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School Seismic Safety: Case Studies

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Synonyms

Education sector; Examples; Policies; Policy; Progress; Schools; Seismic safety

Introduction

The case studies in this entry accompany the previous entry on School Seismic Safety and Mitigation. They tell the stories of a variety of national efforts to improve school seismic safety. The contributors to the case studies are engineers and parents, social workers, and international development specialists. They examine policy, advocacy, vulnerability, and solutions. They contain observations about stepwise progress, motivation, political will, technical approaches, innovations, moderate successes, and long roads ahead. There are more stories to be added. The intention is to provide school seismic safety advocates with both elements of inspiration and way points on a road map with many options to consider.

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It is important to note that school *seismic* safety should not be isolated from school safety from disasters and climate change impacts in general. It cannot be considered responsible to approach the rights of children from our narrow professional silos. It is incumbent upon all advocates for children to see the matter from their point of view, that is, from the perspective of all of the physical threats to their right to survival and safety and from all of the threats to their right to education and development.

Similarly, key stakeholders in the seismic safety of schools (engineers, architects, builders) must make the effort to think not primarily about the *structures*, but rather about the people who *use* the structures. The users must also have safe access and egress. For the users, infill walls that fall out of plane and unsecured nonstructural building elements or building contents are a far greater threat than their "minor damage" designation suggests. If the building is going to be one of the strongest structures in the community, then it may also need to be planned to be as a cyclone shelter or to double as a shelter for people displaced after an earthquake. In that case, water and supply storage and extra sanitation facilities have to be considered. And the job is not complete when the key is handed over. Buildings that do not come with a user's manual and a school maintenance calendar stand little chance of being safely maintained. Thus, the concern for school seismic safety does not begin and end with the structures themselves, but must take a holistic approach and, of course, include the user community.

Algeria

Ninety percent of Algeria's population of 30 million is concentrated in a band about 60 km wide and 1,200 km long along the Mediterranean coast on the African and Eurasian tectonic plate boundary. This region has repeatedly experienced moderate-to-strong earthquakes. During the twentieth century, earthquakes claimed at least 10,000 lives, injured about 27,000, and made about half a million homeless. In addition to building collapse due to earthquakes, considerable damage from liquefaction and landslides was observed.

School buildings have also suffered considerable damage in earthquakes, varying according to the period during which they were built: (1) those degraded through aging and lack of maintenance, built during the colonization era (1830–1962), account for about 30 % of the school building stock; (2) those built after independence, during the 1970s, with rapidly growing population and democratization of educational opportunity (when primary school became free and compulsory), when school construction accounted for the largest single item in Algeria's budget, were designed and built without taking into account seismic risk; and (3) those built with technical supervision after 1983 and the introduction of Algeria's seismic building code in 1981.

Schools in Algeria are all state owned and were built by the government. The government adopted one typical structure for all schools that could be duplicated easily across the country. The standard architectural design of schools involves two fundamental elements: the classroom and the circulatory corridors. Classrooms are 7×4 m and circulatory corridors are 2.5 m wide. These are far from those of an ideal seismically resistant structure as recommended by Algeria's own seismic codes. Other standard design elements also unfortunately reduce the resilience of these school structures.

Numerous reports show the deficiencies in design, construction techniques, and materials (poor quality of concrete) with respect to particular earthquakes at El Asnam (1980), Chenoua-Tipaza (1989), Beni

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Chougrane-Mascara (1994), Ain Temouchent (1999), and Boumerdes-Algiers (2003) (Bendimerad 2004). The following typical damage to school buildings was recorded in recent earthquakes:

- Rupture of staircases
- Destruction of joints
- Destruction of short columns
- Damage in Masonry
- "Pancake" collapse due to weak columns, overly strong beams, and heavy roofs composed of reinforced concrete slabs

Such damage causes enormous financial loss to the government. For instance, after the Boumerdes-Algiers earthquake disaster of 2003, 100 primary schools had to be rebuilt completely for the sum of US$4.28 million and 253 rehabilitated for $10.65 million. In addition, 12 junior high schools were completely rebuilt for the sum of $10.28 million and 111 rehabilitated for $20.85. Also, 10 high schools were rebuilt for the sum of $21.42 million, and 58 were rehabilitated for $12 million.

So far these destructive earthquakes have occurred after school hours or on weekends, and thus, no loss of life or injuries have been recorded at schools in Algeria. This good luck may have made the government and the civil society alike less aware of the high vulnerability of the schools and partially explains why there has so far been no implementation of a Ministerial instruction dating from 1989 that required application of "technical expertise and the eventual reinforcement of all public buildings and in particular schools and universities." Instead, the introduction of new materials such as reinforced concrete in the absence of proper seismic-resistant design, building codes, and enforceable regulations has increased the risk to structures and their occupants. Relatively minor reinforcements could reduce the potential for damage to these structures.

