Post-Mainshock Probabilistic Risk Quantification: Why and How?

2012 EERI Annual Meeting & National Earthquake Conference

Nicolas Luco
Research Structural Engineer
USGS – Golden, CO

Aftershocks can be …

- … closer to your structure of interest,
- … of a larger magnitude,
- … numerous,
- … persistent over a long time period,
- … *and damaging*.

- Same for “triggered” or “clustered” earthquakes.

Risk analysis is already the basis for …

- … long-term or "pre-earthquake" mitigation via insurance,
- … ground motion maps for "building codes" (2012 IBC / ASCE 7-10, ASCE 43-05 for nuclear power plants), and
- … next-generation seismic design procedures for new & existing buildings (ATC-58).

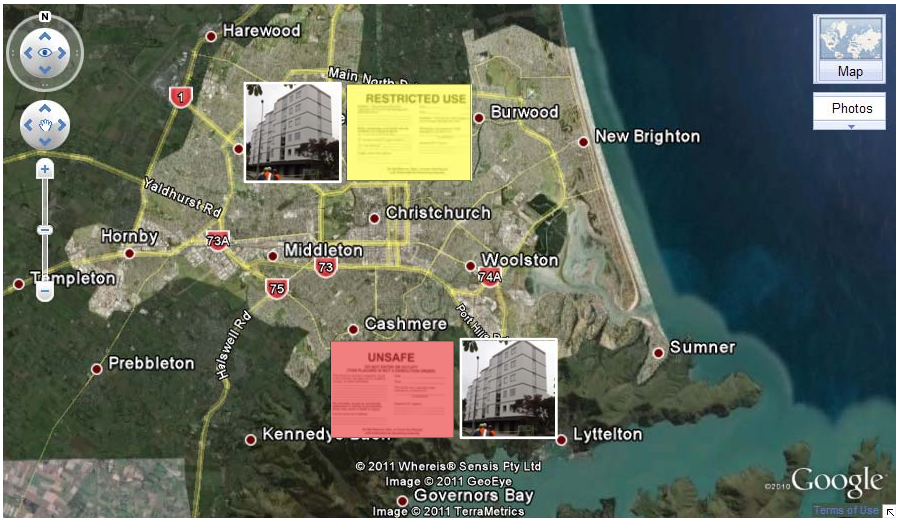
"Aftershock risk analysis" can be basis for …

- … short-term or "post-earthquake" mitigation decisions that hinge more directly on what ***could*** happen (e.g. collapse in an aftershock) that what ***has*** happened (i.e. damage state immediately after mainshock).
- For example …

Building Tagging

- Aftershock risk analysis information can be automated

Inspection Prioritization



"Aftershock risk analysis" projects …

- Yeo & Cornell, 2005 (PEER Report 2005/13)
- PEER "Advanced Seismic Assessment Guidelines" (Bazzurro *et al*, 2006)
- SCEC "Automated calculation of damage state exceedance probabilities from aftershocks" (Gerstenbeger et al, 2007)
- NZ Earthquake Commisssion (Gerstenberger et al, 2012)
- CU Boulder & USGS (Liel et al, 2013)
- NSF (Li & van de Lindt et al, 2014)

"Risk Integral"

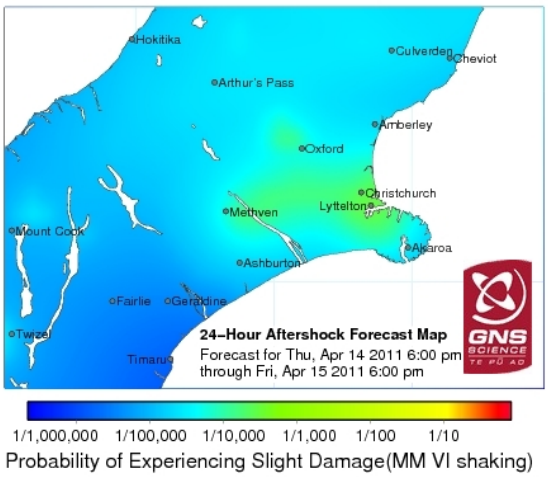
- Combination of *ground motion hazard curve* & *building fragility curve* (e.g. McGuire 2004)

