Traditional is Modern:
Traditional Building Technology for Resilience in the Modern Era

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It is a pleasure and honor to come back to Japan, to participate in this world conference in a place of rich culture and cultural heritage. I am going to do something a little different – I am going to try to get you to see buildings in a slightly different way. This means all buildings – modern buildings, old buildings, historical buildings – because what I'm going to talk about is what the local people have taught me in different parts of the world. What has been revealed to me has often shattered the conventional wisdom about earthquake resistant design, and in particular, the expectation of vulnerability of certain masonry buildings and even of buildings constructed of mud.

Last year, when consulting for the European project called the Global Earthquake Model (GEM) on the development of a 'taxonomy' to be used to evaluate buildings for their risk of collapse in earthquakes, I was told:

> *The GEM taxonomy should be able to distinguish differences in seismic performance between different building types, ranging from the highly vulnerable stone masonry buildings to modern buildings designed in compliance with the latest building codes.*

It is difficult for anyone to argue with this statement. Nonetheless, how is one to reconcile it with what is seen in the view in Figure 1 of Gölcük in Turkey after the 1999 Kocaeli Earthquake.


Fig. 1. Gölcük, Turkey after 1999 Kocaeli earthquake. (*AP photo by Enric Marti (NY Times, Aug.20, 1999.*)

The mosque that is entirely intact, including its tall minaret, is unreinforced stone masonry. All of the collapsed buildings surrounding it were of reinforced concrete (RC), like the one barely still standing. These at least should have conformed to the Turkish building code.

But then, even when confronted with this particular scene, wouldn't it be safe to say that, in general. a minaret and a mosque as a whole would be less likely to collapse if made of RC? Then how does one cope with the scene in Figure 2, or the view of its collapsed RC minaret visible at the link in footnote no. 1.


Fig. 2. Mosque in Adapazari, Turkey, 1999.

Not only is the minaret down but the mosque is down as well, in spite of the fact that Turkey has modern building codes for RC construction. To avoid relying only on the selection of pictures to make the point, I turn to a team of Turkish engineers who did a quantitative study of every single building in a sample of damaged areas to analyze the damage by building type (Figure 3). The white bars are the reinforced concrete frame buildings. All of those of traditional construction, including unreinforced masonry, are the darker bars.

To avoid giving the impression that I believe that all RC frame buildings are bad, I mention the widely circulated photo taken after the 2011 earthquake

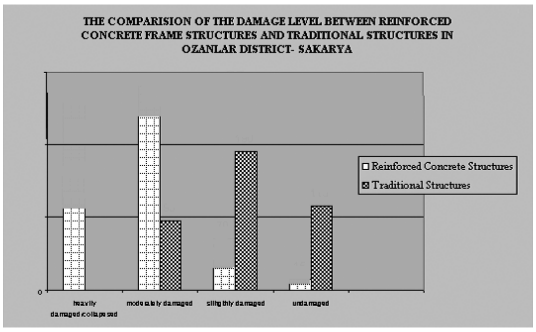

Fig. 3. Gulhan and Guney, 2000.[2]

and tsunami in Tōhoku, Japan, of a building with a large cruise ship on its roof. I'm sure nowhere in the building code is there a requirement that a building should be to hold such a large boat on its roof after enduring a tsunami wave[3]. Only reinforced concrete would survive such a profound event.

Okay, now let's make it easier – how about a building constructed entirely of mud in a large earthquake such as the one that struck the Iranian city of Bam? In that city, the Arg-e-Bam, a world famous archeological site, has been described as the world's largest single interconnected earthen structure. A leading Iranian engineer told me that, because of its collapse, there was a proposal to ban all new earthen construction in the country.

When I got to Bam and started examining the site four months after the earthquake, things got interesting in unexpected ways. All those parts of the construction that had not been restored in the 20th century were still standing. They were ruins, of course, because they had been abandoned without maintenance for almost 200 years, but it was easy to distinguish between the decay over time and the damage from the 2003 earthquake by looking for fresh rubble on the ground.


