EARTHQUAKE HAZARD CENTRE NEWSLETTER

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Editorial: The need for more inclusive earthquake engineering

I've just finished reading a challenging keynote paper presented at the 12th European Conference on Earthquake Engineering. "Earthquake Mitigation", is authored by Ian Davis, Professor of Development and Disaster Management, Cranfield University, UK.

Due to its topic, the paper inevitably concentrates on earthquake engineering in developing countries. Here the most pressing needs for earthquake mitigation reside. In a section on the protection of non-engineered structures, Davis states: "It remains something of a paradox that the failures of non-engineered buildings that kill *most* people in earthquakes attract the *least* attention from the engineering profession." Later he issues a challenge to the earthquake engineering profession by noting the large number of earthquake engineers attending the World Conference on Earthquake Engineering in Auckland 2000. He then poses the question: "surely mechanisms can be developed so that some of their collective skills, experience and resources can be devoted to the challenge of cutting the death toll from the collapse of non-engineered dwellings in earthquakes? How many more Izmit, or Gujarat earthquakes, with massive death tolls, does it need to widen access of powerless, poor groups to vital knowledge and resources held by powerful wealthy groups to ensure their safety? This must constitute a major ethical issue for the twenty first century."

Such a breath of ethical considerations will come as a surprise to many. For example, when "ethics" is mentioned, I tend to think of it in terms of personal ethical standards like honesty and integrity. But here Davis is challenging our profession to pay more attention to earthquake damage mitigation for non-engineered construction. He believes that our profession should be held accountable for its lack of effectiveness in this area. He quotes the EERI publication *Ethical Issues and Earthquake Risk Reduction*: 'Today we need a myriad of specialists. We need brain surgeons and trust lawyers, corporate accountants and physicists, economists and earthquake engineers. And in each case, society makes essentially the same bargain: We will train you and prepare you for your work; and in turn we ask these things of you:

- knowledge
- competence
- dependability
- accountability
- candour".

How to respond to this challenge? Responses are appropriate at both professional institutional levels and individually. The nature of any response will differ depending on whether one is working in a developing country. In more developed countries, such as my own, New Zealand, so called 'non-engineered' buildings have already been pre-engineered. Their seismic performance should be as good as engineered buildings. However in developing countries there is often a vast gulf between the seismic vulnerability of non-engineered and engineered construction. There are many reasons why engineers and architects do not engage with non-engineered construction.

For those of us in more developed countries who are concerned about the vulnerability of non-engineered construction, our assistance might be needed in other countries. But those of you living in developing countries are confronted with hazardous non-engineered construction on a regular basis. For you, this type of vulnerable construction might be accepted without much thought; just part of life.

Let's all pay attention to Ian Davis' challenge and consider how we might respond.

Virtual Site Visit No. 17: Construction of a Geomesh reinforced Adobe House, Peru

This site is located in the coastal region of Peru, near the town of Chincha, south of Lima. This area was badly affected by the 15 August 2007 Pisco Earthquake. Tens of thousands of adobe houses were either badly damaged or destroyed. We visit several houses that are being reconstructed using a geomesh reinforcing system developed at the Catholic University of Peru, Lima.

During the casting of the concrete foundation plinth above a stone and mortar footing, plastic geomesh is embedded so that it can be wrapped up each side of every wall. The adobe blocks consisting of their best-practice mixture of clay, sand, straw and water are then laid. For these houses the adobe block widths and lengths have been increased to 400 mm so that face-laden walls spanning between internal return walls are sufficiently rigid. Every few block courses short lengths of plastic string are placed into the fresh horizontal mortar joints (Fig. 1). When the wall is complete, geomesh is lapped and tied at foundation level and brought up both wall faces and wrapped over the wall top timber bond beam or top plate. Each string tie is firmly knotted to the mesh layer on each side of the wall. Rafters and the roof are then placed and fixed (Fig. 2). Next, adobe blocks plug the gap between wall plate and the underside of the ceiling lining and the wall is mud plastered (Fig. 3). The smooth finished walls are then painted to achieve very good interior and exterior finishes.

Fig. 1 Laying the adobe blocks with string ties placed in the mud mortar joints.

