Earthquake Damage

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Damaging effects of earthquakes

- Direct effects
  - Ground failures or instabilities due to ground failures
  - Vibrations transmitted from the ground to the structure
- Indirect effects
  - Consequential phenomena

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Direct effects of earthquakes

- Ground failures (or instabilities due to ground failures)
  - Surface faulting or fault rupture/movement
  - Vibration of soil (or effects of seismic waves)
    - Ground cracking
    - **Liquefaction**
    - Ground lurching
    - Differential settlement
    - Lateral spreading
    - Landslide

Causes most damage!

- Vibrations transmitted from the ground to the structure – Site effects

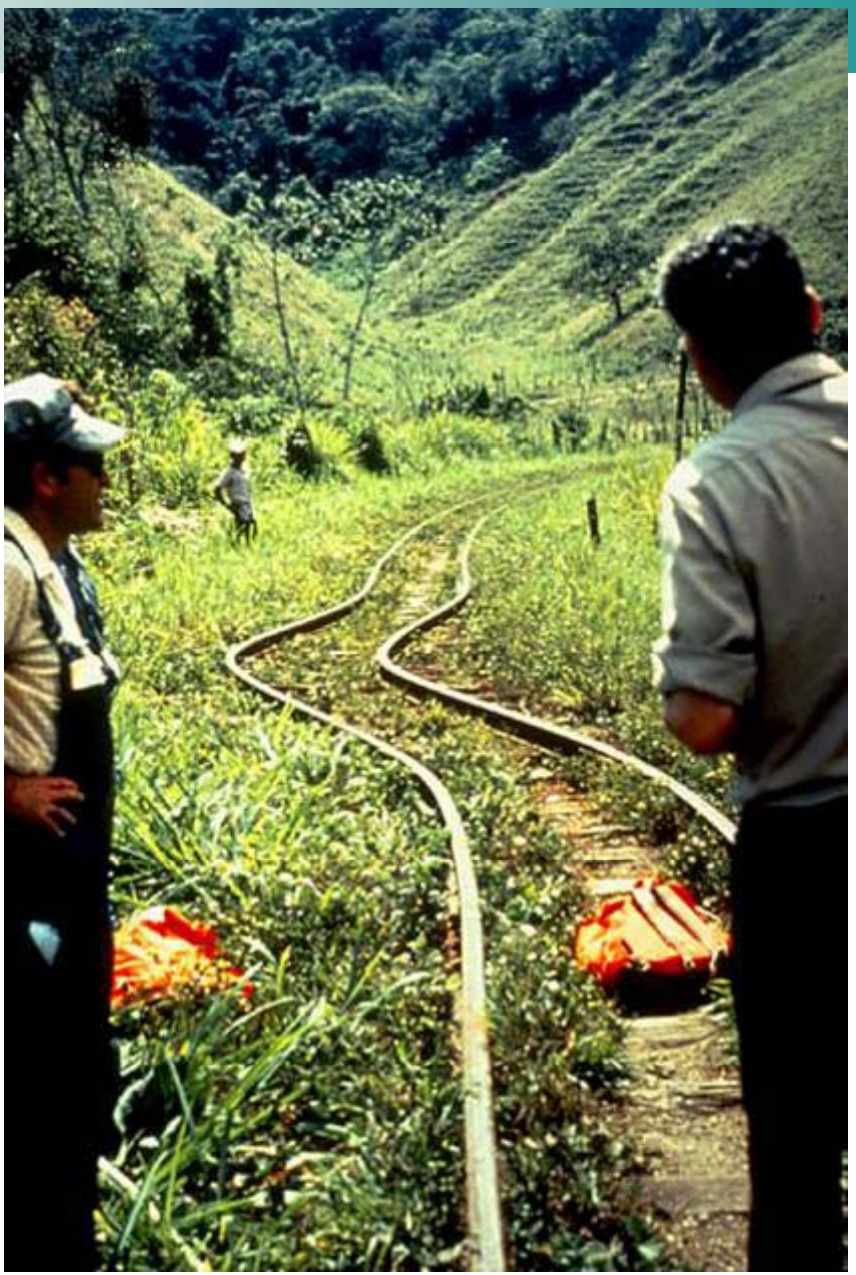
Ground failures

- Surface faulting
  - Ground displacement
  - Ground cracking
  - Ground lurching

