Discussion Paper

Seismic Retrofit of Schools

Feasible? Affordable? Sustainable? Achievable?

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Background

Following the Wenchuan Earthquake on 12/05/08 I sent an email to colleagues associated with disaster risk reduction on 19/05/08 stating the following:

> "Dear Friends,
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> … … … …
>
> We are still reeling from two terrible natural disasters. To add to the media coverage I thought it of value to send you two presentations by Walter Hayes of the Global Alliance for Disaster Reduction. In addition I have attached an analysis of the losses from natural disasters in 2007 by the Centre for Research on the Epidemiology of Disasters (CRED), Louvain. Already in 2008 the statistics are worse than 2007.
>
> I single out one point for comment – the schools. Instead of being refuges and emergency accommodation after disaster strikes they have become tombs. The greatest source of grief in the communities affected.
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> I have tried - unsuccessfully so far - to excite interest in retrofitting schools on coasts and in earthquake prone regions so that they become refuges and sources of emergency accommodation. All this to happen before disaster strikes. There are five major obstacles:
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> 1. lack of awareness of community risk, where the impact of a disaster is greatly magnified compared with an individual risk,
> 2. lack of knowledge on how to retrofit existing buildings using local community resources,
> 3. lack of research to provide the knowledge on how to retrofit,
> 4. lack of government commitment to effect change, and
> 5. lack of resources and funding.
>
> Any suggestions?
>
> Paul"

This message, and the frustrations it reflects, struck a chord with others. Walter Hays distributed it to a wider audience, and I received many responses from people wanting to be involved. Importantly for me, I received practical advice and direction to useful web sites which have provided a solid basis for the comments being offered in this discussion.

Aim of this discussion

The aim of this discussion paper is to enlarge on those five 'obstacles' and to stimulate thinking on making schools seismically safe. This is essentially a transient input to advance preparation for the

major discussion of the Wenchuan Earthquake to take place at the IDRC conference in Davos, 24-29 August 2008.

Since my background is structural engineering, the emphasis, as the title suggests, is on retrofitting. This is just one aspect of disaster risk reduction in schools, but one which is often deficient, thereby negating the whole DRR effort.

A case study of success

While there are many stories of collapsed schools in the Wenchuan Earthquake, we can learn a lot more from the success stories. Of these, the story of the Sangzao Middle School, reported in the *New York Times*, 11th June 2008, is most informative. Sangzao Middle School is about 150 km from the epicentre of the Wenchuan Earthquake, and many buildings in the town collapsed. A transcript of the full report is appended. There will, of course, be other success stories for this earthquake, but success gets much less media coverage than failure in disasters.
See http://www.nytimes.com/2008/06/16/world/asia/16quake.html?_r=2&scp=5&sq=edwa&oref=slogin

Some essential aspects of the success and experience of Sangzao Middle School are as follows:

1. School buildings up to five storeys, one built 1983-85, were perceived to have columns with undersize area of cross-section and insufficient reinforcement, and hollow block reinforced concrete floors of dubious quality.
2. Construction was carried out without independent site inspections to ensure quality.
3. One person in authority – the headmaster, Mr Ye – recognised the serious seismic risk arising from deficient construction.
4. One person – Mr Ye – had the leadership to pursue county funding ($58,000) to strengthen the buildings.
5. Retrofitting took several years to complete. (Details of the retrofit beyond adding concrete and reinforcement to the columns are scant.) Lobbying the county took somewhat longer.
6. More than 5,000 classrooms collapsed in the earthquake. More than 10,000 students and teachers were killed.[1]
7. There was no NGO assistance or external input to the risk reduction process.
8. Earthquake emergency drill, practised twice a year, ensured that the buildings were safely evacuated within two minutes of the first shocks.
9. The buildings are considered unsafe since there is no means of knowing their residual seismic resistance after the earthquake. They remain unoccupied. They will be demolished and rebuilt.

From this report it would appear that the Sangzao Middle School is close to the ideal of disaster risk reduction. Risk was identified. A community based action for risk reduction was developed and implemented. Appropriate education in the process of risk reduction was provided. The outcome was feasible, affordable, sustainable and achievable.

