OPINION PAPER

A Challenge to Earthquake Engineering Professionals

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Recent earthquakes have caused unacceptably high death tolls. We, the editors of the World Housing Encyclopedia, believe that reducing such an unacceptably high loss of life from earthquakes is the most important challenge facing the global earthquake engineering community. This paper acknowledges the continuing disparity between life loss from earthquakes in developing and developed countries, and the increasing vulnerability in developing countries. A sampling of current efforts to improve construction practices includes the publication of earthquake tips in India, construction manuals in Colombia, and the formation of various international networks to promote collaboration and information sharing. Future possibilities include more rewards for research into inadequately engineered construction, greater emphasis on small-scale, local efforts, and a stronger emphasis on advocacy. We believe that all of us, as earthquake professionals, have a responsibility to make the built environment safer worldwide. [DOI: 10.1193/1.1809130]

OUR OPINION

In 2003, at least 26,000 people died in the Bam earthquake in Iran, and almost 3,000 perished in the Boumerdes, Algeria, earthquake. Although news of these events quickly disappeared from the front pages of the western press, these earthquakes represent enormous, long-term suffering for the residents of these countries. As professionals in earthquake engineering and related disciplines, we find these high death tolls emotionally

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wrenching and simply unacceptable. We, professionals who have embraced earthquake risk reduction as our vocation, have the knowledge and resources to save lives and reduce human suffering. Yet earthquakes continue to claim thousands of lives every year. We believe that this is the most important challenge facing the global earthquake engineering community. It is time for us to meet the challenge head on.

THE PROBLEM

Safety in the built environment is a fundamental right. Article 25 of the United Nations Universal Declaration of Human Rights in 1948 states that "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services... ." On May 16, 1994, an international group of environmental experts meeting at the United Nations in Geneva drafted the first-ever declaration of principles on human rights and the environment. These principles were included in the 1994 Special Rapporteur's Report to the United Nations Commission on Human Rights (UNCHR). Principle #10 states, "All persons have the right to adequate housing, land tenure and living conditions in a secure, healthy and ecologically sound environment."

Experiences in recent earthquakes, particularly in developing countries, conclusively demonstrate that we are far from reaching this goal. The gap between developed and developing countries is widening: four of every five deaths caused by earthquakes in the twentieth century occurred in developing countries. Of people living in earthquake-threatened cities in 1950, two of every three were in developing countries; in 2000, nine of ten were in developing countries (Geohazards International 2004). As the world's population grows, particularly in developing countries, this vulnerability becomes even more pronounced. According to the United Nations, in 2000, one-half of the world's population lived in urban areas crowded into 3% of the land area, an alarming increase in population density (EMI 2004). By 2015, the United Nations estimates that 23 cities will have populations exceeding ten million, and of those, all but 4 will be in less developed countries. Of the top ten urban agglomerations projected for 2015, eight are cities with a known moderate to high seismic risk, including Tokyo, Mumbai, Dhaka, Karachi, Mexico City, New York, Jakarta, and Calcutta (United Nations 1999). A major earthquake in one of these cities, particularly in a city with a vulnerable building stock and fragile infrastructure, could cause major devastation and a significant number of deaths.

Not only are urban populations in developing countries becoming increasingly more vulnerable, but also the number of disasters is increasing. In a recent paper, Pantelic (2004) summarizes these trends, citing statistics from Munich Re and a World Disasters Report. Munich Re reports that in 2003 about seven times more lives were lost to earthquakes, heat waves, and tornadoes than in the preceding year. Underpinning the disaster trends of 2003, several previous years have also seen the severity of disasters on the rise, particularly for those in developing countries. Quoting 1999 Munich Re figures, Freeman (2000) indicates that the number of global catastrophes increased fivefold, while damage grew by a factor of nine when compared to the decade of the 1960s. In 2001, earthquakes affected 19 million people—more than any other year of the previous decade—and accounted for over a half of the year's death toll (IFRC 2002).

Adobe and other forms of unreinforced masonry construction are proven "serial killers" in many earthquakes worldwide. It is estimated that around 30% of the world's population lives in such earthen dwellings (Houben and Guillard 1994). The vulnerability of adobe construction in earthquakes is well documented. In 2001 alone, more than one million people living in adobe dwellings were left homeless in El Salvador and Peru after earthquakes struck these two countries. In the recent Bam (Iran) earthquake, many of the thousands of deaths were attributable to vulnerable adobe structures. Adobe construction from several countries, including El Salvador, Peru, and Iran, is described in detail in EERI's and the International Association of Earthquake Engineering's (IAEE's) World Housing Encyclopedia (*www.world-housing.net*).

