its life.

What is more, available know-how, resources and maintenance capacity are very unequally distributed across a country (and, even more so, from country to country). All this means that a student in an old school building is subjected to considerably higher risks. Once again social justice is clearly jeopardised.

One of the possible remedies to all this is to "strengthen" existing school buildings against future natural or man-made hazards. Structural strengthening is thus a strategy of high economic, functional and social importance.

Risk assessment procedures

As an introduction to our subject, a summary of the primary and secondary effects of natural hazards is shown in Table 2 (from "Megacities"", The Institute of Civil Engineering, London, 1995). To this we should possibly add wildfires and winter storms. Man-made hazards might also be mentioned, such as hazardous materials, building fires and arson, radiological accidents, and vandalism and terrorism.

In what follows, only natural hazards will be considered. A valuable source of information on man-made hazards is the FEMA Library (www.fema.gov/library/facts hts.htm).

Since the beginning of the 1980s, the number of insured events has risen steadily, from some 100 per year before 1980 to 250 in the year 2000 (Sigma, N°. 2/2001).

Hazard assessment of educational facilities may normally be incorporated in national hazard assessments. (Only some man-made hazards may possibly be school-specific.) Within national regulatory documents, hazard levels are determined as a function of an "accepted" probability of such levels being exceeded. Lower probabilities may be imposed for some more sensitive educational buildings, especially when they are meant to be used as post-event shelters.

A number of examples of losses of educational buildings caused by natural hazards are listed below. Taken more or less at random, they underscore the need for comprehensive statistics and continuous worldwide monitoring in this field. Otherwise, it will be more difficult to build an effective risk mitigation strategy for educational facilities.

Storms and cyclones

In Belgium, hundreds of schools were damaged during the storm of 25 January 1990. A direct loss of more than EUR 3 million was reported. In the Province of Antwerp alone, 37 school buildings were damaged by the storm of 9 August 1992, causing damage estimated at EUR 100 000.

Between 1985 and 1994 in the United States, lightning damage to seven school buildings was reported. More broadly, "weather-related" disasters in the country between 1988 and 2000 cost over USD 180 billion.

In the past decade the University of Miami, Tulane University and East Carolina University were closed by hurricanes. Similarly, North Dakota, Colorado State, Syracuse and many other universities have faced damage and business interruption from flooding.

Table 2. **Summary of primary and secondary effects of natural hazards**

Natural hazards	Primary phenomena	Secondary phenomena
Cyclone	Strong winds Heavy rains	Flood and sea surge Landslide Water pollution
Flood	Flooding	Water pollution Landslide Erosion Deposition
Tsunami	Flooding	Water pollution Landslide Erosion Deposition
Earthquake	Violent ground motion Fault rupture	Soil liquefaction Fire Flood Landslide Tsunami Water pollution
Landslide	Ground failure	Flooding via river damming Water pollution Debris flows
Volcano	Lava flow Pyroclastic flow/surge Ash fall Volcanic gases	Fire Air pollution Tsunami Lahar flows Water pollution Ground subsidence

Source: Megacities, Inst. of Civ. Eng., London, 1995

Landslides

The scale may be shown, albeit in general terms, by the fact that landslides cause an average of USD 2 billion in damage and take 35 lives annually in the United States alone. Although specific data for school buildings were not available to this writer, the order of magnitude of these overall figures underscores the risk from landslides.

Tsunamis

In the 17 July 1998 tsunami in Papua New Guinea, no structure survived the waves in the villages of Arop and Wanapu. Five schools were located in the devastated area where 233 students and five teachers were killed. Some elderly people understood the relation between ground shaking and tsunami hazard, and told others to move inland after the earthquake (the 15–25 minutes were sufficient for many to reach safety before the first wave).

Earthquakes

A significant proportion of seismic-related school losses is due to non-structural components. If the Northridge earthquake (17 January 1994) had struck on a school day in the Los Angeles Unified School District (900 schools, serving a population of 800 000 students and employing 80 000 staff), thousands of children would have been seriously or even gravely injured by non-structural elements. For example, hundreds of lighting units fell on desks in classrooms that the students would normally have occupied.

More generally, the entire material losses in the 5 500 school buildings affected by the Northridge earthquake were estimated at USD 140 million. However, mainly non-structural and repairable structural damage was observed. The partial collapse of a relatively new building around the Oriatt Library (California State University) is mentioned below.

All in all, thanks to the early steps taken after the Field Act, school buildings in the United States have resisted earthquakes fairly satisfactorily. It is important to remember that losses due to the Northridge earthquake of 1994 totalled USD 25 billion. On the other hand, the Loma Prieta earthquake of 1989 caused minimal damage to public schools; the administrative building of California State University was an exception.

Mexico should also be mentioned in this indicative list of school building losses due to earthquakes. After the Oaxaca earthquake of 30 September 1999, over 1 500 schools were reported damaged, and 300 000 students were excluded pending school inspections. There were few cases of real structural damage, however.

Thirty students were killed when two school buildings collapsed during the Cariaco (Venezuela) earthquake of 1997, due to the failure of short columns (typical in such buildings).

Turkey's seismic events of 1999 also resulted in important losses of school buildings. The earthquake destroyed or damaged many primary and secondary schools in five provinces and 15 sub-provinces of western Turkey, affecting 36 000 students and 1 140 teachers. Forty-three schools were destroyed. Another 380 school buildings were damaged and required rehabilitation. An estimated total cost of USD 40 million was reported, and 550 000 students were affected. A particular feature was that a surface seismic fault in Yuracik passed through a school building.

In this brief review of seismic losses of school buildings, examples from some smaller countries should also be mentioned:

In Guam, the 1993 earthquake damaged several low-rise school buildings constructed between 1965 and 1986. Poor construction practices were revealed in some instances; short column effect and excessively heavy roofs were the main causes of damage.

In West Sumatra, the Bengkulu earthquake of 4 June 2000 destroyed 136 school buildings and damaged another 116.

Incomplete as it is, this reminder of school building losses due to natural disasters shows the need for pre-assessment of the risks and for an appropriate strengthening policy. Hazards can be ranked only country by country; worldwide however, roughly speaking, it seems that earthquakes, windstorms and floods cause equal shares of fatalities and economic losses (Munich Re, Geoscience Research Group, 1999).

Techniques for risk assessment

The most elementary method of assessing the expected risks for a school building consists of vulnerability studies:

- Visual inspection is carried out to identify and appraise the structure, including foundations.
- Information on the design regulations applicable at the time of construction is taken into account.
- The social, functional and economic importance of each particular building is also considered.

All data are empirically quantified, so that a relative risk index (R) is found:

$R = f [I, H - H_o, V]$

I = an Importance index reflecting all kind of potential losses, allowing also for escape routes;

$H - H_o$ = the difference between the expected Hazard level "H" and "H_o", the one taken into account (explicitly or implicitly) in the design of the building;

V = index of Vulnerability, an estimator of the "proneness" of the building to show structural and non-structural damage.

A more advanced (but still very approximate) technique is based on the "vulnerability functions" applicable for buildings of a given type and age. In its simplest version, this technique is based on "damage curves". For the intensity of an expected hazard (*e.g.* depths of water due to flood, ground accelerations due to earthquakes, etc.), the curve predicts the damage loss "D" as a percentage of the total value "C" of the building. Thus a risk index can be estimated as follows:

$R = I.\ D.\ C.$

where "I" denotes social importance, density of occupancy, availability of escape routes, etc.

In the particular case of earthquakes, a more sophisticated technique has been developed in the United States. An earthquake loss estimation methodology is incorporated in the HAZUS computer package intended for local, regional or federal officials performing an earthquake loss study (NIBS/FEMA), for use in:

- Anticipating the nature and scope of the emergency response needed.
- Developing plans for recovery and reconstruction following a disaster.
- Mitigating consequences by various means, including strengthening.

The methodology is ambitious and takes account of:

- Fault rupture, liquefaction, secondary sliding.
- Building stock, facilities, transportation and utility lifeline systems.

Analysis based on default information is also feasible, though with greater margins of uncertainty. The information generated by this methodology covers:

- Quantitative estimates of losses (including casualties and quantity of debris).
- Functionality losses and restoration times.
- Extent of subsequently induced hazards (such as fire ignition and spread, potential flooding, etc).

Another category of risk assessment addresses multiple hazards. For instance, risks due to an earthquake may be generated not only by the direct seismic action on the structure, but by other consequences, *e.g.* flooding after a dam failure or explosion caused by ruptures in nearby pipelines.

This was the approach taken in a special study carried out by the Castraic Union School District, California, operating 63 buildings (1 200 students and 120 staff). The seismic resistance of the dam (three kilometres upstream) was reconfirmed versus the "maximum credible earthquake", though a very small probability of rupture persists. High-pressure crude-oil pipelines crossing the campus were found to have considerable vulnerability to expected earthquakes. Several disaster scenarios were studied, together with mitigation solutions. Based on cost-benefit estimations, a combined decision was taken to rebuild some school premises and relocate others.

Last but not least, we may mention the special case of the United Kingdom, where the major disaster problem in school buildings seems to be arson, rather than any natural hazard. An average annual loss of GBP 45 million has been observed over the last ten years, and 70% of all fires in schools are started deliberately. This (together with the new threats of terrorist events) shows the need for much broader mitigation strategies (with additional moral and political components), which are clearly beyond the scope of this presentation.

"School-specific" vulnerability

Among the general structural and non-structural characteristics of buildings which determine structural vulnerability generally, some are encountered more frequently in school buildings. A brief and necessarily incomplete outline of such "school-specific" characteristics is presented below.

First of all, school buildings (like other public sector structures) show a longer life span than private houses. This means that many of them were designed and put up long ago, with less than satisfactory know-how: early building regulations (or none at all) and older materials and techniques tend to increase vulnerability to natural hazards.

More specifically, roofing systems may induce vulnerability, even in low-rise school buildings:

- Heavy roofs (adobe layers or heavy precast reinforced concrete units) have frequently been observed in school buildings damaged by earthquakes.
- Wood roofs with inappropriate ties may allow (i) additional thrust to longitudinal (otherwise unbraced) walls of one-storey school buildings, as well as (ii) inadequate wind protection.

In intensive construction programmes of school buildings countrywide, precasting is more frequently used, with potential adverse consequences due to occasional non-ductile connections between precast elements.

Structural characteristics of some school buildings are dictated by architectural/functional features:

- Long (and frequently unbraced) walls may be vulnerable to strong wind and also show inadequate transversal seismic resistance.
- Short (reinforced concrete) columns between consecutive long windows are extremely brittle under seismic conditions.

New school buildings may be constructed on the periphery of villages and unstable ground conditions may be encountered (including potentially creeping landslides).

Finally, in most cases in developing countries, self-help construction systems are often adopted, sometimes without full engineering supervision.

Last but not least, occupancy density of educational buildings is higher than for any other social functions, except perhaps for churches, as illustrated by the following selection of daytime occupancy rates (from FEMA 174/1989, "Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings"):

• Permanent dwelling	1.2 occupants per 100 m^2
• Government services	4.0
• Hospitals	5.0
• Fast-food restaurants	10.0
• Educational buildings	20.0

Pre-quake strengthening of school buildings

This section focuses on only one of the natural hazards threatening educational facilities: earthquakes. Southern Europe and South America are principally subject to seismic risks. But seismic strengthening policy may also be relevant to strengthening against other natural hazards too.

General concept of strengthening: pre-event mitigation of building risks

Seismic risk mitigation can be achieved by direct structural intervention and by a number of other means:

- Prediction, forecast, warnings (this is mainly feasible in the case of weather-caused hazards, such as cyclones and wildfires).
- Preparedness (an excellent nationwide programme, "Safe School", was initiated in Italy in 1993).

- Fixing of non-structural elements (another important issue for school buildings in relation to earthquakes).
- Structural strengthening.
- Partial (or total) demolition and rebuilding.
- Relocation of the building.

Only non-structural and structural pre-quake strengthening will be considered, very briefly, here.

Non–structural "strengthening"

"If the [1994 Northridge] earthquake had struck on a school day, thousands of Los Angeles schoolchildren would have been seriously or even gravely injured by non-structural elements (*i.e.* falling lights)." This statement by the Federal Emergency Management Agency (FEMA) highlights the importance of a monograph entitled "Non-Structural Earthquake Hazards in Schools" (FEMA 241/July 1993), published a year before the Northridge event.

One example of strengthening measures concerning non-structural components is at the University of California, Berkeley: Even buildings considered "fair" in its 1997 evaluation may be subject to considerable non-structural and content damage. One third of the replacement value of the campus relates to books, instruments, research equipment and art – all highly susceptible to damage and essential to the teaching and research mission of the university. This adds a "business-oriented" perspective to the traditional loss estimations for universities.

Another example concerns the 5 500 buildings owned by the Los Angeles Unified School District, where provisions for safe lighting upgraded to current requirements were included in the USD 162 million which FEMA allocated to the district for strengthening.

Structural retrofitting or reconstruction of school buildings in the United States

One important example of seismic strengthening of school buildings was provided in California, via the Field Act, as early as 1933. Local society was deeply concerned at the consequences of the Long Beach earthquake (March 1933, M=6.3): 75% of the public school buildings were heavily damaged, with many reduced to rubble. Just a month later the state legislature enacted a law requiring state control of public school construction (the Field Act, named after its author). A second statute, the Garrison Act (1939), set forth corrective steps to be taken by school boards with existing school buildings, within a 30-year period; otherwise, replacement or reconstruction was mandatory. 7 400 public schools and 110 community colleges in the State of California, housing 5 million students, were constructed or reconstructed under the provisions of the Field Act (USD 11 billion, non-actualised value, were spent between 1935 and 1985).[1]

The significance of this remarkable project was reconfirmed during the San Fernando earthquake (1971, M=6.6): "School buildings in the region of strong shaking, designed and constructed since enactment of the Field Act, did NOT suffer damage that would have been dangerous" (Joint Panel on the San Fernando Earthquake, NAS, Washington D.C., 1971). However, during the Imperial County (M= 6.6, 1979) and Coalinga (M=6.7, 1983) events, Field Act buildings suffered non-structural damage.

The Field Act experience in California has shown that old school buildings required rehabilitation costing, on average, the equivalent of 70% of the replacement cost for a new building.

More generally, I wish to reiterate the importance of state-inspired and state-supervised projects for strengthening of school buildings – even under more liberal economic conditions such as those prevailing in the United States. The long time-horizon within which the cost-benefit optimisation needs to be sought, as well as the broader societal interests involved (hardly amenable to monetisation), mean that free-market mechanisms are unlikely to be effective. The Earthquake Engineering Research Institute (United States) went so far as to say, "We would feel very uncomfortable entrusting the safety of our schools to local governments with known poor enforcement practices"" (EERI, October 1998 Report).

Now let us take some other American examples of strengthening educational facilities. University buildings will be more specifically considered here.

- Seismic retrofitting, University of California at Santa Barbara: The North Hall facility (a three-storey reinforced concrete structure, built in 1960) was designed with only one tenth of the 1958 code requirements, creating unsafe conditions for the advanced level of UBC seismic standards (1975). The 1976 cost of retrofitting was USD 120 per square metre as compared to a 1976 cost of USD 600 per square metre for replacement of the building. This 20% cost is a reasonable figure, when compared to retrofit costs which can be as high as 50% on occasion.

The 1978 Santa Barbara earthquake caused USD 4 million damage to unretrofitted buildings of the campus, but, remarkably, no damage to the strengthened North Hall facility.

- San Francisco State University: The administration building (six storeys, built in the early 1970s), made of reinforced concrete frames, was originally designed applying the codes of the late 1960s (5% lateral load). A structural steel movement-resisting frame was selected as the most effective seismic retrofit solution for the building; it was added and connected to the existing external reinforced concrete frames. It was designed to provide the necessary lateral resistance (0.4g) avoiding reinforced concrete column brittleness, and to allow strengthening procedures that did not disrupt normal work in the building or obstruct windows. The project was completed early in 1998.

FEMA and the University of California, Berkeley, have funded the research and development component of the Disaster Resistant Universities (DRU) initiative, to motivate and enable universities to manage their vulnerability to hazards, by means of a model that can be adapted and used by other institutions:

- hazard assessment;
- estimation of direct losses and other economic impacts;

- strategic risk management plan;
- programme for disaster resistance;
- progress on national funding for hazard mitigation in universities.

The university's 2000 report on the subject reviews strengthening projects on the campus:

- Based on a seismic review in 1978, a number of buildings were strengthened (including the University Hall).
- By 2006, ten other major central buildings will have completed seismic strengthening.
- Another 15 buildings are slated for seismic retrofit by 2011.

The current 20-year project will cost USD 1 billion. We should note both the economic sacrifices of the present generation in favour of the next one and the pragmatism of the time-schedule adopted at Berkeley.

School building strengthening in some less developed countries

Pre-quake assessment of risk, strengthening strategy, financing and implementation all necessitate substantial know-how and economic means. These are not available in all countries. But a number of countries, independent of their level of development, have undertaken measures to strengthen school buildings. Some examples are briefly presented below:

Cyprus

First, a visual screening of all school buildings was carried out in 1999, and 13 schools were found to need immediate intervention; this is being carried out. Guidelines were subsequently drafted by a national committee for vulnerability checking and strengthening methodologies, both for school buildings and for refugee housing. Finally, a five-year programme has been launched for the second priority rehabilitation work.

Mexico

Some schools designed in the 1960s and 1970s were moderately damaged during the Michodean earthquake in Mexico City. Some school buildings were retrofitted adding post-tensioned bracing systems composed of prestressed high-slenderness steel strands (tension-only bracing systems). Base-isolation is also contemplated for other school buildings on Mexico's Pacific coast.

Retrofitting of school buildings against hurricane risks

A couple of examples from less developed regions will be presented here, referring to school buildings at risk from hurricanes.

Caribbean (USAID – OAS, Caribbean Disaster Mitigation Project, April 1998)

The Norman Manley Law School (700 m^2, two-storey, reinforced concrete block masonry and steel space frame roof) was constructed in 1974-75. However, there is no clear evidence that the design specifically included a strategy for resistance to hurricanes and to earthquakes. Hurricane Gilbert (9 December 1988) badly damaged the roof of the building, because of:

- inadequate fixing of the deck planks;
- weakening of the roofing material by rain;
- the failure of a clerestory window, which allowed the ingress of the wind (increasing the uplift pressure on the roof deck planks).

A project manager was employed by the university to supervise reconstruction activities, but no firm instructions were given regarding the need to ensure hazard resistance, although only a modest (15%) increase in reconstruction costs would have sufficed to cover the additional investigation and testing needed.