Surface faulting

Normal fault. Scarp near Beni Rached. 1980 El Asnam Earthquake, Algeria

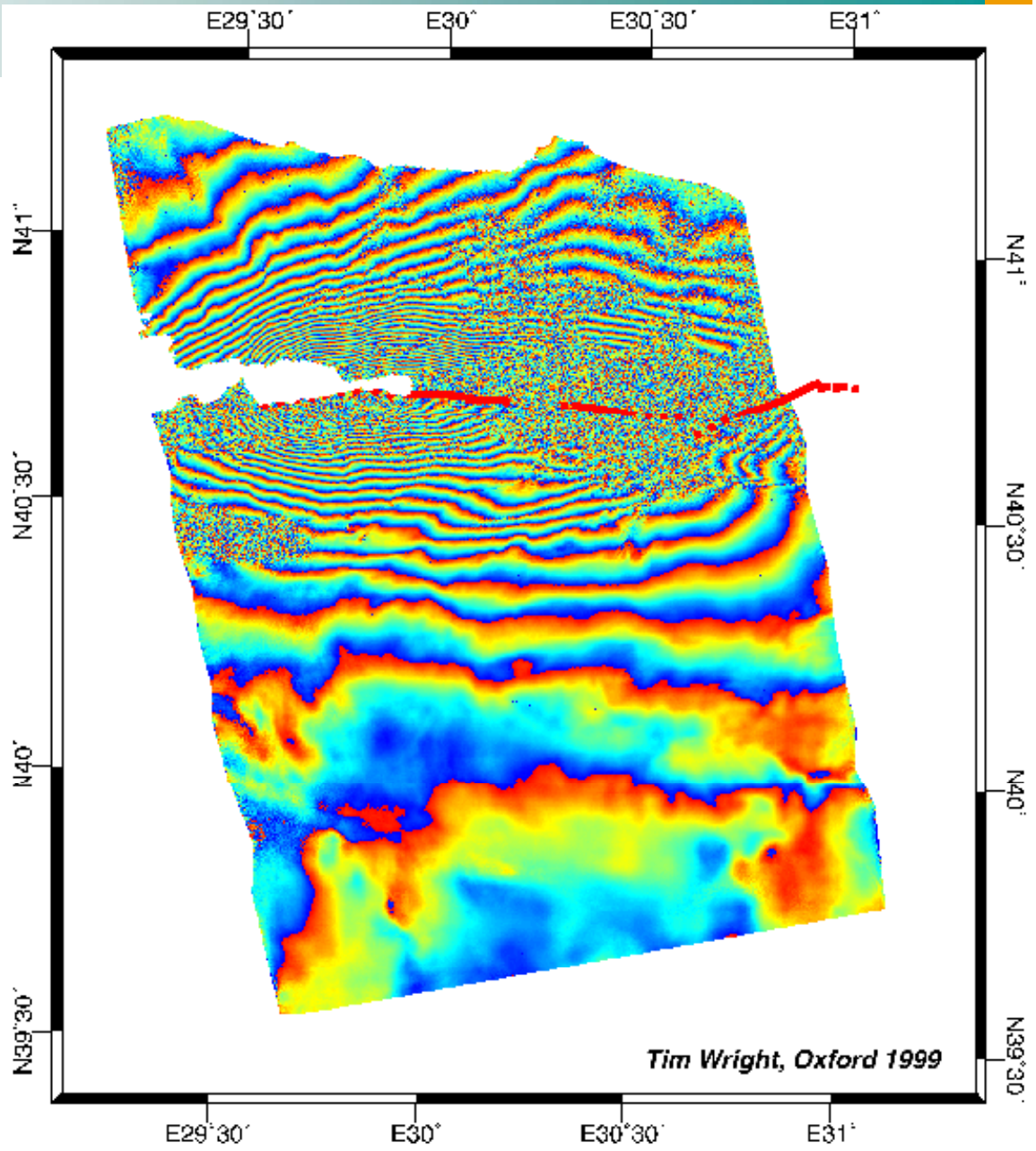
Surface faulting



Bent rails of the railroad between Guatemala City and Puerto Barrios caused by the 1976 Guatemala Earthquake