[1] UNICEF, citing Pakistan Government's estimates, stated that at least 17,000 schoolchildren died when 6,700 schools were destroyed in northwest Frontier Province and 1,300 in Pakistan-administered Kashmir, according to the (BBC online news, 31/10/2005). The Yogyakarta earthquake, 27/05/2006, 05:54 am local time, resulted in 5,782 deaths, but none in schools.

Making schools seismically safe

Space does not permit a detailed review of the many web sites reporting initiatives, mostly from NGOs, to make schools seismically safe. The following is a short list of interesting websites.

The Coalition for Global School Safety (COGSS) http://www.interragate.info/cogss

The right to safety. http://www.un.org/Pubs/chronicle/2005/issue4/0405p59.html
Amongst other matters mentions that "Bottom up (students, teachers, communities) & Top down (government, UN, IOs, NGOs) can be better connected."

"School Seismic Safety: Falling Between the Cracks?"
http://www.radixonline.org/resources/school-seismic-safety-august2004.doc

"Let Our Children Teach Us!"
A Review of the Role of Education and Knowledge in Disaster Risk Reduction
http://www.unisdr.org/eng/partner-netw/knowledge-education/docs/Let-our-Children-Teach-Us.pdf

Keeping schools safe in earthquakes

http://www.oecd.org/document/41/0,3343,en_2649_39263294_8002921_1_1_1_37455,00.html

The Global Alliance for Disaster Reduction http://www.gadr.giees.uncc.edu/

Geohazards International http://www.geohaz.org/ (Links to Stanford University)

School earthquake risk evaluation. http://www.quakeschool.org/

New Zealand Society for Earthquake Engineering Inc
Assessment & Improvement of the Structural Performance of Buildings in Earthquake
http://www.nzsee.org.nz/PUBS/2006AISBEGUIDELINES_Corr_06a.pdf

School Earthquake Safety Initiative (SESI) & Housing Earthquake Safety Initiative (HESI) of UNCRD
www.edm.bosai.go.jp/old/Phase2/2Events/9_MiniWS/8_DRH_MiniWS_Ando.pdf.
Mentions the need for contextualized Guideline for earthquake resistant construction.

Earthquake Engineering Abstracts (EEA), NISEE, UC Berkeley – an important source for structural performance and design in earthquake regions.
http://nisee.berkeley.edu/eea.html

World Housing Encyclopedia - an EERI & IAEE initiative - www.world-housing.net

Seismic retrofit solutions at www.retrofitsolutions.org.nz
http://www.retrofitsolutions.org.nz/pdfs/Ingham%20June%2006.pdf

Most of these web sites raise awareness of the seismic risk in a wider context of all risks and in the context of the importance factor for institutional buildings such as schools. Methodologies are available for tackling the problems are there, but examples of practical implementation are few, and instances of dealing with buildings of uncertain structural integrity with regard to retrofitting rather than reconstruction are sparse.

The five obstacles to making schools seismically safe

Having identified five obstacles to making schools seismically safe it is reasonable that I attempt to address these obstacles myself with a view to stimulating discussion.

1 Lack of awareness of community risk, where the impact of a disaster is greatly magnified compared with an individual risk,

Lack of recognition that the acceptable level of risk for a community exposed to a catastrophe is much lower than for an individual exposed to the same catastrophe. This theme is touched on in a paper I am presenting to IDRC Davos, 25th August. Many do not have the imagination to see beyond personal and family loss when it comes to major disasters. Mr Ye of Sangzao did have the necessary communal vision.

NGOs typically operate (according to their perceived mandate) on the principle that help and support is only provided when requested, i.e., demand driven rather than supply driven. Our challenge is to find ways of raising both regional government and village community awareness of the risks so that they can initiate a partnership of disaster risk reduction.

