EXECUTIVE SUMMARY

The issue

> ...schools built world-wide routinely collapse in earthquakes due to avoidable errors in design and construction...because existing technology is not applied and existing laws and regulations are not sufficiently enforced...Unless action is taken immediately to address this problem, much greater loss of life and property will occur. (extract from "*ad hoc* Experts' Group Report on Earthquake Safety in Schools", in this publication)

This report is the product of an *ad hoc* experts' meeting held at the OECD in Paris from 9 to 11 February 2004 on earthquake safety in schools. The meeting was organised by the OECD Programme on Educational Building (PEB) and GeoHazards International (GHI), a non-governmental organisation comprised of specialists in earthquakes and earthquake risk in academic, business and government sectors in the United States and Japan. The aim of the organisers was to initiate an activity that would improve earthquake safety in schools and education systems. The motivation was simple: schools frequently collapse during earthquakes and will continue to do so unless individuals, communities, scientists, governments and other bodies discuss and devise solutions to address the problem. The expert knowledge, opinions and experiences presented in this report provide valuable insight into the nature and scope of the problems involved in protecting school buildings and their occupants. Importantly, these accounts also give us hope that the seismic risk of schools can be lowered to prevent further injury and death during earthquakes.

The process

In order to explore the issue of *how* to initiate change, the experts were asked to follow an evolution of themes – to acknowledge the problem, to recognise obstacles, to define key safety principles, to assess vulnerability and risk, and to identify strategies and programmes for improving school seismic safety – that would lead to a concrete proposal towards action. Key elements of the themes and the papers contained within them are presented below.

Acknowledging the importance of improving seismic safety in schools

Few individuals will contest the importance of protecting society's most valuable and vulnerable members, children; and few will contest the importance of providing compulsory education for all children. Even fewer people will argue with the fact that earthquakes kill people and damage property. But these three essential principles do not hold up in modern society. In many earthquake-prone countries, a surprisingly high number of school buildings are not constructed to withstand the most moderate of earthquakes. The fundamental question that we must ask ourselves is "Why is it so simple to acknowledge the importance of the education and safety of our children, yet so difficult to ensure?"

From the great Lisbon earthquake of 1755 to present-day disasters, the task of engaging governments, communities and others to reduce the risk and vulnerability of the world's populations has made variable progress. Over the last decade or more, there has been a strong movement towards establishing a culture of disaster prevention and mitigation, which has been reflected in the responses of these stakeholders to the issue of improving the safety of schools in earthquakes. But despite the success of community advocacy groups, the commitment of engineers and other scientists, efforts by some governments to address the problem and the considerable international attention generated by such global initiatives as the International Decade for Natural Disaster Reduction, the human and material costs of disasters are increasing, especially in developing countries. In the face of advancing technologies, growing urbanisation and increasing populations, a new approach to addressing such problems is required.

Recognising the obstacles to improving seismic safety of schools

To first identify the scope of the problem, experts were asked to describe and assess the relative importance of the specific factors contributing to the poor performance of school buildings, and also to measure the extent to which the lessons learned from past earthquakes have been used to improve building codes and construction practices. Common, inter-related and in most cases avoidable obstacles were encountered by experts from Algeria, Former Yugoslav Republic of Macedonia (FYROM), Italy, Mexico, New Zealand, Portugal, Turkey, Venezuela and the United States: from lack of awareness of the threat of school collapse and poor communication between the scientific, public and government communities; to basic deficiencies in the nature, implementation and enforcement of laws and regulations concerning planning, maintenance and construction of schools buildings.

- *On the evening of 21 May 2003, an earthquake in Boumerdes, Algeria, left 2 287 people dead and 11 000 injured.* Schools were badly affected by the earthquake: 122 schools had to be rebuilt and 560 – out of 1 800 schools inspected – were seriously damaged. The cost of the earthquake in terms of school reconstruction and rehabilitation was estimated to be USD 70 million. The failure of school buildings during the disaster can be attributed to a growing urban population and subsequent demand for inexpensive and rapid school construction, poor quality construction, failure to adhere to construction regulations, lack of quality control in construction, absence of licensing for professionals and underestimated code hazard parameters. The earthquake occurred outside of school hours.
- *Following the 1989 Loma Prieta earthquake in California, which demonstrated the weakness of many reinforced-concrete structures, a group of parent advocates in Berkeley found that seven of its 16 district schools posed serious life threats to students.* In 1991, a community group proposed that school district officials embark on a USD 158 million comprehensive safety programme to rebuild Berkeley schools. Since that time, all Berkeley schools have been rebuilt, and the community has approved over USD 362 million in taxes for safety improvements. Improving seismic safety was not only a technical problem but a challenge to prompt community engagement, accountability and action.