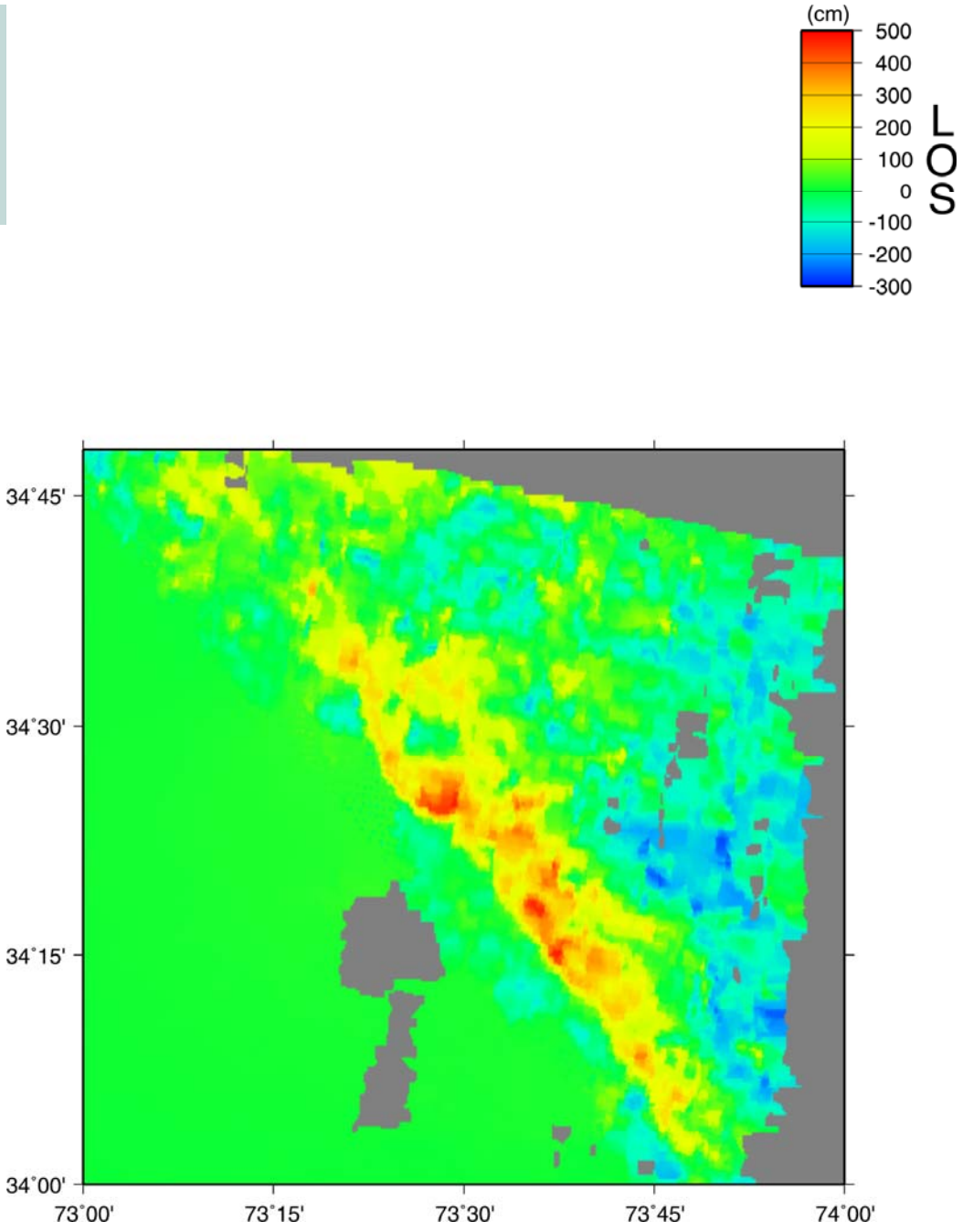
Surface faulting

- The 17 August 1999, Izmit Earthquake
- Displacements from SAR Interferometry



ENVISAT inSAR

- Kashmir Earthquake
- 8 Oct. 2005
- Vertical displacement



Vibration of soil: Liquefaction

Displacement and tilting of houses due to soil liquefaction in the Turnagain Height area of Anchorage during the 1964 Alaska Earthquake

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Vibration of soil: Liquefaction

Tilting of apartment buildings at Kawagishi-Cho, Niigata, produced by liquefaction of the soil during the 1964 Niigata Earthquake

