Mitigating Earthquake Damage for Schoolchildren: Four Case Studies

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In defining a program for disaster mitigation and earthquake risk management in any country, the structural integrity of the nation's schools has time and again proved to be a matter of critical importance. Four case studies exemplify the strengths and weaknesses of international programs designed to address school building construction codes, highlighting the well-designed elements of effective governmental policies in California (the Field Act of 1933) and Japan (June 1981 seismic structural planning) and noting the flaws that undermined implementation of risk mitigation policies in China (2008 Wenchuan quake) and Armenia (1988 Armenian quake).

Case 1. China's Flawed Construction during the 2008 Sichuan Earthquake

Due to China's government structure, the local government plays an important role in establishing and monitoring compliance of building codes. In the case of school building construction, substandard buildings in primary schools and secondary schools were a significant cause of casualties in the 2008 Wenchuan earthquake, an 8.0 magnitude earthquake that struck on May 12, 2008. Some newly built school buildings collapsed instantly during the earthquake, while old buildings nearby stood unscathed; of 44 schoolhouses counted, 57% were deemed as damaged beyond repair.[12]

In the case of Juyuan Middle School, one of the many schools that collapsed during the earthquake and trapped hundreds of students, the school was previously expanded from two stories to four. This was believed to have contributed to the collapse.[3] The pillar of the school was said to be made of soft cement, which violated the building codes.[4] According to residents, the local educational bureau had allocated money primarily for strengthening the structure of school buildings. In reality the buildings were only repainted and were constructed using soft cement.[5]

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* Material on these cases were researched and prepared by Jenny Fan; Lawrence Gu and Xiaochun Ni.

[1] Angry Chinese Demanding Punishment to Corrupted Officials. NTDTV. 2008 May 23. <http://www.youtube.com/watch?v=sldbw1r4t8Q>

[2] Buckley, Chris. "China quake school toll stirs grim findings, anger." Reuters. 2009 March 22. <http://www.reuters.com/article/idUSPEK372953>

[3] Melissa Block. Shoddy Work, Leadership Blamed in School Collapse. NPR Morning Edition. 2008 May 15. <http://www.npr.org/templates/story/story.php?storyId=90462070>

[4] Amina Khan. In China, local government's handling of earthquake raises questions. Los Angeles Times. 2008 May 16. <http://opinion.latimes.com/opinionla/2008/05/in-china-local.html>

[5] Ibid.

This was a widespread phenomenon around the region, and during the Wenchuan Earthquake, countless students were buried under collapsed substandard school buildings and died. According to Ministry of Education official Han Jin, 6.898 classrooms collapsed across Sichuan. Later, reports came out that nearly 2 million square meters of school space had collapsed, 4,737 students were killed, and more than 16,000 students were injured.[6]

A review conducted by the Sichuan Construction Bureau confirmed that the school's collapses were linked to poor structural design, substandard construction, and the failure to meet earthquake prevention standards. The potential causes for the problem are numerous: cost-cutting due to insufficient funding or corruption, lack of third party oversight, lack of centralized management, communication difficulties, and the list goes on. However, a tragedy such as this could have been avoided if the local government had taken the financial and managerial responsibility to assure the high quality of the public school buildings.

Case 2. Armenia's Wide-spread Construction Collapse and Its Long Term Effects on Schoolchildren

As was the case during the Wenchuan Earthquake, the shoddy construction and inadequate preparation of earthquake drills led to widespread destruction when a magnitude 6.9 earthquake struck Armenia on December 7, 1988. The earthquake destroyed four cities and 350 villages, killing over 25,000 people, according to Soviet estimates. Because the earthquake occurred in the late morning, many children were in classrooms, and upwards of 50% of the children were killed in the collapsed buildings. The majority of buildings in Spitak, a city with a population of 30,000, fell. Approximately 50% of the buildings were also destroyed in Gumri, the second largest city of Armenia, which was 20 miles away from the epicenter. [7] However, Yerevan, the capital of Armenia, which was 47 miles away from the epicenter, suffered only mild damage and no significant loss of life.

The drastic differences in what happened in Gumri and Spitak and in Yerevan was mainly due to differences in building structures. In Gumri and Spitak, where nearly all the children were significantly exposed to a direct life threat. The mutilating injuries, death, chaos, separation from their parents and peers, and considerable hours spent trapped beneath the rubble often left deep scars upon the children., The long run affects of the traumatic experience led to multiple instances of post-traumatic stress disorder in the children.

Case 3. California's Response to the Long Beach Earthquake

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[6] Yang Binbin, Zhao Hejuan, Li Zhigang, et al. "Why did so many Sichuan schools collapse?" Caijing Magazine. 2008 June 17. <http://english.caijing.com.cn/2008-06-17/100070077.html>.