- *In 2002, a primary school in San Giuliano, Italy, collapsed, killing 29 children and one teacher.* Further investigation revealed that the area of San Giuliano was not classified as a seismic zone and thus the building was not constructed using seismic criteria. Use of poor quality masonry and a heavy reinforced-concrete roof also contributed to the collapse. The event alerted authorities to the vulnerability of critical structures. In 2003, five months after the earthquake, an ordinance of the prime minister stated that seismic vulnerability of all public strategic buildings, including hospitals and schools, had to be evaluated in the next five years. Soon after, new seismic zonation and seismic codes were introduced.
- *On 1 May 2003, a medium-sized earthquake in Bingöl, Turkey, caused the collapse of three new schools and a dormitory building located next to a school, killing many children as they slept.* These tragic events prompted many to question the seismic safety of school buildings. A subsequent survey of 29 school buildings concluded that none of the structures were built according to the 1998 Turkish Seismic Code. In this case, a shortage of resources and expertise to conduct reliable project and construction supervision, and lack of formal qualifications of contractors, engineers and architects were two factors that led to non-compliance with existing building codes. Of the 29 buildings surveyed, three collapsed, ten suffered severe damage and 12 buildings sustained moderate damage.
- *On 9 July 1997, an earthquake struck north-eastern Venezuela, destroying two school buildings in the town of Cariaco and killing 46 students.* In addition to grave design flaws, the schools were not constructed according to the seismic requirements for that region specified in the 1968 building code. More than 1 000 school buildings of the same structural type exist in areas of high seismic hazard in the country. In response to this tragedy, a three-stage project on reducing seismic risks in schools in Venezuela has been implemented to identify and classify existing schools in terms of vulnerability and to determine and reduce the level of risk to which schools are exposed.
- *New Zealand is one of the most seismically active countries in the world. However, most earthquakes have occurred in sparsely populated areas.* The most damaging earthquake in New Zealand took place in February 1931 in Hawke's Bay and resulted in more than 250 deaths. The city of Wellington was destroyed in the largest earthquake ever recorded in 1855. If such an event should occur again, a number of mechanisms have been established to ensure that school buildings will not collapse. In 1991, the Building Act was created to regulate building design and construction in New Zealand. Between 1998 and 2001, a structural survey of 2 361 public schools was commissioned by the Ministry of Education, and a significant investment programme was initiated to meet the recommendations of the report in terms of specific categories of buildings.
- *On 9 July 1998, an earthquake struck the islands of Faial and Pico in the Azores Islands, Portugal, killing eight people and leaving 1 000 homeless.* Following the earthquake, 21 educational buildings were inspected in an attempt to discern the correlation between general building classification factors – building structure, building quality, conservation condition and number of storeys – and damage state and post-event use of the building. Half of the schools were considered suitable for immediate occupation, two schools were marked for demolition and the remainder of schools could be used after minor to moderate repairs.

Defining seismic safety principles for schools

In order to begin to improve earthquake safety in schools, the fundamental concepts and principles that lead to the construction of earthquake-resilient schools must be identified. This section defines these concepts and principles, taking into account cost/benefit and resource implications; and also uses them as a starting point from which to develop a programme of recommendations for school seismic safety in countries.

A number of safety principles for schools were identified by the group.