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Vibration of soil: differential settlement

One-story masonry house in a main housing development in the town of Caucete, damaged due to differential settlement caused by liquefaction in the 1977 Caucete Earthquake, Argentina

Direct effects: landslides due to topographic amplification

Santa Tecla (Las Colinas) landslide, Jan 13 2001 earthquake, El Salvador

Direct effects: landslides (Kashmir)

Indirect effects of earthquakes, consequential phenomena

- Tsunamis
- Seiches
- Floods
- Fires

Indirect effects: Tsunamis

- Near-shore or undersea earthquake causing sudden (vertical) movement of the seafloor
- As wave approaches shallow water, it slows down, but energy remains constant, causing waves to increase in height (up to 30 m.)

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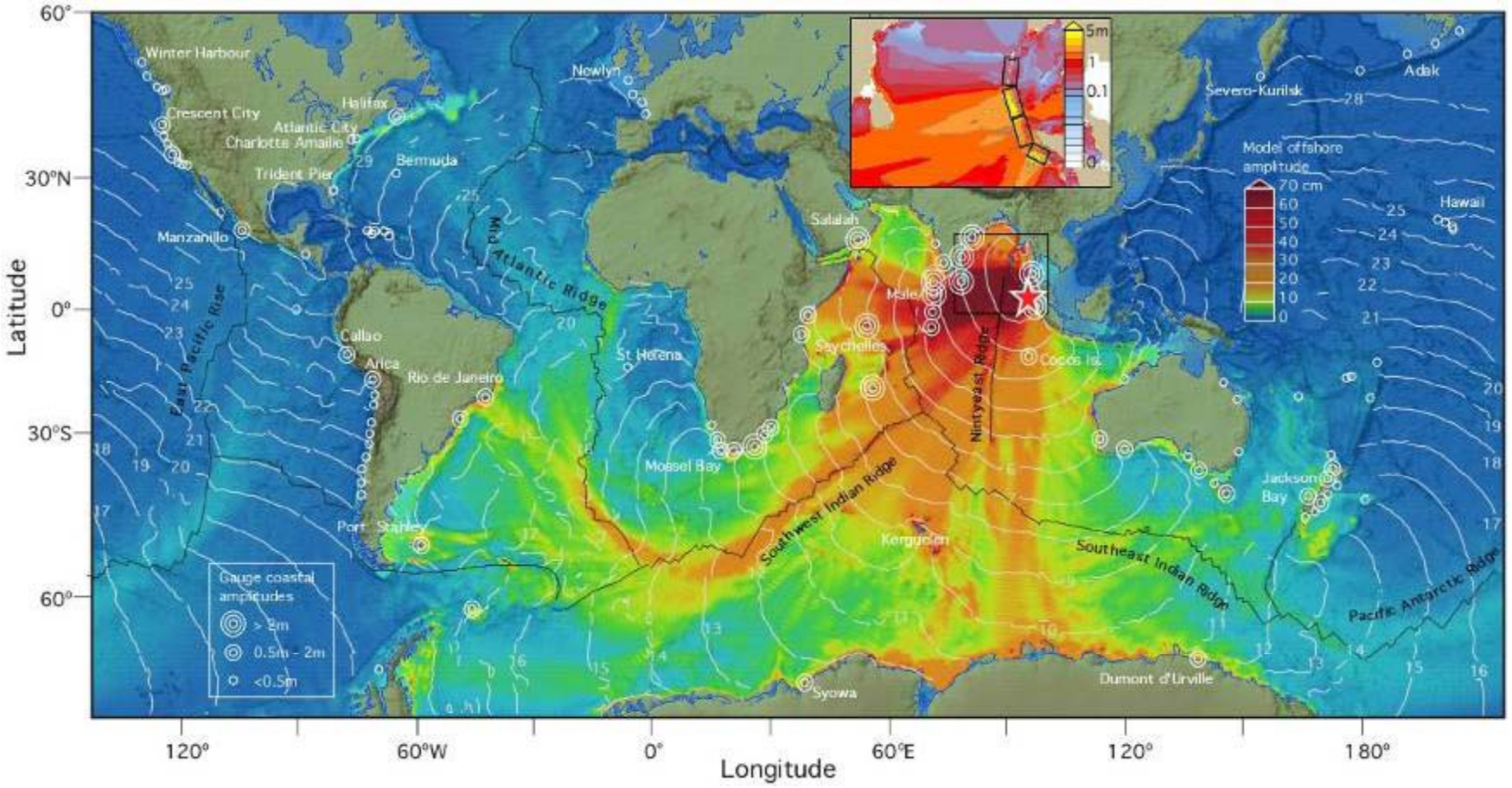
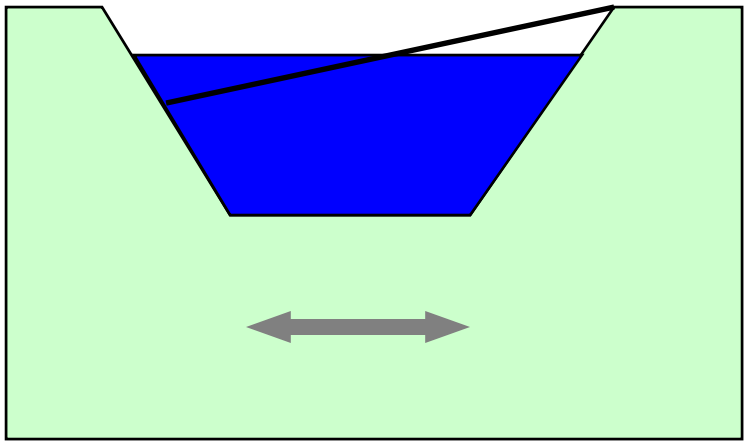
26 December 2004 Sumatra Tsunami