Fig. 2 Geomesh has been wrapped vertically and horizontally around walls.

Fig. 3 Plastering of the walls is about to commence.

This effectiveness of this construction system has been verified by full-scale shaking-table tests in Lima. Detailed construction information is available in the booklet "Construcción de casas saludables y sismorresistentes de Adobe Reforzado con geomallas", by Neumann, J. V., Torrealva, D., and Blondet, M, published by Fondo Editorial, Pontifica Universidad Católica del Perú. A review of this publication will be provided in the next issue of the newsletter.

Selected excerpts from "Implementation of Structural Earthquake-Disaster Mitigation Programs in Developing Countries"

by Roberto Mel and Sergio M. Alcocer from Natural Hazards Review, February 2004

ENGINEERED CONSTRUCTION

Reinforced-Concrete Frame Construction

Moment-resisting RC frame buildings, without walls and braces, have shown a consistently high failure rate in urban areas with severe earthquake damage (Fig. 4). Lessons learned from such failures have motivated a series of changes in design standards. In general, design requirements have become more stringent, not only in terms of safety factors, but mainly with respect to detailing rules. The latter, unfortunately, have increased the structures' cost and decreased their constructibility. Although the cost of detailing may be a small fraction of the building cost, it is still useful to examine whether these costly and rather complex design changes have actually reduce the seismic vulnerability of frames and consequently, their damage intensity.

Fig. 4 Typical failure of poorly detailed reinforced-concrete frame buildings.

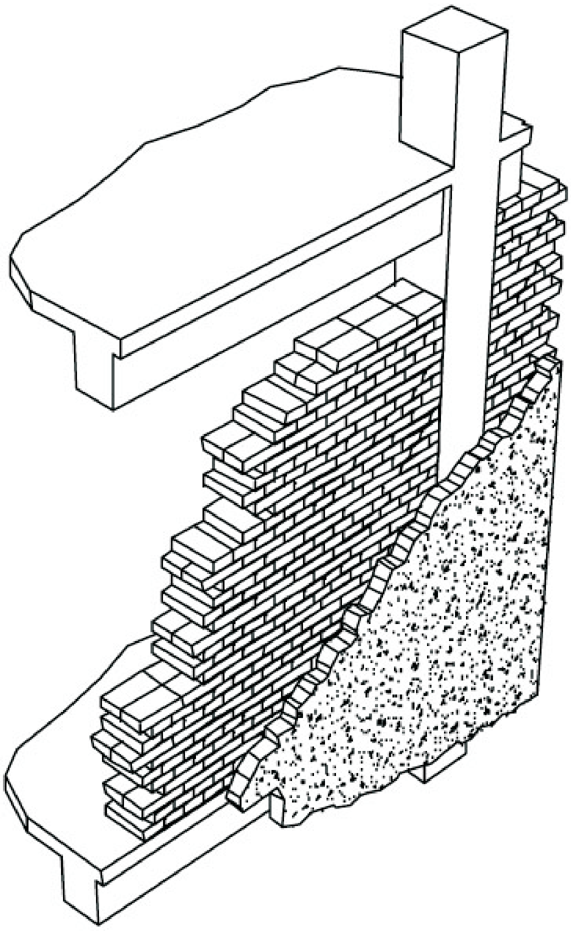

Fig. 5 Schematic view fo reinforced concrete frame infilled with stiff masonry walls typical of pre-1950 buildings in Mexico City.

One fact observed in the Kobe earthquake (Hyogoken Nanbu earthquake of 1995) is that damage in frames designed in accordance with the present strict requirements (including tougher detailing rules) was minor compared to that in frames built during the 1950s and 1960s, when lax design requirements and nonductile detailing were in used (AIJ 1995).

