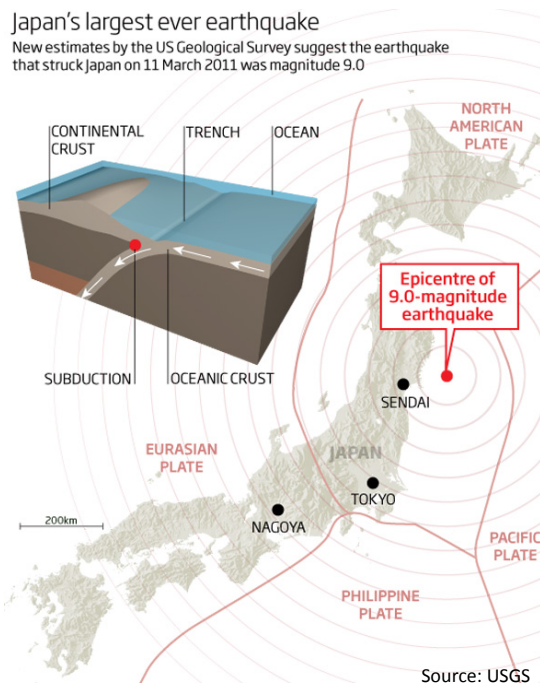


Geotechnical Effects of the March 11, 2011 Tohoku-Kanto Earthquake, Japan

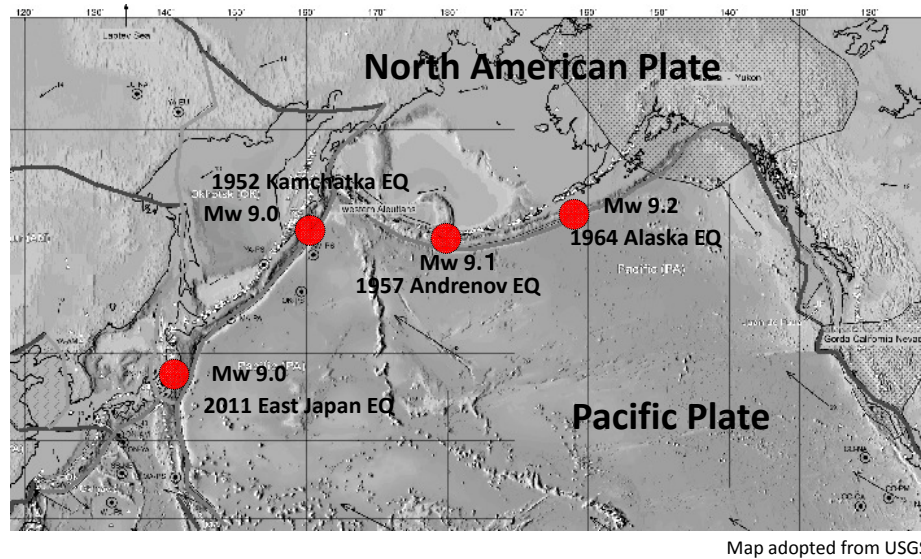
Shideh Dashti
Assistant Professor
University of Colorado at Boulder

Reconnaissance Teams Supported by GEER and EERI:
Ashford, Boulanger, Donahue, Stewart, Harder, Kelson, Kishida,
Kayen, Frost, Dashti

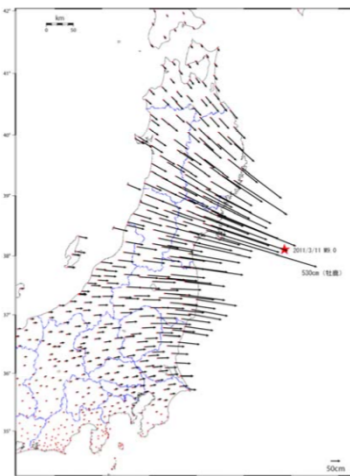
- Largest EQ recorded in Japan (M=9)
- Fault rupture = 450 x 200 km
- Interplate EQ between Pacific and the North American Plates
- Low angle reverse fault (east-west compressional axis)
- Devastating tsunami exceeding 10m in wave height