Fig. 4. Arg-e-Bam, before and after 2003 quake. (*left photo courtesy of Kerman Province*).

Looking further, I found that the only restored parts were completely infested with termites. Thus I could see that we were no longer dealing with the simplistic question of whether unfired clay is vulnerable. Instead, the differences proved that the collapses were a product of the loss of cohesion of the clay itself. In addition, the 20th century restorations had overloaded the much weaker archaeological remains, which as a result were crushed during the earthquake.[4]

Turning now from Iran to Haiti: Haiti was devastated by an earthquake in 2010. Soon after the quake, the numbers of people reported to have been crushed in collapsing buildings rose quickly to more than a quarter of a million. The iconic images in Haiti were of the National Palace and the Cathedral (Fig. 5-left), both of which had collapsed.


Fig. 5. Cathedral (l) and St. Louis de Gonzague Chapel (r) after 2010 earthquake in Haiti.

However, I am sure that few of you have seen photos of the Chapel of St. Louis de Gonzague on the right of Figure 5, standing as if nothing had happened. It is almost as big as the Cathedral used to be. It never shut down. Services continue there to this day. Its structure is a framework of steel or wrought iron imported from France at the end of the 19th century which embraces and reinforces walls of masonry panels.

The Palace and the Cathedral were constructed of reinforced concrete, and both were about a century old. The reason why they fell down is not because of bad construction, but because the rebars had rusted away. So we are now dealing with a modern material, RC, embraced around the world where its lifespan is based on a ferrous metal – steel – embedded into the core of the walls and columns.

Okay, now, why don't we make our expectation of collapse even easier still by going to a Haitian slum settlement where one can reasonably expect to find poorly made buildings which in no way can be expected to be code conforming even if Haiti had possessed a building code, which it does not. Since the first news reports after the earthquake showed bodies of United States and United Nations officials, including the leader of the UN mission, being removed from the pancake-collapsed 5-star hotels that were even further from the epicenter than Port-au-Prince, then expecting to find masses of fatalities in the concrete and masonry slum settlements would not at all seem unreasonable. In fact, news photographs showed many scenes where these houses had cascaded down the hillsides.

Even to this day, the death toll often cited is a quarter of a million or more casualties, but this may have been a result of the quick estimate by a forensics engineering firm, RMS (Risk Management Solutions) Corp. (www.rms.com) of that number only 5 days after the earthquake. As explained to me, the reason for their early estimate was in part that when they saw that the Hotel Montana was down, they assumed that everything else went down too.

Fig. 6. Pictometry Int'l Corp photos of slum settlement (bidonville), and (bottom) upper-class houses, after 2010 earthquake.

When some months later ICOMOS was given access to an aerial survey of the entire damaged district by Pictometry Int'l Corp, I found that except on steep sites, the scene was consistently like that shown in Figure 6-top. The steep site collapses can be explained by the fact that poor people don't build retaining walls. On less steep slopes, most of the slum houses survived. This was true despite their being of bad construction done by untrained people.

Adding to the contrast with conventional wisdom is that the upper-class houses shown in Figure 6-bottom have collapsed, while the massive unreinforced masonry late 19th century "Gingerbread" house, now the Hotel Oloffson, suffered so little damage that it never closed (see endnote 5). Less than a stone's throw behind that hotel was another hotel, an 8-story RC building that completely pancaked.

Moving to even more vulnerable buildings, nobody would claim that river-rock rubble stone is a Class A seismic area building material, yet a number of such buildings, well over 100 years old with little maintenance, have survived, even though in some cases the rubble stone panels have partially collapsed. One such building, the Villa Castel Feuri, featured on the cover of the World Monuments Fund published book *Preserving Haiti's Gingerbread Houses*,[6] once a presidential palace, has only a skin of fired brick while much of the rest of the walls are of rubble stone. It is still standing while a modern reinforced concrete house that the owner built for herself almost a century later in the back garden of the Villa collapsed completely. The only saving grace was that she had died 2 years before the earthquake, or she would have been crushed by the collapsed concrete roof.