From the experience described, one would simply conclude that old RC frame structures are not safe and that an extensive number of partial and total collapses is to be expected should a severe earthquake occur. Earthquakes in Mexico and Turkey, however, have provided evidence to the contrary. In Mexico, for example, buildings constructed before 1950, with flexible, inadequately detailed, and almost unconfined concrete elements, have performed, in several instances, better than those with modern construction (Meli 1993). The difference in response has been attributed to thick infill and façade masonry walls that increased the actual seismic capacity of old mid- to low-rise buildings (Fig. 5). It is significant to note that such elements had not been explicitly considered in design. Over time, in new construction, masonry infills had been replaced by lighter and weaker partition elements, requiring the modern concrete frame to resist the total earthquake-induced lateral loads by itself. At the same time, the detailing rules of the 1950s, inadequate to achieve to achieve ductile behaviour, were not sufficiently amended. As a result, some elements of poorly detailed modern RC frames exhibited more severe earthquake damage than older frames with equally poor detailing but with more substantial non-structural elements.

In Turkey, the most severe damage recorded after the 1999 earthquake was also concentrated in modern buildings (EERI 2000) (Fig. 6). Indeed, in recent years, Turkey's modernisation has led to rapid urban and industrial growth and to a change in housing patterns. Typical, small single-family homes of masonry or timber have been replaced by medium-rise structures, and in fewer cases, by high-rise buildings. These contemporary buildings consist of reinforced-concrete frames or, very often, of flat-slab systems, in which the beamless slabs are infilled with hollow clay blocks. The principal deficiencies of this category of buildings have been an inadequate structure configuration for seismic resistance (probably due to the absence of even a minimum seismic design) and the nonductile detailing of reinforcement. Construction errors and low-quality materials exacerbated the damage level. In general, it is fair to say that design and construction practices in Turkey were clearly inadequate for a zone subjected to a high seismic hazard. In several cases, designers and contractors from abroad, who were quite unaware of the local hazard and construction practice, carried out building design and construction. The latter observation also points out the need for a prior review and assimilation process of new building technologies and construction methods, which are seldom developed and applied for different hazard characteristics and for distinct design and construction conditions.

In the case of Turkey, as well as in most recent earthquakes, deficient structural configurations for

Fig. 6 Typical damage observed during 1999 Kocaeli earthquake in Turkey.

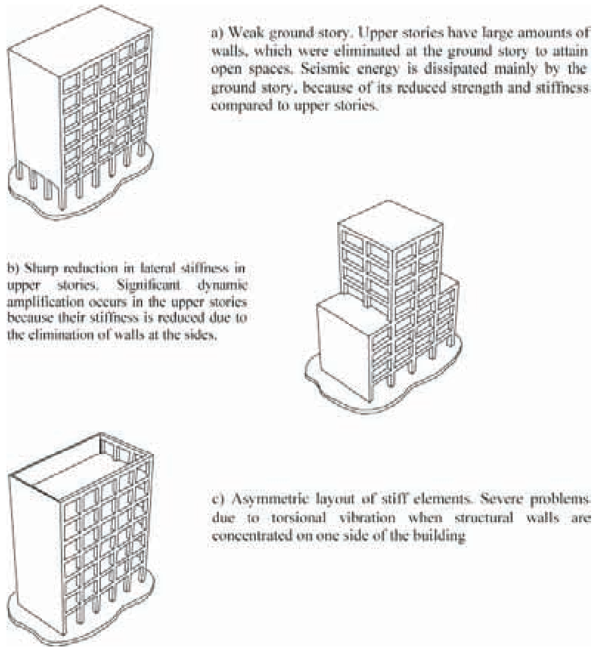

Fig. 7 Examples of inadequate structural layout.

seismic resistance have been found to be the prime cause of failures. Indeed, practically all post earthquake reconnaissance has identified deficiencies such as soft stories, short captive columns, discontinuities, eccentricities, and asymmetries in structural layout as the most recurrent and critical causes of distress (Fig. 7). All textbooks on seismic design discuss in detail the drawbacks and consequences of ill-conceived layout and poor detailing, and give recommendations for avoiding those deficiencies. In this regard, ignorance and inadequate interpretation of design requirements are probably reasons why designers have not followed what has been acknowledged as "good seismic resistance practice" (Fig. 8).

The damage recorded in modern construction in the Mexico and Turkey earthquakes shows that advances in knowledge and expertise are not always transferred and observed in practice, and also that seismic vulnerability is sometimes increased by altering regional, well-established, construction trends.

