

Table 1. Common Structural Systems for Residential Buildings

Structural System	Examples		Problems and Observations	What Should Be Done
<p>TIMBER frame with/without masonry skirt and lightweight wall infill of plastered bamboo mat, pitched timber truss roof with clay tiles</p> <p><i>More common for temples, and community buildings than houses</i></p>	 <p>Jiezi City, Near Dujiangyan</p>		<p>ACCEPTABLE. Very few problems observed; collapses of temple and resort-type structures near Gao Yuan were result of ground displacement, not structural issue.</p>	<p>EXPLORE cultural appropriateness and cost, and PROMOTE this type of construction, but probably less common now due cost and availability of timber, cultural preference for masonry system.</p>
<p>UNREINFORCED MASONRY posts mixed with TIMBER frame elements, masonry skirt, and lightweight wall infill of plastered bamboo mat, pitched timber truss roof with clay tiles</p> <p><i>Older construction common for RURAL workshops, shops and a few houses</i></p>	 <p>Near Xiao Yu Dong Bridge</p>	 <p>Near Xiao Yu Dong Bridge</p>	<p>ACCEPTABLE. Some collapse of URM posts; issues with timber decay; masonry skirt is not connected to the frame elements.</p>	<p>EXPLORE cultural appropriateness and cost, and PROMOTE with some modifications to protect the timber against weathering and pests, anchor the masonry skirt to the frame or posts. Like timber frame, probably less common now due cost and availability of timber, cultural preference for masonry system.</p>
<p>UNREINFORCED MASONRY single story with pitched or hipped, timber log roof covered with clay tiles</p> <p><i>Common for RURAL, single-story houses and other buildings</i></p>	 <p>Near Xiao Yu Dong Bridge</p>	 <p>Gao Yuan Village (Wenchuan)</p>	<p>Performance was MIXED. Performed better than URM with precast concrete plank roof (see next), but buildings of this type collapsed. In some villages, the URM with timber roof remained completely intact or a few cracks, while all URM with precast concrete roofs collapsed. Lighter roof, better workmanship, use of lime in mortar?</p>	<p>For very simple, symmetric, single-story building built with good workmanship, may be a VIABLE low-cost option for rural single family houses. Hipped roofs should be promoted to avoid masonry gables. Technical assistance and some seismic analysis/research needed. Or, shift to confined masonry (more expensive).</p>

Structural System	Examples		Problems and Observations	What Should Be Done
<p>UNREINFORCED MASONRY single or two-story with precast concrete plank roof and floor</p> <p><i>Very common for RURAL and peri-urban, single or two-story houses and other buildings</i></p>	 <p>Near Xiao Yu Dong Bridge</p>	 <p>Near Xiao Yu Dong Bridge</p>	<p>MOST DEADLY type of rural residential construction. Nearly every pile of rubble that hadn't been cleared at the time of the site visit included precast planks. No connection between the wall and plank, planks are not confined by a ring beam.</p>	<p>PROHIBIT the use of precast concrete planks by providing simple information on the dangers of this technology, and promoting alternatives such as single story URM with timber roof and/or confined masonry. <i>Note confined masonry may be too expensive for rural homeowners.</i></p>
<p>UNREINFORCED MASONRY multi-story building with precast concrete plank roof and floors</p> <p><i>3-7 story buildings common in urban areas, often with open RC frame ground floor, occasionally with reinforced concrete confining tie columns in upper floors</i></p>	 <p>Dujiangyan, near Hehuachi Market</p>	 <p>Dujiangyan, near Hehuachi Market</p>	<p>MOST DEADLY for urban residential, school, and commercial construction. Same as the rural dwellings: no or very weak connections between plank and walls, plank and plank; no ring beam, heavy mass above open frame ground floor.</p>	<p>PROHIBIT the use of precast concrete planks. Prohibit use of unreinforced masonry for multi-story buildings. Use confined masonry instead up to maximum three stories (see Chinese Seismic Code).</p>
<p>CONFINED MASONRY two story buildings</p> <p><i>Seen in a rural, hillside setting, although probably increasingly common for new urban multi-story buildings designed according to Chinese Seismic Code. Note news reports indicate that masonry structures greater than 3 stories are no longer permitted in some provinces.</i></p>	 <p>Gao Yuan Village (Wenchuan)</p>	 <p>Pengzhou, confined masonry exterior wall on industrial building. Defining feature of confined masonry is that the tie column is cast after wall is built, and acts primarily in tension to confine the load-bearing masonry.</p>	<p>FLAWLESS – no cracks or other evidence of damage in a quick survey in one village within 500m of possible surface expression of fault rupture.</p>	<p>USE THIS TECHNOLOGY for up to three stories according to the Chinese Seismic Code. Simple, prescriptive design and construction guidelines and technology dissemination are needed.</p>

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<p>REINFORCED CONCRETE FRAME with MASONRY INFILL multi-story buildings in urban areas</p> <p><i>3-7 story buildings common in urban areas, often with soft ground floor</i></p>			<p>DAMAGED buildings are spread throughout Dujiangyan.</p>	<p>A big question I leave up to the structural engineers... RC frame with masonry infill is problematic but so common and prevalent in Asia, it's not possible to simply say don't use it, until another lower-cost, easier to use, more locally available system exists....</p>
	Dujiangyan	Dujiangyan		