Indirect effects: seiches

- Within lake, bay, harbour – enclosed water body
- “Bathtub effect”



Indirect effects: flooding caused by regional subsidence

- Izmit (Kocaeli) Turkey Earthquake, August 17, 1999

Indirect effect: fires

Fire in central Kobe

Large fires following strong earthquakes have long been considered to be capable of producing losses comparable to those resulting from the shaking

17 January 1995, Kobe Earthquake

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Vibrations transmitted from the ground to the structure

- Structural damage:
  - Torsion
  - Soft storey
  - Pounding
  - Short column

- Caused by “site effects”:
  - Resonance, soft ground effects
  - Topographic amplification

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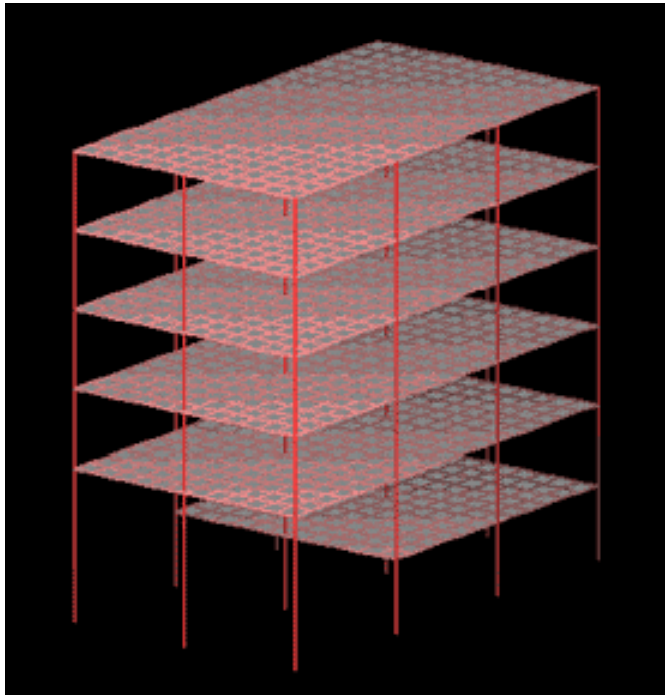
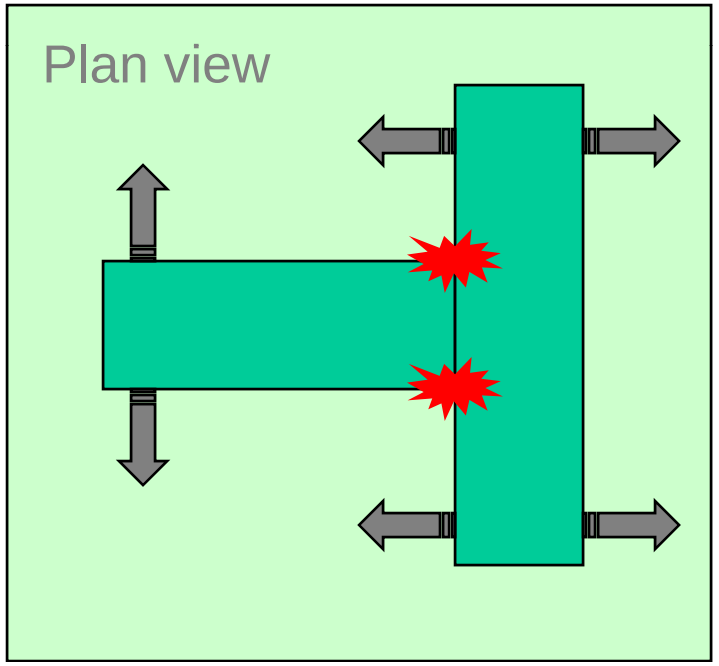
Torsion