So, I have shown one counterintuitive observation after another. One of the reasons why I got into this subject is that, when I moved to California, the only way to really put my arms around the issue of seismic rules for historical buildings which required their demolition or heavy reconstruction was to understand their behavior in earthquakes. Little did I expect to discover that they would frequently be found, not only to survive earthquakes, but actually to do better than the modern buildings in the many earthquakes that have occurred over the 3 decades since my move to a seismically active area.

I now take you to what started me on this whole project – the discovery of this traditional construction in the area of northern India known as Kashmir. What I found there was almost like a mediaeval city of leaning and tipping buildings of different types of construction. My research began because I wanted to understand what they were and why they were like this. What I learned is that there are two types of traditional masonry construction in Srinagar. One is known in as *dhajji dewari*, ancient Persian for "patchquilt wall," visible in the center of Figure 7-left. The other is known as *taq* in Kashmiri, (Figure7-middle). Both evolved primarily in response to the fact that they are on one of the softest soil sites on which a major capital city is built.[7]

I then found reports in the British Library that talked about it in the 19th century, with quotes such as this:

> *The city of Srinagar looks tumbledown and dilapidated…but the general construction in the city of Srinagar is suitable for an earthquake country; wood is freely used, and well jointed; clay is employed instead of mortar, and gives a somewhat elastic bonding to the bricks….If well built in this style the whole house, even if three or four storeys high, sways together, whereas more heavy rigid buildings would split and fall.* [8]

Fig. 7. Srinagar, Kashmir (l & m). Kathmandu (r).

As counterintuitive as to say that it is better to find the use of "clay is employed instead of [lime] mortar…" because it gives a "somewhat elastic bonding to the bricks…" these buildings have actually proven to be earthquake resistant because of the timbers in the walls which hold them together. We can compare them to examples in nearby Nepal in Figure 7-right, photographed before the 2015 earthquakes, which lack the timber ring beams, a shortcoming that became manifest when only a month after the WCDRR, two earthquakes struck Nepal.

The first test of the findings from my research was in Turkey, after the large earthquakes in 1999. There I was able to witness the timber and masonry *hımış* construction next to RC frame construction as seen in Figure 8-left.

Fig. 8. *Hımış* next to collapsed RC (by ©*Adem Doğangün*) (l), and new *hımış* house in Duzce (r).

I even found one family where, at the time of the earthquake, the husband was building a new building out of RC. When he saw the collapsed RC frame buildings compared to the almost no damage to the *hımş* house which his father had built, he stopped and started over with the traditional *hımş* construction seen in Figure 8-right.

The 2005 Kashmir earthquake was the next earthquake to test these kinds of buildings. It mainly struck the Pakistan side of the border. 80,000 people died in northern Pakistan, including downtown Islamabad. In one of the towns to which I was taken to by my colleagues, Maggie Stephenson of the UN-Habitat and Tom Schacher of SDC, rubble stone houses had fallen, but the local residents could see that the one building that had survived was of *dhajji* construction. As a result, the people of this town, contrary to the government's early edict saying they had to use reinforced concrete or concrete block, they proceeded to build *dhajji* houses (Figure 9-left). In Figure 9-right is new post-earthquake stone construction with timber ring beams, which in Pakistan is called *bhatar*.

A year after the earthquake, the government of Pakistan was persuaded (in part by my colleagues listed above) to approve *dhajji*, and the following year *bhatar*. Now, a decade later, there may be as many as quarter-of-a-million new houses constructed in these traditional forms of construction throughout northern Pakistan. [9]

Fig. 9. New *dhajji* house (l) and *bhatar* houses in rural Pakistan after 2005 Kashmir earthquake.