Antigua and Barbuda: national plan to reduce school vulnerability

Thirty government primary schools and nine secondary schools (built over 20 years ago) were to be retrofitted against hurricanes (and used as hurricane shelters), floods and earthquakes. The Board of Education and the Ministry of Public Works have undertaken rehabilitation work on 20 school buildings, made of a variety of materials (timber, reinforced masonry, reinforced concrete and plain masonry). Emphasis was placed on effective government supervision to enforce the building codes and on the need for community action groups to play a full part in policymaking.

Policies to strengthen existing school buildings

A simplified list of the components of a regional or national project for strengthening school buildings is presented below.

Catalogue of existing school buildings

Including information on:

- structural materials;
- age of the building;
- occupancy (number of students, schedules);
- availability of building permits;
- prior damage and repairs;
- current total cost of the building and its contents;
- escape routes, referring to the hazard under consideration.

Hazards and their expected intensity with an (empirically) acceptable probability of levels being exceeded

To this end, other relevant national projects and zoning maps will be used. However, some local particularities may be needed to be added, *e.g.* seismic microzoning or geomorphology-enhancing local vortexes.

Vulnerability data

This is the most important and difficult part of the entire process. The concept of "vulnerability", introduced above, is an estimator of the proneness of the building to show structural and non-structural damage under a certain kind of natural hazard. It can be evaluated on the basis of purely empirical or (if possible) analytical criteria. National and international literature[2] offers a variety of such criteria and vulnerability methodologies – although there is on occasion some confusion between vulnerability and risk.

Relative risk evaluation

The simplest method would be that described above in "Techniques for risk assessment". But selecting appropriate values for the "importance factors" is another difficulty. However, in absence of data in literature, simple engineering judgement may suffice, since absolute values for global failure costs cannot always be obtained. That is why we refer to "relative" risk evaluation.

Pilot study of risk assessment

Before any general application, nationwide, it is suggested that a pilot study be carried out in selected school buildings which have previously been affected by the hazard under consideration, damaged and repaired – with known costs for repair works and for lost school operating time (including loss of availability as a shelter, where applicable). "Relative risk values" estimated by the aforementioned simple technique can be calibrated against the "real risk" (costs) encountered, and the methodology can be corrected as appropriate. Alternatively, calibration can be effected by numerical methods of higher levels of sophistication and precision.

Decision-making

First, some counter-incentives to strengthening interventions in school buildings have to be recognised:

- priorities set by social/political values may be unclear (shortsightedness of the kind "Me, here and now");
- financial and organisational obstacles;
- technical difficulties, such as obstacles to diagnosis, lack of know-how, disproportionate professional responsibilities;
- possible legal problems.

An open-minded discussion of these and other obstacles has to be initiated in school boards and in the local communities.

Second, systematic political pressure has to be generated from the bottom up (from several local communities) before central government decisions can be seriously expected. Priorities for national funding are not set by mathematical calculations performed in the Ministry of Finance; they are built up via political bargaining – sometimes in the aftermath of local disaster, undesirable though this is in every sense.

Third, both channels have to be followed, *i.e.* local and national plans have to be established – even if funding is not secured. While awaiting nationwide plans, municipalities should prepare their own plans for school buildings – rehabilitation against prevailing hazards, together with possible scenarios including:

- priorities for some categories of school buildings;
- alternative financing resources;
- alternative time-schedules; in this respect, pragmatism should prevail;
- management of programming, design, selection of contractors;
- supervision and maintenance; high levels of quality assurance should be sought;
- selection of at least one school building to be strengthened using local funds, design and construction firms, as a pilot effort (guiding all concerned, and as a token of determination).

Local plans, however, should be adapted to national plans once these are finalised.

Implementation

Depending on the scale of the plan (local or national), various forms of organisation will be proposed; normal practice should be followed. On more technical grounds, however, it is important that designers should not be left alone to select fundamental (safety-related and quality-related) parameters. Instead, local, regional or national authorities should issue guidance documents on the following re-design parameters:

- socially acceptable probability of the hazard-intensity value being exceeded to be taken into account;
- performance level expected at that value;
- redesign-hazard-value (slight damage, life protection and repairable damage, close to collapse).

Thanks to the combination of these two specifications, the owner of the school buildings has a realistic possibility of adapting to actual necessities, such as available finance and the social importance of each school building. Otherwise, maximalist specifications may prove impossible for the present generation to comply with, while lack of specifications may encourage opportunistic solutions to satisfy public opinion: "At least we did something".

Furthermore, authorities should formulate criteria to be used in selecting strengthening techniques which are appropriate and feasible in a region with a given level of development and given availability of materials and workmanship (see, for instance, European Design Code E8, Part 1-4).

In drafting these plans, a range of documents and sources of information may be of assistance. An indicative list is given below.

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DIS, Inc, [Seismic Isolation]: www.dis-inc.com

Earthquake Engineering Research Institute (EERI), United States: www.eeri.org

EQE International Inc., Managing Risks through Engineering, Science, Technology: www.eqe.com

Federal Emergency Management Agency, United States: www.fema.gov/MIT

INCEDE, University of Tokyo, Japan: www.incede.iis.u-tokyo.ac.jp

Joint Research Center, European Union, Ispra (Italy), [Risk Assessment]: www.jrc.cec.eu.int

Los Angeles Unified School District, United States: www.lausd.k12.ca.usa

National Information Service for Earthquake Engineering, University of California, Berkeley, United States: www.eerc.berkeley.edu

National Oceanic and Atmospheric Administration, United States: www.ncdc.noaa.gov/ol

Natural Hazards Center, University of Colorado, United States: www.colorado.edu/hazards

OECD Database: www.oecd.org

Organisation of American States, Caribbean Disaster Mitigation Project: www.oas.org./en/cdmp

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U.S. Department of Education: www.ed.gov

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Notes

1. Further reading:
   a) Jephcott, D.K., "50 Years of Field Act Seismic Building Standards for California Public Schools", Seismic Safety Commission Report, Sacramento, 1984.
   b) "The Field Act and California Schools", State Safety Commission, 1979.

2. See also "References" and "Web sites" above.

Chapter 2

The Role of Schools in Creating an Earthquake-Safer Environment

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Introduction

Earthquakes are considered as one of the most destructive natural disasters and can produce many types of loss, including physical, socio-economic and cultural. Although loss of life and damage to buildings and social infrastructures will most directly affect the victims, other types of loss might trigger social unrest and aggravate poverty levels. Earthquakes severely impact the development stages of a country, and in many cases one single event has been observed to significantly affect gross domestic product. To live in a safe environment is a basic human need. In developing countries, to make the development process sustainable it is important to emphasise the prevention and pre-disaster mitigation aspects. The most significant issue in this regard is to have the proper educational training and perspective on earthquake risk and its consequences.

UNCRD's Disaster Management Planning (DMP) Programme was initiated in 1985. Progress in regional development has led to a better and safer living environment, but it has also made the environment more vulnerable to natural hazards. The programme's research and training projects aim to support local governments, non-governmental organisations and academic institutions in creating partnerships for disaster management with communities in developing countries. The goal of this programme is two-fold: 1) to improve the capacity of communities to develop and implement disaster management plans, and 2) to strengthen public awareness of natural hazards.

The School Earthquake Safety Initiative (henceforth termed as SESI) aims to promote self-help and education for disaster mitigation by building safe and sustainable communities. The participatory approach in community development and capacity building among the local people are the key focus areas of the initiative. Schools have been found as the key element for community involvement in Japan and other countries worldwide. Schools not only provide education to children, strong schools also serve as emergency shelters immediately after an earthquake. Through this school-strengthening initiative, a community-based training programme is formulated to spread the knowledge of earthquake-resistant technologies rooted in traditional culture and heritage. In this paper, a short outline of the SESI is presented, and the activities in different countries are described briefly.

Why focus on schools?

In the next decade, there will be a dramatic change in the socio-economic structure of developing countries as many of them transform themselves from predominantly agrarian economies into industrial-based urban societies. Rapid urbanisation in these countries is due to their policy that has emphasised industrial and urban growth; this urban-biased policy has encouraged migrants to flock to cities to take advantage of the relatively better economic conditions. However, cities have weakened the potential of urban regions to absorb the growing urban population and to provide them with necessary employment opportunities and services. As a result in most of the cities of developing countries, informal settlements are developing in the urban periphery. This population pressure combined with many other factors leads to improper construction, and many important buildings like schools are built rapidly without proper seismic design, drastically increasing the population's vulnerability to earthquake disaster. The United Nations International Decade for Natural Disaster Reduction (IDNDR/1990-1999) has made significant progress in raising awareness among diverse communities regarding risks and effects of natural disasters. A strong shift has been observed from post-disaster rehabilitation and reconstruction to pre-disaster mitigation and preparedness policy. As a part of the preparedness process, strengthening the school buildings and disaster education has been emphasised.

Earthquake-threatened communities need earthquake-resistant schools to protect their children and teachers. Moreover, earthquake-resistant schools can be used as relief and rehabilitation shelters during earthquakes. Also, the strong leadership of teachers has been proven very useful in dealing with emergency situations. Thus, schools can play an important role in community training and in building partnerships among various community groups. This is important not only during emergency situations, but also before and after the disasters. School safety issues have several dimensions. The physical aspect is to strengthen the schools and transfer earthquake-safer construction technology to the communities. The second aspect is education, for students, teachers and communities. The third aspect is socialisation of the effort, by creating awareness and capacity building among the communities. These issues are very much inter-related and have been addressed in an integrated manner in the SESI.

Goal and objectives of the School Earthquake Safety Initiative (SESI)

Under the overall framework of "human security", the goal of the initiative is to attain safer and sustainable livelihood for the people in developing countries. Disaster affects both safety and sustainability, in terms of lives and livelihood. To achieve the goal stated above, the initiative will focus on community development and empowerment activities in selected cities and towns in developing countries.

The overall objectives of this project are: (a) to empower the community with know-how and technology for earthquake-safer construction, and (b) to make a disaster-resilient, self-reliant community. To do this, specific focus has been given to school systems, where the vulnerability of school buildings will be evaluated and technically tested; affordable retrofitting techniques will be provided. Raising the educational and awareness level related to earthquake disaster will be another focus area of the project.

There are five direct objectives of the project:

- evaluate the vulnerability of selected school buildings in each city;
- recommend designs and affordable means to strengthen vulnerable schools;

- retrofit one or two model schools using traditional and local technology;
- provide training to workers from the local construction industry who build schools and residential dwellings;
- prepare disaster educational materials for school children, teachers and communities, and use them for training and educational purposes.

Past experiences have shown that the basic problems related to disaster mitigation and preparedness in developing countries are attributed to lack of training, awareness, education and self-reliance within communities. An appropriately educated and self-trained community is much more capable of coping successfully with natural disasters and reducing their impacts. In other words, disaster management and related efforts are very much part of a sustainable development process in developing countries. The current initiative aims to promote the mitigation culture through community participation and an empowerment process tailored to residents' specific needs. There are several completed and/or ongoing projects in the selected cities and town. Some of these efforts are initiated by government organisations, some by non-governmental organisations and many by international organisations. The current initiative will complement, enlarge and sustain the ongoing efforts. The direct beneficiaries of this initiative will be school children, their families, teachers, school authorities, local engineers, masons and homeowners. The indirect beneficiaries will be government organisations and the community as a whole.

Activities and expected outputs of the initiative

The initiative has been formulated based on initial studies and surveys conducted by the Disaster Management Planning Hyogo Office of the UNCRD and is designed as per the need and priority at the local level. There has been a wide range of stakeholders, identified as the counterparts. They vary from country to country and include local governments, municipalities, academic institutions and non-governmental organisations. The initiative has two major phases: preparation phase and implementation phase.

Preparation phase

The activities in this phase include a detailed survey of the schools, retrofit design and design of the educational materials. This phase has two components, one regarding the school buildings and the other regarding the educational materials. For school buildings, the following specific activities will be executed:

- reconnaissance survey and selection of schools;
- detailed survey of schools;
- detailed retrofit design with special emphasis on applying appropriate or improved traditional technology at affordable costs;
- recommendations based on cost performance analysis.

The selection of schools will have the following criteria:

- usage as per the number of students;
- location as per the vulnerability of structures and spatial setting;

- types of construction, to cover common construction practices;
- priority of the local government and/or local counterparts.

For educational materials, the following activities will be done:

- preliminary survey of existing disaster-related educational materials;
- preparation of preliminary booklets for schools;
- testing preliminary educational materials in schools and getting feedback from children and teachers;
- final design of educational materials.

Thus, during this phase, a prototype of the educational materials will be prepared, and its receptiveness will be tested. The initial results will be disseminated by arranging interactive workshops at local levels at different time periods during the preparation phase.

Implementation phase

The purpose of this phase is to prepare a demonstration model with a participatory approach. Major activities in this phase will include retrofitting of school buildings, training of masons and use of the educational materials to raise awareness among the school children. The following actions will be executed during this phase.

- retrofit one or two model schools per agreed design and budget;
- disseminate educational materials through special classes in schools with emphasis on disaster education in curricula.

Training at the local level will be performed during this phase. Earthquake drills will also be planned and conducted in selected schools.

Actual retrofitting of school buildings will involve the local masons, teachers and parents in different ways. A final workshop will be carried out in each project city or town to disseminate the results to a wider audience and to ensure sustainability of efforts among the local stakeholders.

The expected outputs have two aspects: one physical, *i.e.* retrofitting school buildings, and the other social, which is to convert local communities into earthquake-resilient communities. The retrofitted school buildings and associated training programme will serve as a model for the disaster-prepared community for other parts of the country. On the other hand, educating school children and using educational materials will serve as a tool for spreading the disaster prevention culture and sustaining it at the community level through educating children, teachers and community members. The current initiative is expected to raise awareness at different levels. As a long-term project, it can be expected that a comprehensive model of community training and capacity building for disaster preparedness will emerge out of this initiative.

Project cities

Five cities have been selected for this project. These are Bandung and Bengkulu (Indonesia), Chamoli (India), Kathmandu (Nepal) and Tashkent (Uzbekistan). Although these cities vary in size and population, most of them have paid a serious toll in human resources and physical infrastructure due to earthquakes. In spite of damage due to earthquakes and of apparent lack of preparedness at different levels, the institutions at local, county and national levels have shown keen interest in the mitigation activities, and consequently several programmes are currently ongoing in these cities with different focus areas. Three out of the five cities, Bandung, Tashkent and Kathmandu, participated in the RADIUS project of the UN IDNDR (see a more detailed description of RADIUS in the following section).

A powerful earthquake hit Bengkulu in June 2000, with a 7.9 Richter scale magnitude. The area is located in an active seismic zone, and future earthquakes of larger magnitudes can be expected in this region. Although more than one year has passed since the earthquake, the rehabilitation and reconstruction have not been completed. The proposed initiative in the city will be a pilot demonstration project where school-building rehabilitation and earthquake risk mitigation techniques will be carried out in an integrated manner.

Bandung has been a case-study site for the United Nations IDNDR RADIUS project, which aims to raise awareness and build capacity in the local government. Here, the major focus of the project will be an educational campaign. Through the UNESCO project and the Indonesian Urban Disaster Mitigation Project (IUDMP), the vulnerability of some of the school buildings has already been assessed and a preliminary educational campaign has been started. This has been done in close co-operation with the Bandung municipality, and UNCRD played an advisory role in both projects. By accumulating achievements of the above activities, the main goal of the current initiative in Bandung is to integrate these achievements into a comprehensive training programme for school children and local communities.

Chamoli is located in northern India in the foothills of the Himalayas. Strong and sometimes devastating earthquakes often hit this region, the most recent one being in early 1999. The most common residential and school buildings here are of stone masonry, with relatively heavy slate roofs, and there is an upcoming trend of non-reinforced brick masonry buildings. Under the School Earthquake Safety Initiative, several schools will be selected from two different construction types. Through this initiative, time-tested traditional technology and upcoming appropriate and affordable modern technology will be disseminated through a training programme for retrofitting the existing school buildings.

Nepal has a long history of destructive earthquakes; in the 20th century alone over 11 000 people lost their lives in four major earthquakes. School children are especially vulnerable to earthquake hazards in the Kathmandu Valley. A recent study conducted by the Kathmandu Valley Earthquake Risk Mitigation Programme (KVERMP) revealed that the majority of the 644 public school buildings require retrofitting to meet safety standards. The current practice of school construction does not incorporate earthquake-resistant elements. In addition, none of the public schools have any emergency response plans. The current initiative will focus on training local masons for earthquake-resistant non-engineered construction and on preparing risk management plans for the schools.

The city of Tashkent is located in one of the most intensive seismic zones of Uzbekistan and has experienced several earthquakes. A preliminary analysis of the seismic risk for Tashkent shows that more than 25% of school buildings might be completely destroyed and 30% might be heavily damaged in case of a future earthquake of magnitude 6.5. The situation is aggravated by the absence of simple and efficient methods to increase seismic safety of existing school buildings. Training of school administration for proper use of school buildings in earthquake regions and educational materials describing how to behave before, during and after an earthquake will help increase awareness and understanding by children, teachers and local communities.

As observed from the above description, each city has its own perspective and needs at the local level. Therefore, the activities in each city are formulated based on the local priorities and problems. In some cities, school retrofit is a key focus area, where in others, more emphasis is given on the training and capacity building among the masons and disaster education for children, teachers and parents. The levels of intervention are also different from city to city.

Dissemination of the concept of the School Earthquake Safety Initiative (SESI)

The concept of the SESI is not limited in scale nor to specific regions and therefore can be applied anywhere and to any type of disaster. After the recent earthquake of Gujarat, India (26 January 2001), the Hyogo Prefecture of Japan held a fund-raising campaign with the citizens of Hyogo and raised USD 1.7 million. Hyogo Prefecture experienced a devastating earthquake in 1995, and during the disaster many schools were used as temporary shelters for the citizens. Schools play a very important role in the Japanese scenario of disaster management, and therefore the Hyogo Prefecture has been keen to support the concept of the SESI in India, for the victims of the Gujarat earthquake.

The overall objective of the proposed project is to conduct the comprehensive earthquake disaster mitigation training-cum-capacity-building programme for community development and for long-term sustainability; the school system and the non-engineered construction procedures in Gujarat and other parts of India will receive special focus. The scope of work will include the following:

- construction of new schools;
- retrofitting of damaged schools;
- training and dissemination;
- preparation of educational materials for school children;
- monitoring and evaluation of the activities.