- Irregular layout or wrong distribution of weights can create large torsional stresses, resulting in damage and/or failure





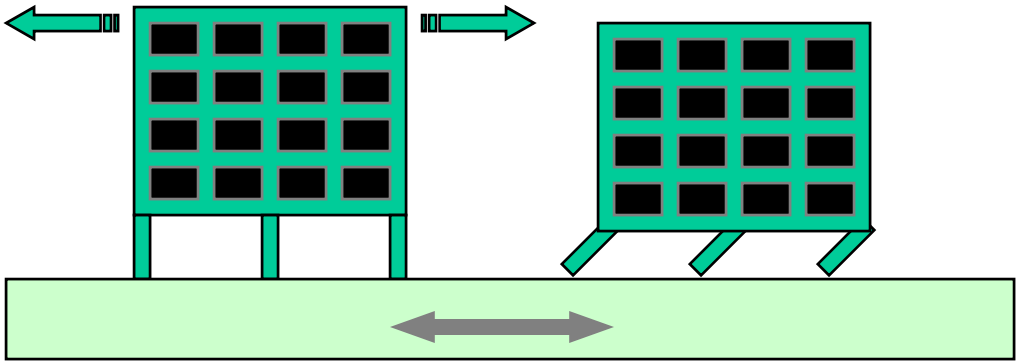
Torsion

Lack of torsional resistance in the columns at the periphery of the building

Armenia, Colombia
25 January 1999, Quindío earthquake, Colombia
M 6.2

Soft storey

Soft storey: stiffer structural elements which are present in the upper stories are missing at the ground floor - Gujarat earthquake, 26 Jan 2001