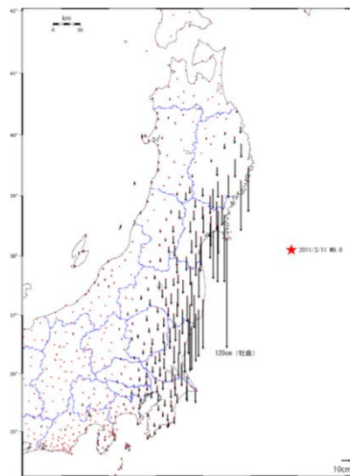
Large Earthquakes Along the Boundary of North American and Pacific Plates



Distribution of Measured Deformations



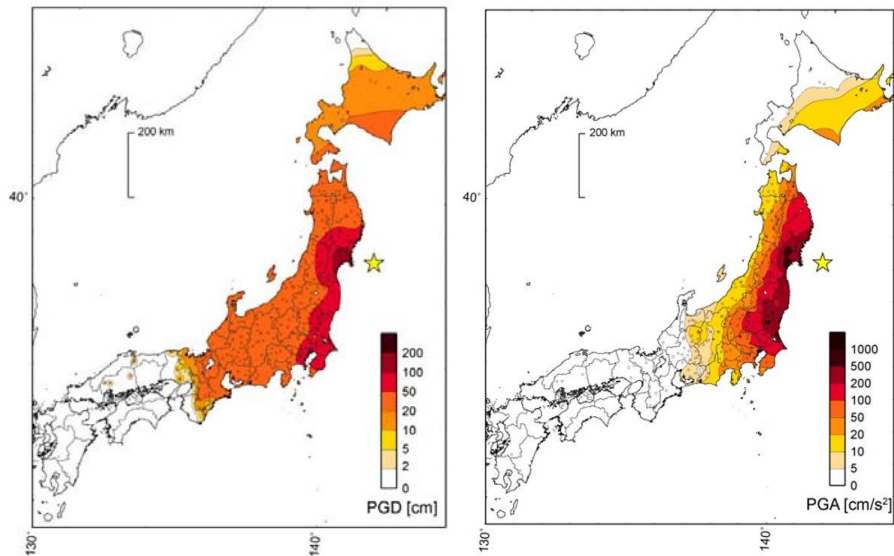
Horizontal (maximum 5.3m)



Vertical (maximum 1.2m, subsidence)

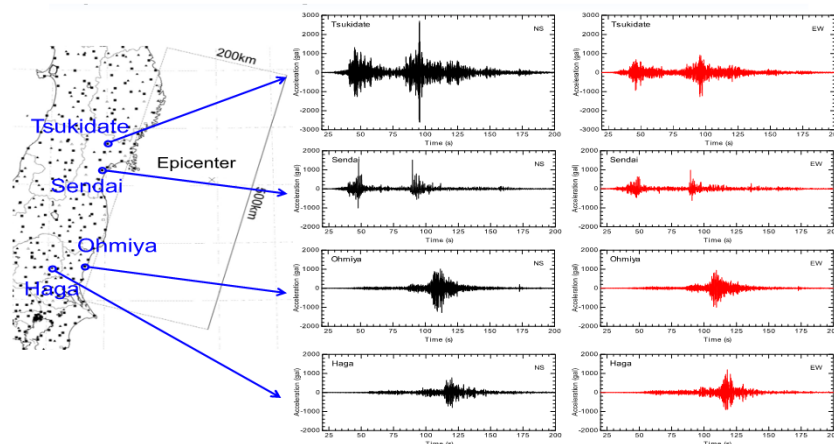
Source: Geospatial Information Authority of Japan