In the process, ten schools will be either newly constructed, reconstructed and/or retrofitted. An educational document will be prepared for the school children. The direct beneficiaries of the school retrofit and training programme will be school children, their families, teachers, school authorities, local engineers and masons. The indirect beneficiaries will be the government, non-governmental organisations and the community as a whole.

Conclusion

The School Earthquake Safety Initiative uses the basic tools of disaster mitigation – self-help, co-operation and education – and aims for the sustainable future of the people through community involvement at an appropriate level. Retrofitting of schools, training of masons, awareness raising among different sectors and disaster education are different elements of this initiative. This initiative is irrespective of region, hazard and scale of application, and therefore can be applied to a wide range of disasters. It is hoped that the SESI can be a global model for the successful disaster mitigation at the community level.

Chapter 3

The United Nations RADIUS Initiative (Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters)

by

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Preamble

Despite our common efforts to fulfil the vision of the International Strategy for Disaster Reduction (ISDR),[1] namely to build disaster resilient societies worldwide, the challenge is now greater and more urgent than ever. The number of disasters is increasing, as well as the number of people affected.

The Secretary-General of the United Nations, Kofi Annan, has reminded us that "we must … shift from a culture of reaction to a culture of prevention. The humanitarian community does a remarkable job in responding to disasters. But the most important task in the medium and long term is to strengthen and broaden programmes which reduce the number and cost of disasters in the first place. … Prevention is not only more humane than cure; it is also much cheaper." This is a principle which should be acted upon with an increasing sense of urgency.

Disasters are not confined to particular regions, nor do they discriminate between developing and developed countries. Nevertheless, the developing countries are much more severely affected, especially in terms of the loss of lives and the percentage of economic losses in relation to their gross national product. Various UN studies have shown that 97% of disaster victims live in developing countries. The World Bank has stated that losses caused by disasters in developing countries, in terms of percentages of the gross national product, are 20 times higher than those in developed countries.

The extent of the damage caused by earthquakes, such as those which occurred recently in El Salvador, India and Peru, is not inevitable. Natural hazards do not in themselves automatically result in a loss of life. Casualties are, to a large extent, the result of collapsed buildings as well as secondary effects such as landslides. It is a fact that seismic activity worldwide has remained relatively constant over short time scales. However, the impact related to earthquakes is increasing globally. The cause of such widespread damage is not due to the lack of capacity to provide efficient and co-ordinated response, or to the lack of search and rescue teams. In reality the cause is linked to the increasing number of people and assets which are vulnerable to disasters.

Poverty is a main factor that has contributed to vulnerable living conditions. But other factors such as inappropriate land-use planning, poorly designed buildings and infrastructure, lack of adequate institutional arrangements to deal with risk reduction and emergency management, not to mention an increasingly degraded environment, epitomised by widespread deforestation, are all linked to the current trend. Recent catastrophic earthquakes highlighted other key deficiencies in the approach to disaster management, such as a poor understanding by decision-makers of seismic related risk, as well as the tendency of some builders to use the cheapest designs and construction materials to increase short-term economic returns on their investment. It is significant that in the case of the earthquake in India, many of the schools, homes and commercial buildings which collapsed in Gujarat were built recently while the older structures survived. This underlines clearly the importance of disaster resistant construction, not only through building codes but through their enforcement.

Human action and political will can reduce the impact of future disasters and avoid the current devastation witnessed in El Salvador, India and Peru. Solutions exist and the knowledge and technology necessary to apply them are widely available. These solutions include proper land-use planning aided by risk/hazard and vulnerability mapping to locate people in safe areas, the adoption of proper building codes based on local seismic risk assessments, as well as ensuring the control and enforcement of such plans and codes based on economic or other incentives. Systematic campaigns to raise awareness, carried out with the active participation of the population, will encourage people to live in safer environments. Scientific research that identifies the causes of vulnerability should also be encouraged. However, long-term commitment by public authorities is essential to building more disaster resilient societies.

It is encouraging to see that a major conceptual shift is taking place in the way disasters are dealt with in the world. An increasing number of governments and international organisations are promoting risk reduction as the only sustainable solution for reducing the social, economic and environmental impact of disasters. These multi-disciplinary and inter-sectoral efforts have successfully reduced the risk related to disasters in some regions of the world. It is vital that such efforts gain momentum. The need for change is further emphasised by the commitment made by the member states of the United Nations in the adoption of the ISDR, and the establishment of an Inter-Agency Task Force and an Inter-Agency Secretariat as mechanisms to advance the objectives of the Strategy, based on the experience of the International Decade for Natural Disaster Reduction (IDNDR/1990-1999).

The implementation of the Strategy, which is premised on the establishment of partnerships between governments, non-governmental organisations, UN agencies, the scientific community as well as other relevant stakeholders in the disaster reduction community, is not only an integral part of efforts aimed at promoting the overall goal of sustainable development, but is also an indispensable element in the search for solutions designed to counter the increasing threat posed to our planet by natural hazards.

RADIUS Initiative – United Nations Initiative towards Earthquake Safe Cities

The Secretariat of the International Decade for Natural Disaster Reduction (IDNDR), predecessor of the ISDR Secretariat, launched the Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters (RADIUS) Initiative in 1996, with financial and technical assistance from the Japanese Government, to reduce seismic disasters in urban areas, particularly in developing countries. The RADIUS Initiative aimed to raise public awareness and to aid vulnerable communities to reduce physical, economic and social damage caused by earthquakes.

The initiative was completed at the end of 1999, achieving its four main objectives:

- to develop earthquake damage scenarios and action plans for nine case-study cities;[2]
- to develop practical tools for seismic risk management;
- to conduct a comparative study to understand urban seismic risk around the world;
- to promote information exchange at city level.

Case studies of nine cities

The nine case-study cities developed seismic damage scenarios and risk management plans for the cities with technical guidance from three international institutes, namely the *Bureau de Recherches Géologiques et Minières* (BRGM, France), GeoHazards International (GHI, USA) and the International Centre for Disaster-Mitigation Engineering (INCEDE)/OYO Group (Japan). The earthquake damage scenarios describe how buildings and infrastructure in a city would be damaged and how many people would be killed by a possible earthquake.

Tools

Two kinds of tools have been developed based on the experience of the case studies.

A tool for earthquake damage estimation

RADIUS developed a simplified tool (software) to promote understanding of the process and preliminary earthquake damage estimation by decision-makers and the public in order to formulate earthquake preparedness programmes.

Guidelines for RADIUS-type risk management projects

These guidelines should be used to:

- explain the philosophy and methodology adopted by the RADIUS Initiative;
- assist in the reading, understanding and interpretation of the reports prepared for the case-study projects;
- provide general guidelines on how RADIUS-type risk management projects could be implemented in other cities.

A comparative study

The Comparative Study on Understanding Urban Seismic Risk Around the World (UUSRAW) project achieved the aims to:

- provide a systematic comparative assessment of the magnitude, causes and ways to manage earthquake risk in cities worldwide;
- identify cities around the world that are facing similar earthquake risk challenges and foster partnerships among them;

- provide a forum in which cities could share their earthquake and earthquake risk management experiences using a consistent, systematic framework for discussion.

The project established an Internet network of more than 70 seismically active cities worldwide, which gathered the information necessary to develop a systematic comparison of the earthquake risk and risk management practices of all participating cities.

RADIUS project information exchange

Information exchange at city level through the RADIUS network was an eminent aspect of the RADIUS Initiative. The RADIUS Web site was created to provide all the information developed under RADIUS. More than 30 cities participated in RADIUS as associate cities in order to offer their knowledge and experience in this field. Seventy-four cities participated in the comparative study, actively discussing issues and exchanging information through the Internet forum.

The International IDNDR Symposium on "The RADIUS Initiative – Towards Earthquake Safe Cities" was held in October 1999 in Tijuana, Mexico, one of the nine case-study cities, to present and discuss the results of the case studies, tools developed, comparative study of urban seismic risk and similar efforts. It was proposed that the network created through the implementation of the initiative should be maintained to take further actions for follow-up activities in the cities. It was also proposed in conclusion that the developed RADIUS tools should be promoted and the RADIUS experiences should be transferred to many other earthquake-prone cities in the world.

Building on the RADIUS experiences

Immediately after the project's completion, a first evaluation of RADIUS was performed in order to evaluate the effectiveness of the project during the 18 months of its implementation. This first evaluation was based on information collected through questionnaires filled out by representatives of the nine cities and showed that RADIUS was successfully implemented in the cities.

A "Year-Later Evaluation" in the case-study cities was carried out in the latter half of 2000 to identify the advances, if any, made by each case-study city in the process of implementing the RADIUS-prepared Action Plan. The following areas of focus were identified:

- the utilisation of the products of the project;
- the subsequent implementation process in each city;
- the promotion of seismic risk reduction and raising of public awareness.

The methodology used in RADIUS triggered additional initiatives which aim to reduce seismic disasters. The Global Earthquake Safety Initiative (GESI), implemented by GHI and the United Nations Centre for Regional Development (UNCRD), builds on the RADIUS methodology to help cities recognise and reduce their risk of life loss in earthquakes. The goal of the initiative is to motivate action by producing results that are non-technical and easy to understand. The results must identify the elements in a city which contribute to its vulnerability, broadly evaluate the effectiveness of mitigation in reducing future casualties and highlight the vulnerability of school children and the potential to reduce that risk. In total, 21 cities participated in the effort, out of which 13 cities also participated in the RADIUS Initiative.

Some of the RADIUS cities are participating in the School Earthquake Safety Project, being carried out by UNCRD, which aims to conduct a comprehensive earthquake disaster mitigation training programme for capacity building and community development with a specific focus on schools and educational systems. The Secretariat of the ISDR shares interest in promoting the building of earthquake-safe schools and providing school children with appropriate disaster reduction educational material.

The RADIUS Initiative is just the first step of a long journey. Seismic risk reduction is a long-term undertaking. The RADIUS methodology is expected to continue raising public awareness among the communities around the world. It will eventually help communities define land-use planning priorities, conform to building regulations, retrofit existing structure and especially promote preventive management of earthquake damage. As Kenji Okazaki, who was the manager of the Initiative, said, “RADIUS does not draw a closed circle but an open circle. It is expected that the circle will grow further and help more cities and more people in the world.”

The RADIUS methodology introduced a new educational process and training materials for communities to understand the risk and to develop risk management plans. The ISDR Secretariat intends to assess what changes in risk management the implementation of the RADIUS methodology has made in communities. The Secretariat also intends to promote the application of the tools developed under RADIUS in other earthquake-prone cities in the world. An expanded evaluation is planned in the coming months in order to evaluate the tools developed as well as the methodology of the initiative.

The ISDR Secretariat, in partnership with relevant international and regional partners and stakeholders in the disaster reduction communities, will continue the efforts deployed for the implementation of the RADIUS Initiative and promote its achievements in order to build earthquake-safe communities in the 21st century.

Publications

Following the completion of the RADIUS Initiative in 1999, the ISDR Secretariat published the summary report of the Initiative in 2000 and produced the RADIUS CD-ROM which contains all the final reports and the tools developed. The summary report has been translated into Arabic, Chinese, French, Russian and Spanish, and will be published soon. The report on the “Year-Later Evaluation” of the case-study cities will also be published soon. All the reports are available on the ISDR Web site at www.unisdr.org and GHI Web site at www.geohaz.org/radius.html

Notes

1. The ISDR vision is to enable all societies to become resilient to the effects of natural hazards and related technological and environmental disasters, in order to reduce human, economic and social losses. This vision will find its realisation by focusing on the following four objectives: a) increasing public awareness; b) obtaining commitment from public authorities; c) stimulating interdisciplinary and inter-sectoral partnership and expanding risk reduction networking at all levels; d) improving further the scientific knowledge of the causes of natural disasters and the effects of natural hazards and related technological and environmental disasters on societies.

2. Addis Ababa (Ethiopia), Antofagasta (Chile), Bandung (Indonesia), Guayaquil (Ecuador), Izmir (Turkey), Skopje (TFYR Macedonia), Tashkent (Uzbekistan), Tijuana (Mexico) and Zigong (China).

Chapter 4

Risk Prevention and School Building Management: Insights from the Storms in France in December 1999

by

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The two storms that hit France on 26 and 27 December 1999, classed by specialists as hurricanes, were exceptionally severe in terms of intensity, geographical coverage, wind force (gusts of over 150 km an hour) and the seriousness and scale of the damage they caused.

On Sunday, 26 December, exceptionally strong winds accompanied a deep trough of low pressure (960 millibars at 7 a.m. over Rouen) moving over northern France, from Finistère at 2 a.m. to Strasbourg at 11 a.m., at a speed of some 100 km an hour. The strongest winds were recorded along a 150-km wide band in the vicinity of the trough from the tip of Brittany, southern Normandy and the Ile-de-France (Paris) region to Champagne-Ardennes, Lorraine and Alsace, with gusts of up to 170 km an hour in Paris.

On 27 December, a second trough of low pressure passed over the southern tip of Brittany at around 4 p.m., the worst hit area being La Rochelle, with winds of over 150 km an hour.

The educational community has been greatly affected by these storms, not just by the scale of the damage but above all by the idea of the disasters that might have occurred. Had schools not been closed for the holidays, there could have been hundreds of casualties.

As well as listing and analysing the main cases of damage, thought has been given to school property management and, more importantly, the preventive steps to be taken in educational facilities facing this kind of natural risk.

Scale and type of damage

Scale of the damage and general observations

5 489 educational facilities reported some damage: 1 777 public primary schools (3%),[1] 1 720 lower secondary schools (35%), 1 248 upper secondary schools (48%), 578 private schools and 166 university premises. These high figures should not give the impression that educational facilities suffered more than other types of construction. In two thirds of all cases, the damage was slight. In 9% of cases, it was serious. A small proportion of educational facilities (5%) reported major damage accounting for half of the overall repair bill, which came to an estimated FRF 600 million (EUR 91 million). In all likelihood these were buildings incorporating a high proportion of "vulnerable" construction techniques, probably poorly built and with design faults, problems compounded in some cases by a bad state of repair.

The average cost of repairs per facility was around FRF 125 000 (EUR 19 000) for primary and lower secondary schools, FRF 250 000 (EUR 38 000) for vocational upper secondary and FRF 400 000 (EUR 61 000) for general upper secondary schools.

All the general, load-bearing structural parts of the buildings – posts, beams, walls and floors – proved resistant. With the exception of very specific types of construction (pre-fabricated buildings, greenhouses, etc.), load-bearing structures proved satisfactory, despite evidence of pressure in excess of their specifications.

The damage was quite evenly spread, regardless of construction date. The worst damage affected pre-1960 buildings and recent ones alike. No period of construction stands out as having suffered more damage than others. The evidence also shows that every branch of education was similarly affected, apart from recently built upper secondary vocational schools, which suffered major damage to special buildings or facilities (workshops, greenhouses, etc.). The most notable damage to primary schools was to main roofing sections, whereas secondary schools suffered more damage to roofing features and terraces (protruding features and extremities).

Damage to roofing

In a number of premises, whether concrete or metal-framed structures, there was major damage to roofing. Steel roof-deck sections with heat insulation and false ceilings were lifted by the wind once the connectors had come away, whereas frontages remained intact.

In some cases, roofing sections came away when awnings or air vents exposed to prevailing winds were ripped off. Eyewitnesses during the early hours of the storm spoke of roofs "peeling off" and described how sheet metal tore away at connector points. This raises questions about parts of buildings that are vulnerable to high winds, but also about connectors and their inspection.

Older buildings were not spared more than others in terms of damage to roofing, in spite of the fact that many had had their tiled roofs inspected annually. One traditionally built primary school, sited head-on to the high winds, had its entire roof blown away.

Specific types of roofing or waterproofing structures proved to be eminently fragile, and research will be required into their design, construction and ways of ensuring public safety if they give way. With large roofing sections (steel roof-deck sections, corrugated fibre cement sheets and flat-rolled zinc, copper, aluminium or stainless steel), there was evidence that weak points could lead to a series of collapses, causing serious damage.

Broken glass and indoor damage

In the cases we have studied, the full or partial loss of a roof was not always the factor that triggered the disaster. Glass was smashed by debris from other buildings or falling trees but more often by decorative features from the frontage, torn off by the wind and blown more than 100 metres, subsequently breaking sheet glass and letting in the wind which then lifted the roof. Buildings with large glass frontages suffered considerably more from this type of damage, in particular those with glass conservatories facing prevailing winds. Buildings with roller shutters did not find them particularly effective. The main types of indoor damage – bay windows coming away from their frames, the tops of partition walls between classrooms and corridors shifting, expansion-joint battens between two buildings ripping off, heat-insulation cladding coming away – were all caused by the wind forcing its way into buildings once the roof had come off or the windows had shattered.

In several cases it was found that building safety calculations were conducted for closed spaces, without allowing for residual safety when a secondary element collapsed.

Impact of the environment

Special emphasis should be placed on facilities built in positions particularly exposed to high wind. This appears to be an additional risk factor. The building's position was a particularly vital factor in cases where protruding architectural features were blown away.

One example was a new lower secondary school in Charente-Maritime, severely damaged soon after completion. Only a few kilometres from the sea, the school had window frames built to resist winds of 150 km an hour but proved extremely vulnerable when the wind actually reached 180 km an hour. Those responsible for commissioning the building said that it should have been built to the specifications used for buildings on the coast.

Another school in the Paris region was exposed not only to prevailing winds but also to greater risk by the removal of an embankment bordering the motorway. A building's position should be viewed as one of the major factors to aggravate risk under exceptional circumstances.

A further risk factor is woodland. A wooded environment does not necessarily have to be ruled out altogether, but does require special maintenance. Areas in which trees were correctly pollarded or cut back proved to be more resistant. Schools built among trees are advised to draw up a woodland compliance plan, possibly recommending the removal of certain species such as poplars and umbrella pines, and giving instructions on cutting back and on planting smaller trees.

Building regulations and precautions

French building regulations and "snow and wind" rules

Any building that allows access to the public is exposed to a number of hazards. Educational facilities are particularly vulnerable in that they provide access to children or teenagers whose youthful behaviour may be unpredictable enough to increase the existing risk.

Hence the care required when building educational facilities. They should be built and maintained with safety in mind. Educational facilities, however, are not covered by special rules. Like any other building, they must comply with existing regulations, including the town planning code and the building and housing code that lay down outline rules, as well as technical specifications, standards and standardised technical literature.

Among all the technical regulations covering the effects of wind, one set of rules in France covers "snow and wind". Their purpose is to determine the wind-related loads required to calculate the proportions of a building. Although wide in coverage, except for special buildings such as tower blocks, in practice these rules are used mainly for load-bearing structures (beams, posts, frameworks, porticoes, etc.), whether of concrete, metal or wood.