Canada

British Columbia's (BC) west coast is Canada's region of highest seismic hazard. Two-thirds of the province's 3.9 million people live within the zone of highest risk. The region has experienced ten moderate-to-large earthquakes since 1870. In recent millennia, an earthquake on the order of the largest magnitude experienced globally in the last 100 years has struck approximately every 500 years. In addition to potential building collapse induced by ground shaking, significant damage from liquefaction, tsunami, and landslides are expected.

Older BC schools were built from some of the most seismically vulnerable materials – in the early 1900s, unreinforced masonry and then, in the mid-1900s, non-ductile concrete frame. Thus, in many communities, the school might be one of the buildings at highest risk for earthquake damage. A formal risk assessment of all BC school buildings was initiated in June 2004 with the full report due in October 2004. Initial estimates from the provincial government suggest that 800 of BC's schools might need some form of seismic upgrading.

In Vancouver, BC's largest city with a core population of about 560,000 and a metropolitan population of about two million, a 1989 rapid seismic risk assessment found that 30 % of the city's school buildings were at high risk of experiencing structural damage in an earthquake, and 15 % were at moderate risk (Taylor 1989). Between 1990 and 2004, 11 schools have been upgraded, so if the current pace continues, this work would be completed in 2064.

While the seismic hazard facing schools in greater Vancouver is similar to that in Seattle, Washington, school safety has not been a priority on the Canadian side of the border. Indeed, differences in seismic

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hazard mapping techniques used by Canadian and US geoscientists may actually underestimate the risk to Vancouver schools.

The current National Building Code of Canada ranks buildings according to their priority as critical infrastructure. The higher the number assigned, the higher the priority. Average houses are assigned an Importance Factor of 1.0, schools are designated 1.3, and hospitals, police stations, and prisons are assigned 1.5. Schools – unless they are designated as post-disaster shelters – get a lower priority than hospitals, police stations, and prisons. Vancouver City Council is funding the seismic upgrading of community centers so that they could be used as post-disaster receiving centers. Due to the differences in funding sources, some community centers are being upgraded, while nearby schools, which might be less seismically resistant, are sometimes not.

In general in BC there is high awareness of earthquake risk. For example, the City of Vancouver has seismically upgraded its water supply system and bridges, and the electric utility, BC Hydro, is systematically upgrading its buildings and infrastructure, including dams. Even some provincially run liquor outlets have been seismically upgraded. With seismic safety so clearly on the policy agenda in many sectors in British Columbia, why have public schools received so little attention?

The answer is that in BC funding for public school seismic upgrades has been part of the capital budget of the provincial Ministry of Education. Local school boards oversee this work and must proactively request provincial funding for projects that they deem to be high priority. Advocacy work by one of the authors on behalf of Families for School Seismic Safety British Columbia (FSSS) identified and tackled concerns with this funding system.

First, there was no district-to-district standardization of approach. Each local school district was individually approaching the issue of seismic safety for only their schools. FSSS pressed the government to unify the approach taken by centralizing expertise. The earthquake engineering community, through its professional association, the Association of Professional Engineers and Geoscientists of BC, is now advising the government on standardized, peer-reviewed methods for assessing and addressing seismic risk to schools.

Second, local authorities were concerned that informing parents of the seismic risks to local schools could cause panic and could be politically damaging. FSSS's and others' work has ensured that Vancouver parents are now well informed about the issue and are actively involved in trying to solve it. This process did not cause panic. Instead, bringing parents into the consortium has yielded an active and effective lobbying group.

Finally, there is the problem of setting priorities. The primary concern of school boards – quite rightly – is the day-to-day education of children. Seismic safety of a school building does not lead to improved education, so school boards have sometimes had difficulty making the issue a high priority. FSSS is trying to help public officials see school seismic safety as an infrastructure, public health, and human rights issue and to obtain new funding from outside of the Ministry of Education, that is, from provincial and national, authorize with mandates in those areas. The aim is that this work be seen as an infrastructure project for children and not perceived as competing for funding with their day-to-day educational needs.

Ultimately, the two basic human rights of children, to an education and to physical safety, should not be competing for the same funds. The expert community is now driving the initiative and the government appears to be listening. Many positive steps have been taken in BC, but there is much work left to be done.

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China

Following the 2008 Sichuan earthquake in which at least 15,000 children lost their lives in schools, the Ministry of Education and the Ministry of Construction and National Development and Reform Commission (NDRC) jointly released the Design Instructions for School Planning and Construction after the Sichuan earthquake. These standards require that school sites are assessed before the schools are built in accordance with national regulation, performance objectives are determined by the country-level government, schools are built or retrofitted to meet performance objectives, and schools' furnishings and equipment are designed and installed to minimize potential harm they might cause to school occupants. The quality-monitoring bureau leads monitoring on the safety of equipment installation.

In Sichuan in the spirit of "building back better," the investigation, design, construction, supervision, inspection, and acceptance of school construction are conducted in line with relevant national construction standards. In Sichuan, steps were also taken to make sure that there are mechanisms to ensure that schools' maintenance is financed and executed. From 2000 to 2005 the first and second session of school renovation and maintenance was conducted. After 2006 a long-term mechanism for school building maintenance was put into place. MOE and UNICEF collaborated and prepared and revised the National Guidelines for Safe School Construction and Management and also collaborated to develop construction standards for kindergartens and preschools.