PGA and PGD Contours Recorded by K-NET Network



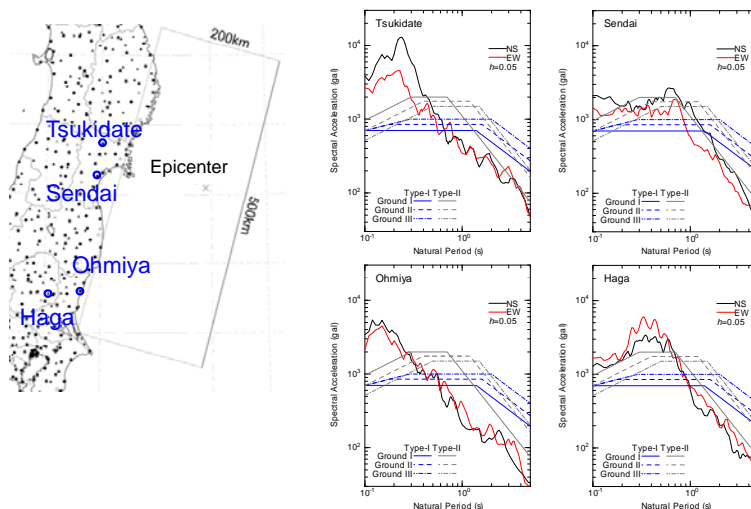
Source: Earthquake Research Institute (ERI), University of Tokyo

Typical Strong Motion Recordings



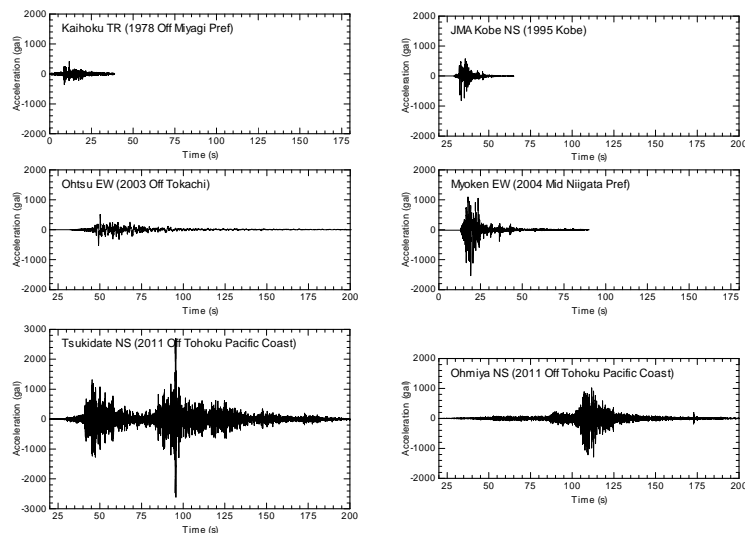
Source: National Research Institute for Earth Science and Disaster Prevention