Conclusion:

So how can the traditional ways of construction here inform us of how to fix the modern buildings from collapse? We are no longer just talking about how to protect heritage here. In the process of understanding heritage, I have discovered ideas which potentially are of great pertinence today. This also can change the argument over whether an historic building can be saved when instead of presenting as a risk, it can be shown in fact to be safer than newer buildings of RC nearby.

At this point, in my WCDRR Keynote, I described the transformation of engineering design of buildings in the modern era to an emphasis and focus on structural frames – braced frames and moment frames – leading up to the invention and proliferation of 'skyscrapers.' This has left behind what had been for thousands of years an emphasis on masonry construction with timber floors and roofs, from small houses to massive structures from Hagia Sophia in Istanbul to St. Peters in Rome. These are what I call by comparison to frames, 'solid wall' buildings of mud, stone or brick.

When it comes to earthquakes, the frame structures have had a mixed history – from extraordinary resilience, to catastrophic collapse. The point to be made here is not to say that masonry buildings have now proven to be better than referenced in the quote by GEM at the beginning of this talk, or that the examples of modern building collapses are all explained because they failed to be in conformance to the building codes. The recent earthquakes in Nepal, that have occurred subsequent to the presentation of this address in Japan, certainly has shown a preponderance of examples of failure of masonry buildings while many concrete buildings have done better.

The point is actually much more basic, and yet timeless. It is that the art of building in general for a community, society, and nation as a whole most importantly must focus not on what is possible, but what is probable.

If one focuses on this basic philosophical point, one inevitably must come to the conclusion that alongside of the understanding and further research on structural design of frames, solid wall buildings need to be understood as well. This is because they most often are the technology and materials that ordinary people have affordable access to. A good example of this difference is demonstrated by the fact that the sections of the Indian and the Nepal National Building Codes that deal with non-engineered construction are specific only to timber and masonry construction of stone, brick or unfired clay. They definitively do not include RC moment frames.

In Haiti, it is the solid walls of masonry that kept the still standing slum settlements from collapsing while almost half of the contractor-built concrete frame structures in Port-au-Prince collapsed both from poor construction and environmental decay. It was in fact the infill masonry that actually was responsible for the survival of the first generation skyscrapers in San Francisco during the 1906 earthquake, rather than their frames alone. It was the timber-laced and infill masonry that kept houses standing, both in 1999 in Turkey, in 2001 in Gujarat, India, and in 2005 in both in India and Pakistan,

