Earthquake and Tsunami Mitigation in Japan

Summary of observations from field investigations of the engineering effects of the Great Eastern Japan Earthquake Disaster

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The Great East Japan Earthquake and Disasters: One Year Later
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The Great East Japan Earthquake and Disasters: One Year Later
The Great East Japan Earthquake and Disasters: One Year Later

Date: March 11, 2011
Magnitude ($M_w$): 9.0
Depth: 32 km
Rupture zone: 500x200 km
PGA: 2.9g
Tsunami: >35 m
Casualties: nearly 16,000
Missing: >3,200
Injured: >6,000
Evacuees: still 342,000
Economic Loss: >$309 B
Cost of Recovery: >$615 B

Source: Ministry of Economy, Trade and Industry
Unprecedented challenge for Japan

Comparison of Slip Fault Size
(Asahi Newspaper)

Enormous earthquake, tsunami and nuclear accident

Source: Ministry of Economy, Trade and Industry
Unprecedented challenge for Japan
Overcoming crises and embarking on new frontiers
-The Strategy for Rebirth of Japan (December 24, 2011)

Overview of the Strategy for Rebirth of Japan

- Drive recovery and reconstruction from the Earthquake and control the nuclear incident
- Achieve both economic growth and fiscal health
- Implement the New Growth Strategy and revive Japan’s large middle class, thereby ensuring the sustainability of the economy and society overall

Pioneering examples of Japan’s rebirth through the reconstruction
- Swiftly implement the New Growth Strategy in the affected areas, based on the concept of reconstruction open to the world. Special zones for reconstruction and private funds are key tools, leading to the development of new industries.

Realizing growth by exploring new frontiers
- Identify new opportunities in various areas, including the exploration of the oceans and space, the development of new ideas to advance the economy, society, science and technology, education and human resource development, international relations and the public sector.

Presenting models as an advanced problem-solving nation
- Demonstrate a new growth model to the world and make a contribution by being a leader in solving pressing issues on the global agenda, including those related to disaster risk reduction, aging society, the declining birth rate, and environmental problems.

Source: Office of the Prime Minister
Key Engineering Issues

- Tsunami and its effects
- Liquefaction and settlement
- Effect of shaking on structures
- Nuclear Power Plants & Lifeline Issues
- Disruption of business and social systems
The Eastern Japan Earthquake: Special Ground Motion Characteristics

From S. Midorikawa

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Comparison of ground motions from earthquakes affecting Sendai area

Recorded strong motions from 2011 events compared to 1978 and 2005 Miyagi-ken Oki earthquakes at Sumitomo Building (near Sendai Station)

March 11, 2011 M9.0
April 7, 2011 M7.1
Miyagi-Oki, June 12, 1978 M7.4
Aug. 16, 2005 M7.2

Courtesy: Prof. Motosaka, Tohoku Univ.
Numerous Aftershocks: Cumulating/Repeated Damage

Sendai

Tokyo

From: JMA
Improve understanding of hazard posed by subduction zone events

New NGA-Subduction project in development by PEER

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WIDE SPREAD damage due to soil liquefaction and permanent settlement
Relatively limited damage to structures due to shaking during M9.0 earthquake

Downtown Sendai
Buildings near K-NET Site: PGA = 2.7g

Ref: Midorikaway, Tokyo Tech
Older buildings vulnerable (e.g., Sendai)

Adjacent undamaged buildings
“Non-Structural” Damage - Sendai
“Non-Structural” Damage - Tokyo

Concert Hall – Kawasaki (near Tokyo)

Moderate Shaking PGA ~ 0.15g

unoccupied at time of earthquake

Ref: http://sankei.jp.msn.com
Buildings in Tokyo?
US-Japan Collaborative Research on Seismically Isolated Buildings

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Transportation Systems Disrupted

March 11 damage
March 26, 2011

March 11 damage
March 19, 2011

After Takahashi, JSCE

26 Shinkansen bridges damaged
Tsunami Effects

Arahama
On coast near Sendai,
4 km penetration
Arahama: 4-story School Building, Vertical Evacuation Facility

Inundation into 2nd floor
Rikuzen Takata – Typical coastal bridge damage

Route 45, Rikuzen-Koizumi (3 span bridge, washed away)
In general, shaking had little effect.

Tsunami affected some substations, but had major impact on generation stations.