The results of many research programs and, especially, the observation of failures during earthquakes have led to the conclusion that concrete frames are potentially too weak to resist earthquake-induced loading. It has also been found that such deficiencies can only be overcome through careful designs aimed at avoiding irregular structural configurations, and at the expense of achieving rather complex reinforcement details. In fact, the design and construction of complex detailing solutions is particularly difficult and time consuming; furthermore, errors can be easily produced and grossly repeated, leading to poor performance, often of catastrophic consequences and

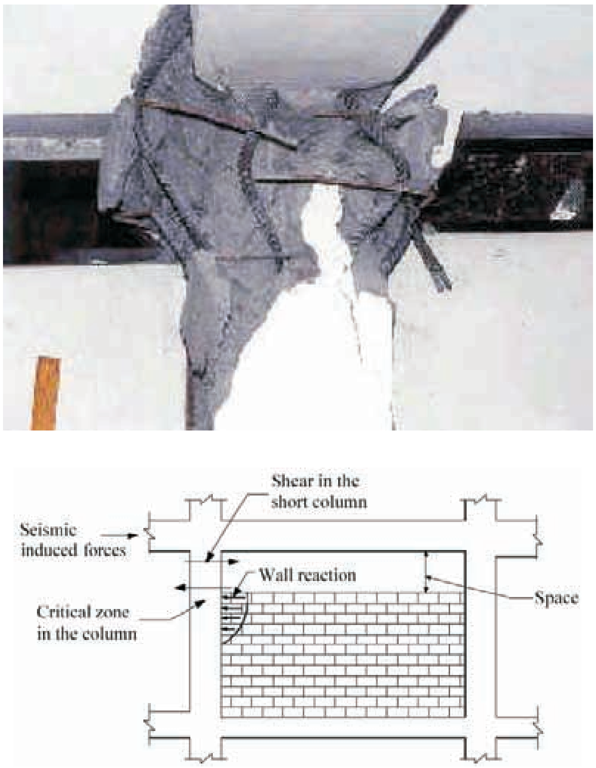

Fig. 8 Failure of short column.

proportions (Meli 1993; AIJ 1995; EERI 2000). To cope with the difficulties of elaborate reinforcement detailing, it is advisable to promote the use of other structural systems with built-in large seismic capacity, which in turn can depend on simple and general structural characteristics, related to geometry, rather than on refined design and detailing procedures.

The last statement should not be understood as the writers' denial of the importance of detailing. On the contrary, to attain adequate performance in a RC frame, a minimum level of detailing is warranted. In this regard, however, improper detailing is simply the result of poor understanding of the flow of forces within a member. This can be explained by examining the scope of structural courses in modern engineering curricula. Admittedly, curricula overemphasize computerized structural analysis methods and tools, as well as the precise calculation of seismic force demands, almost disregarding subjects dealing with basic statics, flow of forces, and detailing. It is not uncommon to hear that detailing should be developed and defined by contractors, and not by designers.

One structural system that does not heavily depend upon complex detailing is the frame with walls and braces; in fact, this structural type can be readily designed following easily codified procedures. The seismic performance of concrete frame buildings with walls and braces has been remarkably better than that of bare moment-resistant frames. A convincing example of the advantages of using walls is the performance of Chilean buildings (Fig. 9). In the 1960s, as a consequence of the extended damage observed in bare concrete frame buildings, placement of an abundant number of walls in multistorey structures, though not required by Chilean codes, was encouraged by earthquake engineers in Chile. An assessment of structural performance during subsequent severe earthquakes clearly indicated that the adoption of this design and construction practice led to a drastic reduction in damage and loss of human lives. In regard to braced frames, although they have also shown better seismic performance that bare RC frames, their behaviour strongly depends on the bracing slenderness and the detailing of the connections between the braces and the frame elements.

Vulnerability of Critical Facilities

A second case of engineered construction that is highly vulnerable to earthquakes is critical public facilities. Almost everywhere, modern building codes require stricter rules for earthquake resistance of buildings that are regarded as critical because of their occupancy (schools), their function after a major disaster (hospitals and communications centres), their cultural value (museums), or the toxicity (waste storage) of their contents. Specifically, hospitals must remain fully operational, and schools must suffer minimal damage cause they are typically used as shelters.