In 2009 the Ministry of Education (MoE) initiated a 3-year national "School Construction Safety Programme" to upgrade the safety of primary and middle school buildings all over the country with the aim of making schools the safest places in China. The program has several key elements:

- To screen and assess the quality of all school buildings across the country, to understand the qualities of buildings resistant to local disaster risks, and to input the data and information of the assessment into a database
- To understand disaster risks in the regions where the schools are located, such as determining whether local disaster risks come from floods, landslides, earthquakes, or rainstorms threatening the safety of the school buildings
- To determine whether to repair, strengthen, or reconstruct school buildings that have not reached official standards based on the intensity of the identified disaster risks in the region where the schools are located
- To allocate funds and to start the construction work to upgrade the primary and middle school buildings that are at risk (International Recovery Platform 2010)

Colombia

The capital city of Colombia, Bogotá, is the most important political, administrative, economic, and cultural center of the country and has one million school children. Bogotá's population was estimated to be around 7.6 million in 2013. As a result of social investment over the past decade, more than 12 % live below the poverty line.

Among the most common hazard events affecting Bogotá are earthquakes and landslides. Although there has not been a severe earthquake in Bogotá since 1917, there is certainly the potential for one. Also, elsewhere in Colombia, 74 % of the schools in the cities of Pereira and Armenia suffered damage in the 1999 earthquake. Fortunately this occurred during the lunch hour, when no children were in the school buildings.

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Several risk identification methods were put in place in the city prior to 2004. These include compilation of records of hazard events, generation of hazard maps, studies of physical and social vulnerability, and studies of environmental degradation. One of the means of reducing risk from earthquakes and landslides in Bogotá is the assessment of seismic risk of bridges, hospitals, and schools. This has become a core part of the city's economic and social development plan. Of these assessment programs, the best-known is the Department of Education's effort to identify school seismic risk and to reinforce schools.

Much of the educational infrastructure in Bogota is more than 50 years old and does not meet minimal standards of safety. The Department of Education commissioned a systematic review of schools that ran from 1997 to 2003 (Secretaría de Educación del Distrito Capital de Santafé de Bogota 2000). This study covered approximately 2,800 buildings at 706 schools serving roughly 54 % of the student population in Bogotá. The other 46 % of the student population attends private schools and was not covered in this review. The review found that 434 of the schools presented high risk to students. Some 772 buildings at these schools fell into this category (16 %). The study also found that 60 schools had buildings in immediate and urgent need of reinforcement.

During the next city administration, from 2004 to 2008, after a detailed technical explanation on the need of schools' retrofitting, the city mayor decided to implement a retrofitting program of the 200 most vulnerable schools. A special risk analysis was performed on each building that was identified and prioritized. From this analysis, the structural reinforcement requirements were defined according to the seismic building code updated in 1998, with new special provisions for schools. The comprehensive improvement program had to be adjusted. Taking into account other technical, urban, economic, and environmental issues, many schools were not retrofitted: 67 schools were demolished and full restitution was made for a total of 107 new schools. This additional program was called the "50 Macro-schools plan" whose goal was to provide an educational infrastructure of maximum specifications and supplement the retrofitting and integrated improvement program. At the end, due to the costs involved in reducing vulnerability for 434 vulnerable schools, 201 schools were considered in critical condition according to risk studies that were conducted to prioritize and rank the schools. The reinforcement of these buildings had a cost about US$ 200 million and the total program including the new schools was about US$ 430 million. Additionally, this program was based on the implementation of a teaching strategy to incorporate risk management into the culture. Both structural and nonstructural objectives were implemented to obtain a comfortable and safe school environment and a high-quality education service.

Assessing and reducing the risk to schools in Bogotá took place in a more general planning and management context. For example, zones of high risk of landslide, where no mitigation works are possible, are declared to be protected land. Human occupation is restricted in these areas as well as those considered at high risk to floods. In 2003 it was estimated that some 185,000 people lived in informal settlements in a total of 34,230 informal housing units. In Bogotá there are 173 illegal settlements that account for 14 % of the total land area. The city administration has developed a massive legalization program since 1995, thus reducing the number of informal settlements from 1,451 to its current number, an eightfold reduction in less than 10 years.

Nevertheless, as much as 60 % of the population of the city lives in informally constructed dwellings. While most of these are located in legal settlements, they still represent a challenge to seismic safety. The year 2000 land-use master plan for Bogotá contains hazard and risk maps that determined land use, details of special treatment for high-risk areas, and arrangements for issuance of building permits, as well as protection plans for utilities and services. The city also relies on community-based networks to control illegal land occupation and has developed a large-scale relocation program for families living in high-risk conditions.