Recent earthquakes have also revealed that so-called modern building construction practices are not necessarily safe. Nonductile reinforced concrete construction, often with unreinforced masonry infill, is popular worldwide. A search for concrete frames in EERI's and IAEE's World Housing Encyclopedia reveals 23 reports from 17 countries. These reports describe the same vulnerable features and poor performance in earthquakes all over the world. We all recall the scenes from TV or our own reconnaissance missions after the 1999 Turkey earthquakes, 1999 Chi Chi, Taiwan earthquake, 2001 Bhuj, India, earthquake, and 2003 Boumerdes, Algeria, earthquake where many lives were lost in these "modern" buildings.

CURRENT EFFORTS

There are many people around the world who are working diligently on the problem of improving construction practices and earthquake safety. Links to more information on many efforts are available at the EERI and IAEE World Housing Encyclopedia web site (General Resources section). Just a few examples of these many activities are as follows:

- The Indian Institute of Technology at Kanpur is currently developing a set of earthquake "tips" explaining basic concepts of earthquake-resistant construction in simple language (Jain and Murty 2003). The project consists of developing 24 two-page tips ranging from a basic introduction to earthquakes to aspects of seismic design and detailing of reinforced concrete and masonry buildings. These are colorful and easy-to-read, and they are published periodically in professional journals and daily newspapers throughout India. The tips are also posted at the web site of the National Center of Earthquake Engineering (*www.nicee.org*) in India.
- IAEE has developed comprehensive guidelines for earthquake-resistant nonengineered construction (IAEE 1986), that have been used in post-earthquake rehabilitation efforts after earthquakes and translated in several languages (e.g., Hindi in India, Bangla in Bangladesh, and Spanish).
- After the 2001 Bhuj earthquake in India, Indian and Japanese researchers collaborated on demonstration testing of strengthened and unstrengthened masonry, with film clips available online showing results and reactions of the masons and villagers who observed the tests (UNCRD 2003).

- Earthquake engineers in Colombia have developed several guidelines and manuals on masonry construction, many with clear illustrations that could easily be adapted by other countries (ACIS n.d., Mejia n.d.).
- Peruvian researchers have developed a reinforcing system for existing adobe houses and applied it to houses in Peru, Bolivia, Ecuador, Chile, and Venzuela (CERESIS 2001). Six of these houses were subjected to the Mw 8.4 June 2001 earthquake and demonstrated excellent behavior; they exhibited no cracking, while neighboring houses had severe damage. These researchers have also developed a construction manual for new construction, a training program for laborers, and two DVDs to support the training and dissemination (CTAR/COPASA et al. 2002).

Several international networks exist to promote risk reduction:

- The Earthquakes and Megacities Initiative (EMI) formed in 1998 as a not-for-profit international scientific nongovernmental organization to promote research and capacity building in megacities. The primary objective of EMI is to establish and promote a program aimed at the mitigation of earthquake risk to megacities.
- GeoHazards International is another global network of people concerned about the world's growing earthquake risk. Their approach is to work directly with vulnerable communities in developing countries, raising awareness, reducing the identified risk with "international assistance and local responsibility," assuring that new construction is earthquake resistant, and involving local experts with their counterparts abroad.
- The World Seismic Safety Initiative, which is an activity of IAEE, was established to provide an organizational framework capable of raising financial resources and undertaking projects that require multinational efforts.
- The web-based EERI/IAEE World Housing Encyclopedia continues to add participants in building an online network of information about housing construction practices worldwide, including both the vulnerable housing that performed poorly in earthquakes and good practices (including both the traditional construction and new technologies) that performed well in earthquakes. An online tutorial on adobe construction has also been prepared by participants. The information is available through the project web site and is continually changing.

FUTURE POSSIBILITIES

These current examples demonstrate that, indeed, something can be done to improve earthquake safety globally. They also warrant taking important actions in the future, including the following:

- **Encourage collaboration among those from different countries on efforts to develop and implement simple building technologies for improved seismic resistance of inadequately engineered construction.** The problems of adobe and masonry in particular are often more challenging because of the complexity of the materials and the wide variation in materials, and are not as widely addressed in research as more "modern" construction materials. Engineers and re-

searchers gravitate toward advanced engineering research that can be published in international journals and brings academic credit and promotion. We need to encourage and reward research into more traditional and vernacular building materials and strengthening schemes. We need to encourage researchers worldwide to adapt and apply state-of-the-art knowledge to solve real problems, including the implications for local economies and cultural traditions. Such accomplishments are worthy of merit and recognition both academically and professionally.