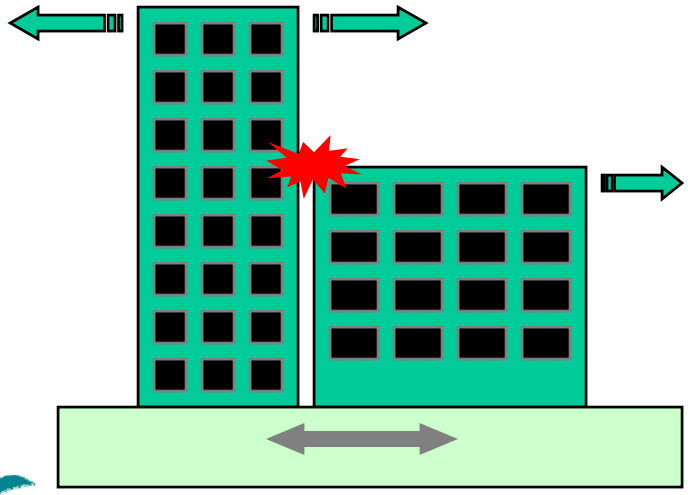


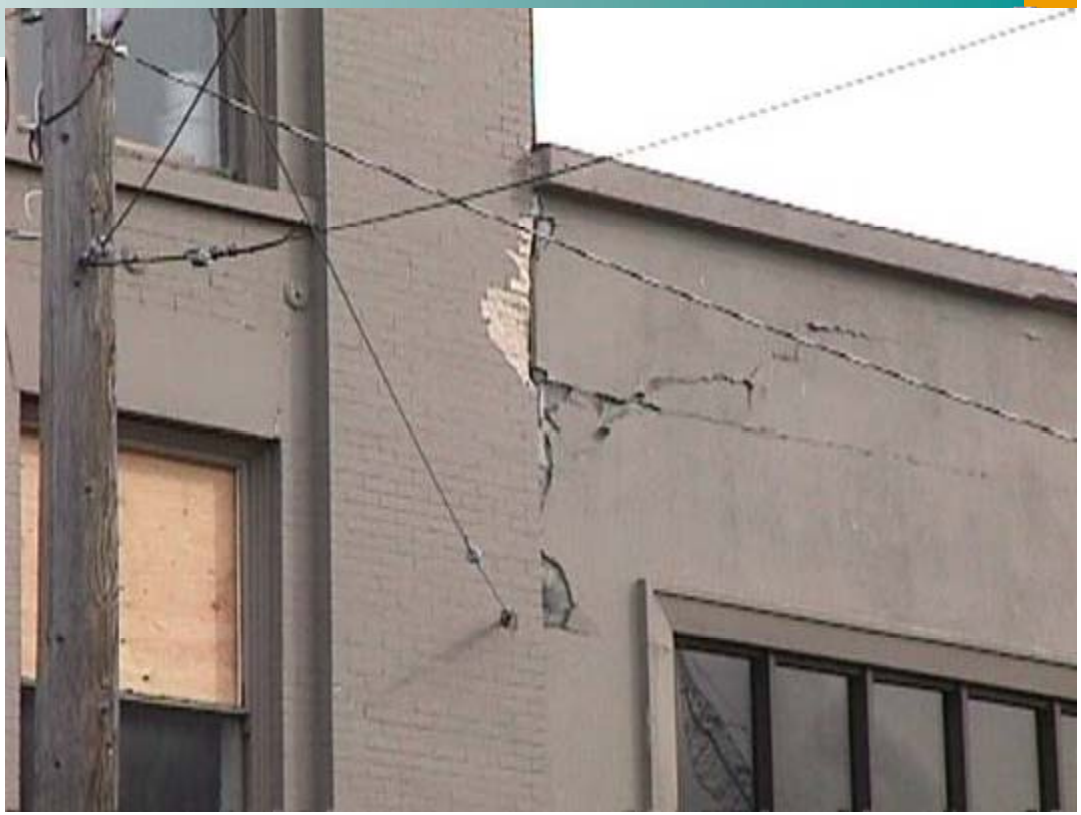
Soft storey

The ground floors of many buildings in Turkey are open spaces reserved for stores and show rooms, with insufficient numbers of columns to support the upper floors – Duzce, Izmit earthquake, 17 August 1999, Turkey (M_W 7.5)