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The city of Bogotá has disaster risk reduction at the center of its planning process, and in this context school seismic safety ranks very high. Having diagnosed the scale and urgency of the problem in Bogotá, steps were being taken to reinforce the most hazardous school buildings. The challenges the city still faces include completing the program, making the retrofitting of the second priority group of vulnerable schools, extending its school safety program to private schools that cover nearly half the school-aged population, and accelerating the rate of school reinforcement to improve the safety of children and teachers. Bogota has had different governance problems during the last two administration periods. Unfortunately, two mayors have been removed or suspended by the national general attorney due to corruption and inefficiency. Due to these situations and perhaps changing priorities in risk management, the school safety retrofitting program was not continued.

India: Delhi

NGO partners SEEDS and GeoHazards International (GHI), working with the Government of Delhi, demonstrated earthquake nonstructural risk reduction in a public school. The school welfare committee comprised of faculty, staff, and local community members learned to identify the nonstructural building elements and building contents that could fall, slide, or collide during a likely Delhi earthquake, as well as fire and evacuation hazards. They were exposed to simple low-cost techniques for reducing these risks (moving some items, fastening others) and came up with innovative solutions of their own. The logic of regular fire and earthquake drills became readily apparent to these new stakeholders. A handbook for schools on nonstructural risk reduction developed by the NGO partners and published by the Government of Delhi provides a new resource for generalizing these lessons.

India: Shimla

A small-scale demonstration project for school retrofit was carried out by SEEDS of India and GeoHazards International. Structural assessment of school buildings was carried out using a filtering method: The first step was low-cost mass scale Rapid Visual Assessment Survey of school buildings for potential seismic hazards. Based on these surveys a smaller number were selected for Simplified Vulnerability Assessment using limited engineering analysis. The highest-risk buildings were identified for detailed vulnerability analysis. Retrofitting designs were drawn up for 20 schools and implementation of retrofit carried out in 8 schools. Guidelines were developed for retrofit and training of local masons and engineers and delivery of skill training. “Nonstructural mitigation plans” were carried out in 20 schools. An awareness campaign was designed to reach all 750 schools in the region including nearly 100,000 students, 7,500 teachers, and local builders, engineers, and officials (SEEDS 2006).

India: Uttar Pradesh

There are 23.5 million children attending school in this moderate-to-severe seismic risk zone. As part of the Education for All campaign, the State Government of Uttar Pradesh constructed 82,000 additional elementary school classrooms and 7,000 buildings in 2006–2007. To ensure seismic resilience of the buildings, UNDP provided earthquake engineers who examined the blueprints for the schools and modified the design to integrate seismic resilience. The marginal cost increase of 8 % to assure seismic safety was funded by the government.

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For effective implementation of the new modified designs, training and orientation programs were initiated by the government, supported by the local UNDP office, building the capacity of 40 architects, over 200 engineers, and over 10,000 masons. To ensure transparent monitoring, the designs were widely circulated to the local communities where the schools were constructed, so they could monitor the quality, along with support of departmental engineers. To complete the safety of the schools, school-level safety committees were established, school emergency plans developed, and mock drills became a part of the school program.

In 2006–2007 the Elementary Education Department proposed to integrate earthquake-resilient design into all new school buildings. To prepare for this, one design of primary school buildings and two upper primary and three additional classroom designs were prepared with detailed construction manuals. The disaster-resilient measures added 8 % to the construction costs. To cope with the massive scale of the project, a cascading approach prepared 4 master trainers for each of the 70 districts. These individuals in turn conducted trainings for 1,100 fellow Junior Engineers and Education Officers. Ten thousand masons were also trained. This program ensures that *every new school will be a safe school*. The problem of preexisting stock of 125,000 unsafe school buildings in need of retrofit remains to be tackled (Bhatia 2008).

Italy

Of the 8,102 municipalities in Italy, all are regarded as “seismically active.” Up until 2003, 2,965 of them (representing 40 % of the land surface and 45 % of the population) were considered “highly seismic” category. As a result, new construction in this category must observe stringent anti-seismic building codes. Subsequently, a more sophisticated classification was introduced, based on a 50-year recurrence interval and local estimates of peak ground acceleration (PGA). This had the effect of increasing the areas classified as highly seismic. Whereas in previous classifications, some municipalities were effectively regarded as aseismic, that is no longer the case and all 8,102 are now considered to be in a seismic zone to a greater or lesser extent. Italy bases its seismic classification on historical records and calculated return periods. Where these are a poor reflection of seismic hazard, it can underestimate the earthquake threat. Hence, severe damage occurred in northern Emilia and southern Lombardy in the earthquakes of May 2012, an area that had not had a major seismic disaster since 1574.

Several hundred municipalities are faced with the highest seismic risk in the Strait of Messina (including eastern Sicily) and southern Calabria (the Aspromonte) areas. The Apennine Mountains, which form the “backbone” of the Italian peninsula, are, in a tectonic sense, divided into blocks, which means that seismicity varies significantly from one locality to another. However, the vulnerability of buildings, including schools, is almost universally high: modest local taxation revenues inhibiting retrofitting and maintenance. The largest seismic event of the past century remains that in Avezzano, in 1915.