- Need for *"champions" of seismic safety*, who can promote a risk-averse society and effectively communicate the risks involved in earthquakes to all stakeholders.
- Acknowledgement of the *important role of school buildings within the community as post-disaster shelters*.
- Establishment of a *system for assigning risk ownership and a legal or regulatory basis for action*, which contains clear lines of accountability and achievable performance goals with an incremental implementation strategy.
- Clear understanding of *financial responsibility and cost*.
- Availability of *detailed and up-to-date hazard maps and building codes*, which are implemented by strong and stable institutions.
- Establishment of a *well-monitored process for quality control,* with certified design professionals, independent plan review, checking and approval, independent inspection and testing and final reporting.

California's 1993 Field Act illustrates how effective legislation can lead to developing and implementing a successful programme.

Assessing vulnerability and risk to schools and education systems

Is it feasible to develop norms for assessing risk and for quantifying structural and non-structural hazard, vulnerability and exposure in schools and other public buildings? Importantly, if establishing and monitoring norms is realistic, to what extent are these norms transferable across cultures and countries?

A number of risk scoring and assessment systems have been developed that could be adapted to schools in different countries, as seen in the case study of the collaborative United States-Italy programme to improve seismic safety in Italy's hospitals. Common performance objectives, standard criteria for specifying expected ground-shaking severity, and standards, regulations, licensing, education and training could be realistically implemented across countries. Similarly, United States' processes of code administration, plan review and field inspection used in grading systems could be adopted as standard procedures across countries.

The *ad hoc* Experts' Group on Earthquake Safety in Schools concluded that adequate risk assessment methodologies and metrics currently exist to evaluate the state of school seismic safety, and to monitor the progress and success or failure of school seismic safety programmes throughout the world.

- In 1994, the Northridge earthquake in California caused USD 7 billion of insured losses to properties. The Insurance Services Office (ISO) – an independent statistical, rating and advisory organisation that serves the property/casualty insurance industry in the United States – helps distinguish between communities with effective building-code enforcement and those with weak enforcement through a comprehensive programme called the *Building Code Effectiveness Grading Schedule (BCEGS).* The concept behind BCEGS is simple. The prospect of minimising catastrophe-related damage and ultimately lowering insurance costs gives communities an incentive to rigorously enforce their building codes. ISO collects information on a community's building-code adoption and enforcement services; analyses the data by looking at the administration of codes and reviewing building plans and field inspections; and then assigns a Building Code Effectiveness Classification from one to ten. Class 1 represents exemplary commitment to building code.
- In the 1990s, the *Applied Technology Council (ATC) in the United States* and the *Servizio Sismico Nazionale (Italian National Seismic Service, NSS) in Italy* embarked on a collaborative programme to improve seismic safety in Italian hospitals. In the first phase of the programme, recommendations were made, addressing issues of regulation, design of new hospitals and implementation of earthquake mitigation measures such as planning for earthquake response and recovery. In the second phase, completed in 2002, ATC and NSS prepared emergency response procedures. In the third phase, completed in 2003, collaborative guidelines were developed for bracing and anchoring non-structural components. In all three phases, the recommended procedures and guidelines were developed from existing guidelines and regulations in both countries, with innovations added.

Identifying strategies and programmes for improving school seismic safety

In this section, the experts were invited to describe the application of known seismic safety concepts and principles to existing strategies and programmes for school safety, and to consider the most effective ways to encourage, facilitate and assess progress made towards seismic safety goals. Importantly, the experts were also asked how best to motivate countries and political leaders to consider that it is in their interest to establish programmes that build seismically-resistant schools. Awareness-raising through the dissemination of knowledge and data regarding school seismic safety using both formal and informal channels plays an important role in empowering and motivating individuals for change. Examples of formal channels include a National Programme on Earthquake Engineering Education in India and establishing criteria and procedures to compare the vulnerability national building typologies in Italy. Informal channels include delivering lectures to school communities on seismic resistance improvements to school buildings and simply distributing leaflets on better construction practices to workers at construction sites.

In developing countries, implementing a strategic programme is further complicated by such factors as lack of local knowledge, shortage of finances, disagreement between external experts and scarcity of materials. In a European context, while the material, financial and human resources exist to establish a number of programmes for screening, evaluating and strengthening existing buildings in earthquake-prone countries, much greater regulatory effort is required in all countries to significantly reduce the highest risk to public buildings.