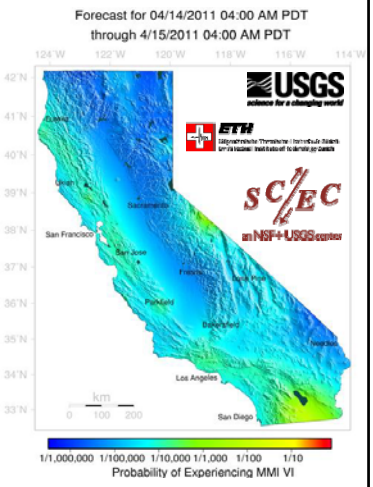
$$\lambda[\text{Collapse}] = \int_0^\infty \Pr[\text{Collapse} \mid \text{IM} = a] \left| \frac{\mathrm{d}\lambda[\text{IM} > a]}{\mathrm{d}a} \right| \mathrm{d}a$$

Collapse Risk (in time T) — Building Fragility Curve — Ground Motion Hazard Curve

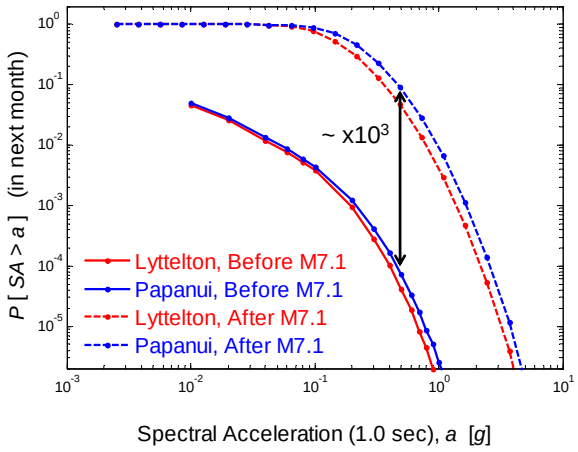
- An application of the total probability theorem

Aftershock Ground Motion Hazard

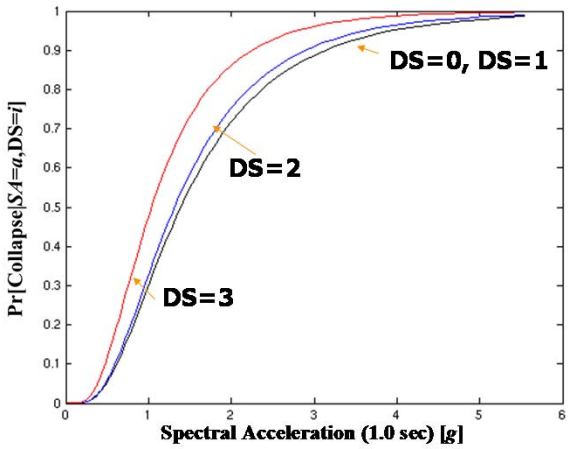




Aftershock Hazard Curves



Damaged-Structure Fragility Curves



Post-Earthquake Damage State?

- Can be ascertained by …
  - post-earthquake building inspection
  - risk integral with ShakeMap ground motion "hazard"
  - building instrumentation
- Uncertainty in post-earthquake damage state accounted for via theorem of total probability, i.e. …

$$\Pr[\text{Collapse} \mid \text{IM} = a] = \sum_{i=1}^{n} \Pr[\text{Collapse} \mid \text{IM} = a, \text{DS} = i] \Pr[\text{DS} = i]$$

Related Problems

- Pre-mainshock risk analysis that accounts for aftershocks, triggered earthquakes, and clusters (e.g. van de Lindt & Li's NSF project)
- Deterministic scenarios of sequences of large earthquakes like New Madrid 1811-1812 (using damaged-structure fragilities)

Parting Thoughts

- Earthquake engineers should more fully utilize aftershock hazard information from earthquake scientists
- Building tagging & inspection prioritization should be (at least partially) based on post-mainshock probabilistic risk quantification
- Reconnaissance data should include performance of mainshock-damaged buildings in aftershocks