An event that for Italians most encapsulates the seismic risk to schools was that of 31 October 2002 at 11:40 a.m. where in the Apennine town of San Giuliano di Puglia (population 1,195), the infants’ school collapsed onto a class of small children (Augenti et al. 2004). Twenty-six small children and three teachers were crushed to death, and 35 children were rescued and lived. The building had been constructed with regional development funds in the early 1960s and had had its roof renewed a year before the earthquake. Evidently, the roof, of reinforced concrete with a ring beam, was too rigid and too heavy for the underlying structure, a concrete frame building with hollow-brick infill. There were signs that the quality of the cement was poor and the reinforcing steel was not used as it should have been. Moreover, despite mounting evidence that the Molisan Apennines are significantly affected by periodic earthquake activity, the revision of local building codes to take account of the new data on seismic risk cannot be applied as easily to existing structures as it can to ones that are about to be built (Augenti et al. 2004, p. S258).

The school at San Giuliano di Puglia succumbed because it contravened simple, well-known laws of dynamic response in structures affected by seismic acceleration. Inertial forces applied to a heavy roof sitting upon a weak frame structure amount to a recipe for tragedy.

Consider the schools of the Lunigiana, a surprisingly remote mountainous area of northwestern Tuscany. The Lunigiana has a sparse and dispersed population. Children attend elementary schools in the villages and secondary schools in major population centers, which they reach by bus or car. Many of the school buildings were constructed in the 1950s and 1960s to cater for the postwar population boom, and, in a rural area of relative economic stagnation, they have neither been built to be fully anti-seismic nor retrofitted. Indeed, in the minor population centers, they are decidedly dilapidated, nor do their staffs seem to have much interest in repeatedly practicing evacuation drills. Yet the area awaits a magnitude 6 earthquake, which it is predicted may kill up to 120 people and injure more than a thousand. How many of them will be school children? This situation is typical of the seismic risk that affects highland Italy.

Elsewhere in Italy, much more progress has been made. The civil protection departments of several regional governments have introduced comprehensive *Scuola sicura* (safe schools) programs, notably in the northern regions of Lombardy, Piedmont, and Emilia-Romagna and in the autonomous Region of Sicily. The programs involve a combination of structural measures and school disaster management efforts, such as evacuation drills and lessons in civil protection. In many of the major cities, fire brigades and volunteer civil protection services are heavily involved in the programs, with public-private partnerships supporting attractive safety literature for school children.

Despite these developments, as in other seismic countries so in Italy, the building stock of schools continues to age and the civil protection educators must fight against the indifference of teachers, principals, and administrators. In many respects, mass mortality in Italian schools during recent seismic events has been avoided mostly by the lack of major earthquakes during school hours, a situation that will not prevail forever. Given an overwhelming need to upgrade the seismic performance of schools in Italy, the response of the national government has been to rank the buildings in terms of the deficit between design requirements (a function of the rules that prevailed at the time they were built) and the latest assessment of peak ground acceleration (PGA). Priority funding is given to those schools that have the greatest “PGA deficit” (Grant et al. 2007). However, the problem of unsafe school stock is simply too expensive to solve in the short to medium term.

Japan

In general, Japan is understood to be a leader in evaluating seismic risk and in implementing building codes for seismic-resilient construction. Two publications available in English are MEXT’s school seismic retrofit handbook (MEXT 2008a) and school nonstructural reference book (MEXT 2008b). In addition to high seismic performance standards for schools, following the 1995 Kobe earthquake, Japan also began providing guidance for mitigation of hazards due to building nonstructural elements and contents in schools. Nonetheless, the East Japan earthquake and tsunami [of 11 March 2011, with magnitude 9.0 earthquake off coast of East Japan], destroyed 6,284 in the affected region with different damage levels. Most of these were affected by tsunami waves, rather than earthquake. This was due to the location of the school buildings [proximity to coastal areas], the layout and structure of the buildings, and the subsidence of local tsunami retention walls. At the immediate aftermath, some schools [with higher stories] were used as temporary evacuation sites, and later people were rescued by helicopters. In some

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schools, located in higher ground, people took shelter, which lasted till 6 months in some cases, which caused serious disruption of school education.

The disaster pointed out several dimensions of role of schools and disaster education: (1) Schools can play an important public infrastructure of the community; however, the structural safety of the building needs to be linked to operational [including supplies of emergency kit] and locational issues. (2) School-community linkage is an important element, and local communities played an important role along with school teachers for the management of the evacuation sites. (3) While it is unavoidable to use the school as shelter, the continuity of education in emergency is a crucial issue. (4) School-based community recovery emerged as an effective concept, where the reconstruction of school building was linked to enhanced community cohesion (Shaw and Takeuchi 2012).

Nepal

A risk estimate for Kathmandu Valley, the economic, political, and technological hub of Nepal, based on a scenario earthquake similar to the 1934 Bihar-Nepal earthquake, suggests that more than six million children and 140,000 teachers are at risk in schools (Bothara et al. 2002). A survey of 900 public schools in greater Kathmandu Valley estimated that more than 75 % of school buildings would suffer severe damage beyond repair (estimated at US$7 million), and other 25 % would suffer repairable damage. In the absence of intervention, an estimated 29,000 children could be killed in their schools. With intervention 24,000 of these could be saved and buildings protected (NSET 2000).