- **Support local initiatives in communities throughout the world.** Encourage local government officials, local builders, and community advocates to take ownership of the problem, and develop solutions that are most appropriate to their particular situation and culture. The broader global community can provide assistance from technical knowledge to actual construction resources. But the problems of developing countries cannot be solved by outsiders. Examples of locally based initiatives include the following:
  - Establishing exchanges worldwide that allow builders, masons, community organizers, housing advocates, engineers, and architects to share knowledge and experiences. Set up visits among influential stakeholders—a community organizer in Venezuela travels to Mexico and learns how technical advice was provided to homeowners rebuilding after Colima; a housing policy expert in Indonesia visits the United States and learns how the building trades are involved in promoting earthquake-resistant construction practices (through regulation as well as education); an adobe expert from Iran travels to Peru to learn about local retrofit strategies and implementation techniques; a building official in Algiers travels to Los Angeles to witness the day-to-day tasks involved in overseeing the permitting and construction practices in a big city. There are models for such exchanges, including the United Nations Center for Regional Development (UNCRD) program that brought masons from Nepal to a village in Gujarat, India, after the 2001 earthquake there (NSET-Nepal 2002), and the Cluster Cities concept of EMI where officials from different cities, such as Los Angeles and Mexico City, share experiences and knowledge. Establish internships and field work opportunities for engineering students to learn about constraints and conditions in non-engineered and poorly designed and built construction, with the idea that such engineering students may pursue research in this area, developing low-cost and effective strengthening strategies.
  - Establishing global workshops on particularly unsafe structures (e.g., adobe, infilled concrete frames) that will allow builders, masons, community organizers, housing advocates, engineers, and architects to share knowledge and experiences. The objective would be to develop consensus strategies to reduce vulnerability, and to widen the network of concerned professions and individuals.
  - Supporting networks and activities that can provide good, low-cost information in developing countries, including support of low-cost printing and

dissemination alternatives. Support the printing and dissemination of posters and other low-cost, easy-to-use materials that can be easily and widely disseminated for use by homeowners and community organizers. Building and design professionals in most developing countries cannot afford textbooks that cost upwards of $100 USD. If the experts in developing countries cannot keep pace with the latest books, how can they be expected to play leadership roles in their own countries? In India, several important U.S. textbooks have been reprinted in Indian editions, ranging in cost from $4 to $7 USD. The printing costs are underwritten by cement manufacturers and others for free dissemination.

- Supporting innovation among young researchers and practitioners especially from developing countries who work "close to the ground" and know firsthand the type of challenges that need to be resolved. One of the resources that can be used to promote this type of activity is ProVention, an initiative established by the World Bank (ProVention 2004).

- **Advocate in our own communities and countries for good governance as a fundamental requirement for promoting mitigation and safer construction.** Good governance relies on a partnership among communities, the private sector, and the public sector (Pantelic 2003). In such a decentralized environment, communities initiate actions, and identify their own risks, priorities, and strategies for mitigation. The private sector must invest in hazard reduction, and the public sector must create an enabling environment through regulatory reforms in support of hazard reduction and safer building. Encouraging good governance creates the environment within which safer building construction, regulation, and strengthening can take place.

MEETING THE CHALLENGE

So, where can we go from here? We begin by acknowledging the responsibility that the earthquake engineering community has in reducing the earthquake risk associated with non-engineered or inadequately engineered construction in countries of high seismic risk and repeated high death tolls in earthquakes. Each of us can help in this effort by applying our skills and expertise to these problems, and by volunteering some of our time to help develop and/or disseminate the required resources. We challenge you to join us in fulfilling this responsibility.

The EERI/IAEE World Housing Encyclopedia is a valuable platform. It is much more than just a web site. It is a network of like-minded individuals from around the world. Together we have worked hard to pursue our mutual interests. In so doing, we have gained inspiration from one another and witnessed together the emergence of a wonderful resource. We want to build upon the Housing Encyclopedia platform to allow EERI members and others to join us as we pursue some of the goals outlined in previous sections to make buildings safer from earthquakes around the world. Specifically, we propose the development of an action plan to expand the scope of the effort and engage broader participation. While we do not offer a preconceived notion of exactly what should be included in the plan, we know that the following basic principles are important:

- This is an independent effort. While we have every reason to believe that we will gain the moral support of the leadership and members of EERI and IAEE, we do not expect to rely on ad hoc funding from the Institute, nor do we wish to impose an additional financial burden on the membership in the form of increased dues. This initiative should be capable of generating support on its own merit and value.
- We wish to join others, individuals and organizations, with a mutual humanitarian interest in earthquake safety. We hope to offer our resources in a coordinated manner to enhance and expand the existing efforts worldwide. We do not intend to duplicate or displace the work that is going on right now.
- Cooperation and collaboration among many with diverse perspectives are critical to success. Making the built environment safer worldwide is a complex and multidimensional problem. While earth sciences and engineering technology are critically important, the context is social and cultural. We need to ask architects, building officials, community organizers, builders, social scientists, housing advocates, and public policy experts to join with us.