Regarding school rehabilitation, one success story deserves mentions. After the 1985 Mexico earthquake, more than 2,000 school buildings were rehabilitated, not only in Mexico City where damage has been sever, but also in other regions of significant seismic hazard. Rather simple and unobtrusive strengthening schemes were used, capable of being executed in a few months during summer vacations, to avoid interrupting educational activities. External strengthening elements were favoured to avoid disturbing internal finishes, furniture, or equipment. An example of the techniques used was external post-

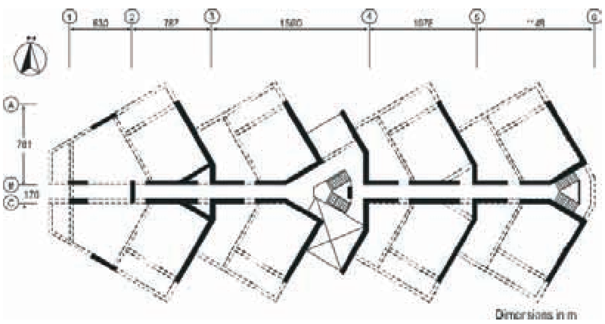

Fig. 9. Typical Chilean building with structural walls (plan view of a 25-storey building in Viña del Mar.

Fig. 10 Strengthening of school buildings by external post-tensioned cable bracing.

tensioned diagonal bracing (Fig. 10).

Additionally, emergency staircases were built for fast evacuation of classrooms to a central open area, in case of an emergency warning. Evacuation drills have been carried out regularly to ensure orderly, swift evacuation. In Mexico City, the program is complemented by a seismic warning system that takes advantage of the fact that seismic waves coming from the distant epicentres of major earthquakes travel for almost one minute before reaching the city.

Conclusions and Recommendations

1. In general, poor performance of buildings in major earthquakes can be partially attributed to insufficient transfer of knowledge, technology, and expertise to designers, contractors, and construction practitioners. Lessons learned over time seem to remain in the custody of academics and a few practitioners.
2. For engineered construction, the gulf between complex and refined buildings standards and the unimpressive level of knowledge and quality of practice of most practitioners is apparent. This is a major reason for incorrect understanding of, and compliance with, building codes.
3. To reduce the seismic vulnerability of engineered construction in developing countries, the following recommendations are made:
   - Promote the use of structural systems with inherently high seismic capacity, such as walls and braced systems, rather than complex design and detailing procedures
   - Avoid the adoption of structural systems and engineering that is largely different from the local expertise and technology without a thorough review, refinement, and local assimilation.
   - Develop specific design rules and vulnerability-reduction programs for critical facilities, as well as cost-effective, unobtrusive, and robust rehabilitation techniques.
   - Implement seismic design codes with procedures and requirements of different levels of complexity. For important and essential structures, a registry of specialists and peer reviews should be considered as complementary measures to reduce vulnerability. For ordinary structures, simple design approaches, with safety checks based on key structural features, should be favoured.
   - Strengthen and improve the technical expertise of building officials and groups that, at the municipal level, must overview the construction process.
   - Apply tax and financial incentives.

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Book Review: Manual on Hazard Resistant Construction in India

The following description of the manual is provided on the NCPDP web site:

> "UNDP and National Disaster Management Authority (NDMA), Ministry of Home Affairs, Government of India released in July 2008 a "Manual on Hazard Resistant Construction in India" for non-engineered buildings. It is authored by Mr. Rajendra Desai (a structural engineer) and Ms. Rupal Desai (an architect), the Joint Directors of National Centre for Peoples'-Action in Disaster Preparedness (NCPDP)" (Fig. 11).