[7] Goenjian, Armen, et al. "Psychiatric Comorbidity in Children after the 1988 Earthquake in Armenia." Journal of the American Academy of Child and Ad*olescent Psychiatry, 34:9. September 1995.

On March 10, 1933, the 6.3 magnitude Long Beach earthquake in California destroyed 70 schools and caused major damage at 120 other schools. While the buildings were fortunately unoccupied when the damage was caused, many schoolchildren would have lost their lives had the quake hit just a couple of hours earlier. The outrage and parental concern led to the creation of the Field Act, which passed on April 10, 1933. The Act required that plans for school buildings be prepared by competent designers qualified by state registration. The design professionals, an independent inspector, and the contractor had to verify under penalty of perjury that the building was constructed according to the pre-approved plans.[8] The Field Act applied to schools built after 1933, though the 1971 San Fernando earthquake encouraged the California government to provide funding for retrofitting schools built prior to the Field Act.

The effectiveness of the Act was tested on February 9, 1971, when the 6.6 magnitude San Fernando earthquake hit the San Fernando Valley. It was an unusually valuable test for school safety because several hundred schools, with structures of all different types, were in the heavily damaged area. Ten schools were within five miles of the epicenter, often with pre- and post-Field Act campuses standing next to each other. The severity of ground motion was believed to have been near the maximum expected for an earthquake of any size, and a number of the schools were subject to major ground cracking and deformation. The details of this earthquake ground motion were better recorded for this quake than any other, because of the many instruments in the area.

The results of the quake clearly demonstrated the successful implementation of the Field Act. Schools built under earthquake resistant design codes that followed the California State Office of Architecture survived the earthquake with virtually no hazardous structural damage. Several older schools erected prior to the Field Act did suffer hazardous damage, which was what later created the push for retrofitting the buildings.[9] The steps taken by the California State government in responding to the situation and following through can be positive models on which to base a building code enforcement plan for schools.

Case 4. Japan's Implementation of Reinforced Concrete Buildings in Shizuoka Prefecture

Unlike the previous cases, the "Tokai Earthquake" is a predicted earthquake that has yet to occur in the Shizuoka Prefecture. The pattern of earthquakes in Tokai has been stark and consistent, happening about every 110 years, plus or minus 33 years. (As of 2010, however, it has been 156 years and counting.) The previous earthquakes in 1707 and 1854 were all very significant occurrences, with a magnitude of around 8.4. If this earthquake were to strike, it would be beyond the scope of the deadly 7.3 magnitude Kobe earthquake of 1995 that killed

[8] Bellet, Dennis. "The Field Act." Excellence in Public Educational Facilities. California State Government. 2 August 2010. <http://www.excellence.dgs.ca.gov/StudentSafety/S7_7-1.htm>.

[9] Kromer, Clarence. "Structural Problems in Connection with the Design of Earthquake-Resistive Buildings." Bulletin of the Seismological Society of America. P. 405

6,430 people and destroyed more than 100,000 homes. It would even be greater than the 7.9 Kanto Earthquake of 1923, which killed more than 120,000 people.

With such high stakes, in June 1981 the Shizuoka Prefectural government passed legislation that required seismic structural planning and began implementing various projects to mitigate seismic hazards. The government spent 136,000,000 yen in construction from June-September 1985. Additionally, studies showed that the older buildings could be reinforced rather than simply destroyed and rebuilt from scratch, a much more costly process and one that would have been more difficult to coordinate logistically.

The government examined the seismic performance of 1,896 reinforced concrete buildings and increased the strength of the structure by adding new shear walls and increasing the story ductile capacity.[10] The specific methods used included changing the failure mechanism of the brittle columns by adding new shear walls or adding slits between columns and spandrel walls, using steel braced frames in longitudinal direction to minimize incremental dead load and using reinforced concrete shear walls to traverse direction.[11]

The Hyogo-ken Nanbu Earthquake occurred in Japan on January 17, 1995, and damaged a large number of buildings including about 4,500 educational buildings. The Japanese government appropriated 94 billion yen to rebuild damaged educational buildings in FY1994 and 1995. After the earthquake, the Ministry of Education requested to the Architectural Institute of Japan (AIJ) to study the extent of damage of reinforced concrete school buildings. AIJ's investigation revealed that most of 272 damaged buildings were constructed before the June 1981 law while the buildings constructed after that date were much less damaged.

The Japanese decision to reinforcing older structures rather than rebuilding them from scratch after an earthquake is highly relevant to developing countries likely Haiti that are highly constrained by costs. Though the expected "Tokai earthquake" has not yet occurred, the extensive mitigation measures undertaken by the government promises to reduce losses in the event such a severe seismic event in Japan in the future.

[10] Usami, Hiroyasu, et al. "Seismic Strengthening of Existing Reinforced Concrete Buildings in Shizuoka Prefecture, Japan." Proceedings of Ninth World Conference on Earthquake Engineering. 9 August 1988.
[11] Ibid.