The next step is to solicit the support and ideas from the broader earthquake engineering community in formulating a targeted action plan. We have posted a short questionnaire on the World Housing Encyclopedia web site at *www.world-housing.net* to actively solicit reaction from EERI members and others. The World Housing Encyclopedia Editorial Board will review results and use them to guide the formulation of the action plan. We are eager to learn what others think and feel about the challenge of improving earthquake safety of buildings around the world.

We admit that the challenge can seem daunting. Nonetheless, there are others whot share our concerns. There have been encouraging successes and no lack of good ideas for the future. If we do not face this challenge with the knowledge and resources that we have collectively, who will? Is there anything that we could be doing that is more important?

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REFERENCES

ACIS (Colombian Association for Earthquake Engineering), (n.d). *Manual de Construcción, Evaluación y Rehabilitación Sismo Resistente de Viviendas de Mampostería* (Manual for the Construction, Evaluation and Seismic Strengthening of Masonry Houses) (in Spanish), web address: http://www.asosismica.org.

CERESIS (El Centro Regional de Sismología para América del Sur), 2001. Reforzamiento Sismo-Resistente de Viviendas de Adobe Existentes en la Región Andina (Seismic Reinforcement of Existing Adobe Housing in the Andean Countries) (in Spanish), web address: http:/www.ceresis.org/proyect/padobe.htm.

CTAR/COPASA, GTZ, PUCP, SENCICO, 2002. *Terremoto? ¡Mi casa si resiste! (Earthquake? My House Withstands!)* (in Spanish), Arequipa, Peru.

Earthquakes and Megacities Initiative (EMI), 2004. Earthquakes and Megacities Initiative: About EMI, web address: http://www-megacities.physik.uni-karlsruhe.de/.

Freeman, Paul K., 2000. Infrastructure, natural disasters and poverty, in *Managing Disaster Risk in Emerging Economies*, edited by Alcira Kreimer et al., The World Bank, Washington, D.C., USA.

Houben, H., and Guillaud, H., 1994. *Earth Construction—A Comprehensive Guide*, ITDG Publishing, London, UK.

Geohazards International, 2004. At Increasing Peril...People in Cities of Developing Countries, web address: http://www.geohaz.org/ginfo/atperil.htm.

International Association for Earthquake Engineering (IAEE), 1986. *Guidelines for Earthquake Resistant Non-Engineered Construction*, Tokyo, Japan.

International Federation of the Red Cross and Red Crescent Societies (IFRC), 2002. *World Disasters Report 2002: Focus on Reducing Risk*, Kumarian Press, Bloomfield, CT, USA.

Jain, S. K., and Murty, C. V. R., 2003. Some innovative education and outreach projects in India for earthquake risk reduction, *Seismol. Res. Lett.* **74** (5), 545–551.

Mejia, L. G., (n.d). *Notas Acerca del Diseño Sismoresistente Para Casas de 1 y 2 Pisos* (Notes about the Seismic Resistant Design of 1 and 2 Story Houses) (in Spanish), Medelin, Colombia.

NSET-Nepal, 2002. Nepal Gujarat Mason Exchange & Training Program (NGMET), web address: http://www.hyogo.uncrd.or.jp/publication/documents/pny/NSET.PDF.

Pantelic, J., 2003. Governance and urban earthquake hazard reduction—An emphasis on decentralization, in *Proceedings of 7th U.S.-Japan Workshop on Urban Earthquake Hazard Reduction*, Earthquake Engineering Research Institute, Oakland, CA, USA.

Pantelic, J., 2004. Urban earthquake risk reduction for the 21st century: The lessons and the way forward for developing countries, *Proceedings of 13th World Conference on Earthquake Engineering, Vancouver, Canada, August*.

ProVention Consortium, 2004. Applied Research Grants for Disaster Risk Reduction, web address: http://www.proventionconsortium.org/projects/appliedres.htm.

Special Rapporteur's Report, 1994. Draft Principles on Human Rights and the Environment, as included in Special Rapporteur's Report to the United Nations Commission on Human Rights, web address: http://www.anped.org/docs/ER UN Draft Principles.doc.

United Nations, 1999. World Urbanization Prospects, The 1999 Revision, web address: http://www.un.org/esa/population/publications/wup1999/WUP99CH1.pdf.

United Nations Centre for Regional Development (UNCRD), 2003. FIELD SHAKE TABLE PROGRAM for Confidence Building in Quake Resistant Building Technology, web address: http://www.hyogo.uncrd.or.jp/publication/pny-documents.htm-documents.

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