Comparison of Response Spectra with Design

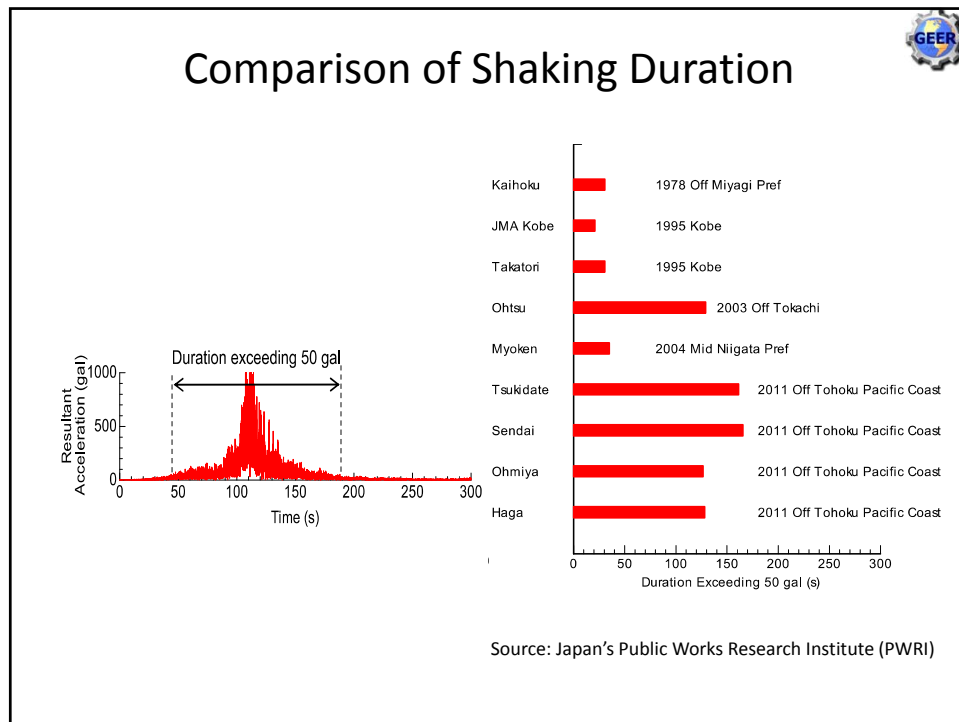


Source: National Research Institute for Earth Science and Disaster Prevention

March 11, 2011 Tohoku, Japan Earthquake



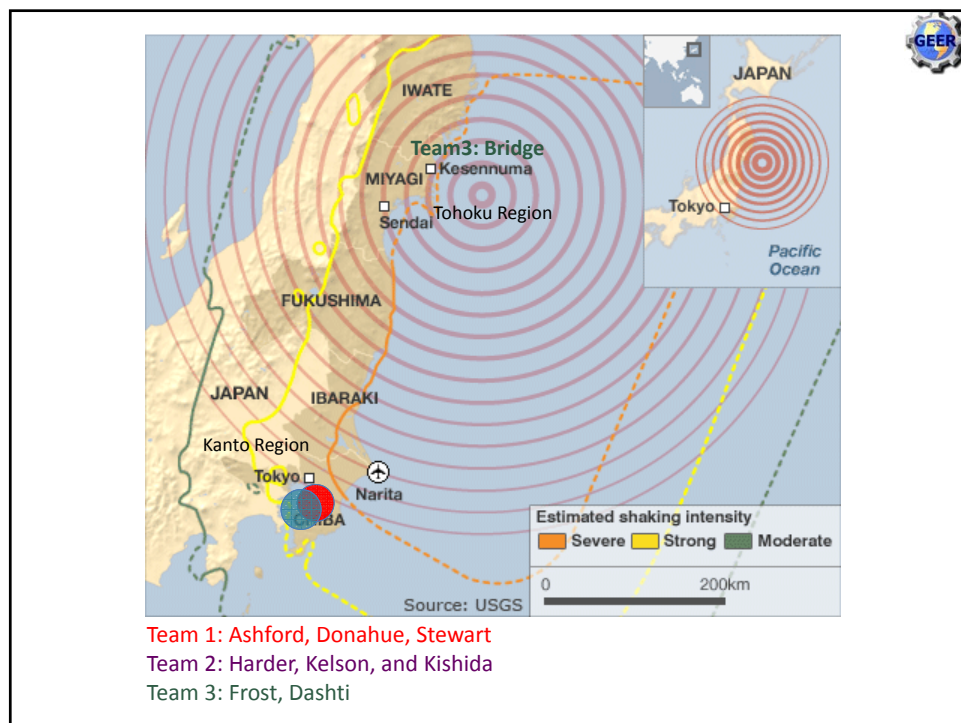
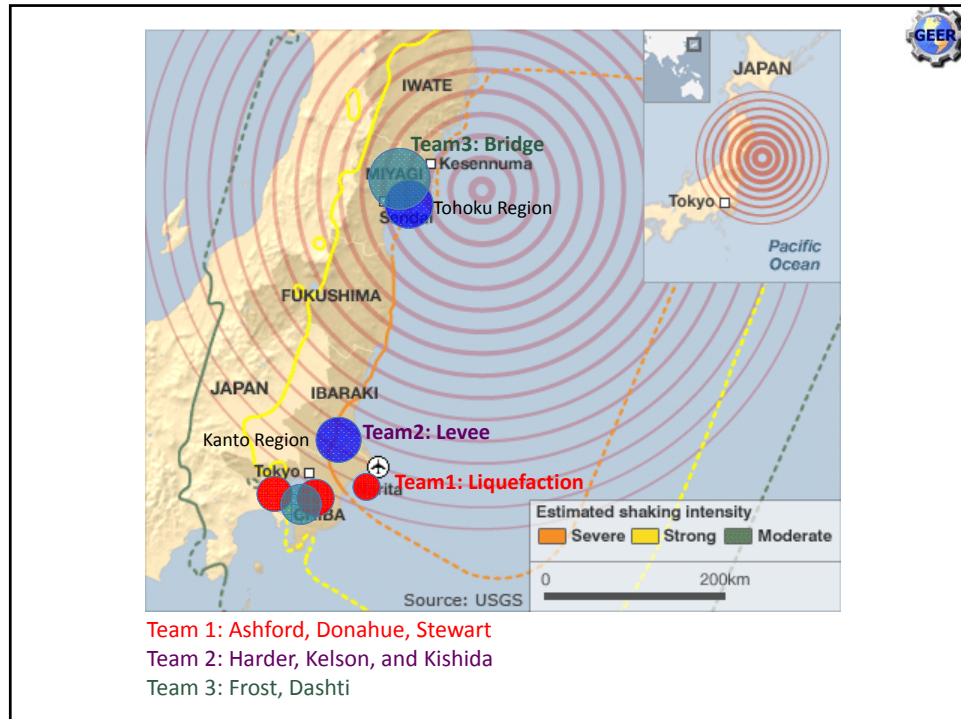
Source: Public Works Research Institute