Wind-related loads are based on these rules and more specifically on:

- the position of the building (area and surroundings);
- the shape of the building (height, width, overhang, etc.);
- the permeability of the frontage (percentage of the surface allowing the wind to penetrate through openings such as doors and windows, assumed to be closed).

As part of the Eurocode work, a map of wind activity in each part of the country was amended in December 1999. The changes are based on meteorological data from recent years and divide France into four zones, with extreme wind force figures ranging from 136 to 182 km an hour.

Educational building trends and better construction planning

Since 1986, responsibility for educational buildings in France has shifted from central government to local authorities. This shift is not just a transfer of authority and funding to the *départements* and the regions. It has also removed responsibility for technical specifications from the Ministry of Education. The long period of rigorous planning and systematic standard-setting by the ministry came to an end in the 1980s. Now each authority determines its own requirements in terms of the construction, reconstruction or renovation of school premises. It must simply comply with the standards applying to public buildings. And today the main concern emerging among public authorities is architectural excellence.

With more diverse commissions, an end to standard models and a "return to architecture", a new era of educational building design opened in 1986. Greater creative freedom has been accompanied by more numerous controls, the outcome being a kind of pendulum swing in architectural design in recent years. Recent projects now appear to be predicated on architecture that is "subtle rather than ornate". Users are opting for buildings with simple layouts that are easier to maintain.

At the construction planning stage, the emphasis is on quality, safety and execution, and also on how the building relates to its surroundings and on environmental management. Another emerging preference is for more constraints to be factored in at the design stage, instead of more extensive regulation.

Risk management should include building inspection and preventive maintenance

Since 1978, an Act on liability in construction has placed the onus for the technical inspection of new or renovated buildings on the owner at the time.

It does not, however, provide for periodical inspections to help the owner or operator to identify subsequent anomalies that might result in risks to users. Although periodical inspections are not mandatory, owners may decide to order them as part of a pre-determined maintenance plan.

Inspections to ascertain the sturdiness of a building are carried out by technical inspectors approved by the Ministry of Public Works in the case of building projects. Each *département* has an advisory commission on safety and accessibility but it is not authorised to inspect the sturdiness of a building.

Although not mandatory under the regulations, periodical inspections are highly recommended. One of the main insights from the storms that damaged educational facilities is that inspections should focus on:

- the more easily damaged parts (awnings, chimney-stacks, ridge tiling), which require closer analysis in terms of design, construction and steps to rectify faults;
- larger roofing sections, since weak points may cause serious damage.

Certain steps need to be taken from the outset as soon as specifications are drawn up for preventive maintenance, including decisions as to which parts of the building will be subject to regular inspection.

Warning and prevention systems

The main insight from these devastating storms concerns warning and prevention. It is advisable to anticipate the impact of this kind of major risk by reviewing all warning systems, with a special focus on the safety of students and staff.

Educational facilities and warning systems

The first stage in the emergency alert procedure for educational facilities, either locally, regionally or countrywide, is the weather warning, which should play its full role. It may take the form of regional weather warnings or national severe weather warning bulletins, but it is the task of the security services and the prefect to alert the population to serious risks. The media are sent special weather reports and broadcast the information in their radio and television programmes.

Radio and television messages announcing the storms do not always capture the full attention of listeners and viewers, often distracted by other news. Messages should therefore include instructions on what to do in an emergency. There should be special emphasis on the question of possible school closures due to storm warnings according to government instructions. In southwest France, one severe weather warning was issued ten hours before the storm on 27 December.

The severe weather warning system, both in theory and in practice, contains no specific information for the school network in cases of exceptional risk. Once a risk has been detected, there could be, for instance, a system whereby schools would be informed via a hotline. This would be feasible when schools were open. From one day to the next, schools could be closed to avoid endangering the lives of students, either in school buses hit by falling trees or on school premises exposed to severe weather conditions. In this case, even if the local or national media relay the information, students could take home information sheets to directly inform parents.

Because meteorological data, obtained by satellite or other leading-edge techniques, now provide fairly reliable five-day weather forecasts, the National Observatory for Safety in Schools and Higher Education Institutions recommended the kind of weather watch used elsewhere for cyclones. METEO-France put the recommendation into practice on 1 October 2001. An emergency warning map now informs each *département* about possible weather hazards within the next 24 hours. If the *département* is indicated in yellow, this means locally hazardous weather events, while orange means hazardous and red very hazardous and exceptional. Included with the map are the instructions to be followed. Regional warnings, which require as yet unavailable processing power, are still difficult to issue several days in advance, but more general forecasts, issued advisedly, have the advantage of triggering an active watch at various levels of responsibility in the education authority. However, it should be borne in mind that wind force can be underestimated. In the first storm on 26 December, the forecast was lacking, since it announced winds of 130 km an hour and not the gusts of 170 or even 200 km an hour that were actually recorded.

Protection measures

When decisions are not taken to close educational facilities under proper safety conditions, due to inadequate or late weather forecasting, then a protection plan must come into play. This means coping as well as possible under the circumstances with the major risk that threatens the facility.

Emergencies, by definition, leave little time to take decisions and carry out instructions. While in most cases the best arrangement is clearly to close the facility in time – even the same day if students have enough time to get home before the severe weather hits the area –, a sudden tornado can never be ruled out altogether. In the past years, 130 km-an-hour gusts have been recorded locally, ripping off roofs and bringing down ceilings in schools, fortunately at night or when schools were closed. Boarding schools (upper secondary and more rarely lower secondary schools) require special attention, particularly when bad weather hits the school during the night.

In all of these situations, merely applying general regulations will not suffice. A safety plan needs to be worked out before a disaster occurs, taking into account the precise geographical location and immediate surroundings. It should be based on sound knowledge of the buildings, gained by conducting an inventory with the local authority's technical department of all the risks relating to the premises. The preparations should be carried out in every facility and parents should be involved, thereby helping to cut the number of panic reactions (*e.g.* making telephone calls that block the lines required for emergency services, or making dangerous trips). In every case, the steps to be taken in an emergency should be laid down in advance. While the external warning and protection plan is a matter for the prefect, responsibility for the school's "in-house" plan lies with the head of each facility.

Clear instructions should not only be issued but also explained and above all tested at regular intervals by organising rehearsals, where the rationale is diametrically opposed to that of evacuation exercises. Rehearsals are intended to familiarise students and staff with alarm signals, planned itineraries and safety instructions. The seriousness of the events that might occur is such that improvisation is out of the question.

Training provisions

In 1989, France appointed "major risk co-ordinators" in each *académie* (educational area) to create training tools for students. Appointed by the area head (*recteur*), they report to "security officers" responsible for ensuring that safety rules are taught and for conducting initial and further training initiatives.

A "National Education – Environment" agreement has led to setting up a "major risk" network of 450 training staff who form a team in each of the 30 educational areas. Teaching staff, heads and education inspectors are just some of those who have benefited from the courses they offer.

The major accident assistance scheme for educational facilities known as SESAM (*Secours dans les Établissements Scolaires en case d'Accidents Majeurs*), initially drawn up by a group of major risk trainers, has been validated by the ministries of the Environment, Education and the Interior. The plan is a national template that is adapted by each facility to enable its community to cope with major accidents. The work is done by members of staff in a "major risk" working party, chaired by the head and prepared by approved trainers from the area team.

Evacuation or safe areas?

There is also the question of activating the protection plan, which is the direct responsibility of school or university heads as soon as they learn of the national emergency warning. But since this may be confused with an evacuation exercise as used for fires, warning systems in facilities with public access should not be activated when evacuation is not advised. One possibility is to use a two-tone alarm. Another is to equip facilities with loudspeaker systems to warn each class of imminent danger and pass on initial instructions.

Heads often decide to keep students indoors, well aware that once weather events are under way and debris is flying around outside it would be irresponsible to attempt any kind of evacuation. During most storms, there is much less risk indoors than out, and great care should be taken not to give in to the reflex to evacuate everyone. There is one exception, however, namely the case of prefabricated buildings. We found evidence of a prefabricated building that had been simply blown to pieces. Extreme caution is therefore required when this type of building is used, and access to it must be closed if risk is imminent.

When a warning is issued during school hours, the recommendations are as follows: stay away from windows and doors, and if possible remain on the lower floors, avoiding frontages exposed to prevailing winds. This information, and that given by the emergency services, should guide the choice of a safe area in the building for taking shelter. It is more realistic to designate the safest areas or ones that might be made safe, rather than designating a special shelter reserved for that purpose. A number of educational facilities, however, have virtually no safe areas for use in an emergency. Even corridors may be unsafe when located between the exposed frontage and the opposite side of the building, vulnerable to a drop in pressure.

The safe area should include access to water supply and toilets, with the fewest possible windows onto the outside, and one square metre of space should be allowed per person. Other recommendations relate to vital basic equipment, in particular if access cannot be gained to water supply or toilets. There is also the question of generators. Having a telephone that works, at least for outgoing calls, implies that power is available. As for mobile phones, they in turn will only work if antennae are still functioning and weather conditions permit. Advice should be sought from the emergency services when drawing up the educational facility's emergency plan.

Conclusion

In the hardest hit schools, the December 1999 storms deeply affected the educational community. Apart from the sight of all the damage and the thought of the disasters avoided because schools were closed, students and staff are still suffering the psychological consequences. As well as the traces of damage on buildings and impatience with delays in repairs, there is also the shock factor that was deeply traumatising. For every facility that suffered serious damage, regardless of the scale, these events were disastrous.

Faced with what might after all appear to be a not too costly warning, the educational community has begun to gain some insight into emergencies, prevention and forecasting. Boards of governors, health and safety committees and school councils are all re-thinking their safety plans, in liaison with the emergency services. Heads supervising the repair work are making a point of tapping the expertise of their local major risk co-ordinators and safety officers. The SESAM scheme, implemented by only a few educational teams, should once again be brought to everyone's attention. All these initiatives to reactivate the safety process can draw on clear, updated documents as produced in October 2001 in conjunction with the Observatory. Most of them are tools that should not only be familiar but rehearsed in properly prepared safety exercises.

Major natural risk prevention is now an integral part of the safety culture.

Notes

1. The low percentage can be attributed to the fact that most of these schools were older premises in town centres, designed with a simple layout.

Chapter 5

Design and Construction Regulations for School Buildings in Mexico

by

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and

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Introduction

The Administrative Committee for the Federal Programme of School Construction (CAPFCE) is a decentralised public agency reporting to the federal government. It was established in 1944 to supervise the construction, equipment and renovation of public educational infrastructure in Mexico. In 1996 the federalisation process devolved responsibility for school construction, and a specialised agency was established in every federal state.

The committee is now responsible for regulating the construction and equipment of educational facilities, and serves as co-ordinator between federal and state agencies.

Mexico is exposed to a range of natural phenomena that can produce disaster situations. The most significant are earthquakes, tropical storms, hurricanes, flooding, volcanic activity and landslips (natural and man-made slopes).

Since the earthquakes in September 1985, the government has strengthened the design and construction regulations and civil protection systems, introducing a stricter building code and establishing the Civil Protection Agency and the National Disaster Prevention Centre.

These two agencies have introduced measures to enhance the response of government and civil society to events causing loss of life and material loss. They have drawn up maps highlighting the following hazards:

- seismic and volcanic activity, soil instability and landslips;
- hurricanes, flooding, erosion and landslides;
- industrial discharges and forest fires;
- man-made events.

Below we focus on seismic activity alone.

Research and training

- Earthquake research.
- Identifying and evaluating risk zones.
- Education and research.
- Special training and development programmes for civil protection staff.
- Increasing the coverage of the accelerograph network.
- Installing monitoring devices in buildings.

Civil protection

- Developing and rehearsing contingency plans for natural disasters.
- Raising awareness and readiness among the general public.
- Earthquake warning systems (SAS).

Technical construction (educational facilities)

- Damage assessment.
- Safety assessment.
- Strengthening and retrofitting programmes.

Regulatory codes

- Urban development plans.
- Periodical review and updating of regulations.
- Development and enforcement of regulatory codes throughout risk zones.

Vulnerability

Cities in developing countries at risk from earthquakes, hurricanes or other destructive events are increasingly vulnerable. Natural disasters cause death tolls and material damage there that are far higher than in advanced nations. In addition, such events strike the poor hardest.

Vulnerability amplifies a disaster and general public helplessness, and diminishes the capacity to respond. Many factors are involved, including:

- high population density;
- areas of poverty and inequality;
- no civic tradition of disaster prevention;
- unauthorised or improper development in high-risk areas;
- ecological imbalance, deforestation, etc.;
- lack of enforcement of building codes.

Charting the country – seismic events

Regional seismic activity

The purpose of drawing up regional seismic charts is to determine which regions have a similar earthquake risk, on the basis of geology and terrain. The whole of Mexico has been classified into four zones, A to D, reflecting low to high risk.

The Guerrero seismic gap

A seismic gap is the area of contact between tectonic plates where no major earthquake, with a magnitude above 7.0 on the Richter scale, has occurred over a relatively long period.

A large geological fault generating major earthquakes is located off Mexico's Pacific coastline. A seismic gap is developing in a particular area of this meso-American trench where major earthquakes may occur in the near future. It is located off the coast of Guerrero State as a result of the Cocos plate slipping under the North American plate, where Mexico is located. In the northern portion of the gap, major earthquakes occurred in 1899, 1907, 1908, 1909 and 1911: 90 years have now passed without a major seismic event in this zone. At the southern end of the gap, from Acapulco to the border with Oaxaca State, no significant earthquakes have occurred since the 1957 and 1962 events.

Seismologists agree that there is a high probability that a major seismic event will occur in this area of Mexico. The size of the gap and the period without energy release point to an earthquake of 8.0 magnitude or more. It is possible that energy will be released through a series of significant events, of lesser magnitude, over a relatively short period.

Site effects

Site effect is the seismic response of the soil in a given area – producing particular amplitude, duration and frequency compared to the response in the region as a whole – and is largely determined by geological characteristics. It is a feature of a place where seismic intensity differs considerably from that at other points at the same distance from the epicentre of the event, independent of normal distance-attenuation of energy.

During the 1985 earthquakes, the damage to buildings in Mexico City were determined by the soil properties in the valley; the dynamic amplification on the surface was due to site effects. The greatest intensities occurred where aquifer deposits were 25 to 45 metres deep. They diminished as the compressible strata narrowed, becoming insignificant on firm terrain.

Seismic alert system

Accelerographs obtained over a period of six years have increased our understanding of the Guerrero gap and of its potential to generate a major earthquake that could affect Mexico City in the near future.

In order to mitigate the disastrous effects that a new major earthquake generated by the Guerrero gap could impose on Mexico City, the Centre for Instrumentation and Seismic Recording obtained funding from the city government to design, build and operate a Seismic Alert System (SAS).

The system has 12 seismic sensor stations on the coast of Guerrero that can anticipate and track the effects of a major event developing there. The fact that radio waves travel faster than seismic ones can be of assistance when the epicentres are over 300 km from Mexico City.

The alert system goes on when the sensor stations automatically activate on the verge of a major earthquake. The signal is relayed into Mexico City's valley, where every broadcasting station (television and radio) alerts the population giving an estimated 60 seconds prior to the event.

The system is not activated when tremors in the valley are due to minor quakes or events occurring outside the Guerrero gap.

Advanced seismic alert is of value in evacuating people and safeguarding hazardous industrial zones.

Since 1993 the Ministry of Education requires all schools in the metropolitan area to be tuned to AM or FM radio stations, enabling evacuation procedures to be launched as soon as the alarm activates.

SAS also provides valuable services for the subway network, the civil protection agencies of the metropolitan area and of the State of Mexico, Mexico City's Department of Public Services and Construction, the autonomous and metropolitan universities, and the El Rosario Housing Unit in which close to 15 000 people live.

Discussions are under way on expanding coverage to other sensor stations throughout regions adjoining the fault, in particular the coast of Michoacan and Oaxaca states.

Regulatory development

Regulatory development has generally been propelled by destructive events that have required design parameters to be upgraded, and by damage necessitating fundamental changes in design and construction.

This goes much further than just increasing load or seismic resistance factors. It extends to design policy, methodology and calculation, structural systems, strength of materials and quality assurance, structural behaviour and professional liability.

CAPFCE regulations governing the anti-seismic design and construction of school buildings have regularly been upgraded in line with changes in general building regulations, in particular the Mexico City Construction Code, and with experience of building performance during seismic events.

The current construction code is based on seismic-resistant structural design giving the following performance:

- With low-intensity seismic activity, the structure and its secondary elements (non-structural) must remain unharmed.
- With moderate seismic activity, the structure must remain unharmed, though non-structural elements may be damaged.
- With high-intensity seismic activity, the structure must not collapse and it must preserve the physical integrity of its occupants.

Specific case of educational facilities

In the specific case of educational facilities, the structure must meet additional criteria, outlined below.

Limiting displacement

The aim is to avoid excessive lateral deformation produced by cross momentums, and in particular to significantly reduce horizontal movement during earthquakes.

Confining damage

Limiting displacement will reduce structural damage to a minimum and hence cut the cost of repairs and rehabilitation.

Diagnosis of educational facilities

Mexico's educational infrastructure consists of approximately 200 000 facilities. After the 1985 earthquakes that rocked Mexico City, CAPFCE established a facelift programme. It includes structural reinforcement and rebuilding for the units located in high-risk zones, to comply with construction codes and regulations imposed after those events. 2 400 facilities were rehabilitated between 1986 and 1991.

National disaster fund

To tackle natural disasters and provide prompt and effective assistance to those suffering personal injury or material loss, a National Fund for Natural Disasters (FONDEN) was established in 1996 by the federal, state and municipal governments.

The fund is a federal government financial mechanism that responds in the following ways:

- A revolving fund can provide assistance to people under imminent threat from a natural disaster.
- When a disaster occurs, the fund provides assistance to meet basic needs, such as health care, food, clothing and shelter.
- All public infrastructure damage within the disaster area is repaired, along with uninsured public property.
- The fund controls damage to forests and other protected areas, and fund rehabilitation.
- The fund provides support to low-income families, via relief for damage to their housing and means of livelihood.
- The fund provides support for consolidating and restoring national monuments.
- The fund provides temporary support for federal and state agencies in refurbishing damaged infrastructure, while insurance payments are pending.
- The fund covers the purchase of goods and equipment for prompt and effective disaster response.

Shelter

Educational facilities that comply with structural safety requirements may be used as shelters during a disaster. Regulations on the assessment of buildings for use as shelters are currently being drafted.