- *During the Bhuj 2001 earthquake in India, 971 students and 31 teachers died, and 1 051 students and 95 teachers were injured.* After the earthquake, the Ministry of Human Resource Development of the Government of India launched a comprehensive National Programme on Earthquake Engineering Education (NPEEE). In the project, eight institutes of technology serve as resource institutes to train teachers from colleges of engineering, architecture and polytechnics. Components of the project include one to four-week and one-semester training programmes for faculty members in the country; international exposure for faculty members; development of resource materials and teaching aids; development of library and laboratory resources; and organisation of conferences and workshops. The programme is open to all recognised engineering colleges/polytechnics and schools of architecture – both public and private – with related academic degrees or diploma programmes.
- *The following example from Nepal illustrates the importance of considering simple solutions to solve seemingly complex problems.* As in many countries, it is common practice to bend hoop steel for reinforced-concrete columns, without using the hooks necessary to make the hoops effective in large earthquakes. This is similar to having the belt in one's trousers constantly undone. After failing to persuade the authorities to undertake a simple campaign of distributing leaflets on best practice to local construction sites, one of the national project team members decided to produce the leaflets privately, which he distributed from his motorcycle bag.
- *A cost estimate for strengthening all school building stock in the six European Union countries with a significant seismic risk* (Table 1) shows that Italy is the country with the highest relative cost, followed by Greece, Portugal and Austria. The costs do not seem completely unmanageable given that the estimated length of such a programme is 20 years and also considering that these costs should be offset by the ensuing reductions in damage, disruption and human casualties. In practice, a 20-year programme could be designed in such a way that retrofitting work would be carried out alongside other necessary maintenance or refurbishing work; and the natural process of replacement of older school buildings already planned and budgeted for would avoid the need for upgrading some of the oldest and most vulnerable school buildings. Thus, the real additional costs would be significantly less.

Table 1. Likely cost of school strengthening programmes in high-risk countries in the European Union

	Austria	France	Greece	Italy	Portugal	Spain
Total strengthening costs (millions euro)	84	250	350	1670	80	130
Education capital expenditure (ECE) (millions euro)	614	6 297	751	3 513	376	3 725
Strengthening costs as % ECE	14%	4%	47%	48%	21%	4%
...or annual cost as a 20-year programme	0.7%	0.2%	2.3%	2.4%	1.1%	0.2%

The outcome

The final recommendations of the *ad hoc* Experts' Meeting on Earthquake Safety in Schools represent the culmination of three days of discussion on the fundamental principles and elements of a national school seismic safety programme. These recommendations present a call to action for all governments in OECD and non-OECD countries to facilitate the implementation of these recommendations.

Further resources

The Web site *www.oecd.org/edu/schoolsafety* provides up-to-date information on earthquake safety in schools, in addition to material on related OECD activities on school safety and security.

The Web site *www.oecd.org/edu/facilities* contains information on other activities of the OECD Programme on Educational Building (PEB), such as the Programme's journal *PEB Exchange*, which is published three times per year; international conferences; related publications on school facilities; and other resource material.

READER'S GUIDE

This guide provides the reader with information on three terms that are used throughout this publication to describe the size of an earthquake: magnitude, intensity and peak ground acceleration.

Earthquake magnitude

Magnitude is the most common measure of the relative size of earthquakes, and is based on the maximum movement of the ground caused by the earthquake and recorded by seismographs. Unlike measures of earthquake intensity, which vary with distance from the earthquake source, magnitude is an inherent characteristic of the earthquake.

While a number of magnitude scales exist – each measuring the amplitude of ground motion at different frequencies – all magnitude scales yield approximately the same value for any given earthquake. In this publication, all earthquake magnitudes are reported as an "M" followed by a value (*e.g.* M6.8, M4.5). Although the magnitudes of some of the earthquakes mentioned here were originally reported using different magnitude scales, the differences are not important for the purposes of this text.

The most commonly-used magnitude scales are:

- Local magnitude (ML), commonly referred to as the "Richter scale" (Table 1). The Richter scale is logarithmic, meaning that an increase of one magnitude unit represents a factor of ten times in amplitude.
- Surface-wave magnitude (Ms).
- Body-wave magnitude (mb).
- Moment magnitude (Mw).