Geotechnical Effects

Liquefaction Induced Damage

- Building settlement and tilt (Ashford, Donahue, Stewart & Frost, Dashti)
- Lateral spreading (Ashford, Donahue, Stewart)
- Levee failure (Harder, Kelson, and Kishida)
- Uplift of underground structures (Ashford, Donahue, Stewart & Frost, Dashti)

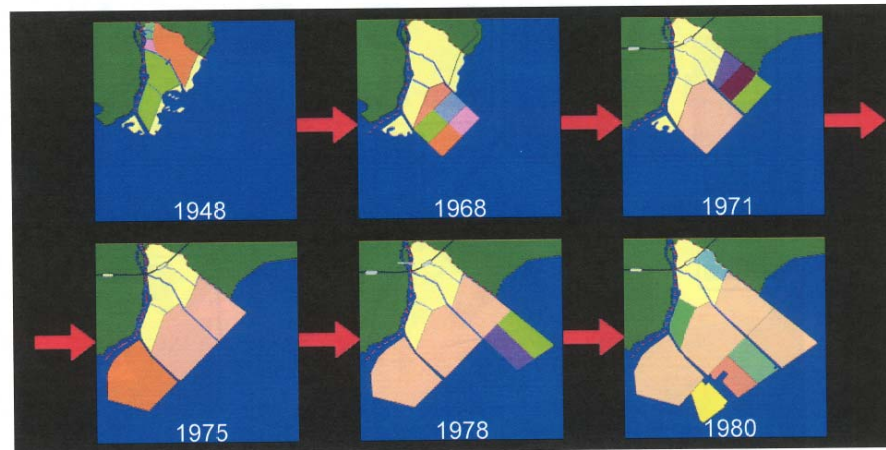


Investigated liquefaction locations in Tokyo Bay Area

- 1) Shin-Kiba (extensive liquefaction)
- 2) Shin-Urayasu (extensive liquefaction)
- 3) Maihama (Disneyland) (various extents of liquefaction)
- 4) Daiba (very limited liquefaction)



Land Reclamation in Tokyo Bay



Source: Tokimatsu Laboratory
Tokyo Institute of Technology



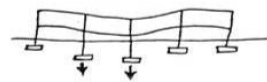
Effects of Liquefaction



- Settlement/Tilt



Post-Liquefaction Reconsolidation



Localized bearing failure; settlement depression around buildings

Source: Seed et al. (2003)

Excessive Settlement and Tilt



GEER 2011 (photo: Donahue)