2 Lack of knowledge on how to retrofit existing buildings using local community resources

In my view it is more difficult to assess the robustness of buildings built with limited or no standards of design and supervision in construction, than for larger and more complex buildings built to standards for which drawings likely to reflect what was actually built are available. The typical structural engineer has no training in this art. Further, most retrofitting will be carried out by local communities themselves with outside assistance from people who are themselves trained in translating engineering specifications in procedures understood by local artisans. This requires skilled translation of technical specifications into layman's terms. This too, is a gift which not many structural engineers have.

[The aim of the Joint Working Commission on Disaster reduction on Coasts is to assist in the development of a *Guide to Disaster Reduction on Coasts*, which will be in three tiers. Tier 1 will develop risk reduction options and procedures which are comprehensible at the village level. Tier 2 will address risk reduction options at the regional level, including issues of continuity of function of key infrastructure and essential community operations and services. Tier 3 will be for professional use providing rational underpinning of Tiers 1 and 2.]

3 Lack of research to provide the knowledge on how to retrofit

There is far more research on ensuring that new construction is seismically robust than on retrofitting existing buildings and infrastructure for robustness. Quite often the option is taken to demolish and rebuild to a known higher standard simply because there is insufficient knowledge on retrofitting. Retrofitting can have minimum impact on community life style compared with rebuilding, which is highly valued in most communities.

There is a lot of research already completed relevant to this issue. However, further research is needed to see how to use this research for retrofitting.

[My own experience is that it is much easier, for political reasons, to get money to replace a weak bridge than to strengthen it – at much less cost.]

4 Lack of government commitment to effect change

We all know how difficult it is to commit resources to disaster prevention, while there are always disasters in progress demanding immediate funding for mitigation and recovery. In this context some observations by Andrew Healy are pertinent. See

http://econlog.econlib.org/archives/2008/07/disastrous_voti.html, and
http://myweb.lmu.edu/ahealy/papers/healy_prevention_070808.pdf

Healy states: "I show that voters reward disaster relief spending but not disaster prevention spending." And further: "…the regression estimates that a $1 increase in prevention spending resulted in an $8.30 decrease in disaster damage…" (in the USA). These remarks back up with economic and political analysis what we already know on the difficulty of changing the culture to disaster prevention. There are of course, enlightened ministries such as DFID (UK) which search for a balance between disaster risk reduction and disaster relief and reconstruction.

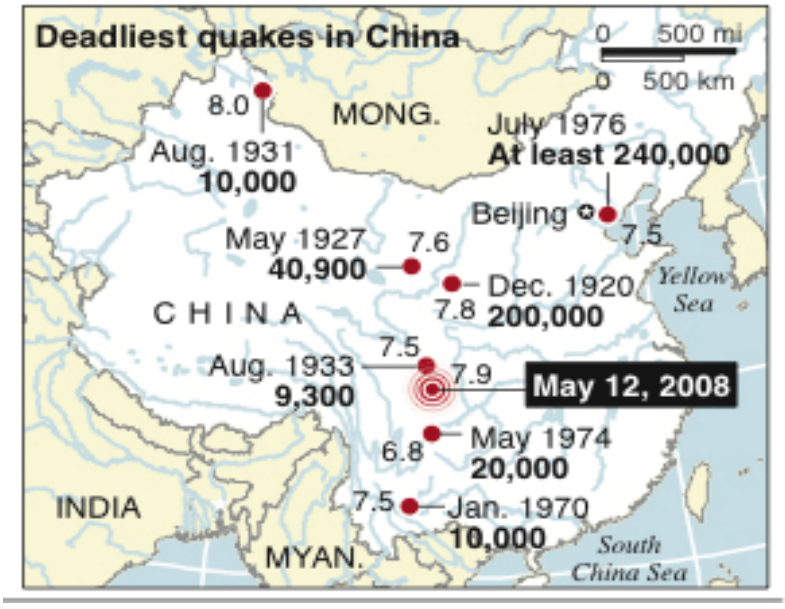
This simply underscores what we already know: retrofitting is not sexy compared with new construction. Fortunately, there are some notable instances of communities fully embracing disaster risk reduction.

5 Lack of resources and funding.

Lack of resources and funding arises out of the previous four obstacles, discussed above.