While the first three scales have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes, the moment magnitude scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types.

Table 1. Richter magnitudes and measurable earthquake effects

Richter magnitudes	Effects near earthquake source
< M3.5	Generally not felt, but recorded.
M3.5 – M5.4	Often felt, but rarely cause damage.
> M6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
M6.1 – M6.9	Can be destructive in areas up to about 100 km.
M7.0 – M7.9	Major earthquake. Can cause serious damage over 100 km.
> M8	Great earthquake. Can cause serious damage in areas over 1 000 km.

Earthquake intensity

Intensity is a measure of the shaking and damage caused by the earthquake. Unlike values of magnitude, rating the intensity of an earthquake's effects does not require any instrumental measurement, and the earthquake intensity value changes from location to location, in general decreasing with distance from the earthquake source.

The Modified Mercalli Intensity (MMI) scale is the most commonly-used earthquake intensity measurement. It describes the severity of an earthquake in terms of its effects on the earth's surface and on man and built structures (Table 2). Intensity ratings are expressed as Roman numerals between I and XII.

Table 2. Modified Mercalli Intensity (MMI) scale and description of effects and corresponding peak ground accelerations (PGA)

MMI	PGA (g)	Earthquake effects
I	<0.002	Not felt except by a very few under especially favourable circumstances.
II	0.002-0.003	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	0.004-0.007	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognise it as an earthquake. Standing automobiles may rock slightly. Vibrations felt like passing of truck.
IV	0.015-0.020	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking a building. Standing automobiles rocked noticeably.
V	0.030-0.040	Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	0.060-0.070	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.

MMI	PGA (g)	Earthquake effects
VII	0.100-0.150	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.
VIII	0.250-0.300	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.
IX	0.500-0.550	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	>0.600	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.
XI		Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in the ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII		Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

Source: Federal Emergency Management Agency (FEMA).

Peak ground acceleration

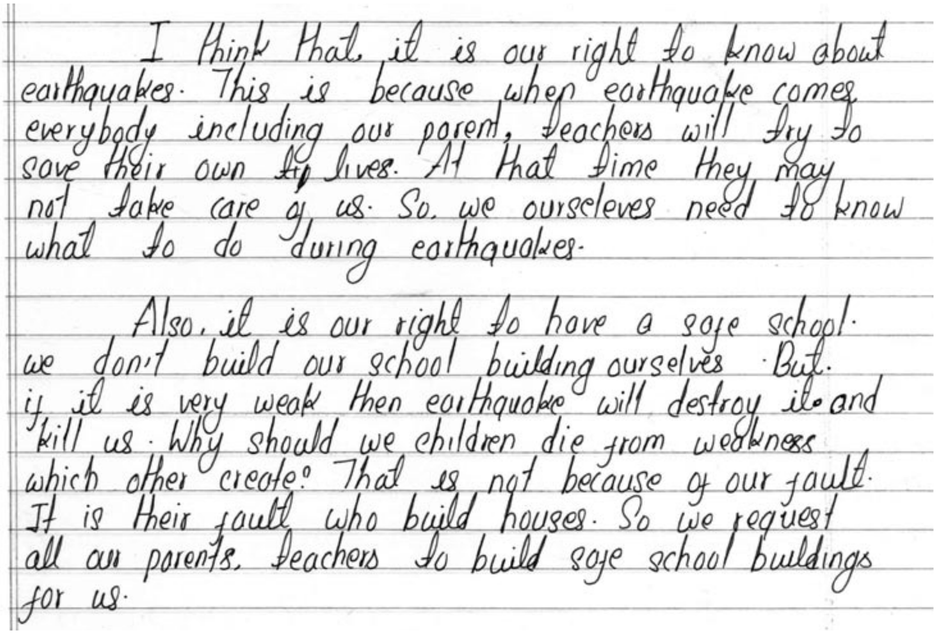
Peak ground acceleration (PGA) is a measure of the ground motion severity experienced during an earthquake. It is expressed as a fraction of gravity, so a vertical acceleration of 1 g means that an individual or object has been pushed hard enough to leave the ground. Peak ground acceleration usually refers to the maximum horizontal acceleration measured at the site, although PGA can also refer to the peak in vertical accelerations. A PGA of 0.2 g means that the maximum horizontal acceleration is 20% of the earth's gravity. Since force is proportional to acceleration, that would mean that the earthquake generated horizontal forces equivalent to 20% of the structures weight at its base (Table 2).