Excessive Settlement and Tilt



GEER 2011 (photos: Donahue and Boulanger)

Excessive Settlement and Tilt

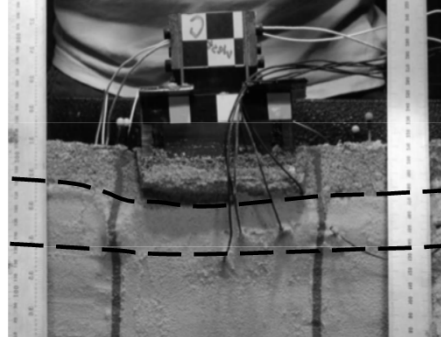


Dashti and Frost (2011)

Excessive Settlement and Tilt



Dashti and Frost (2011)



Dashti et al. (2010)

Excessive Settlement and Tilt



GEER 2011 (photo: Boulanger)

Excessive Settlement and Tilt



Source: Dashti and Frost (2011)



Settlement of sidewalk relative to the building
founded on piles \approx 14 inches

Ground Improvement

Ground settlement small due to ground compaction



Source: Omer Aydan

Ground Improvement

Ground settlement is small due to ground compaction

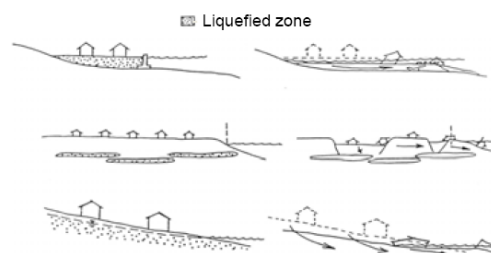


Source: Prof. Yasuda

Effects of Liquefaction



- Settlement/Tilt
- Lateral Spreading



Source: Seed et al. (2003)