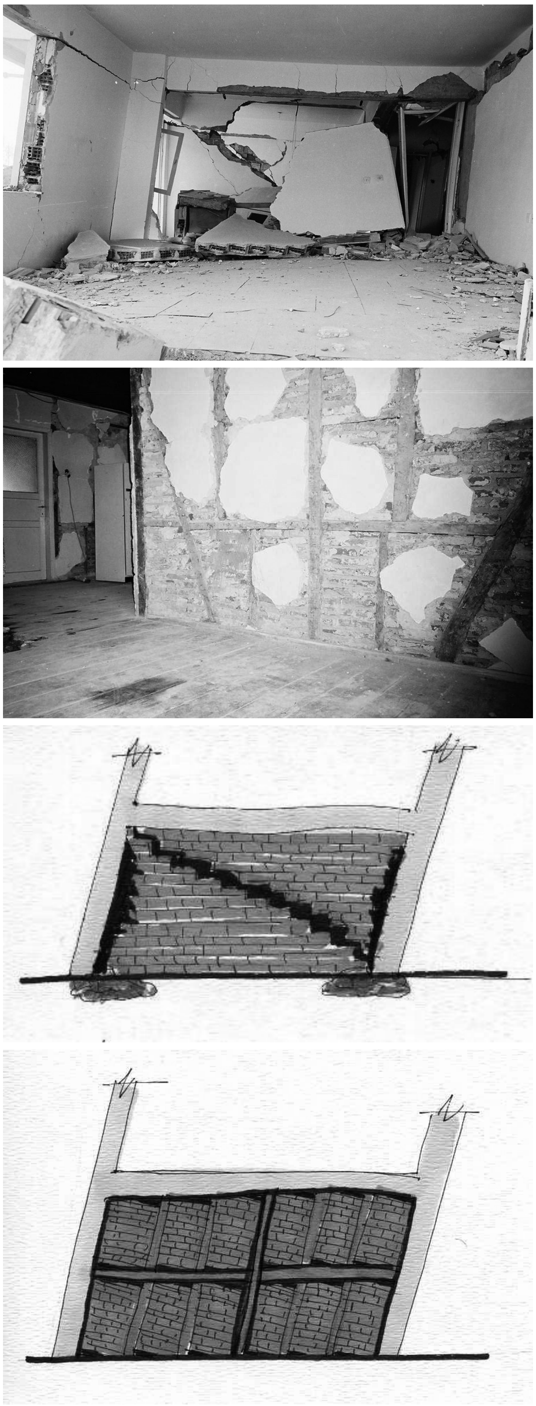

Fig. 10. Brittle infill walls (top photo and top drawing) compared with traditional *hımış* (2nd from top) and with proposed "Armature Crosswall" (bottom drawing).

while scores of modern concrete buildings crumbled.

It is from these examples that the concept of "Armature Crosswalls" was proposed and described at the WCDRR illustrated in Figure 10. The principle is to replace the usually stiff but brittle infill masonry walls in modern concrete moment frame construction with a sub-frame with smaller more flexible masonry panels that can give in an earthquake without collapsing, providing the kind of friction and ductile behavior that can contribute to preventing the RC frame from collapsing.[10]

In closing, I want to give homage to concrete where it is due. Here shown in Figure 11 is a building shown in a drawing by the 18th century Italian artist Piranesi combined with a photo of it taken by me only a decade ago.

It is 2000 years old, and it has probably not seen any maintenance for probably 1800 of those 2000 years. This roof is of concrete – unreinforced concrete! It gives real pause to look at this example and think about buildings, and about what we can learn from what people have done in the past. Thank you.

1 Collapsed minaret and mosque in Sakaria, Turkey, 1999 http://www.epa.eu/disasters-photos/earthquake-photos/turkey-earthquake-collapsed-mosque-photos-99450569
2 Gülhan, Demet, and İnci Özyörük Güney(2000) "The Behaviour of Traditional Building Systems against Earthquake and Its Comparison to Reinforced Concrete Frame Systems," *Conference Proceedings for Earthquake-Safe: an International Conference on the Seismic Performance of Traditional Buildings*. Istanbul, Turkey, 2000. (http://www.icomos.org/iiwc/seismic/Gulhan.pdf)
3 See photo at https://www.pinterest.com/pin/284852745157800104/ or Google search string: "tsunami tohoku japan boat on roof"
4 For more information, see : 2004 "Soil Dynamics and the Earthquake Destruction of the Arg-e Bam," *Iranian Journal of Seismology and Earthquake Engineering*, Tehran, Iran, Special Issue on 26 December 2003 Bam Earthquake, 2004, Volume 5:#4 & Volume 6:#1. (www.conservationtech.com) .
5 See http://www.conservationtech.com/haiti.html for link to free PDF. Page 48.
6 IBID, Cover + pages 29 and 64.
7 For a detailed description of the subject of Kashmir, please see the book by Langenbach, *Don't Tear It Down! Preserving the Earthquake Resistant Vernacular Architecture of Kashmir*, published by UNESCO, 2009. (www.traditional-is-modern.net)
8 Arthur Neve, *Thirty Years in Kashmir*, E. Arnold, London, 1913.
9 See *World Disaster Report 2014*, Int'l Red Cross and Red Crescent Societies, Chapter 5. (http://www.ifrc.org/world-disasters-report-2014).
10 See http://www.conservationtech.com/armaturecrosswalls.html

Fig. 11. Grandi Terme in Hadrian's villa, near Rome, Italy, with engraving by Piranesi, ca. 1750.