A more recent assessment of school buildings in other parts of the country shows that more than 9,000 school buildings, more than 10 % of the total in Nepal, would suffer partial to complete collapse, resulting in very high casualties.

Most Nepalese school buildings are community built, by local craftsmen who have no formal training and are often illiterate. Technically trained people are not part of this process, unless it is funded by the government. Construction is characterized by the high degree of informality. The local availability of the construction materials, such as fired or unfired bricks, stone in mud mortar, and timber, controls the construction process. The use of modern materials such as cement, concrete, and steel bars is limited by affordability and accessibility and is confined to urban areas and areas accessible by transport.

In Nepal, there is no mandatory policy to control school design and construction. While some schools are supported by international donor agencies and/or the government requires design/drawing details, many are directly constructed by the communities without standard design criteria or technical supervision. Likewise, site-specific hazards are also not considered during the design and construction. Some design details are available, but they may not be entirely suitable for specific sites/locations. At most local levels, people lack the capacity to understand and implement the earthquake-safe construction method.

Low budgets for most school construction and lack of awareness and knowledge on the part of graduate engineers of traditional and informal construction methodology result in most school buildings lacking earthquake resilience.

The National Society for Earthquake Technology in Nepal (NSET), a national NGO, conducted a program to strengthen existing school buildings and promote structural as well as nonstructural components of the school buildings for seismic safety, leveraging the decentralized, traditional, and informal approach to construction (Bothara et al. 2004). This program involved craftsman training, technology development and transfer, and community awareness raising. Many local masons became master masons. On-site master masons worked in residence, supported by visiting engineers with far-reaching effects. Shake-table demonstrations of typical versus seismic-resilient construction impressed communities with the effectiveness and feasibility of seismic-resistant measures. By raising awareness in schools, the entire community is reached because lessons trickle down to parents, relatives, and friends.

The approach developed took into account sociocultural and economic issues, with outreach to all stakeholders – school staff, students, local community, local clubs, and the local and central government. They have all been involved in the process so that they become aware of the risk and support the solution. School building construction was taken as an opportunity to train masons and to transfer simple but effective technology to others in the community, including house owners.

Following this approach, NSET retrofitted more than 40 schools, mostly of unreinforced masonry buildings. The program was found successful in transferring technology to local craftsmen who were quite keen to learn about the complete process and to adopt the technology. These masons became the propagators of the safety message in the vicinity of these schools and the replication of earthquake-resilient construction. The long-term sustainability of these impacts has yet to be assessed, but NSET's experience shows that seismic retrofitting and earthquake-resistant new construction are both affordable and technically viable.

Turkey

Turkey has more than eight million children attending schools in 64 provinces in the first- and second-degree seismic risk zones. The 1999 Kocaeli (moment magnitude Mw 7.4) and Duzce (Mw 7.2) earthquakes with approximately 20,000 fatalities raised awareness of the school safety question, and the 2002 (Mw 6.0) Afyon-Sultandagi and 2003 Bingöl (Mw 6.4) earthquakes kept awareness high.

During the 1999 earthquake in Kocaeli, 43 schools were damaged beyond repair, and 381 sustained minor-to-moderate damage. School was suspended for 4 months causing major disruption to the lives of families and children. In Istanbul, 60 km away, there was damage at 820 of the 1,651 schools. Damage at 131 of these sites necessitated at least temporary school closure. Thirteen were immediately demolished, and another 22 were later slated for demolition when retrofitting proved too costly. Fifty-nine schools were strengthened and 59 repaired.

In the Bingöl earthquake of 2003, out of 29 schools in the affected area, 4 school buildings collapsed completely, 10 were heavily damaged, 12 slightly or moderately damaged, and 3 undamaged.

Public schools in the Kocaeli earthquake fared better than residential buildings and private schools. Had children been at school during the Kocaeli earthquake, far fewer would have lost their lives. The fatality rate in residential buildings in the Kocaeli earthquake was 1.5 % in heavily damaged buildings and 16.5 % in totally collapsed buildings (Petal 2009). Similar damage in higher occupancy buildings of the same type would cause higher fatality rates. In the single example of the school dormitory in the Bingöl earthquake where 84 children died, the fatality rate was 44 %. Average risks are theoretical and don't occur. Instead, the reality is that either the school is not occupied and no one dies or it is occupied and the fatality rates are high, and the tragedy is wholly unacceptable.

There is much that is right with school construction in Turkey. As a result of an assigned importance factor of 1.5, public schools are designed to withstand a 50 % increase in earthquake design loads. Schools have regular symmetrical structural designs, and those that are only one or two stories have fared well, for the most part meeting standards for life safety, if not continuous occupancy. The lethality of school buildings is almost entirely attributable to shoddy construction and is particularly lethal in taller buildings that may also have design defects.

For decades all public construction was under the authority of the Ministry of Public Works and Settlement. Earthquake building codes on the books since the 1930s were updated most recently in 1976 and 1998, yet the existence of these laws has not guaranteed the safety of construction. The reasons are numerous.

