Earthquake Hazard Information – Photos of Earthquake Damage, Modes of building Failure – Part 1 (Information for interpreting the results of building contest and shake table testing; L. Braile, 03/12/03)

In the building contest, we test model buildings on a shake table using accelerations and frequencies that are similar to those associated with actual earthquake shaking that affects buildings. Many types of building, structure or ground failure are observed in actual earthquake damage. Many of these failure modes are also visible in the shake table testing of model buildings. Others, such as poor connection to foundation, fallen objects, or ground failure can be simulated with appropriate modification of the model building and the shake table testing. Photos of some building damage form some notable earthquakes and some associated intensity maps are shown below. The examples are classified by the dominant mode of failure observed.

1. Soft first story/inadequate shear strength

Loma Prieta earthquake damage in San Francisco. The soft first story is due to construction of garages in the first story and resultant reduction in shear strength. (Photo from: http://earthquake.usgs.gov/bytopic/photos.html)
Northridge earthquake soft first story (parking level) damage. (Photo from: http://www.ngdc.noaa.gov/seg/hazard/slideset/earthquakes/)
Horizontal-component peak acceleration versus distance from the earthquake fault. The solid circles represent Northridge data from free-field sites underlain by stiff soil or soft rock. The curves represent the average peak acceleration (solid line) and the corresponding ±1 standard-deviation accelerations (dashed lines) expected for a magnitude 6.7, reverse-faulting earthquake. Graph provided by David Boore.

Northridge earthquake location map. The dashed line encloses the area of strongest shaking, where peak horizontal accelerations exceeded one-half the acceleration of gravity. Especially high accelerations are shown for Tarzana, Granada Hills, Sylmar, and Newhall. The star designates the epicenter of the Northridge earthquake, the point on the surface directly above the hypocenter, where the initial rupture on the fault occurred.

Area of strong ground shaking (>0.5 g) for the Northridge earthquake. (Map from: Celebi, Mehmet, and R. D. Brown, Jr., Structural damage, Earthquakes and Volcanoes, Vol. 25, No. 2, 94-102, 1994)
2. Inadequate attachment of building to foundation
Wood-frame house shifted off its foundation in Fillmore. In many cases, damage to older wood-frame houses could be attributed to their not being securely bolted to their foundation or to failure of cripple-stud walls in the crawl space between the foundation and first floor. Photograph by J. W. Dewey.

House shifted off its foundation, Loma Prieta earthquake. (Photo from: http://earthquake.usgs.gov/bytopic/photos.html)

3. Column failure/ broken joints/too much weight for building design or construction
Column failure, Loma Prieta earthquake. (Photo from: http://earthquake.usgs.gov/bytopic/photos.html)
Column failure on interstate highway overpass, Northridge earthquake. (Photo from: http://www.ngdc.noaa.gov/seg/hazard/slideset/earthquakes/)
Column failure on interstate highway overpass, Northridge earthquake. (Photo from: http://www.ngdc.noaa.gov/seg/hazard/slideset/earthquakes/)
Column failure on interstate highway overpass, Northridge earthquake. (Photo from: http://earthquake.usgs.gov/bytopic/photos.html)
Column failure (inadequate connection to decking) on interstate highway overpass, Northridge earthquake. (Photo from: Cover photo, Earthquakes and Volcanoes, Vol. 25, No. 2, 1994)