Site selection

The surprise factor is always involved in natural disasters, and in most cases their effects can be mitigated but not prevented.

However, some events triggered by natural forces are in fact due to human failings: ignorance, negligence, lack of foresight, corruption, etc. For instance, if housing is authorised on high-risk sites, then sooner or later a high human price will be paid.

Sadly, across the world each year, there is substantial loss of life and infrastructure damage due to settlement in high-risk zones such as riverfronts, hills, faulty landfills, areas susceptible to flooding, mining regions, etc.

Mexico is no exception. Mandatory regulations are being prepared for the selection of sites for the construction of school buildings, to safeguard the school population in our educational system.

The scientific community has a duty to raise awareness among government officials, and society at large, that life in high-risk areas does indeed entail risk from the natural disasters which have always occurred there – before nature gives us a reminder.

Chapter 6

Disaster Preparedness Education: Strategies for Turkey's Schools

by

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Background: prior to the 1999 earthquakes

Prior to the Kocaeli and Düzce earthquakes in Turkey in 1999, the Ministry of Education in Istanbul had named Professor Ahmet Mete Isikara as Director of the Bosphorus University Kandilli Observatory and Earthquake Research Institute. He was asked to chair an Earthquake Education Committee charged with attending to the development and dissemination of earthquake education in public schools.

The committee was responsible for the declaration of an annual "Earthquake Education Month". But they were not entirely satisfied that the month was being observed widely.

Shortly after the Adana Ceylan earthquake, in April 1999, the committee's first significant publication, *Earthquakes: The Way to Prepare to Live with Them*, was issued with a target audience of secondary school students. The book was distributed in small quantities, but not distributed commercially.

Although the Adana Ceylan earthquake provided a window of opportunity for earthquake education, it was not until two devastating earthquakes in the Marmara Region that the broad pubic began to heed important messages about earthquakes. There is a saying in Turkey that "winter hasn't arrived until it snows in Istanbul" which reflects the importance of the Marmara Region to the Turkish economy and to the nation's collective consciousness. Whereas previous earthquakes in Turkey had been devastating in Central Anatolia (especially, in Erzincan) and in nearby Armenia, it was not until the Kocaeli earthquake hit the heartland of the industrial northwest, and rocked Istanbul, that Turkey recognized itself to be a country with a serious seismic risk.

After the Kocaeli and Düzce earthquakes: 1999-2000

Shortly after the Kocaeli and Düzce earthquakes, Bosphorus University Kandilli Observatory and Earthquake Research Institute signed a protocol with the Ministry of Education to provide earthquake preparedness education for schools. Professor Isikara embarked upon an extensive year-long tour throughout the country, bringing earthquake education to school children in 29 provinces.

The first books for young children about earthquakes were published with the support of Professor Isikara and Kandilli. One of these, for pre-school children, was sponsored by the Mother Child Education Foundation and featured popular singer Baris Mancho; the title of the book, *Getting Ready for Earthquakes with Barish*, was a play on the singer's name which means "peace". The second book, "Restless Earth", was aimed at early elementary-aged school children.

Simultaneously, a small American non-governmental organisation, American Friends Service Committee (AFSC) provided community disaster preparedness training in Istanbul and sponsored the development of some core documents for basic disaster awareness, *e.g.* the Earthquake Hazard Hunt and the Family Disaster Plan. These documents were designed to be distributed on a single double-sided sheet of paper. The design deliberately focused on a simple, consistent message, and two worksheets that required individual and family action.

AFSC partnered with CNN Turk in the production of 12 five-minute interstitial segments entitled "Five Minutes for Life" which was prepared for the first anniversary of the earthquake. Later this series would be adapted for presentation on a CD-ROM, with individual segments separately accessed and with accompanying fact sheets.

The Suadiye Rotary Club and a commercial animation studio co-operated to produce a three-part cartoon series entitled "Uncle Quake and Nature" which was released to the delight of children and educators.

The Istanbul Community Impact Project (ICIP)

A year after the Kocaeli earthquake, the U.S. Agency for International Development, Office of Foreign Disaster Assistance, funded a three-year project hosted by the Bosphorus University Kandilli Observatory and Earthquake Research Institute. The Istanbul Community Impact Project (ICIP) established a focus on the development of basic disaster awareness educational materials and on the training of trainers in basic disaster awareness and community emergency response teams. Its advisory committee and steering committees included representatives of the mass media, regional and local government, chambers of commerce and industry, and representatives of non-governmental and community-based organisations.

As ICIP began to develop the basic disaster awareness curricula, the Ministry of Education's Disaster Preparedness Committee proposed that the basic disaster awareness instructor's curriculum be delivered to one teacher from each of Istanbul's 3 000 schools.

Fall 2000 - Fall 2001

ICIP's major efforts in its first year included the successful proposition that the Ministry of Education designate 12 November as a school day of remembrance and preparedness, known as "Disaster Day". Since the anniversary of the Kocaeli earthquake on 17 August falls during the summer break, it made sense to acknowledge the anniversary of the Düzce earthquake in November which is a good time for schools to plan preparedness activities. This single day would permit more focus than unstructured attention throughout a month. In particular it would provide an important opportunity for every school to practice their earthquake drill.

The Earthquake Hazard Hunt and the Family Disaster Plan were distributed by the Ministry of Education to every school child in Istanbul, and subsequently throughout Turkey, in the winter of 2000. Children were give the document with their report cards and asked to bring them back with parent signatures. A press conference was held in early January 2001, promoting the campaign with the slogan "We're Getting Ready, Are You?". Thanks to support from the mass media, the kick-off received extensive print media and television coverage.

During the next few months, the ICIP team worked on the development of a full ABCD Basic Disaster Awareness Curriculum.

ABCD Basic Disaster Awareness curriculum and instructor training

The Basic Disaster Awareness curriculum is comprised of two parts. The core text of 26 pages covers: Disaster Awareness, Earthquake Hazards and Risks, Before an Earthquake, During and After an Earthquake, and Next Steps. The second part of the book consists of more than 30 pages of fact sheets, each covering a separate subject. The curriculum was designed to be delivered in a 1.5- to 3-hour seminar depending on audience and needs.

As we began to deliver ABCD seminars to the public, we trained a cadre of 11 instructor trainers (four ICIP staff, four Kandilli professors and three part-time instructors). We developed an ABCD Instructor's Handbook with guidance as to how to teach the curriculum in the handbook and an ICIP Instructor's Guide providing some standards and tricks of the trade in adult education.

The instructor training process entails three steps, beginning with attendance at a regular ABCD seminar of 1.5 hours or more. Second the instructor candidate completes his own Earthquake Hazard Hunt and Family Disaster Plan at home to an 80%, or a "life-safe", level. The third step is successful participation in a full-day training programme where the candidate repeats the ABCD seminar, delves deeply into the background and reasons for each explanation, takes a written test and participates in practice teaching.

ABCD in co-operation with the Ministry of Education

Our Earthquake Committee proposed that we deliver the ABCD Instructor training to one teacher from each of Istanbul's 3 000 schools. This proposal was accepted by the Istanbul Governor's Office. In view of the magnitude of the objectives we modified the programme to deliver it in a single day, without any pre-requisite. Instead of practice teaching, we organised an interactive session with the teachers who would discuss in small groups how to modify the programme to deliver it to different age groups. The programme was delivered in the fall of 2001 in 100 sessions delivered by six trainers over a seven-week period.

Feedback so far indicates that the programme is well-accepted in terms of quantity and clarity of content, and legitimacy of instructors. Instructors are grateful. While those who are required to attend and given no advance information are inclined to be more resistant than those who volunteer or are well-informed ahead of time, all express appreciation and significant learning.

Within three months, the new school-based ABCD instructors are to deliver training to all school personnel, all school children and at least one parent group. While most teachers express enthusiasm for the task, some are concerned about whether there will be administrative support for the logistics required to carry it out, and others are concerned about their own ability to convey the information. It is too early yet to know how successful dissemination will be. However, we believe that even a modest rate of implementation will yield significant ripple effects, and lead rapidly to a new level of basic disaster awareness in the region. The total school-age population of Istanbul is 1 500 000.

ABCD instructor support materials

As we began to train ABCD instructors, there was an immediate demand for more than just the ABCD manual to support the delivery of the curriculum. We have begun developing a series of support materials to meet this need. The first resource was a CD-ROM built around the 12 five-minute segments, "Five Minutes for Life". A fact sheet was created to accompany each segment. On the same CD we included a pictorial slide-show of non-structural hazards and mitigation techniques, and the first version of the ABCD curriculum. The CD development was supported by American Friends Service Committee, and distribution of the first 7 500 copies was supported by the American Red Cross and Turkish Red Crescent Society.

A second CD-ROM is now being developed for instructors which will contain the curriculum in the form of a slide show (including two short video segments). There will be three different versions of the slide show, geared towards different age groups.

For teachers who would not have access to a computer with CD-drive, we also developed a set of 60 overhead transparencies to mirror the curriculum in the handbook. ICIP also set to work on the development of our Web site for information dissemination (www.iahep.org).

Instructor's also requested a full tool-kit. A lower-cost version of the ABCD instructor's bags was created, containing the overhead transparencies set, basic evacuation items (flashlight, batteries, work gloves, first aid kit, water, high energy foods) and a set of sample materials used for non-structural mitigation.

Since non-structural mitigation was so unfamiliar, we created a Non-Structural Mitigation Tabletop Model which could be reproduced for USD 90. We sought sponsorship to be able to provide at least one of these to each educational district, to be shared by the schools in the area.

We began to explore partnering both our non-governmental organisation and celebrity volunteers (as models) with school-based instructors.

Non-structural mitigation, youth leaders

On a related front, American Friends Service Committee sponsored a modest but very effective demonstration project in six Istanbul neighborhoods: Moda, Altunizade, Ataköy, Bahcelievler, Gayrettepe and Kuzguncuk.

Fifty-six young people ages 16-19 were recruited and provided with a 32-hour training programme which included: Basic Disaster Awareness, a simulation centre experience, hands-on skills training in non-structural mitigation, on-the-job training in the neighborhoods, an exhibit created for the S.O.S. Fair and a certificate ceremony (replete with T-shirts and caps). The young people proved to be extremely effective communicators of basic disaster awareness concepts, and their knowledge and confidence inspire the neighbourhood organisations that recruited them. Follow-up programmes are being conceptualised now to consolidate these advances. One idea includes a regional summer camp programme to transfer knowledge among young leaders.

As a matter of strategy, we felt it important to also develop focal public events to promote awareness. Upon our suggestion, a commercial fair operator agreed to host the first ever Emergency Preparedness Fair, to coincide with the second anniversary of the Kocaeli earthquake. ICIP's exhibit occupied 100 square metres and included an impressive poster display showing the Earthquake Hazard Hunt and the Family Disaster Plan, several models created to reinforce many basic concepts (*e.g.* a tectonic plates puzzle, a shake table showing unstable versus stabilized structures, fault models, a shake table showing protection of heirlooms, a non-structurally mitigated house and laminated oversized children's books). At selected times during the day, Professor Isikara signed and gave away copies of his books for children.

A special section of the exhibit for the non-structural mitigation youth leaders attracted a good deal of attention. This included a hands-on demonstration of mitigation techniques, youth-made posters and more. The second fair was planned for November 2002, for the third anniversary of the Düzce earthquake, especially to accommodate field trips by schools students.

We piloted the use of a multi-media bus to show a variety of CD resources during the fair.

Expanded dissemination opportunities

As we began to demonstrate our progress in Istanbul, we were approached by Local Agenda 21 (UNDP) to implement a project sponsored by the International Union of Local Authorities (Eastern Mediterranean and Middle East) and the Swiss Development Corporation to extend the programme to Bursa, Sakarya and Canakkale, to reach another 1 200 schools and 500 000 students. The programme will support each school with two CDs and each education district with one ABCD Instructor's bag and one non-structural mitigation table-top model.

Challenges

Getting more training materials into the hands of teachers

We continue to work on the development of educational support materials. One avenue for this is the development of "fact sheets" on a wide variety of disaster preparedness topics. Another is mass distribution educational materials with enhanced content.

One innovative item is the ABCD Information Card. This is a double-sided, full-colour fold-out brochure, contained in a tab-closed card-cover just about the size of a business-card. The card will contain the Earthquake Hazard Hunt; Family Disaster Plan; details on what to do in case of a fire, how to use a fire extinguisher, how to purify water, evacuation, what to do during and after an earthquake, and an incident command system; an out-of-area contact card and emergency telephone numbers.

Additional CD-ROMs and video materials are being planned including a series of 32 public service announcements produced by the Turkish Television and Radio Foundation and sponsored by Turkcell, the leading cellular telephone company. Three new cartoon films have been created: "Uncle Quake and the Earthquake Hazard Hunt", The School Hazard Hunt and a rap music cartoon video "Is it Gonna Quake? Get Ready!".

We have submitted proposals to develop non-structural mitigation training materials geared towards adults and youth, a non-structural mitigation handbook, a training programme for handypersons and neighbourhood activists, and a video and CD-ROM.

We are also proposing a significant new project to develop a full range of educational materials for children along with teacher guidance materials, a Web site with activities for children, a celebrity hosted documentary video for secondary school children, and the refitting, staffing and deployment of the "Hope Bus" as a mobile education centre.

Conflicting wisdom and the need for more research

Although we forge ahead with strategies for public awareness, as educators, social scientists and earth scientists, we recognize the significant need for more research. For instance, despite a variety of conflicting wisdom, we know little about what behaviour is possible and safe during an earthquake. Most advice given about what to do during an earthquake is not supported by systematic research. We know little about the causes of deaths and injuries in earthquakes in our region, and little about patterns of building collapse. There is an urgent need for a great deal of research to support our disaster awareness education.

Another interesting issue is that of the school earthquake drill. The first question is "Whose problem is it?". Does it belong only to educational policy-makers and educational administrators or should it also concern earthquake engineers, school architects and engineers, earth scientists, civil defense, search and rescue and first response workers, and public educators? At what point should we sit down together to provide consistent answers to these questions: What should the earthquake drill consist of? Why? Where? When? What about area evacuation? Are responses based on the probable risks and type of damage to school buildings?

Keeping open the windows of opportunity

Several public health educators have written about the two-year post-disaster window of opportunity for changing public behaviour. Since we passed the two-year mark we have not experienced any waning interest, and the demand for education far exceeds our ability to meet it. We believe that we have succeeded in wedging one foot firmly inside that window of opportunity. We intend to keep the window open and keep the fresh flow of new recruits and new ideas as long as possible. We have derived great support from those around the world who have gone before us, and hope in turn to inspire others with our continued efforts to reduce the impact of disasters.

Chapter 7

Earthquake Preparedness and Risk Mitigation: Lessons Learned in Iceland

by

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Introduction

Iceland is a land of natural hazards. Through the centuries, its settled areas have been threatened by violent storms and blizzards, avalanches, mud- and landslides, floods from rivers and the sea as well as glacier bursts. Last but not least, earthquakes have been a threat. The severe, windy climate has resulted in buildings that are generally well built and resistant to horizontal excitation like earthquake action. This chapter will emphasise earthquakes and earthquake-related problems. The seismological background will be explained, building tradition and seismic design outlined, earthquake mitigation measures summarised and, finally, the lessons learned from the South Iceland earthquakes of 2000 will be presented.

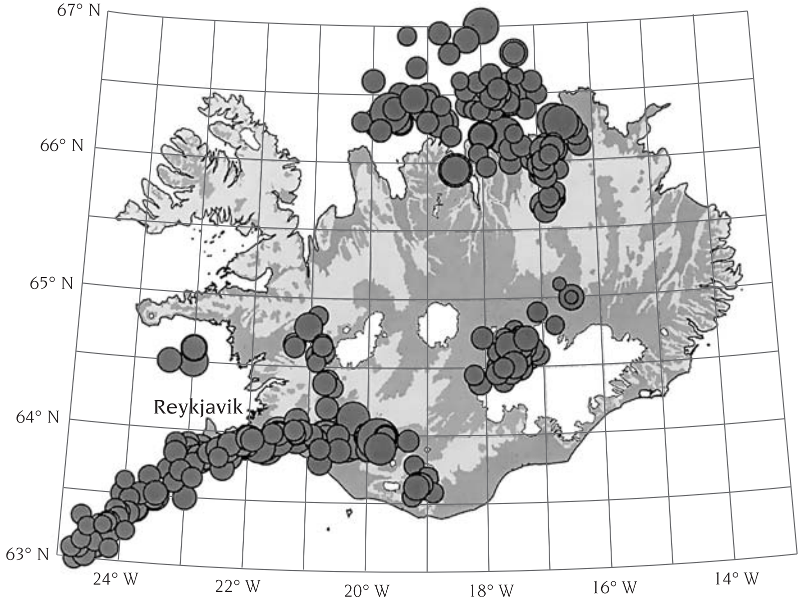
Seismological background

Iceland is an island in the North Atlantic Ocean, located just south of the Arctic Circle. The island straddles the Mid-Atlantic ridge, which marks the boundary between the North-American Plate and the Eurasian Plate. Where the ridge crosses the island, it shifts eastward through two major fracture zones, one in the south, *i.e.* the South Island Seismic Zone, and one in the north, commonly called the Tjörnes Fracture Zone, which is mainly located off the north coast of the island. All major damaging earthquakes in Iceland have originated within these two zones. Outside these two major earthquake areas, there is significant seismic activity that is often related to volcanoes.

Significant recorded earthquakes in Iceland are displayed in Figure 1 below. The circles indicate earthquake epicentres, and the size of the circles reflects the size of the events. The earliest recordings of earthquakes in Iceland date from the greatly destructive South Iceland earthquakes of 1896. The recordings were obtained from primitive seismographic stations in Italy and Russia. The first seismographic stations in Iceland started operating in Reykjavik, for a few years in the beginning, from 1910 to 1914, and have operated regularly since 1928. The first strong motion stations were installed in 1972 and have been augmented and operated continuously since 1984 as the Icelandic Strong Motion Network. In addition to the instrumental data, annals and historical writings are important sources that go back to the first years of Iceland's settlement. According to written annals, the first destructive earthquake in Iceland resulting in casualties occurred in 1013.

In the last century, three destructive earthquakes struck coastal villages in North Iceland: in 1934, 1963 and 1976. In addition, the largest recorded earthquake in Iceland struck in 1910, reaching a surface wave magnitude of 7.19 (Ambraseys and Sigbjörnsson, 2000).

Figure 1. **Significant earthquakes in Iceland**



Note: The circles indicate the earthquake epicentres, and the diameter of the circles reflects the relative magnitude of the earthquakes. (Adopted from Ambraseys and Sigbjörnsson, 2000.)