Beyond an undergraduate or graduate degree, there have been no independent or nonacademic professional qualifications, proficiency standards, continuing education requirements, or licensure for architects or engineers nor any qualifications for building contractors. There are also no guidelines for reliable and systematic building inspection during construction. Penalties for noncompliance with building codes are beset with bureaucratic and social impediments and often are simply not applied. Legal liability in some future event with low-frequency occurrence can hardly be a deterrent with so many to share blame. Public construction has also suffered from a standard (though not legally required) preference for the lowest bid in public tenders. The civil service employment system also lacks proficiency standards and qualifications for professional staff; so at the local level there is a wide variety in the capacity for project supervision and control. Wage and salary levels are low, and there has been opportunity for both favoritism and corruption. There are no ombudsman or advocacy services to support consumer whistle-blowers.

Istanbul provides a dramatic example of three overlapping tasks:

- Immediate response to damages caused by the 1999 earthquake
- Implementation of a comprehensive retrofitting and replacement for seismic risk mitigation
- Follow-through on an ambitious program of school expansion and construction initiated to respond to the acute shortage of class space occasioned by three additional years of compulsory education enacted in 1998

After the 1999 earthquake, the responsibility for school construction was shifted to the Ministry of Education's Division of Investments and Facilities (DIF). In turn, DIF appointed consultants from the private sector to oversee the new facility design and construction. DIF also developed standard designs for the new facilities, and new school construction was financed by a combination of government funds and charitable contributions raised by not-for-profit foundations. New construction and procurement laws also went into effect; however, the cumulative impact of these changes and pressures is not yet known (Gülkan 2004).

In Istanbul of all projects the highest priority is given to regional boarding schools, then to schools in the 12 highest-risk districts, and to those in proximity to the Marmara seacoast. The overall mitigation and retrofit effort targets more than 1,800 buildings that constitutes the 80 % of stock predating the 1998 Building Code. This ambitious program is budgeted for US$320 million (Yüzügüllü et al. 2004).

An additional problem in Turkey is that awareness of nonstructural hazards remains low. Classroom doors often open inward and shelving and laboratory equipment remains unfastened. However, concern that children advised to "drop, cover, and hold" might be injured by flimsy wooden desks led to production and distribution of 80,000 steel desks to more than 500 schools in the most vulnerable areas.

Schools are a well-distributed means of public education, and children can play a leading role in the dissemination of public safety messages. Thus, Professor Isikara, former head of KOERI, a major earthquake research institute in Istanbul, toured the country visiting schools, becoming known as "Grandpa Quake," and produced the first children's books and popular educational and rap music cartoons for earthquake awareness. Both the Istanbul Governor's Office and KOERI's newly established Istanbul Community Impact Project (ICIP) produced handouts distributed to all school children. Schools also received books and CDs. At the national level an introduction to natural hazards was integrated into the primary school curriculum in Environmental Studies in 2002. Annual school-wide earthquake drills and preparedness and remembrance activities were initiated on 11 November 2001, to coincide with the Duzce earthquake anniversary.

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Between 2001 and 2003, a cascading model of training and instruction called "ABCD Basic Disaster Awareness" was implemented by KOERI's Istanbul Community Impact Project. A curriculum was developed to address specific assessment and planning activities, physical risk reduction, and response preparedness measures to be taken prior to a disaster. This was a significant reorientation from previous "awareness" programs that began with what to do "during the shaking." A single full day of instructor training for 3,600 teachers was provided in collaboration with the Ministry of Education Provincial Directorates and outside donors. These teachers in turn communicated with 121,000 school personnel and through them with 1.68 million school children as well as with 700,000 parents. The project established an Internet-based monitoring system to monitor dissemination. Based on the success of this project, almost a decade later an even more ambitious scale-up was attempted.

In 2010 the Ministry of National Education is committed to taking the program nationwide with technical support from Risk RED, in a follow-up project supported by the American Red Cross. A - distance-learning self-study curriculum was developed consisting of 1 course (10 lessons) in household disaster preparedness and 1 course (9 lessons) in school disaster management, with the goal of reaching 25,000 school-based instructors (Petal and Türkmen 2012). During the first year of deployment of the courseware in 2012, more than 79,000 MoNE employees completed one or more lessons. More than 65,600 users completed the School Disaster and Emergency Management Course and more than 50,000 passed the final test. Almost 50,000 users have completed the Individual and Household Disaster Preparedness Course and more than 40,000 users have passed the final test. There were a total of 114,700 course completions, 92,800 final tests passed, and more than one million lessons were successfully completed by users. Within the first year, active users completed an average of almost 15 lessons each (Petal and Türkmen 2012).

In 2005, a loan to implement the Istanbul Seismic Risk Mitigation and Emergency Preparedness (ISMEP) was funded by the World Bank and European Investment Bank, to help prepare Istanbul for a probable earthquake in the Marmara Region. The project had broad aims to enhance the institutional and technical capacity of emergency management-related institutions, raise public awareness, assess priority public buildings for retrofit or reconstruction, and support building code enforcement (www.ipkb.gov.tr). "Component B" addressed seismic risk mitigation for priority public buildings. This included a feasibility study for retrofit of 1,128 education buildings on 796 school sites. Of these, 506 were strengthened and 148 were reconstructed. At the time of completion of the project, further 34 were slated for retrofitting and 27 for reconstruction.