Peak ground acceleration is measured using an accelerogram. Accelerographs refer to the paper/electronic trace of the acceleration time histories recorded at a station during an earthquake. To obtain a complete definition of ground motions, most stations record in two horizontal directions (one perpendicular to the other) and one vertical direction.

INTRODUCTION

ACKNOWLEDGING THE IMPORTANCE OF IMPROVING EARTHQUAKE SAFETY IN SCHOOLS

Hannah von Ahlefeld
OECD Programme on Educational Building



I think that it is our right to know about earthquakes. This is because when earthquake comes everybody including our parent, teachers will try to save their own ~~li~~ lives. At that time they may not take care of us. So, we ourseleves need to know what to do during earthquakes.

Also, it is our right to have a safe school. we don't build our school building ourselves. But. if it is very weak then earthquake will destroy it and kill us. Why should we children die from weakness which other create? That is not because of our fault. It is their fault who build houses. So we request all our parents. teachers to build safe school buildings for us.

Letter written by Sony, a student in Nepal

Introduction

Few individuals will contest the importance of protecting society's most valuable and vulnerable members, children; and few will contest the importance of providing compulsory education for all children. Even fewer people will argue with the fact that earthquakes kill people and damage property. But these three essential principles are not valid in modern society. In many earthquake-prone countries, a surprisingly high number of school buildings are not constructed to withstand even moderate-sized earthquakes. The fundamental question that we must ask ourselves is "Why is it so simple to acknowledge the importance of the education and safety of our children, yet so difficult to ensure them?" This paper explores the development of man's consciousness concerning natural disasters, particularly those involving schools, and the nature and effectiveness of his response to natural disasters, especially to earthquakes.

From the great 1755 Lisbon earthquake to the recent tragedies in Algeria, Italy, Japan and Turkey, governments, communities, scientists and decision-makers have all witnessed the collapse of school buildings and other essential structures. In the Kobe earthquake, for example, approximately 40% of the city government employees were victims of the disaster and 300 000 people lost their homes (Tierney and Goltz, 1997). The extent to which such disasters act as a catalyst for change is a reflection of the willingness of these groups to acknowledge that a problem exists and thereafter empower themselves and others to mitigate future disasters. In an effort to comprehend this process of realisation and action, the responses of communities, governments, inter-governmental organisations and the scientific community to the problem of earthquake safety in schools must be closely examined.

The lessons of Lisbon

> When they had recovered a little, they [Candide, Pangloss and the "brutal sailor"] walked towards Lisbon. They still had some money, and hoped, having escaped from the storm, also to save themselves from starvation…At this moment the earth shook, the sea rose up foaming in the harbour and dashed to pieces the ships lying at anchor. The streets and squares were filled with whirling masses of flaming and cinders. The houses collapsed, the roofs crashing down on the shattered foundations. Thirty thousand inhabitants were crushed beneath the ruins. (extract from *Candide*)

Next year marks the 250th anniversary of the great Lisbon earthquake, in which up to 70 000 people were killed. Only 3 000 of 20 000 dwellings were inhabitable after the event (Dynes, 2000). This event is significant for two principal reasons.

First, while formerly earthquakes had been perceived as catastrophic events unleashed on a deserving populace, this event served as a catalyst for great philosophical, religious and scientific debate, signifying the union of fatalistic ("Act of God"), scientific ("Act of Nature") and sociological ("Acts of Men and Women or Society") paradigms on disasters (Quarantelli, 2000). Voltaire used the earthquake as a vehicle to attack the prevailing Enlightenment views on optimism, while his antagonist in correspondence, Rousseau, suggested that urbanisation and inappropriate construction in a seismic zone contributed to the damage in Lisbon (Dynes, 2000).