The popular load bearing masonry building systems in different parts of the country are covered in the manual. It

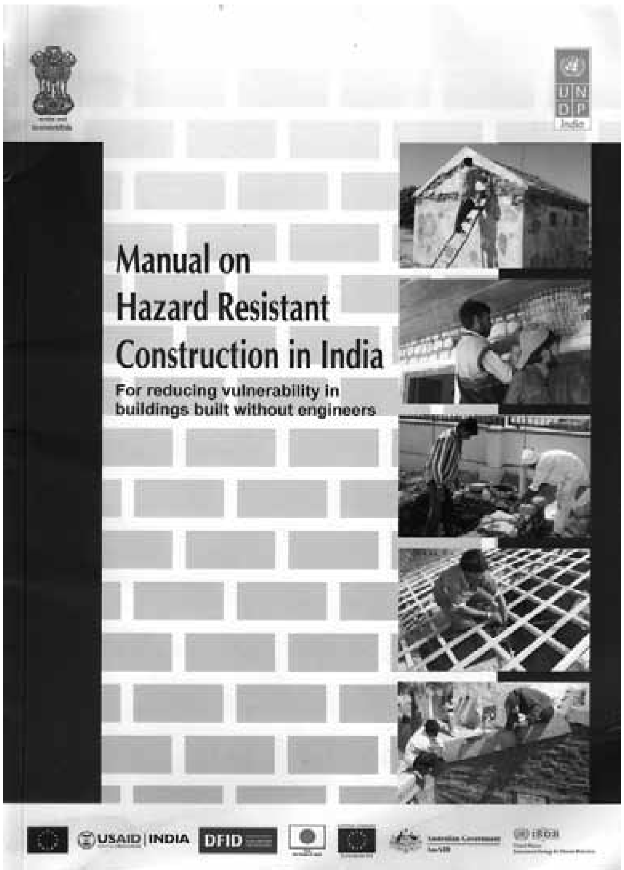

Fig. 11 Cover of UNDP's "Manual on Hazard Resistant Construction in India".

covers various hazards in India including those in Seismic Zones III, IV and V, Wind Speed Zones of 47 to 55 m/second and areas prone to severe floods. Relevant building codes and guidelines of the Bureau of Indian Standards form the basis for this manual. In addition, two decades of work carried out by the authors focusing on the promotion of suitable building technologies in different parts of the country and on the on-site training of building artisans and engineers, as well as the post disaster assessments of damage in various disasters provide the backbone of this manual. The in-depth documentation of their work provides a huge resource of visuals to tap from for this publication with the main purpose of ensuring effective communication.

The manual would be invaluable to the house designer, field engineers, contractors, site supervisors, literate artisans, and even a potential house owner. It covers not only new construction, but also the repairs and the retrofitting of existing structures. It also throws light on the critical aspects that must be adhered to in new construction to ensure good performance in a likely disaster. Appropriate visuals have been used to make this manual user-friendly (Fig. 12). In the section on repairs of damage and retrofitting of existing buildings, every important aspect has been covered step-by-step using visuals. Finally, a small chapter covers the non-engineered RC construction focusing specifically on the most critical aspects of reinforcement details which are routinely violated, resulting in much destruction in the event of the earthquake or a cyclone.

It is hoped that this manual will contribute towards ensuring better structural performance in the face of potentially destructive natural hazards, and thus bring safety to the people, rich and poor alike in India."

This is an accurate description of a very well produced and colourful manual extensively illustrated with photographs and drawings. Although the Indian context is quite obvious due to the authors' experiences, the material has international relevance. Its principles and construction details are transferable to other countries with similar construction materials and methods.

The manual will be a welcome construction guide for many groups. NGOs involved in disaster reconstruction, contractors and builders will appreciate the detailed seismic and cyclonic resistant details, all clearly illustrated. Teachers of civil engineering, architecture and technical engineering students should use the content of this manual to disseminate widely the sound seismic resistant principles contained within it.

A copy of the manual can be obtained from UNDP, India while copies last.