USA: California

In 2008, seismic safety advocates in California launched the first Great Southern California ShakeOut. The now annual event has grown to include five western states and several central US states and has been conducted in cities in five other countries. In its first year four million children and adults participated through 207 school districts plus almost 750 individual schools (Risk RED 2009). In 2013 there were more than 9.6 million participants in the Great California ShakeOut drill. Globally there were almost 25 million registered participants in similarly inspired Great ShakeOut Drills. Of these almost 75 % were school-based participants (Earthquake Country Alliance 2013). This regular public awareness event has heightened interest and concern in safe school facilities. With 3.6 million children enrolled in 262 public school districts in seven counties in Southern California, a major earthquake in the region could cause an unprecedented catastrophe for schools, children, and teachers.

School seismic safety has been a policy and a community concern in California since the 1933 Long Beach earthquake, and school emergency planning has been required statewide since 1984. With 75 years of public policy leadership to support school safety, new school construction standards are higher than those for regular buildings and come close to assuring life safety. An advice regarding non-structural mitigation measures (fastening furnishings, etc.) has been in place for 20 years and requirements for such mitigation have been in place for 10 years.

The 1933 Field Act implemented immediately after the Long Beach earthquake that year required that schools be built to 15 % higher performance standards than normal construction. In 1938 the Garrison Act required examination and improvements to pre-1933 construction, but went unenforced until 1968. The Uniform Building Code enacted in 1976 is now the current standard for safe school construction. The Field Act has been hailed as a high point in school seismic safety and California schools are considered the safest in the United States. Some school facility managers feel that its requirements are too stringent and too costly, and many seismic safety advocates feel that it does not go far enough. The Act requires that structural plans be prepared by licensed structural engineers and approved by an independent state agency (the Division of the State Architect (DSA)). Schools have continuous on-site inspection (rather than periodic), by a DSA-approved project inspector. Project architect and engineers must perform construction observation and administration, and a final verified report must be filed by the project architect, engineers, inspectors, testing labs, and the contractor (State of California, DSA 2007, 2009).

In 2007 the California Seismic Safety Commission found that: (1) The cost of compliance with the Field Act is incremental and minimal. (2) Timeliness, consistency, accuracy, and communication are being improved by the Division of the State Architect. (3) The exemplary performance of school buildings is directly attributable to the stringent seismic design provisions, plan review, field inspection, and testing required by the act and which go beyond the standard building codes. (4) All public schools should be covered. A 2009 study reported that in the four major earthquakes since the Field Act, there have been no public school collapses. The construction to Uniform Building Code, the special enforcement and quality control provisions, an oversight by the Office of the State Architect, and the 2003 publication guiding mitigation of nonstructural hazards are all judged to be successful. Nonetheless, the work is not yet complete.

In 1999 Assembly Bill 300 required desk assessment of 9,659 pre-1978 school buildings. The final report based on woefully incomplete records was released in 2002 and found 7,537 potentially vulnerable buildings requiring detailed seismic evaluation. The cost of retrofit was estimated at $4.5 billion (State of California 2002). Due to fear of planning and financial implications, details were not released to the public. In 2005 an investigative reporting series by California Watch finally achieved this (Risk RED 2009). In 2011, 20,000 uncertified projects were released on an interactive map (California Watch 2011).

A review of school seismic safety in California identifies four remaining areas of concern:

- There are still some 7,537 school buildings in California constructed before 1978 that are of questionable safety.
- Portable classrooms, which may account for one-third of all classrooms in California, may be particularly hazardous if not properly supported and fastened.
- Private schools are not currently required to meet these same construction standards as public schools.
- Nonstructural mitigation measures continue to require consistent application to protect children and adults from both injury and death.
- Each school district and private school is strongly recommended to conduct its due diligence and report on these issues transparently to parents, staff, and students, so that collective action can be taken to address these serious vulnerabilities. Neither fear nor California's persistent financial crisis in the education sector should be acceptable excuses for inaction (Risk RED 2009).

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Summary

Most of these case studies have focused on the primary importance of safe school facilities, through both standards for new school construction and strategies for school vulnerability assessment and planning for retrofit and replacement. While sound earthquake engineering expertise is fundamental to advocacy, communications, planning, and execution of these efforts, it is also important to retain the perspective of the primary beneficiaries: children, teachers, and school communities. This necessitates going beyond the obvious: site selection, design, and construction. As some of these case studies indicate, it is also important to consider nonstructural mitigation, ongoing maintenance, safe access to school, school function as temporary emergency shelters, and even structural awareness education and the use of construction as an educational opportunity for children and communities. By taking this wider (and multi-hazard) view, the focus on safe school facilities overlaps with both ongoing school disaster management and with risk reduction education.

Cross-References

► School Seismic Safety and Risk Mitigation

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