Pounding

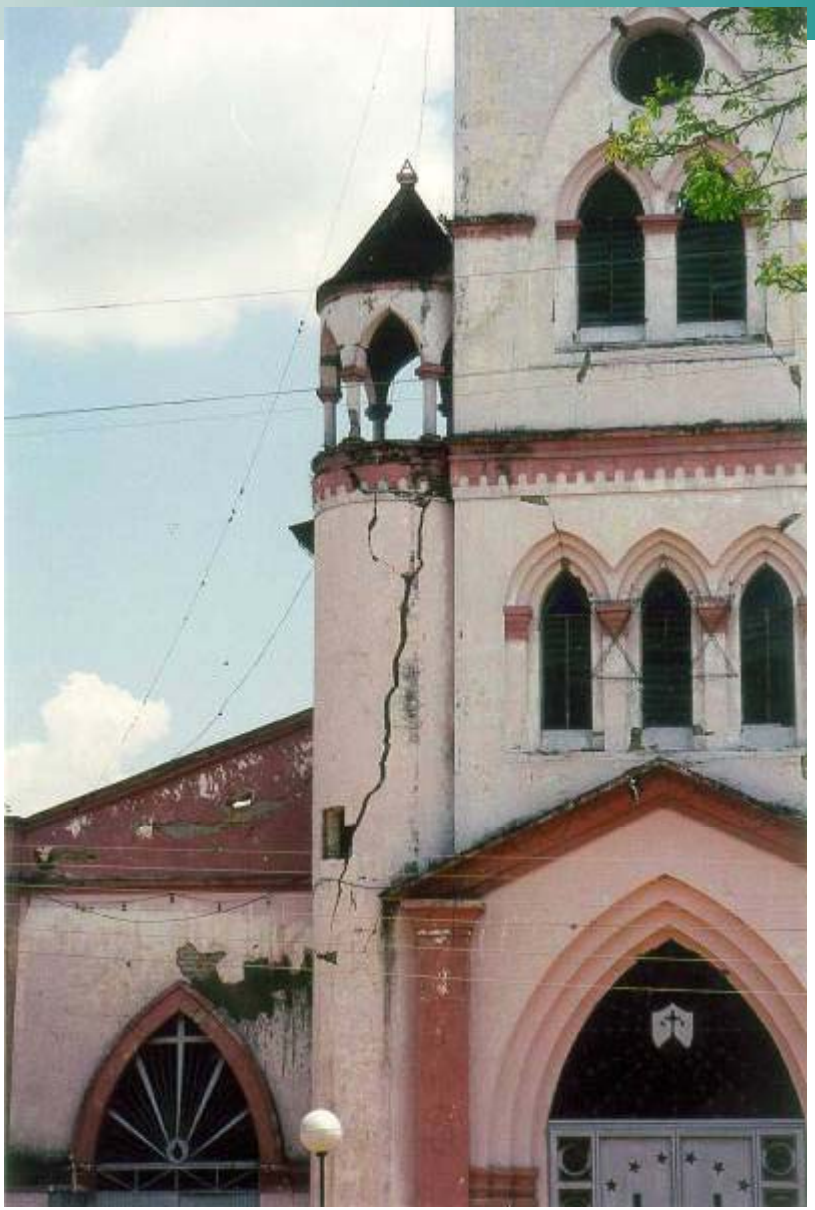
- Impact damage
- Asymmetry





28 February 2001, Mw 6.8 Nisqually, Washington Earthquake

Pounding



Armenia, Colombia
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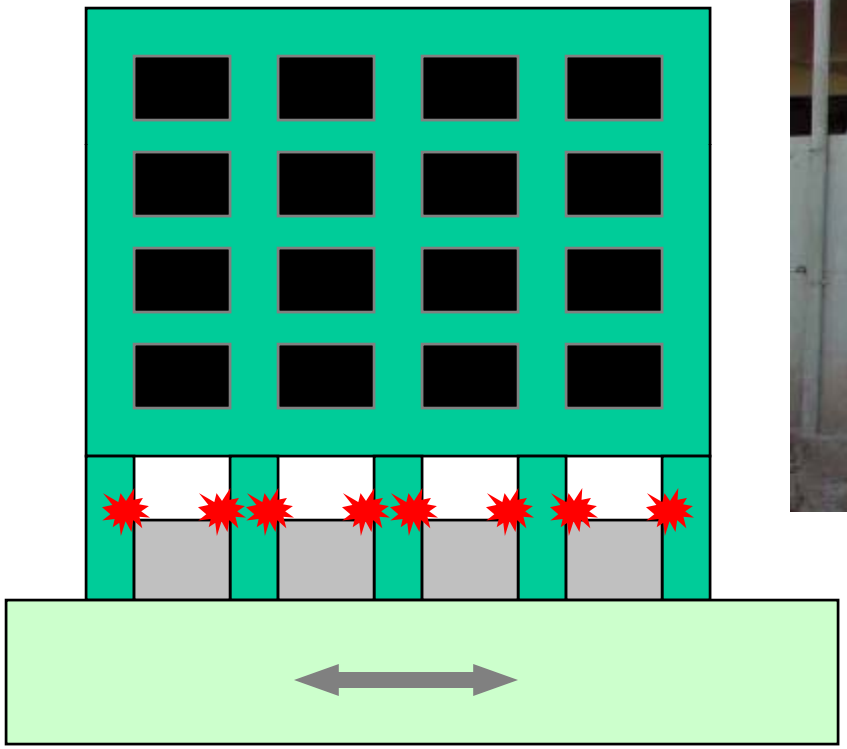
Short column



Short column

Balcony and inserted brick wall cause short column failure, in combination with bad detailing (lateral reinforcement) - Armenia, Colombia

Detailing

Insufficient transverse reinforcement to prevent buckling of the vertical reinforcement

Unsufficient lateral reinforcement, bad concrete quality, discontinuity

Masonry

- Insufficient cohesion of the masonry walls due to weak mortar or the absence of mortar

Stone masonry: behavior during an earthquake

Picture: NSET