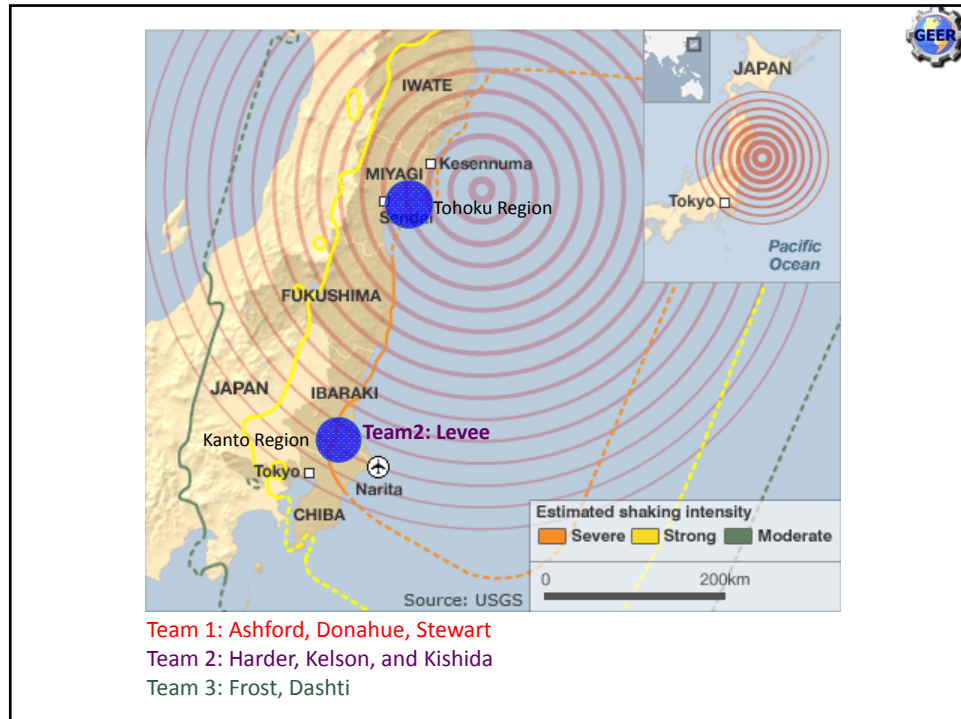
Effects of Liquefaction



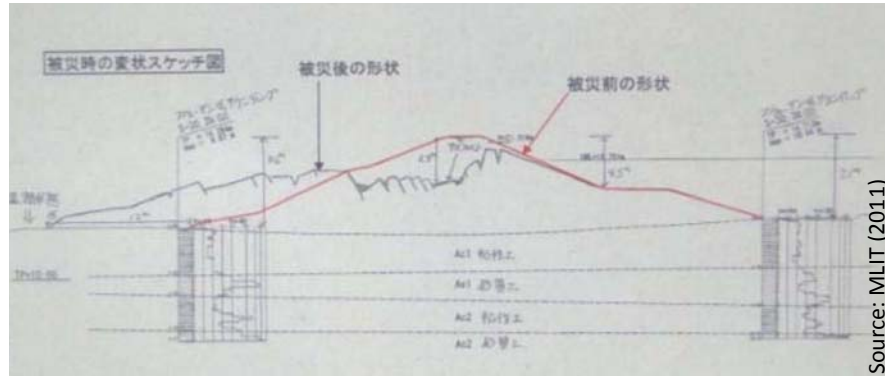
- Settlement/Tilt
- Lateral Spreading
- Stability Problems



Source: Seed et al. (2003)



Levee Damage



Major Levee Damage Along Naruse River Due to EQ Induced Foundation Liquefaction

Levee Damage



Moderate Slumping and Cracking of Levee Crown and Residual Sand Boils (Miyagi Prefecture)



Levee Damage



Moderate Cracking and Slumping of Levee Slope (Kitikami River)

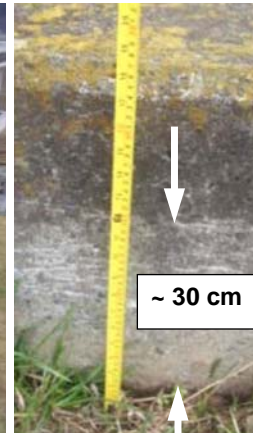


Source: Harder et al. (2011)

Levee Damage



Source: Harder et al. (2011)



Differential Settlement at Concrete Water Tank at Landside Levee Toe on Kitikami River Left Levee

Levee Damage



Bridge across the Naruse River and Levees (Google Earth, 2011)



Source: Harder et al. (2011)



View Looking Downstream (east) at Separation Between Bridge Span (on left) and Right Levee/Abutment Fill (on right)



Levee Damage and Bridge Settlement at Naruse River
(Kilometer 30.0 – Dashti/Frost)

Levee Damage



Failed Naruse River Left Levee Adjacent to Matsuyama Bridge



Source: Dashti and Frost. (2011)

Levee Damage



Looking South (across river) at Settlement and Separation of the Left Levee/Abutment Fill



Left
Abutment

Source: Harder et al. (2011)

Repair Measures



Construction of Large Waterside Berm as Part of an Interim Repair of the Naruse River Left Levee



Source: Harder et al. (2011)

Repair Measures



Source: Dashti and Frost. (2011)

Repair Measures



Source: Dashti and Frost. (2011)

Repair Measures



Source: Dashti and Frost. (2011)

Repair Measures



Source: Dashti and Frost. (2011)

Effects of Liquefaction



- Settlement/Tilt
- Lateral Spreading
- Stability Problems
- Floatation of Buried Structures

Floatation of Buried Structures



Source: Donahue (2011)

Floatation of Buried Structures



Source: Dashti and Frost. (2011)



http://www.youtube.com/watch?v=ryTkUY_49Lk



Conclusions

- Excellent test of ground settlement estimation procedures
 - Are the effects of **fill age**, **ground improvement**, and ground motion characteristics such as **duration** adequately accounted for?
 - Investigate variations in foundation settlement for various types of foundations and structures.

Conclusions



- Damage to gas, water, and sewer systems: dataset for evaluating system fragilities.
- Well-mapped cases of **lateral spreads**, **levee slumps**, and **structural displacements** – valuable for improving empirical procedures.

Thank You