To put this issue in perspective, consider the incidence of major earthquakes in China.

China has an area about 9.6 million km2. The map shows eight major earthquakes since 1920. Assume the major impact of an earthquake is confined to an area 10,000 km2, and that high seismic activity is confined to a quarter of theland area. A resident in a region of high seismicity would be exposed to an annual probability of a major eaarthquake of 1 in 25,000. (This is a very crude calculation for illustrative purposes.) In spite of the 7 to 1 benefit to cost ratio of spending on disaster risk reduction rather than post disaster recovery it will always be hard to forego current income to insure against a future loss which might never happen. Of course, the 7 to 1 ratio does not include social cost, which is very much greater and much more important.



Major earthquakes in thepast century in China
(Compiled by Walter Hays)

Concluding remarks

It comes down to perception of risk, and acceptance of risk.

One can insure against financial loss by paying an annual premium forever. One cannot insure against loss of social cohesion or the destruction of social order by paying an annual premium. However, paying for disaster risk reduction with community engagement, education, planning and retrofitting is a once only 'premium' over a few years, which thereafter requires relatively low cost maintenance.

There is no silver bullet.

Addendum

How Angel of Sichuan Saved School in Quake

By EDWARD WONG

Published in the *New York Times*: June 16, 2008

http://www.nytimes.com/2008/06/16/world/asia/16quake.html?_r=2&scp=5&sq=edwa&oref=slogin

SANGZAO, China — The students lined up row by row on the outdoor basketball courts of Sangzao Middle School in the minutes after the earthquake. When the head count was complete, their fate was clear: all 2,323 were alive.

Parents covered in blood and dust hugged them and cried. So did the school principal, Ye Zhiping.

"That was the single most joyful thing," he said.

Given that some 10,000 other children were crushed in their classrooms during the devastating quake on May 12, the survival of so many students in Sangzao counts as a minor miracle.

Students and parents credit that to the man they call Angel Ye.

Nervous about the shoddiness of the main school building, Mr. Ye scraped together $58,000 to renovate it in the 1990s. He had workers widen concrete pillars and insert iron rods into them. He demanded stronger balcony railings. He demolished a bathroom whose pipes had been weakened by water.

His school in Peace County probably withstood the 8.0-magnitude earthquake because he pushed the county government to upgrade it. Just 20 miles north, the collapse of Beichuan Middle School buried 1,000 students and teachers.

Mr. Ye's tale sheds light on the lax building codes in this mountainous corner of Sichuan Province and what might have been done to address well-known shortcomings. In his case, a personal commitment and a relatively petty amount of cash sufficed to avert tragedy.

"We learned a lesson from this earthquake: the standards for schools should have been improved," Mr. Ye, 55, said in an interview. "The standards now are still not enough."

Mr. Ye not only shored up the building's structure, but also had students and teachers prepare for a disaster. They rehearsed an emergency evacuation plan twice a year. Because of that, students and teachers say, everyone managed to flee in less than two minutes on May 12.

"We're very thankful," said Qiu Yanfang, 62, the grandmother of a student, as she sat outside the school knitting a brown sweater. "The principal helped ease the nation's loss, both the psychological loss and the physical loss."

The Chinese government estimates that more than 7,000 schoolrooms collapsed in the earthquake. The destruction has prompted grieving parents to take to the streets to demand investigations, and that in turn has become the biggest political challenge to government officials in the aftermath of the earthquake. The police began clamping down this month on the protests.

It has been difficult to establish responsibility for the school collapses partly because it is unclear in many cases which level of government is responsible for the original school construction and for ongoing inspections.

The building codes Mr. Ye criticized had been set by the central government in Beijing, he said. While county education officials did not take the initiative in improving Sangzao Middle School, they acceded to Mr. Ye's requests and gave him money, he said.

Huang Zhichun, an official in the county's education department, said in a telephone interview: "Based on the fact that so many schools have collapsed, the standard is not good enough. The central government sets the standard."

