OVERVIEW
The Mw7.9 earthquake in Wenchuan, China on 12 May 2008 was catastrophic in terms of lives lost and buildings destroyed or damaged: 69,185 people killed, 374,171 injured, 18,467 still listed as missing. More than 7.79 million houses were destroyed, and 24.5 million damaged.

The overwhelming losses in this earthquake in both urban (multi-story) and rural buildings can be attributed in large part to use of unreinforced masonry with precast concrete plank roofs and floors (Figs. 1 and 2). There is, however, at least one compelling example of excellent performance of confined masonry houses reportedly built according to the Chinese Seismic Code (Fig. 2).

This report provides more details on the three masonry systems: (1) unreinforced masonry with timber roof, (2) unreinforced masonry with precast concrete plank roof, and confined masonry. See Table 1 for a listing of the types of residential structures surveyed during the reconnaissance.

Observations were made by Dr. Elizabeth Hausler during a field reconnaissance to the earthquake-affected area between 15 and 24 June 2008. Dr. Hausler’s visit to Sichuan was coordinated through the 10 + 10 Strategic Partnership between the University of California system and 10 universities in China. This report includes a short list of opportunities for collaboration identified during the field visit, in single family housing and other areas.

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The visit was made possible by Dr. Gretchen Kalonji on the UC side and Profs. Guan Ping and Tang Ya on the Sichuan University side. Dr. Hausler was hosted by Prof. Li Bixiong, the director of the civil engineering department at Sichuan University. Kind assistance from all parties, including several students at Sichuan University, is greatly appreciated.
Exact positions are not available. Upon learning that visitors had been detained for traveling with GPS units in China, I opted to leave my GPS unit in left luggage at Jakarta airport. More detailed location information is available upon request.
(1) Unreinforced Masonry with Timber Roof

Single story unreinforced masonry buildings with pitched or hipped timber roofs experienced light to heavy damage. Compared to their counterparts with precast concrete planks roofs discussed in the next section, these simple URMs with lightweight roofs performed better. See Figs 3 through 18 for examples. As is typical for unreinforced masonry, gable wall cracks and failures wire common. Materials used are as follows:

- FOUNDATION: Shallow strip footing using the same material as the wall.
- WALLS: Fired brick or concrete block masonry in cement or cement/lime mortar. Some collapsed buildings and walls appeared to have very little cement in the mortar. Half-brick wide wall using running bond is more common than the full-brick wide bonding used for houses with precast concrete plank roofs, discussed in the next section. The solid, fired clay bricks sampled during the reconnaissance measured 24 by 11 by 5 cm and are machine-pressed at local factories and fired with charcoal. Based on limited sampling, bricks in Pengzhou appear to be slightly better quality than those in the Jiezi area, which may be hand-pressed. Brick quality may be variable throughout the affected region, but in general, appears to be higher than in Southeast Asia, where bricks are mixed and pressed by hand and baked in wood-fired kilns. Timber is used for window and door frames.
- CEILING AND ROOF: Pitched or hipped timber trusses or timber rafters. Timber is not sawn; elements are tied with wire or joined or steel pins. Roofs are covered with clay tiles or corrugated ceramic or cement fiber sheets. Bamboo was common for ceilings.
Fig 7. Crack in masonry gable wall, Danan Village. IMG0116

Fig 8. Undamaged masonry gable wall, Danan Village IMG0118

Fig 9. Typical ceiling. IMG0115

Fig 10. Typical truss. IMG0098

Fig 11. Corrugated cement and fiber sheets. IMG1130

Fig 12. Typical traditional roofing system with simple clay tiles, free to slide during shaking. IMG0094

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New (2006) unreinforced masonry buildings with pitched timber roofs were observed in Gao Yuan village (Figs. 13 and 14). Damage was limited to the gable walls, except for the only building that wasn’t finished (Figs 15 through 18). This building was more heavily damaged, perhaps because the interior and exterior wall tiling had not been completed.
(2) Unreinforced Masonry with Precast Concrete Plank Roof/Floor

These buildings collapsed in massive numbers. Nearly every pile of rubble observed during the reconnaissance in the rural areas included these precast planks. They were responsible for building collapses in peri-urban areas as well; this structural system is the first collapsed encountered when traveling on local roads out of Chengdu towards Dujiangyan.

These buildings differ from their URM with timber roof counterparts in that the masonry bonding is usually full-brick wide for the first story, and a second story is common. The second story may use half-brick wide bonding. The precast concrete planks are not connected to the walls, nor were they confined by a ring beam, as is required in the Chinese Seismic code. Some of the planks have very short steel reinforcement available for a connection, but this steel appears to have been bent out of the way and plastered over. The planks are prefabricated by small businesses and sold for around US$13 per plank, depending on the vendor and the size.

**Fig 19.** Collapsed URM with precast concrete plank, near Xiao Yu Dong Bridge. IMG0433

**Fig 20.** Lack of connection or confinement of precast concrete plank with URM wall, near Xiao Yu Dong Bridge. IMG0431

**Fig 21.** Collapsed two-story, rural unreinforced masonry with precast concrete plank floor and roof, Danan Village. IMG0085

**Fig 22.** Partially collapsed two-story, rural unreinforced masonry with precast concrete plank floor and roof, near Xiao Yu Dong Bridge. IMG0436
(3) **Confined Masonry**

Two-story confined masonry residential buildings built in 2006 reportedly according to the Chinese Seismic Code performed well in this earthquake. Located in Gao Yuan Village, within 500m of evidence of permanent ground displacement and a bridge collapse, no cracks or other damage was observed during a quick survey. These buildings were designed and built by a private company. Efforts to obtain detailed design drawings are currently being made. The walls are full-brick wide, the columns are cast after the wall is built as is typical practice for confined masonry (see an example of the toothing used at another building site near Pengzhou in Fig. 26), and the floors are cast-in-place reinforced concrete slab.

**Fig 23.** Two-story confined masonry, no damage, Gao Yuan village. IMG0552

**Fig 24.** Two-story confined masonry, no damage, tiled exterior, collapsed URM gate in foreground, Gao Yuan village. IMG0545

**Fig 25.** Two-story confined masonry, no damage, collapsed URM with precast plank in foreground, Gao Yuan village. IMG0586

**Fig 26.** Confined masonry exterior wall for industrial building under construction, note toothing and steel connection between column and wall, near Pengzhou. IMG0347
A Note on Transitional Shelter
Transitional shelters consisting of Styrofoam panels on steel frames were being erected in large numbers during the reconnaissance (Figs. 27 and 28). Rural homeowners had also taken the initiative to erect simple shelters using recycled materials (Figs. 29 and 30).

Fig 27. Transitional shelter near Jiezi. IMG1164

Fig 28. Transitional shelter near Jiezi. IMG1163

Fig 29. Homeowner-built transitional shelter, rural Pengzhou. IMG0072

Fig 30. Tents and transitional shelter, Danan Village. IMG0146