The South Iceland Lowland is the most active seismic region in Northern Europe. The above-mentioned earthquakes of 1896 along with the destructive 1912 earthquake are the most noteworthy instrumentally recorded events in that area. In addition, the 1929 earthquakes whose epicentre was on the Reykjanes Peninsula are also worth mentioning. The first major event recorded by the Icelandic Strong Motion Network was a magnitude 6 earthquake with an epicentre in the Vatnafjöll Mountains south of Mt. Hekla. By far the most important seismic event recorded in Iceland to date is the South Iceland earthquakes of 2000. This event will be discussed below in its own section.

Seismic design

Earthquake design provisions in Iceland have been improved gradually over time. Especially after major damaging earthquakes, designers and engineers have tried to improve their methods.

In the destructive South Iceland earthquakes of 1896, the majority of the buildings in the epicentral area collapsed. The buildings at that time were mostly traditional Icelandic houses made of turf and stone, but there were also a few wood frame houses. This experience clearly revealed the high seismic vulnerability of traditional Icelandic houses. Wood frame buildings, on the other hand, were found to be robust and earthquake-resistant, even though a lack of sufficient stiffening and poor foundations resulted in deformations. After the earthquakes, some guidelines for earthquake-resistant buildings were issued, including architectural and construction drawings. The recommendations favoured timber houses, and a proposal for a base-isolated sleeping cabin was put forward. The proposal was regarded with scepticism, and such cabins were never built.

The experience gained in the 1929 earthquakes also showed that the timber houses, if well built, were seismically robust. On the other hand, "masonry" and non-reinforced concrete buildings were highly vulnerable. Engineers recognised the importance of reinforcing concrete with steel bars as well as the continuity built into the concrete structures poured *in situ*.

The findings from the 1934 earthquake, which badly hit a fishing village in northern Iceland, were similar. The traditional houses collapsed easily. Non-reinforced buildings were vulnerable, cracked easily and suffered severe damage. Wood frame and timber houses, on the other hand, proved to be very earthquake-resistant. The primary damage, in most cases, was related to foundations and not the superstructures. At that time, there were only two buildings in the epicentral area made of reinforced concrete, one of them being the school building. They resisted the earthquake without any visible damage. After the 1934 earthquake, an engineer put forward a remarkable design for reinforced concrete buildings. It included most of the features regarded as state-of-the-art today. These principles were applied in repairing and retrofitting some of the damaged buildings, a few of which still exist.

Construction of multi-storey buildings increased after the Second World War, especially in Reykjavik. In the design of important buildings at that time, the effects of earthquakes were accounted for as a static horizontal force equal to 1/15 of the weight of the building. Also, limitations were put on the distance between adjacent buildings to prevent pounding effects in earthquakes.

Following this development and the destructive earthquake of 1976, a seismic design code was issued that year as Icelandic Standard IST-13, using the California Uniform Building Code (UBC) as a model. In IST-13 the first zonation map of Iceland was introduced, dividing the country into three seismic zones. This code has been revised several times. Currently, the building authorities are heading towards adoption of Eurocode 8, including necessary national application documents (NAD), as the future basis for seismic design in Iceland.

School buildings are generally treated as important within the framework of the codes. This implies that the seismic design load is increased, compared with the requirements for ordinary buildings. In this context, it is worth pointing out that school buildings are commonly used as emergency centres during crises as a part of the civil defence emergency response system, for instance after major earthquakes.

The older school buildings in Iceland are commonly low-rise simple structures, built either of timber or concrete. Such buildings have proven to be seismically robust due to their high specific strength. Modern school buildings are characterised by elegance and functionality obtained through new materials and new building forms, leading to increasing complexity compared with the older buildings (see Figure 2).

Figure 2. **Modern school building at Selfoss in South Iceland**

Note: The building withstood peak ground acceleration equal to approximately 18% g on 21 June 2000. The strength demand is assessed to roughly 50% g. Distance from the building to the causative fault was about 14 km. No significant damage to the building was reported.

These new buildings may be more vulnerable than the simpler buildings of the past. However, improved design provisions, computer modelling and advanced engineering analysis have apparently given designers the tools needed to design earthquake-resistant structures.

The most important consideration in the seismic design of structures, up to now, is the prevention of catastrophic failure and loss of lives. The knowledge to achieve this is now widely available. The latest trend in seismic design is to ensure acceptable performance in earthquakes, with the intention of minimising damage to structure, its fit-out and architectural finishes, as well as damage to the building's contents. To achieve this, the induced seismic motion must be kept at a minimum in terms of deformation and acceleration. In modern society, it is also necessary to design the infrastructure and lifeline systems to remain operational during and after earthquakes. This applies especially to the lifeline systems in Iceland, where, for instance, the geothermal heating system is of vital importance due to severe weather conditions.

Risk mitigation

The South Iceland Lowland is the most active seismic region in Northern Europe and the area most threatened by earthquakes in Iceland. Important farmland and a few villages are located within the seismic area. The buildings are mostly one-story, single-family houses built of concrete during the post-war period. In the area there is also one hospital and several healthcare centres, schools and a few industrial facilities. Important hydroelectric power plants are located in the outskirts of the area and high-voltage overhead transmission lines cross through the seismic zone, supplying the capital region with electricity. A significant geothermal area located north of the western part of the seismic zone provides the capital region with hot water, through a surface supported pipeline, for the heating of houses and for household utilities as well as for industrial purposes.

In 1996 an earthquake risk mitigation project was initiated for the South Iceland Seismic Zone. The objective of this project was not only to collect data and obtain new information through analysis of the data but also to apply the acquired knowledge, along with existing earthquake engineering techniques, to mitigate the impact of future earthquakes on Icelandic society. This second part of the objective was in accordance with the World Seismic Safety Initiative (WSSI), supported by the International Association of Earthquake Engineering, to endorse the United Nations' resolution on the International Decade for Natural Disaster Reduction (IDNDR). The project was initiated by local authorities in the area and supported by Catastrophe Insurance of Iceland and the Icelandic Research Foundation.

Based on the findings of this project, the following actions for mitigation were put forward (Sigbjörnsson *et al.*, 1998):

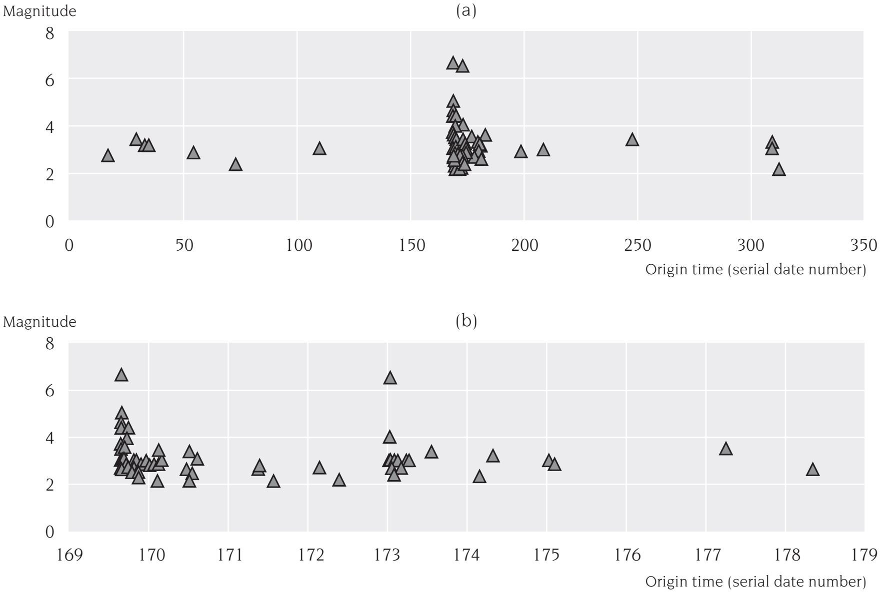
- **Earthquake awareness.** The first step, and perhaps the most important one, is to increase people's earthquake awareness by disseminating objective information.
- **Earthquake preparedness.** Homeowners can significantly reduce potential loss as well as injuries and even casualties by preventing objects and household articles from falling, for instance by fastening them properly. Furthermore, the findings showed that the technical systems of buildings, especially the (geothermal) heating systems, required some modifications in the form of adequate fasteners. Every homeowner participating in the field survey received guidelines regarding specific improvements. General guidelines were also issued.
- **Insurance.** Homeowners should insure their property in addition to taking out the obligatory disaster insurance.
- **Strengthened and improved design.** Feasible strengthening and retrofit procedures to improve the earthquake safety and resistance of existing buildings as well as lifeline systems should be used. This includes long-term renewal planning and prioritisation aiming at risk reduction and risk management.

South Iceland earthquakes of 2000

The above-mentioned mitigation project was barely finished when a full-scale test came – a great sequence of South Iceland earthquakes. The first earthquake struck on 17 June 2000, the Icelandic National Day. In the days and weeks to come, there was enormous earthquake activity throughout the South Iceland Seismic Zone and Reykjanes Peninsula. The timeline and the geographical distribution of this earthquake activity are indicated in Figures 3 and 4 below.

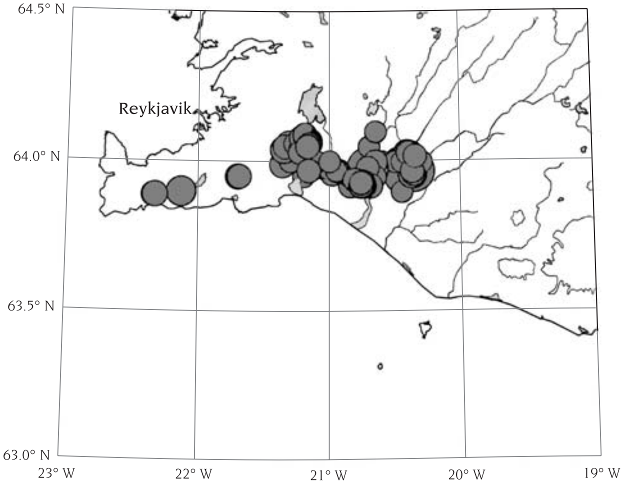
The physical effects of the earthquakes could be seen as surface faults, landslides and rock fall, change in ground water level and disturbance of hot wells, and damage to buildings and lifeline systems. The social effects surfaced through a psychological strain and post traumatic stress disorder that may take a long time to heal. The economic effects were mitigated through obligatory disaster insurance.

Figure 3. **Timeline of earthquake activity in Iceland in the year 2000 showing the South Iceland earthquake sequence starting on 17 June**



Note: The magnitude of events is given as a function of origin time represented as a serial date number. (a) Earthquake activity in Iceland in the year 2000. (b) Ten days with the most intense earthquake activity starting with day 169, that is 17 June 2000. Day 173 is 21 June 2000.

Figure 4. **Geographical distribution of the South Iceland earthquake sequence of 2000**



The two biggest earthquakes occurred on 17 and 21 June 2000, both of them about magnitude 6.5. These earthquakes, which were felt in most of Iceland, caused great damage to structures and building contents, but there were no serious accidents involving people. The structures damaged were mostly older buildings, buildings raised on poor foundations, "masonry-type" buildings made of blocks of lava aggregate and buildings with non-structural masonry partitions. Also, many non-reinforced or scarcely reinforced concrete buildings were severely damaged, especially outbuildings in rural areas. Some damage occurred to communication structures in the epicentral areas where cracks went through roads. School buildings in the area were not damaged severely, and necessary repairs were easy to undertake. It was also fortunate that the greatest earthquake activity occurred during the summer holidays.

The biggest earthquakes were recorded on nearly every station of the Icelandic Strong Motion Network located less than 150 kilometres from the origin. The highest peak ground acceleration measured in the first big earthquake was about 64% g (g being the acceleration of gravity) on the foundation of a building in the epicentral area, approximately six kilometres from the causative fault. In the second big earthquake, the highest peak acceleration measured was approximately 84% g on the west pillar of the Thjórsá River Bridge, only three kilometres from the causative fault. These extreme values of peak ground acceleration are among the highest in the world recorded during earthquakes. Based on these recordings, it is clear that the horizontal seismic action on low-rise buildings exceeded one g in the near source area, *i.e.* the horizontal strength demand exceeded the dead weight of the buildings. Hence, structures near the origins of the earthquakes sustained considerably greater excitation than the design excitation assumed in the current seismic design code.

When the effects of the earthquakes are assessed and the destruction following in their wake is examined, it can be said that the inhabited areas in South Iceland survived amazingly well and better than one would have expected. There are many reasons for this. However, it is obvious that the preparedness initiative and risk reduction programmes of companies, municipalities and individuals, over the previous decades, produced the desired results of reducing damage from what it otherwise would have been.

Conclusions

The main lessons learned in Iceland can be summarised as follows:

- **Objective information.** Spreading objective information through the mass media helps to reduce psychological stress and strain in critical situations. It is important when presenting sensitive matters not to frighten people.
- **Earthquake awareness.** It is essential to increase people's earthquake awareness. This helps people to deal with the reality of the earthquake threat.
- **Earthquake preparedness.** In an earthquake-prone country, it is necessary to be ready for an earthquake at all times. The key to this is a carefully planned preparedness programme, for individuals as well as companies and municipalities. Experience shows that it is possible to reduce or remove potential threats of damage simply and cheaply.

- **Improved design.** Today, we possess the knowledge required to design buildings and structures capable of withstanding earthquakes of moderate size without collapsing. Structural design methods that aim at reducing damage, including damage to building contents, are under development. The design of infrastructure and lifeline systems should be improved.
- **Retrofitting.** Strengthening existing structures can, in some cases, be beneficial, for instance by applying base isolation.
- **Long-term planning: risk reduction and risk management.** Earthquake risk can be reduced and managed by applying available earthquake engineering methods. However, it may seem costly, at least on a short-term basis. Therefore, long-term planning is required to obtain economically acceptable results.
- **Insurance.** It is very important to have insurance in respect of critical situations. This became clear after the South Iceland earthquakes of 2000.

School buildings in Iceland are generally designed as important structures, having increased requirements regarding earthquake resistance. This is all the more important as school buildings are utilised as emergency response centres in critical situations, *i.e.* when natural catastrophes occur. During the summertime, it is also common to use the school buildings as guesthouses or hotels. It should be kept in mind that the serviceability of the school, or the emergency centre, depends not only on the building as such but also on the lifeline systems that are vital in the severe Icelandic climatic conditions.

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Chapter 8

The Restoration of School Buildings: Operational, Scientific and Social Aspects

by

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School buildings, as places of learning and everyday life that are closely linked to youth, are focal points of the social organisation of neighbourhoods, districts or towns. As such, besides their essential educational and aesthetic functions, they must inspire in their users and the community at large a sense of security with respect to all forms of danger and, especially in earthquake-prone areas such as Greece, they need to inspire confidence with respect to the dangers posed by seismic activity.

Earthquakes will always be a cause of fear and distress and, by current standards at least, represent the most uncertain of all natural dangers. They are stochastic phenomena which rarely repeat themselves and which result from tectonic and geophysical activity lasting thousands of years. Because we have only been observing them for what is comparatively a short period of time, each new earthquake brings ample scope for surprises and new data. It is not one of the objectives here to address the historical, geophysical or philosophical aspects of earthquakes. However, as members of the academic community have pointed out: "The seismic wave is a purely natural phenomenon which, in passing through the built environment, is transformed into a technological problem with tremendous material, psychological and social impact on the environment, people and the economy." We shall therefore attempt to deal here with the effects of earthquakes on school buildings and their subsequent impacts on the educational and social life of the urban community.

On 7 September 1999, the Attica Basin was struck by an earthquake measuring 5.9 on the Richter scale. Thirty-seven buildings collapsed and many were severely damaged. After the earthquake, structural and other damage was observed in school buildings. The effects of the earthquake on school buildings were addressed by Greece's School Buildings Organisation S.A. (OSK) promptly and effectively.

In order to ensure a return to normal school life in the stricken area as soon as possible, the OSK immediately drew up a plan of action on the night of 7 to 8 September. By as early as 8 September, teams of OSK engineers conducted surveys and tests on school buildings owned by 20 municipalities located in the area immediately above the earthquake's epicentre (634 in all). Over the following days, the OSK had to extend its actions to all municipalities in the Attica region. Schools opened again on 20 September 1999, and in the intervening period all schools in the Attica region were issued (for public information) with special building safety certificates.

Buildings housing 2 465 school units were surveyed and assessed as follows:

- Safe: 2 036
- Unsafe: 427
- Requiring demolition: 2

On 18 October 1999, the OSK invited 20 academic or specialised civil engineers to join it for scientific support, and 25 building contractors for repair work and the installation of pre-fabricated constructions. Three-member scientific committees were set up to conduct a second round of surveys on 149 cases where such action was judged necessary, while repair work began on buildings that have suffered light and superficial damage.

The final assessment was that 44 buildings had sustained extensive damage and required special studies to be drawn up for their restoration, while six buildings had to be demolished.

On 31 December 1999, buildings housing 396 school units had been repaired and returned to use. The plan as a whole involved the following operations:

- 2 465 surveys;
- repair of 377 buildings by the OSK and of 123 buildings by local authorities with the assistance of the OSK, of which 44 had sustained extended damage;
- requisition of 22 sites;
- installation of 530 light or heavy-duty pre-fabricated classrooms;
- construction of 25 new school units (replacement of demolished or heavily damaged units).

The programme lasted 400 days and cost 42 billion drachmas.

The methods and problem-solving strategies adopted in the course of the programme prompted a number of conclusions of a technical, scientific and social nature to be drawn. More precisely:

- Apart from its immediate mission (to test the safety of school buildings), the active presence of the OSK in stricken areas exactly one day after the earthquake provided a practical boost for the morale of the population and contributed significantly to alleviating distress.
- The body which undertakes this kind of initiative (from administrators to employees) has to be in high standing, to be recognised for the quality of its conclusions and to inspire confidence in its activities during periods of relative calm. This was already true of the OSK and is so to an even greater extent now.
- The first visual inspection of a building following an earthquake is of vital importance to safety since it is the only means of inspection open to the engineer. The procedure for assessing the school building in the most detailed way possible, internally and externally, has to be designed in such a way as to result in its evaluation as:
  - safe for immediate use;
  - safe for use following the repair of damage to elements not concerning the load-bearing structure, or else following the repair of light damage restricted to the load-bearing structure (in such cases repair work was begun as quickly as possible);
  - unsafe for use and requiring special measures.