- 8 major fossil stations down.
- Fukushima NPP crisis.
- 11% national power generation lost.
- Currently, ALL NPPs are being shut down.
Fire Following Earthquake

260 Immediate
345 Total
Non-structural damage contributed to loss of services

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Courtesy: Carlos Cabrera, RMS
In tsunami areas, heavy industrial facilities were closed for long times

Sustained light physical damage but heavy business interruption

Ishinomaki – Pulp and Paper

Ofunato – Cement

Nippon Paper – Ishinomaki Pulp and Paper Mill

Taiheiyo Cement Corporation - Ofunato City

One of its two kilns sustained damage, raw materials and fuel-feeding equipment were damaged, rubble and debris impair its operations, and the plant had no electricity as of April 18

Courtesy: Carlos Cabrera, RMS
Supply chains are complex and interdependent
Supply chains are complex and interdependent
Structures Should Not Be Considered in Isolation: Disaster vs Catastrophe

Natural disasters cause widespread moderate to severe damage that may strain ability of a community to respond.

Widespread damage can have substantial long-lasting social, economic and cultural impact on the well-being and vitality of a city and nation.
### Resilient structures, networks, and communities

#### The Great East Japan Earthquake and Disasters: One Year Later

#### Resilient structures, networks, and communities

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#### TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

<table>
<thead>
<tr>
<th>INFRASTRUCTURE CLUSTER FACILITIES</th>
<th>Event occurs</th>
<th>Phase 1 Hours</th>
<th>Phase 2 Days</th>
<th>Phase 3 Months</th>
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<tbody>
<tr>
<td>CRITICAL RESPONSE FACILITIES AND SUPPORT SYSTEMS</td>
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<td>4</td>
<td>24</td>
<td>72</td>
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<tr>
<td>Hospitals</td>
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<td>Police and fire stations</td>
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<td>Emergency Operations Center</td>
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<td>Related utilities</td>
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<td>Roads and ports for emergency</td>
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<td>CalTrain for emergency traffic</td>
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<td>Airport for emergency traffic</td>
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<tr>
<td>EMERGENCY HOUSING AND SUPPORT SYSTEMS</td>
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<tr>
<td>95% residence shelter-in-place</td>
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<tr>
<td>Emergency responder housing</td>
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<tr>
<td>Public shelters</td>
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<tr>
<td>90% related utilities</td>
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<td>90% roads, port facilities and public transit</td>
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<tr>
<td>90% Must and BART capacity</td>
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<td>HOUSING AND NEIGHBORHOOD INFRASTRUCTURE</td>
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<tr>
<td>Essential city service facilities</td>
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<td>Schools</td>
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<td>Medical provider offices</td>
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<tr>
<td>90% neighborhood retail services</td>
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<td>95% of all utilities</td>
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<td>90% roads and highways</td>
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<td>90% transit</td>
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<td>90% railroads</td>
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<td>Airport for commercial traffic</td>
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<td>90% transit</td>
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<td>COMMUNITY RECOVERY</td>
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<tr>
<td>All residences repaired, replaced or relocated</td>
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<tr>
<td>95% neighborhood retail businesses open</td>
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<td>50% offices and workplaces open</td>
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<tr>
<td>Non-emergency city service facilities</td>
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<tr>
<td>All businesses open</td>
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*Image of a building with text: When is a building safe enough? The Resilient City Part 1: Before the disaster.*
Next challenge for engineers: Earthquake-Resilient Structures

In *Earthquake Engineering*, our future challenge is to develop new or improved structures and infrastructure systems that:

- protect public safety, and are
- economical,
- can be constructed quickly with minimal disruption to the public and environment, and
- can withstand strong earthquake ground shaking (and other hazards) safely, with little disruption or cost associated with post-earthquake inspections and repairs.
Concluding Remarks

- Buildings, bridges and other facilities generally performed well under strong ground shaking
  - Nonstructural components (and contents)
  - Existing (deficient) structures
  - Critical transportation links (Shinkansen bridges)
  - Correlation of ground shaking characteristics to structural damage requires more study

- Tsunami inundation was major source of damage and over 90% of deaths.
  - Inundation depths > 1 to 2 meters:
    - Timber and light frame buildings totally destroyed
    - Engineered RC and steel buildings generally survived
  - Inundated bridges often failed
  - Substantial business interruption consequences
Concluding Remarks

- Permanent movement of ground caused wide spread and extensive damage
  - Tilting and settlement of structures
  - Substantial damage to utilities
  - Soil improvements seemed to work as intended

- Critical lifeline systems had extensive damage
  - Electric Power
    - On-going NPP issues
  - Other utilities (water, gas, etc.)
  - Large impact on industry and quality of life

- Substantial business interruption consequences
  - Nonstructural components, equipment, contents
  - Tsunami impacts
For More Information

- PEER and EERI websites
  http://peer.berkeley.edu

- CUEE, AIJ, JSCE, ERI and many other websites in Japan (see report for links)