> Without departing from your subject of Lisbon, admit, for example, that nature did not construct 20 000 houses of six to seven stories there, and that if the inhabitants of this great city had been more equally spread out and more lightly lodged, the damage would have been much less and perhaps of no account. (Masters and Kelly, 1992 in Dynes, 2000)

The Lisbon earthquake also prompted Kant to write three essays on earthquakes. Kant's theory that earthquakes occurred as a result of explosions of combustible gases in subterranean caves in mountain ranges proved incorrect – it was not until 1855 that faults were recognised as the source of earthquakes – but his search for a proto-scientific explanation for the disaster was a considerable departure from prevailing religious interpretations (Oeser, 2001).

Second, the Lisbon earthquake can be considered as "the first modern disaster in which the state accepted the responsibility for mobilising the emergency response and for developing and implementing a collective effort for reconstruction" (Dynes, 1997). One of the most significant figures in Lisbon at the time of the earthquake was the Marques de Pombal, who organised the emergency response and reconstruction of the city of Lisbon. For emergency response, he appointed 12 district leaders and gave them emergency powers, disposed of bodies immediately to avoid plague, ensured a continued food supply, controlled the price of food and increased security to prevent looting; even the weekly newspaper was published on time. For reconstruction, Pombal appointed engineers and surveyors to draw up plans for the new city and to ensure that sanitary and levelling operations were carried out correctly, controlled land rents, passed laws prohibiting landlords to evict tenants, and prohibited unauthorised construction that did not conform to planned reconstruction. A wooden frame or *gaiola*, which was known to provide flexibility in the case of earthquakes, was required for all construction (Dynes, 1997).

Earthquakes in the world today: Towards a culture of disaster prevention and mitigation

As societies have developed and knowledge about seismic events has improved over the centuries, the task of engaging governments, communities and others to reduce risk and vulnerability of the world's populations has made variable progress. Over the last decade or more, there has been a movement towards a "culture of risk prevention", meaning that the focus of many programmes has moved from response and recovery towards prevention and mitigation. The responses of the principle stakeholders described in this paper attest to this evolution. Yet the fact that structures continue to collapse as a result of earthquakes would indicate that insufficient priority is being given to this issue by decision-makers. Some of the most recent tragedies are described in Part I of this publication.

Building strong communities

Disasters can often provide a strong impetus for social change, and an increasing amount of anecdotal evidence illustrates the fundamental role of concerned citizens and communities in advocating not only social, but also political and economic change (Nigg and Tierney, 1993). The disturbing post-disaster reality is that the "window of opportunity" for action is only open for a short period of time following a disaster, and without concerted and continued intervention and pressure by individuals and groups, there is a real danger that systems will return to their pre-disaster states. Several case studies from Canada, the United States and elsewhere attest to the effectiveness of this "bottom-up" approach to disaster mitigation with regard to school buildings – where mitigation activities are initiated at the community level and communities leverage moral and financial support from public and private sector partners.

> When Jules Quesnel [elementary school] parent Tracy Monk went looking for information about her daughter's school's ability to withstand an earthquake, she thought what she found out must be a mistake. "I discovered that the co-efficient of risk for my child's school building was a hundred times greater than that of the typical wood-frame houses of the neighbourhood…At first I thought, this can't be right…" Not only was her school – Jules Quesnel – found to be seismically at-risk according to the school district's most recent assessments, so were 46 other Vancouver schools. (Ince, 2004)

This realisation marked the starting point of one parent's quest to improve the basic safety of the structure in which her child is schooled. After geologists informed Monk that an earthquake "strong enough to cause serious damage" could occur in the next 20 to 40 years, she and a group of equally committed colleagues – who came to be known as Families for School Seismic Safety (FSSS) – lobbied seismic experts, national and local government officials, and school board members. After establishing support from experts and public officials, FSSS worked to obtain numerous endorsements for a programme of seismic upgrades for at-risk schools in Vancouver.