Clearly the decision to classify a case under one of the damage categories is all-important. Factors that facilitate the success of this initial activity (surveying, classifying and determining the degree of risk) are the creation of a code of internal communication, the existence of a scale of degree of risk and the existence of a form that guides surveying practice and that obliges the surveyor to record the necessary information. It is worth noting that there were differences of opinion among engineers examining the same building (due to differences in experience), and that the conclusions reached by the same engineers changed as the date of the original event (7 September 1999) receded.

- It should be borne in mind during the surveying and restoring of buildings that vulnerability and risk do not concern solely the load-bearing structure. "Structural weakness" is defined as weakness that is capable of leading to the collapse of a building or to dangerous damage to its constituent elements.
- "Non-structural weakness" is defined as weakness with regard to the partition walls, furnishings and contents of a building. For example, the overturning of a bookcase, cupboard or lamp, or breakage of a glass panel, is sufficient to cause serious injury.
- A fundamental conclusion inferred from the studies carried out on school buildings in Attica as a whole is the following: A building constructed in rigorous compliance with the stipulations of earthquake regulations responds well and without significant damage to earthquakes. During the last earthquake in Athens, few buildings sustained extensive damage to their load-bearing structure and most of those which did were over 25 years old. On the other hand, for reasons that will be given below, buildings constructed after 1985 responded to the earthquake well and with minimal damage even when very close to the epicentre. Buildings have responded similarly in previous earthquakes in Greece.
- At the stage when repair work is being planned, speed of response is an important factor in success. The prompt and safe restoration of a school building greatly facilitates the return of families to normal activity and alleviates the effects of the earthquake during the aftermath, thus contributing to a smooth return to normal social and economic activity.

  In this sense, the methodology, timing and entire operational programme for return to normal school life of each population unit (neighbourhood, ward or municipality) have to be prepared in co-operation with social actors (parents, educators, students, local authorities), so that the programme can be incorporated into the economic and social planning of that unit.

  The involvement of such agents in the procedures and work to restore a school building is considered a positive factor because it:

  - imposes a productive schedule;
  - improves the quality of the actions required;
  - produces a greater sense of security in users.

- When drawing up studies for the repair of buildings that have sustained particularly heavy damage to their load-bearing structures, a question of a political nature often emerges as to whether the building should be repaired or demolished.

  Decisions concerning the repair, reinforcement or demolition of a school building are not taken solely on the basis of a comparison between the cost of repairing the building and the cost of constructing a new one, as would be the case with a private dwelling. They also take into account social aspects of the school building, the need to generate confidence in the safety of school buildings generally (during periods when there are no earthquakes), and the historical and cultural role of the school building for a neighbourhood and its inhabitants.

  In the aftermath of destructive earthquakes, two kinds of opinions are generally voiced regarding the approach that should be adopted towards damaged buildings:

  - The first is that "since the building survived the earthquake with only some cracks, it does not require further action", without giving much consideration to the extent and location of the cracks and to their prospective role in future situations.
  - The second is expressed by those who have been terrorised by the disaster and irrationally suggest the reinforcement of everything, whether damaged or not, and irrespective of the economic cost that such a policy would imply.

  The best solution is clearly to adopt a cool-headed, scientifically grounded approach informed by an assessment of international practice. The repair and reinforcement of buildings is a difficult problem on which the international anti-earthquake technology community has only recently focused its attention.

- The reinforcement of damaged school buildings through comprehensive application of the complete existing framework of regulations – which is, in fact, intended for new buildings – is not feasible in practice. With a view to tackling this problem, the OSK, assisted by the academic community and specialised scientists, has drawn up an outline for the restoration of school buildings based on current standards. This outline makes the provision that in ambiguous cases, where the level of anti-earthquake protection ensured is doubtful, studies can be accompanied by pushover analysis according to United States standards (FEMA 273/97) currently in force for the control of risks in existing buildings.

  We believe that an adequate procedure for the reinforcement of damaged school buildings should ensure the following:

  - reinforcement of the resistance and plasticity of vertical elements;
  - construction of apparent seismic shock-absorbing structures in cases when these are not present;
  - enhancement of the construction's rigidity in order to limit damage to the non-load-bearing structure;

  - reinforcement of horizontal elements and of foundations in cases where their function is considered to be determining in terms of seismic response.

  In order to avoid random, improvised or dangerous approaches and to ensure the successful resolution of problems of this nature, it is our belief that national legislatures should define a clear and concrete procedure for conducting repair and reinforcement studies on school buildings and public premises more generally.

- Finally, there are other aspects of the operational programme which constitute important conditions for the operation's success and its swift prosecution such as:
  - the existence of a legal framework to facilitate the acquisition of land (requisitions);
  - the relaxing of procedures for obtaining the relevant permits;
  - increased scientific understanding of pre-fabricated constructions, whose wider use greatly facilitates a swift return to normal school life.

Let us now address the issue of what our responsibilities are in periods other than that of the earthquake itself and its aftermath. Seismic activity is always anticipated probabilistically and with great uncertainty. Systematic recording of earthquakes is, relatively speaking, a recent activity. Parameters determining the destructiveness of seismic activity – its epicentre, depth, duration, etc. – are also approximated with a great degree of uncertainty. Since we cannot control seismic risk, we have to intervene with the aim of reducing the vulnerability of existing school buildings.

The surveys carried out on all the school buildings in Athens as a result of the earthquake in 1999 show that maintenance is deficient in many of those schools. When deficient maintenance leads to the presence of materials that do not meet the strength requirements of the building's design, it affects the ability of the building to respond well to seismic activity. Characteristic examples of this include eroded reinforcements in reinforced concrete structures and the disintegration of roughcast in stone edifices.

In the buildings belonging to one school complex, erosion of the reinforcement had caused the very fine concrete covering to break off, leaving the reinforcement exposed. The maintenance personnel thought it fitting to colour the reinforcement with the acrylic paint that covered the building's concrete surfaces. In Greece, there is an institutional shortcoming where maintenance contracts are concerned. In order to deal with this problem in schools in the Attica region in a concerted and comprehensive way, the OSK has submitted a proposal to the divisional programme of the Ministry of Education (3rd KPS) to conduct quality and pre-earthquake analysis of all school buildings in Attica.

Finally, a number of points concern the earthquake design of new buildings: Our knowledge in the area of earthquake protection technology has increased significantly in recent decades. In Greece, the need to factor seismic activity into our calculations was first introduced in 1959. The lack of suitable computing methods and tools had led surveying practices to adopt an approximative method in calculating the impact of seismic forces on structures. Rapid developments in computing and statistical analysis programs in this area have dramatically reduced the inaccuracies of simulations and of less fine-grained methods of analysis. This has resulted in a reduction of the seismic vulnerability of reinforced concrete edifices built after 1985. In 1995, earthquake regulations and regulations relating to the design and construction of concrete buildings were radically reviewed, bringing them up to international standards and up to the standards of scientific knowledge for the first time. Despite some shortcomings, which led to their revision in 2000, these regulations vastly improved the seismic resistance of concrete edifices. It should be noted that Greek engineers feel reasonably confident about the earthquake design of new buildings.

To conclude, in earthquake-prone countries, a well-conceived and properly prepared plan of action for dealing with the aftermath of earthquakes results in educational, functional, economic and, more generally, qualitative improvements in school premises and succeeds in reinforcing buildings for the future by raising them to the standards of current earthquake regulations.

Lastly, the establishment of post- or pre-earthquake operational programmes requires the existence of central government agencies functioning at an executive level, in a permanent state of readiness, and fully equipped with the scientific, technical, functional and economic means to undertake the necessary action. In Greece, the OSK is such an agency, with a record of 40 years of service to the country's educational community.

Chapter 9

Earthquake Safety Planning in Schools

by

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Schools are a focal point for many people and are attended by young people on more or less a daily basis. Before an earthquake occurs, it is therefore necessary to ensure that both pupils and teachers are made fully aware of what they should do in the event of an earthquake so that basic safety principles become second nature. In other words, all teaching communities must address the issue of earthquake safety in schools.

Earthquake safety planning in schools encompasses all measures and efforts aimed at minimising personal injury or damage to the infrastructure of school buildings. Similarly, earthquake safety training procedures are designed to raise awareness of the appropriate response to adopt in the event of an earthquake.

Informing and advising the population is one of the main activities of the Earthquake Planning and Protection Organisation (E.P.P.O.). After assessing the implementation of various earthquake safety programmes, the E.P.P.O. decided that the most effective means of ensuring that the population adopted "safe behaviour in the event of an earthquake" was for the relevant training to be incorporated into the educational process.

Role and activities of the E.P.P.O. in earthquake safety planning in schools

The E.P.P.O. plans, carries out and co-ordinates all activities related to training and raising the awareness of both the public and government officials with regard to earthquake safety and emergency response measures. More precisely, the E.P.P.O.:

- designs and conducts educational and training programmes in earthquake safety at all levels of the educational system;
- publishes teacher instruction manuals for on-going pupil training;
- publishes books on earthquake safety in schools such as *Earthquake – Knowledge Means Protection*;
- produces and publishes technical manuals for specialised earthquake emergency response teams (rescue teams, teams responsible for making buildings safe);
- informs the public, distributes written information, organises public talks and film projections on earthquake safety;
- co-ordinates emergency drills in prefectures, schools, etc., in accordance with their emergency plans;
- plans, organises and follows up on the execution of emergency drills.

The task of providing information and instruction includes large-scale earthquake safety programmes involving actions such as:

- drafting of instruction manuals for the general public indicating how people should respond before, during and after an earthquake;
- public exhibitions of posters illustrating how people should protect themselves in the event of an earthquake;
- articles in the press;
- television and radio programmes;
- training courses for pupils at all levels;
- public lectures under the auspices of cultural and other organisations;
- lectures at educational institutions and special units, using film projections;
- special lecture courses for groups which are professionally or otherwise concerned such as engineers, local government and municipal officials, and technical services.

Training the educational community

Teachers

The E.P.P.O. has focused recently on training teachers in earthquake planning and safety in school units. A number of training programmes have been developed in which teachers have an important role to play in instructing pupils in how to respond in the event of an earthquake. Seminars have already been held for 600 headmasters in the Attica Prefecture and for primary and secondary school teachers in the regions. These seminars primarily include practical sessions aimed at developing effective earthquake safety strategies for schools. They consist of up to 18 hours of instruction and deal with issues relating to earthquakes, the impact of earthquakes on buildings and people, as well as earthquake protection and safety in schools. Two to three teachers from each school in a given prefecture are allowed to take part in these seminars. Emphasis is placed in particular on issues relating to personal protection and emergency safety plans in schools, which are discussed in working groups of ten to 12 teachers moderated by E.P.P.O. staff.

Pupils

Lectures are given to pupils on earthquake prevention and safety under the aegis of the E.P.P.O. and at the initiative of the relevant agencies (PTAs and local authorities).

Evacuation drills

Evacuation and earthquake drills, in which teachers and pupils work together to implement the school's earthquake emergency plan, are carried out in schools under the supervision of the E.P.P.O. Participants practise responses to different earthquake scenarios in order to learn how to behave in the event of an earthquake. The emergency plan is then assessed and reviewed.

Pre-earthquake protection measures in school units

Inspection of school buildings

The most important aspect of a building, especially a school building, is how it will behave under emergency conditions and, in particular, how well it will withstand an earthquake. School buildings are constructed in accordance with Greek earthquake safety regulations. However, in cases where a building already exhibits cracks, it is advisable to have experts carry out a preventative inspection of the static efficiency of the building and, if necessary, reinforce its structure.

It is worth noting at this point that all new school buildings are designed to meet the needs of both pupils and teachers (large playgrounds, suitable staircases and exits, etc.), ensure a safe environment and allow the building to be safely evacuated in the event of an emergency. However, there are older school complexes which have no playgrounds or have exits giving onto main roads and busy streets, or which occupy sites that are surrounded on all sides by high-rise buildings. Such features cause problems in everyday life but are particularly hazardous in the event of an emergency such as an earthquake. It would therefore be wise for headmasters to report such problems to the competent authorities and suggest appropriate solutions – which might even include relocating the school if necessary.

The E.P.P.O. initiates, monitors and collaborates with teachers on the preparation of earthquake emergency plans specifically designed for use by schools.

Preparing an emergency plan

The emergency plan is designed to ensure a calm and orderly response by teachers and pupils to the effects of earthquakes through actions determined prior to the actual occurrence of an earthquake. The plan describes the conditions prevailing both inside and outside the school and identifies potential hazards.

To be operational, the plan should be clear and straightforward and should contain the following:

- analysis of the actions to be taken before, during and after an earthquake;
- assignment of specific duties to teachers;
- memorandum of actions;
- implementation of the above at different times during the school day, namely: morning, afternoon, during class time, during break time with pupils in the playground and during break time with pupils inside the school building.

Risk prevention

The term "risk prevention" covers all the actions to be undertaken by teachers before an earthquake to prevent serious injuries resulting from damage to non-building materials and items of equipment.

- For classrooms, staff room and corridors these include:

  - securing and anchoring of glass panels;
  - anchoring of furniture;
  - securing of books and other items on bookshelves;
  - storage of dangerous and fragile objects in safe locations;
  - securing of miscellaneous objects and instruments;
  - securing of lighting fixtures or ceiling fans;
  - securing of notice boards, frames or hangers;
  - purchase and installation of hand torches, medicine cabinets and fire extinguishers;
  - securing of reagents in the school's chemistry lab;
  - arrangement of desks in classrooms;
  - removal of unnecessary furniture;
  - securing of external power cables or radiator pipes.
- For the playground, risk prevention includes:
  - securing of poles, boards and television antennae;
  - installation of safety glass panels;
  - securing of external power cables;
  - maintenance and securing of roof tiles, fencing or metal railings.

Pupil information and education

Earthquakes create fear and insecurity, particularly among young pupils, who tend to panic. The aim of the E.P.P.O. is to ensure that both individuals (pupils and teachers) and groups (departments, classes, schools) know what to do in the event of an earthquake (rules on personal protection). It achieves this by means of emergency preparedness and evacuation drills and through safety awareness and information campaigns managed by the competent authorities.

The following actions are undertaken during the period prior to an earthquake:

- acquisition of basic knowledge regarding the natural phenomenon of earthquakes;
- organisation of presentations and lectures in collaboration with the competent authorities, with a view to raising the awareness of pupils and teachers;
- organisation of emergency preparedness drills in school buildings;
- preparation of individual emergency plans for each school.

It should be noted that the role played by teachers in the event of an earthquake is of paramount importance. They must react calmly, quickly and decisively, and set an example for pupils. In other words, it is the teachers who will calm pupils' fears, prevent them from panicking and generally react in a calm and measured fashion. Obviously they need to be perfectly familiar with earthquake safety rules and must know what individual actions, depending upon their position, they will need to take in the event of an earthquake since it is these actions that will ensure the orderly evacuation of the school building and hence the safety of pupils.

It must be stressed here that teachers bear sole responsibility for the protection and safety of pupils from the time that the earthquake strikes until children are handed over to the safekeeping of their parents. Parents also have a role to play in helping to co-ordinate the actions taken in the event of an earthquake.

Actions to be undertaken in the event of an earthquake

Earthquakes can occur at any time, either during class time or during breaks.

Earthquake during class time

During the earthquake

- Pupils and teachers should take shelter under their desks for the duration of the earthquake.
- Pupils should wait calmly for their teacher to give them instructions.
- They must not leave the building.
- They must not go out onto balconies.
- They must stay away from windows or glass panels.
- They must not try to escape through windows.
- They must not try to use the lifts.
- If outside at the time the earthquake strikes, they must not enter the building and should move away from exterior walls.

After the earthquake

Evacuation of classrooms: Under the supervision of the teachers, all exits from the school are opened and main water and power supplies turned off.

- Each teacher is responsible for evacuating his/her classroom.
- Teachers should check the condition of the building along the evacuation route and identify potential risks.
- They should guide pupils to exits, each group in turn.
- They should co-ordinate the evacuation of the building to avoid crowding and possible injury to pupils and then lead their pupils to the assembly area.

The ground floor is evacuated immediately, followed by individual classrooms in turn, the first being the classroom nearest to the staircase.

Assembly area

The playground is the designated assembly area.

- Teachers:
  - assemble their pupils by class and count them;
  - identify any injured pupils;
  - extinguish small fires.

- Pupils:
  - must not re-enter the building;
  - must remain at a distance of at least five meters from building frontages and fencing;
  - must not drink tap water;
  - should avoid any contact with power cables or metal railings.

Everyone must remain in the playground until further notice. If any pupils or teachers remain trapped in the building, or if fires have broken out, the emergency services should be notified. If the playground is deemed hazardous for pupils, teachers must move them to an open space nearby which has been designated as an assembly area prior to the earthquake.

Earthquake during break time

During an earthquake

- If located indoors, in classrooms or utility rooms, pupils and teachers must not leave the building and should move away from hazardous locations while taking care to protect themselves against falling furniture or other objects.
- If located outdoors, they should remain where they are and attempt to avoid any potential hazards.

After an earthquake

- Teachers and pupils should follow the evacuation procedure described above and assemble in the playground.

Preparedness drills

Preparedness and evacuation drills are considered an essential part of the earthquake emergency plan for teachers and pupils. These drills should be carried out regularly, each time under different conditions.

The drill procedure is organised as follows:

- A date is chosen for the drill.
- The alarm signals for the beginning, duration and end of the earthquake are explained to pupils.
- The warning signal for the start of an earthquake sounds.
- The teacher calls out: “Earthquake! Everybody under their desks!”
- Teachers and pupils take shelter under their desks, firmly grasping one of the legs. No one must move until the alarm signal for the end of the earthquake sounds.
- The designated signal for the end of the earthquake sounds.
- The teacher carefully opens the classroom door.
- The teacher checks the corridor and supervises the evacuation of other classrooms nearer to the exit.

- The teacher tells the children in the first row to get up one after another.
- Once the preceding classroom has been evacuated, the teacher gives the signal to the first row of children to leave the building.
- The children enter the corridor in single file and in an orderly and calm manner. Usually the corridors are wide enough for pupils to evacuate the building in pairs. The main point, however, is for all pupils to keep moving at a steady and relatively fast pace to avoid potentially dangerous crowding in the corridors.
- The teacher in the classroom nearest to the staircase remains in the corridor to supervise the evacuation of remaining pupils.
- Pupils gather at the shelter/assembly area, making sure to remain at the appropriate distance from building frontages and walls.

Chapter 10

The Structural Restoration of Educational Buildings in Greece

by

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Introduction

The Greek State has shown great concern for the conservation of educational buildings from the late 19th and early 20th centuries. Although most of these buildings do not strictly meet present building standards for schools, their merit as part of the country's cultural heritage is considerable, and they further stand witness to the passion for educational progress and development in the impoverished Greece of the late 19th century. To this passion of the Greek people for education must be attributed, to some degree, the financial development of Greece in the last 30 years.