Government officials in Beijing and Sichuan have said they are investigating the collapses. In an acknowledgment of the weakness of building codes in the countryside, the National Development and Reform Commission said on May 27 that it had drafted an amendment to improve construction standards for primary and middle schools in rural areas. Experts are reviewing the draft, the commission said.

They could do worse than consult with Mr. Ye. A squat man who speaks in sharp bursts, he now lives with his wife in a refugee camp of green tents on the school's basketball courts. He started working at the school 30 years ago as an English teacher and has taught in every classroom. Some students say he is more playful than the teachers.

Sangzao is a farming town of 30,000 where merchants sell vegetables from blankets on the road. It has two middle schools, one administered by the township, where a dormitory collapsed during the earthquake, and the other administered by the county. Mr. Ye works in the second. Families from across Sichuan send their children there because of its reputation.

A large billboard on the school grounds lists the names of 90 students who earned top scores on a national exam last year. The school is one of the largest in Peace County. It has a half-dozen dormitory buildings and two classroom buildings, all five stories or lower. One of the classroom buildings was constructed after 2000, the other between 1983 and 1985.

The older one worried Mr. Ye when he became principal 12 years ago.

It is a four-story, white building with large, tinted-glass windows and blue, metal railings running along balconies onto which classrooms open.

"Quality inspectors were supposed to be here to oversee construction of this building," Mr. Ye said. "When the foundation was laid, they should have been here. When the concrete was put into the pillars, they should have been here. But they weren't. In the end, no government official dared to come inspect this building because it was built without any standards."

Mr. Ye walked down the hallways with a visitor and pointed to the corners where the ceiling met wall. He said workers had stuffed trash into those crevices to seal them. In addition, the surfaces of the walls were coarse rather than smooth, a sign of shoddy construction, he said.

The balcony railings were originally made of cement, not metal. They were shaky and a foot too short, Mr. Ye said. They also lacked vertical pillars for support.

"I was among the first teachers who moved into this building, and I was pretty young," Mr. Ye said. "Our awareness of safety wasn't the same as now."

He said his attitude changed after he became principal.

"If I knew there was a hidden danger, and I didn't do anything about it, then I would be the one responsible," he said.

From 1996 to 1999, Mr. Ye oversaw a complete overhaul. He said he pestered county officials for money. Eventually the education department gave $58,000. It was a troublesome process because the county was poor and thus tight with money, Mr. Ye said, but officials saw the need to ensure the safety of children.

So the renovations began. Most crucial were changes made to concrete pillars and floor panels. Each classroom had four rectangular pillars that were thickened so they jutted from the walls. Up and down the pillars, workers drilled holes and inserted iron reinforcing rods because the original ones were not enough, Mr. Ye said. The concrete slab floors were secured to be able to withstand intense shaking.

Structural engineers and earthquake experts outside China who have examined photos of collapsed schools point to two critical flaws: a lack of adequate iron reinforcing rods, and poorly built, hollow concrete slab floors.

Mr. Ye said construction codes improved after 2000, and buildings are now supposed to be rated a 6 or 7 on a scale of earthquake resistance.

“But we see from this earthquake that the standard should be lifted to 11 or 12,” he said.

Each classroom in the main school building holds about 60 students. Each room is now a frozen tableau of 2:28 p.m. on May 12. Backpacks and textbooks are scattered all around. A bag of oranges sits on a desk.

Students said they dove under desks when the tremor hit. Then teachers led them onto the basketball courts outside.

“Many parents ran to the school afterward,” said Yang Shihui, 40, an English teacher. “One mother started hugging her daughter and saying, oh my daughter. The daughter was fine. It was actually the mother who was covered in dirt and bleeding.”

Mr. Ye was in a city 30 miles away when the ground began shaking.

“On my way back, I saw that many buildings had been seriously destroyed,” Mr. Ye said. “I was pretty concerned. But when I saw that all of my students were safe, I was very happy.”

These days, students dart in and out of the school to grab textbooks, ducking beneath a thin blue ribbon with a handwritten sign that says “Danger.” To them, the building seems sturdy enough.

But Mr. Ye said it will be torn down, never again used for classes.

Huang Yuanxi contributed research from Beijing.