A similar story of community advocacy started in the 1990s in California. Following the 1989 Loma Prieta earthquake, which demonstrated the weakness of many reinforced-concrete structures, a group of parent advocates in Berkeley found that seven of its 16 district schools posed serious life threats to students. In 1991, a community group proposed that school district officials embark on a USD 158 million comprehensive safety programme to rebuild Berkeley schools. Since that time, all Berkeley schools have been rebuilt, and the community has approved over USD 362 million in taxes for safety improvements. Achieving improved seismic safety was not only a technical problem, but also a challenge to prompt community engagement, accountability and action. (see Chakos in this publication)

In a national effort to reduce the escalating social and economic costs of natural disasters, a pilot community-based national disaster mitigation programme was initiated in 1997 by the Federal Emergency Management Agency (FEMA) in the United States (Wachtendorf, 2000). The objectives of Project Impact were to build community partnerships, involving federal and local government, schools, local businesses and federal agencies; to identify hazards and community vulnerability; to prioritise and complete risk reduction actions; and to develop communication strategies to increase public awareness of the importance of reducing disaster losses. In 2000, more than 250 communities and 2 500 businesses partners were involved in Project Impact (FEMA, 2000). An independent assessment of the project (Wachtendorf, 2000) found that valuable local partnerships, particularly between schools and local government agencies, had been developed and strengthened; although Project Impact communities need to work to include all members of the community, particularly its most vulnerable members, and to better capitalise on regional partnerships and those involving other Project Impact communities. Other countries such as Canada, New Zealand and Turkey are considering implementing similar studies (Wachtendorf, 2000).

Scientific expertise

> The knowledge presently exists to significantly lower the seismic risk of schools and to help prevent further injury and death of school occupants during earthquakes…at reasonable cost and in a reasonable time frame. (extract from "*ad hoc* Experts' Group Report on Earthquake Safety in Schools", in this publication)

Scientists and communities have often worked together to gain the attention and support of the wider community and government. In the case study of Vancouver schools, engineers from the Association of Professional Engineers and the Director of the Earthquake Engineering Research Facility at the University of British Colombia worked with the parent advocacy group to identify and explain the seismic risk in Vancouver's schools. A number of university research centres such as the European Association for Earthquake Engineering (EAEE), the Earthquake Engineering Research Institute (EERI), the Disaster Management Research Centre in the Middle East Technical University in Turkey, the Italian National Association for Earthquake Engineering at the University of Basilicata and the Disaster Research Centre at the University of Delaware are heavily involved in national research projects on earthquake safety in schools. A number of non-governmental organisations such as GeoHazards International (GHI) and Volunteers for India Development and Empowerment (VIDE) are also working with communities to reduce seismic risk, particularly in developing countries, where there is an even greater need for expert knowledge and experience and for collaboration on the part of all stakeholders.

But while experts possess the knowledge and experience required to advance the cause of important issues such as seismic safety, they may encounter any number of obstacles applying this expertise. Sharpe (in this publication) recounts the reluctance of authorities to implement a simple and cost-effective measure to improve the seismic resistance of school buildings. In other cases, public bodies may be unwilling to allocate resources to improve existing seismically hazardous structures. Spence (in this publication) states that the annual cost of a 20-year school strengthening programme in the six European Union countries with the highest seismic risk is between and 0.2% and 2.4% of total capital expenditure on education.

The response of governments

> The Commission deeply regrets the loss of human lives and the damages caused to the population of San Giuliano di Puglia. At this stage, the Commission does not envisage any specific proposal for legislation in the field of earthquake mitigation. (EU Environment Commissioner Margot Wallström, cited by Spence in this publication)

This is the disappointing response by the European Commission to the request by a member of the European Parliament to establish a directive requiring member states to set up programmes for assessing all buildings in high seismic zones. The statement was made in the wake of an earthquake in Molise, Italy, in which a school building collapsed, killing 25 children. The reluctance of this body to establish a regulatory framework at a European level, as Spence notes, is related to preference for other methods of "achieving desirable social and environmental goals", which probably cost less and do not require the enforcement of regulations. The effectiveness of the non-regulatory approach was tested less than three months later, when more than 100 schoolchildren were killed as a result of a school collapsing in an earthquake in Turkey.

In some cases, individual governments have been more willing to take regulatory action, particularly following devastating earthquakes. Within months of the Molise earthquake, the Italian government drafted an earthquake code, which introduced new seismic zonation for the whole of the Italian territory and set out a detailed process for evaluating and