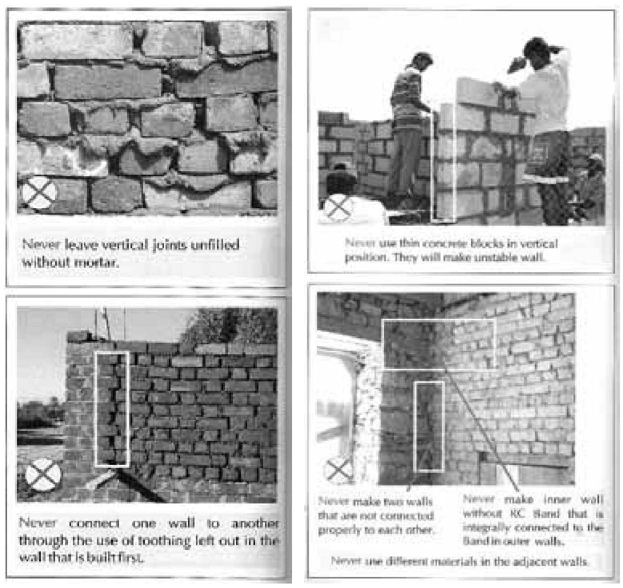

Fig. 12. Examples of the user-friendly visuals in "Manual on Hazard Resistant Construction in India".

"Chinese Earthquake Increases Focus on Children in Disaster" by Corey Reynolds from *Natural Hazards Observer*, Volume XXXIII, Number 1, September 2008.

On May 12, 2008, the Sichuan Province of China was rocked by a 7.9-magnitude earthquake. At least 4.8 million Chinese were forced out of their homes and left homeless, 69,196 have been confirmed dead, and 374,176 are left with injuries today. But what shook China even more was the horrific number of children's lives lost.

More than 7,000 school rooms were destroyed in the quake, the majority in poor districts. And because of China's "One-Child Policy," a population control tactic that was established in 1979 to alleviate the social and environmental problems caused by overpopulation, most grieving parents who lost a child lost their only child.

The enormity of the devastating numbers forced citizens of China to question if their government did everything possible to ensure each and every citizen's – especially children's – safety in what is now dubbed the "Great Sichuan Earthquake." *The New York Times* reported that the Chinese government's efforts to enforce building codes have been spotty. In 1996 the Sichuan Province mandated that local governments inspect schools because too many remained unsafe.

"If we want to protect children, we must address the structural issue of thousands and thousands of schools that are unsafe, not only in China, but in most countries of the world," said Dr. Fouad Bendimerad, chairman of the Earthquakes and Megacities Initiative. "We can't keep misleading children (and everybody else) by telling them that they will be safe from crushing-heavy concrete slab buildings by ducking underneath their desks." After the 1933 Long Beach Earthquake, California enacted the Field Act, a revolutionary law mandating that school buildings be earthquake resilient. After the mass destruction in China, experts hope China will follow in California's footsteps. "For those who are not convinced I give one single undeniable fact: Since the Field Act — that demands and imposes competent earthquake construction for schools — not a single school has collapsed or was heavily damaged, and not a single child, teacher, or parent was injured or died in a school due to earthquakes," Bendimerad said.

The vulnerability of children in disaster is an often overlooked phenomenon. The April 2008 edition of the journal *Children, Youth and Environments*, published before the Sichuan earthquake, took a critical look at the unique challenges facing children before, during, and after disaster.

"As the frequency and intensity of disaster events increase around the globe, children are among those most at risk for the negative effects of disaster," wrote Lori Peek in the journal's introduction. Peek is a professor of sociology at Colorado State University and is considered an expert in the emerging field of children and disaster. "Children are psychologically vulnerable and may develop post-traumatic stress disorder or related symptoms; are physically vulnerable to death, injury, illness, and abuse; and often experience disruptions or delays in their educational progress as a result of disasters," she wrote.

Since the electronic journal went live in April, it has been downloaded more than 200,000 times — this represents twice as many downloads as other editions of *Children, Youth and Environments*. Peek sees this as evidence of an increased interest in the field. She has created a list of references—organisations, agencies, educational materials, and other resources—that help children prepare for, respond to, and recover from natural and human-induced disasters. The resource list can be viewed at www.colorado.edu/journals/cye/18_1/18_1_21_ResourceList.pdf.

Earthquake Hazard Centre

Promoting Earthquake-Resistant Construction in Developing Countries

The Centre is a non-profit organisation based at the School of Architecture, Victoria University of Wellington, New Zealand. It is supported financially by Robinson Seismic Ltd.

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