Most of these buildings, due to the high level of seismic activity in Greece, frequently suffer damage to their structural system, which is mainly made of masonry. Structural restoration work in a number of cases of interest are presented in this chapter with emphasis on the approach that has been followed in elementary and high schools in West Macedonia and in the National Library of Greece in Athens.

Structural typology

Three main types of structural typology may be identified:

- Two- or three-storey masonry buildings with timber decks and trussed roofs [Trambazion Elementary School at Siatista (Figure 1), Valtathonio High School in Kozani (Figure 2), former Elementary School at Vlatsi, etc.].
- Two- or three-storey masonry buildings with reinforced concrete decks and roofs. These decks, actually rigid diaphragms, replaced the old timber decks and roofs in the early 1960s [Tsotili High School, the 5th (Figure 3) and 15th Elementary Schools in Kozani, etc.].
- Two- or three-storey masonry buildings with semi-rigid diaphragmatic decks and roofs consisting of steel girders and masses with brick infills [the old building of the University of Thessaloniki, the National Library of Greece (Figure 4), etc.].

Type of pathology

The pathology of these buildings after a strong earthquake depends on their structural typology and may also be classified in three categories.

- In buildings with timber roofs and decks, where the diaphragmatic action is very poor, the structural walls respond, to a degree, independently one from the other, and as a result they present the following types of damage:
  - inclined cracks at the edges of the buildings, typical damage of independent out-of-plane behaviour of the walls;

Figure 1. **Trambazion Elementary School, Siatista, West Macedonia**

Figure 2. **Valtathonio High School, Kozani, West Macedonia**

Figure 3. **5th Elementary School, Kozani, West Macedonia**

Figure 4. **The National Library of Greece, Athens**

  - horizontal cracks at the foot and at the top of the wall-piers between the windows due to in-plane flexure;
  - vertical cracks indicative of tensile stresses due to the independent vibration of the walls, presented by the spandrels of the external walls at the position of the door and windows.

- In buildings with rigid reinforced concrete decks, which provide strong diaphragmatic action, the masonry walls respond mainly in-plane; as a result they present the following types of damage:
  - x-shaped cracks at the piers between the windows due to shear–compression action;
  - horizontal cracks at the top and the bottom of the piers due to in-plane bending.

The x-shaped failure at the piers often causes the collapse of the building.

- In the case of semi-rigid diaphragms at the decks and at the roof, a mixture of damage is usually observed.

Design of structural restoration

The design procedure for reconstructing and conserving a building includes the following steps:

- Structural survey.
- Site investigations.
- Laboratory tests.
- Analysis for gravity and seismic loads.
- Choice of intervention scheme.
- Reanalysis and redesign.
- Drawings, descriptions, specifications.

It should be noted that all these actions must comply with the principles included in the Venice Charter. Due to the special characteristics of masonry – low tensile strength, orthotropic behaviour and the wide spread of mechanical properties – a variety of methods of analyses are used for a reliable assessment of the response of the building to earthquakes (Figures 5, 6 and 10).

Finally, much attention is paid to the materials and techniques employed for the structural intervention.

Case study: The National Library

Introductory remarks

The following is a short presentation of the structural restoration procedure in the case of the National Library of Greece in Athens, which is owned by the Ministry of Education.

Figure 5. **Stress pattern, Trambazion, for earthquake excitation in transverse direction**

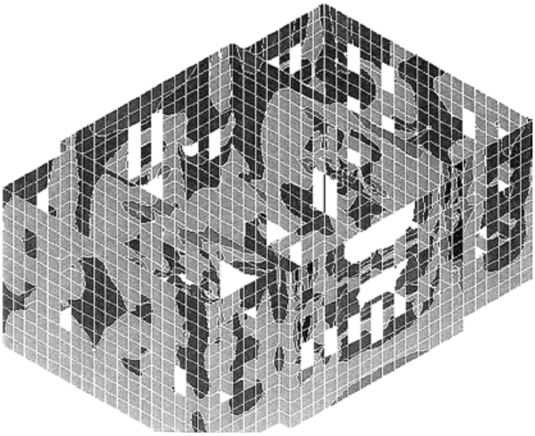
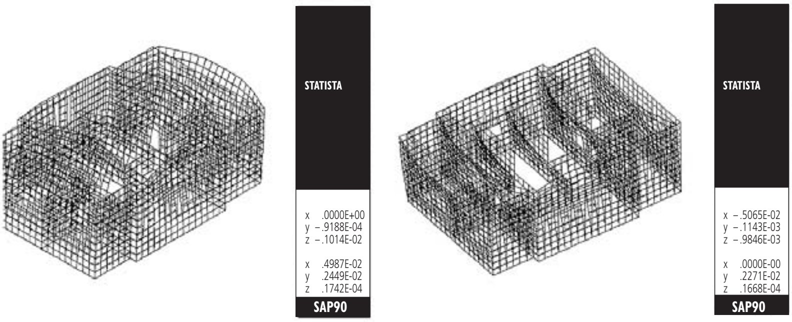


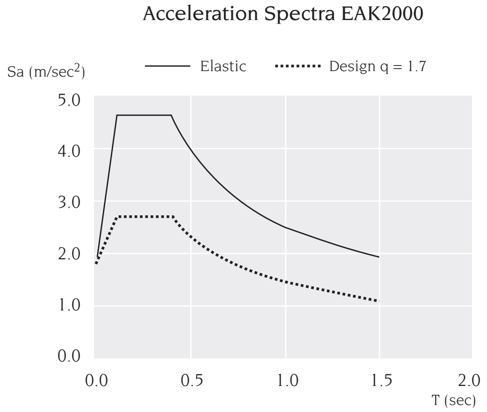
Figure 6. **Deformation pattern, Trambazion, for earthquake excitation in longitudinal direction**



During the Athens quake on Mount Parnitha in September 1999, many buildings within the city limits were damaged. The National Library is a neo-classical complex of buildings located in the centre of the city, on Panepistimiou Street, and was designed and built at the beginning of the 20th century by the famous architects Hansen and Schiller. The complex is composed of three independent rectangular parallel wings and three walkways connecting the two side wings to the main wing. The buildings are unreinforced masonry (URM) constructed externally with smoothened marble megastones combined with marble kions, while the floors are composed of steel beams filled with brick vaults in between. The main wing is decorated with beautiful frescos, which should obviously be preserved.

As the building is the current National Library of Greece, besides being a historical monument it is used every day by hundreds of people who, during and after an earthquake, would be at great risk.

Figure 7. **Elastic and design spectra as defined in Greek Seismic Code**



Building pathology

The buildings had three different types of damage:

- Type 1: time-related damage;
- Type 2: damage from the 1981 quake which had not been repaired;
- Type 3: damage from the 1999 quake.

In all three wings type I damage consisted mainly of water leakage and oxidisation of the steel beams, while damage of types II and III is different for each wing.

More specifically, the two side wings presented inclined cracks at the edges of the transverse walls typical of independent out-of-plane behaviour of these walls due to the lack of diaphragm constraint at the floor and roof levels. Furthermore, horizontal cracks were presented at the foot of the piers of the longitudinal walls due to in-plane flexure. The spandrels of the longitudinal walls suffered small vertical cracks indicative of tensile stresses.

The main wing had significantly less damage, which can mainly be attributed to its higher rigidity and robustness (longitudinal walls) and the intermediate transverse walls which prevented independent out-of-plane behaviour of walls.

Site investigations and laboratory tests

The site and laboratory investigations and tests were to determine the type of ground and the mechanical and chemical characteristics of the masonry. According to the Athens Metro boreholes performed by MECASOL, just in front of the complex, and their evaluation, the ground is slightly weathered limestone classified as type A with regard to seismic forces and certainly able to bear the foundation loads.

Regarding the URM the investigation consisted of destructive (six core samples) and non-destructive (hammer test for masonry) tests and analysis. Special chemical and mineralogical analyses were performed at the AUTH Reinforced Concrete Lab in order to determine the chemical and mechanical characteristics of the mortar so as to achieve high compatibility (chemical, mechanical and aesthetic) in the restoration grouting to be used, bearing in mind the importance of the building and the sensitivity of the frescos. The mechanical properties of the URM as derived from the tests [EC6 and DIN1053 (1974)] are shown in Table 1.

Table 1. **Mechanical properties of URM; characteristic values**

Compressive strength	f_{wk}= 4.50 MPa
Shear strength	f_{vk} =0.22+0.40σ_d MPa
Tensile strength	f_{wt} = 0
Tensile strength (out of plane)	f_{wx1} = 0.18 MPa (Horizontal cracks) f_{wx2} = 0.31 MPa (Vertical cracks)
Elastic modulus	E = 4500 MPa
Shear modulus	G = 1800 MPa
Poisson ratio	υ = 0.25

Analytical models

Two different analytical approaches were selected for the buildings. In the first stage all three wings were analysed using elastic dynamic spectral analysis of a F.E. mesh of plane (shell) elements in order to identify the areas of stress concentration and the overall behaviour of each wing. In the second stage, nonlinear static (pushover) analysis of the two side wings (which presented extensive cracking during the earthquake) was performed, using equivalent frame models, since their cracking suggested nonlinear behaviour. For both analyses the seismic loads were determined by the Greek Seismic Code spectra for seismicity zone II (pga=0.16g) (Figure 7).

Dynamic F.E. analysis

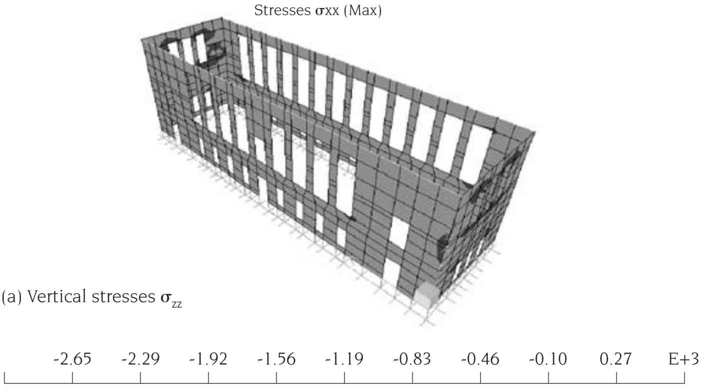
Side wings

The results for the two side wings were similar and they are therefore presented together. The building had a low period of 0.21 sec and presented only transitional modes due to its symmetry. Tensile stresses developed locally at the spandrels, explaining the cracks there, and higher tensile stresses developed at the piers, accounting for the horizontal cracks there (Figure 8). Analysis of the model did not produce the pathology attributed to the out-of-plane behaviour of the two transverse walls since, in the analytical models, they were connected with the longitudinal ones, which suggested that the main deficiency of the structural system is this connection which, obviously, had to be restored.

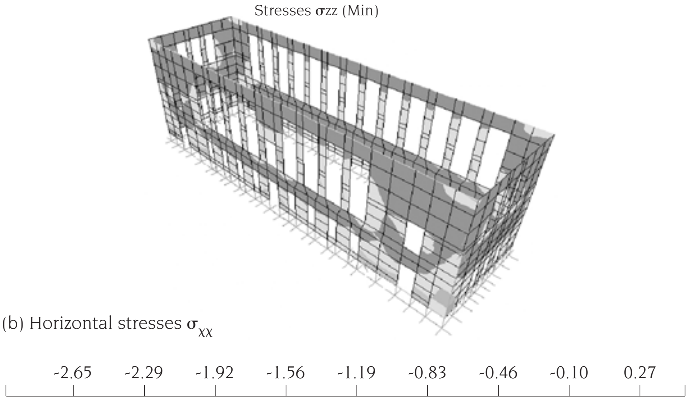
Main wing

The main wing building was found to be stiffer than the two side wings with a natural period of 0.165 sec. It presented only transitional modes due to its symmetry and high torsional restraint attributed to the perimetric masonry walls. The stresses

Figure 8. **Elastic dynamic analysis of side wings**



(a) Vertical stresses σ_{zz}



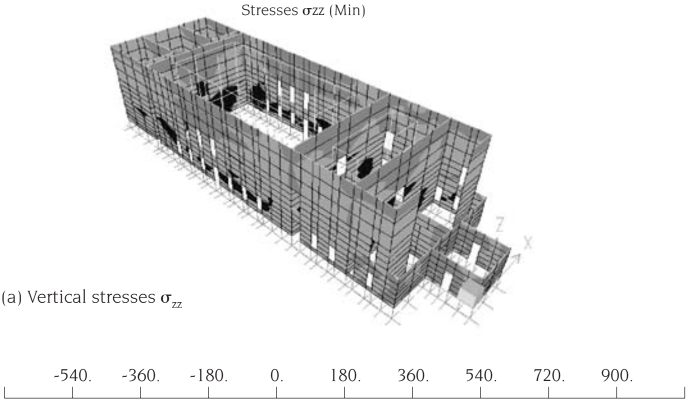
(b) Horizontal stresses σ_{xx}

were significantly lower that the ones that developed in the side wings (Figure 9), since there are no openings on the first floor, smaller openings on the ground floor and the ratio of URM wall over square meters of plan is higher in both directions. These results were in complete agreement with the minimal damage observed in this wing and led to the conclusion that more sophisticated analysis was not required for this wing and only local restoration would be needed.

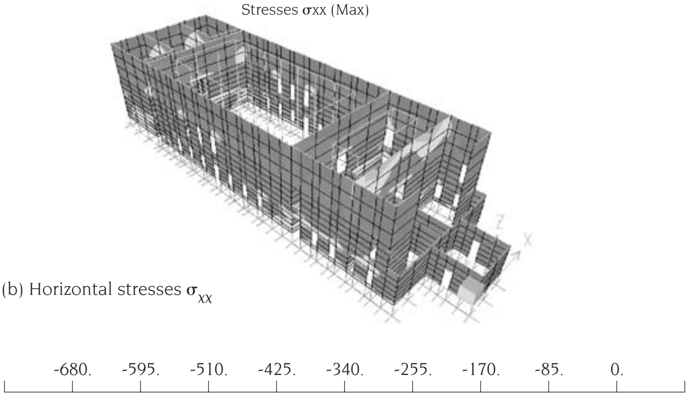
Nonlinear static analysis

The pushover analysis of the two side wings was performed using plane equivalent frames. The model used was a frame element model with areas of concentrated inelasticity. The nonlinearity was concentrated in rotational springs located at the ends of the piers and the spandrels. The Moment-Rotation (M-θ) diagrams of the URM elements had been derived using a procedure validated in Penelis (2000),[1] and these had been used as constitutive laws for the nonlinear springs.

Figure 9. **Elastic dynamic analysis of main wing**



(a) Vertical stresses σ_{zz}



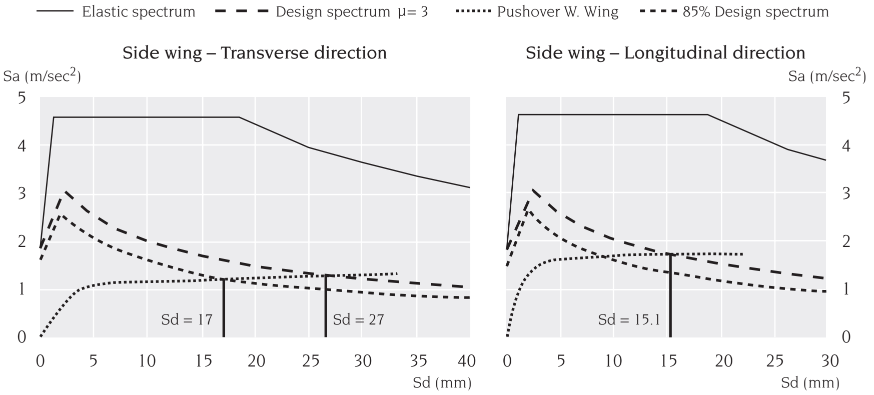
(b) Horizontal stresses σ_{xx}

The use of two independent plane equivalent frames (one per direction) is obviously a conservative assumption since the participation of the transverse walls is disregarded and, as the dynamic analysis showed, torsional modes do not exist.

The evaluation of the pushover analysis and the determination of the target displacement were based on the Acceleration – Displacement Capacity – Demand (ADRS) spectrum procedure prescribed by ATC-40.[2] The inelastic spectra have been derived by applying the formulas of Fajfar[3] on the Elastic Acceleration Spectra of the Greek Seismic Code for zone II.[4]

From these (Figure 10) it is obvious for both directions that the building can withstand the design earthquake, but only by consuming most of its inelastic capacity. This means that in both directions the building would sustain serious but not critical damage under the design earthquake. So the pushover analysis completely validated the results of the elastic dynamic analysis and indicated moderate intervention.

Figure 10. **ADRS format capacity demand spectrum**



Proposed intervention scheme

As already mentioned, the intervention mainly concentrated on the side wings, except for type I damage (time-dependent) which was also found in the main wing. Furthermore, the whole intervention was designed so as to be moderate and reversible.

In that context, the structural restoration for the two side wings consisted of introducing a perimetrical internal zone comprised of beams on the roof level, in order to restore the diaphragm constraint, using either concrete with stainless steel as reinforcement or a uniformly stainless steel profile in order to avoid future corrosion. Four titanium stitches per corner per wall were also suggested in order to secure uniform behaviour of the longitudinal and transverse walls. The cracks on URM were filled with specially selected grouting so as to be compatible chemically, mechanically and aesthetically with the existing mortar, using the sophisticated laboratory tests that had been performed and the existing database at the AUTH Reinforced Concrete Lab.

Conclusion

This chapter, and in particular the case study of the National Library, indicates the attention devoted to old traditional educational buildings in Greece. The most modern procedures, analysis and design are employed to secure long-term conservation in compliance with the principles of the Venice Charter.

Notes

1. Penelis, Gregory (2000), “A New Approach for the Pushover Analysis of URM Structures”, 5th International Congress on Restoration of Architectural Heritage, Florence, Italy.
2. ATC-40 (1996), “Seismic Analysis and Retrofit of RC Buildings”, ATC, California, United States.
3. Fajfar, P., and M. Dolsek (2000), “A Transparent Nonlinear Method for Seismic Performance Evaluation”, 3rd Workshop of the UK-Japan Seismic Risk Forum, Imperial College Press, London, United Kingdom.

4. EAK2000 (2000), "Greek Seismic Code", OASP, Athens, Greece.

5. Tassios, T.P. (1986), "The Mechanics of Masonry" (in Greek), National Technical University of Athens, Greece.

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