Tohoku Off Shore Earthquake & Tsunami, Japan
M_W=9.0 11 March 2011

Lifelines Performance Assessment
Preliminary Summary

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PROPOSED ORGANIZATION OF THIS SESSION

BY LIFELINES

- BRIEF OBSERVATION OF DAMAGE
- COMMENTS & DISCUSSIONS
- FOLLOW-UP ITEMS

WAKE-UP CALL – TSUNAMI PREPAREDNESS

REDUCE TSUNAMI LOSS

GOOD ENGINEERING WORKS

BALANCED LOSS – LIFE SAFETY NO COMPRIMISE

Lifelines & Geotech

- Geotech/Geology/Tsunami
- Electric Power
- Gas & Liquid Fuel
- Ports & Harbors
- Telecommunication
- Transportation
- Water (Dam) & Wastewater
- Hospital
- Debris Management
- Emergency Response & Social Impact

Geology

Observation:

Probabilistic Hazard Maps for Earthquake Area Were Not Accurate

Recommendation:

Update Probabilistic Maps with Japan Trench Data

Future Needs:

-Hazard Maps: liquefaction, tsunami inundation, slope stability, & tsunami zones for design

-3.11 maps of liquefaction, slope failures, and tsunami inundation

Geotechnical Aspects

Observations:

1. Overall Performance was Good
2. Ground Improvement Worked Well
3. Poor performance of hydraulic Fill Areas and cut/fill Slopes
4. Shaking damage observed was significantly less than what would be expected based on measured accelerations

Recommendations:

Consider Ground Improvement in Fill and cut/fill slopes for Future Developments and Reconstruction

Future Needs:

Further Study on Shaking Damage/Measured Intensity Discrepancy

Tsunami

Observations:

1. Paleo-seismic Records not reflected in determination of inundation zones and sea wall heights
2. Over reliance on tsunami walls for protection
3. Recovery will be a long and expensive process

Recommendations:

1. Incorporate past data as well as data from the Tohoku tsunami into inundation zone maps and design parameters for reconstruction and rehabilitation of coastal communities and sea walls.
2. Educate public on tsunami hazards and evacuation procedures

Future Needs:

Data and Information on recovery and reconstruction progress, problems, and successes. Future visit for Oregonians needed!

Background Information

USA's Similar Setting to Japan

- Geologic Evidence of 40 Cascadia Subduction Zone historic earthquakes
- Last Cascadia earthquake on January 26, 1700
- Magnitude 9 Expected
- Geologic, Shaking & Tsunami hazards

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Seaside Schools with Tsunami Hazards

Schools in Tsunami Zone

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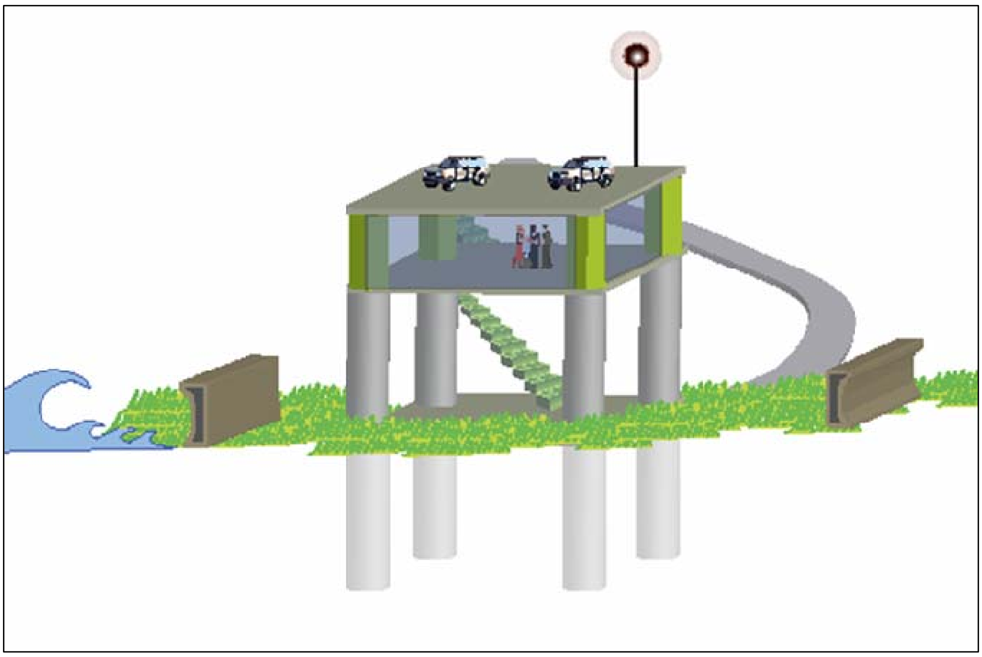
Schematic Design

Tsunami Evacuation Building (TEB)

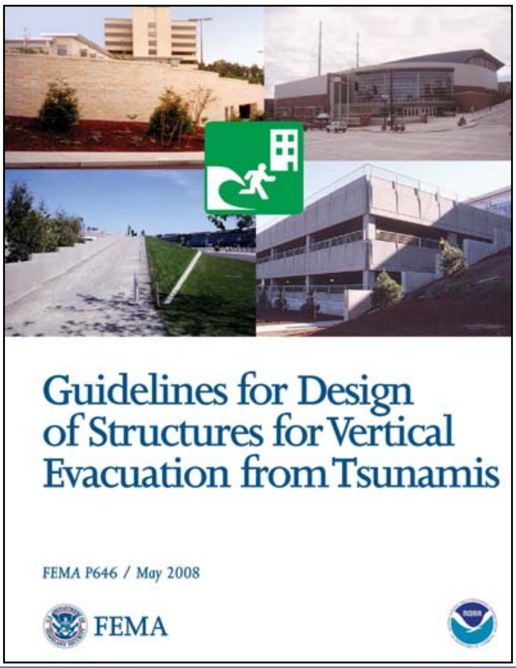


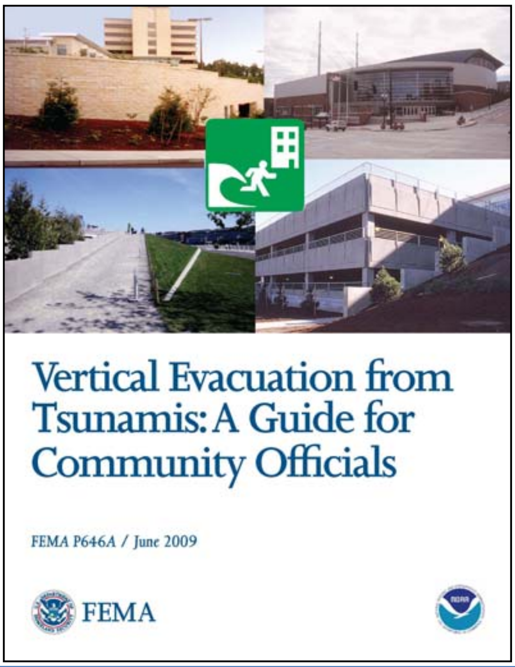
Tsunami shelter in Japan

USA

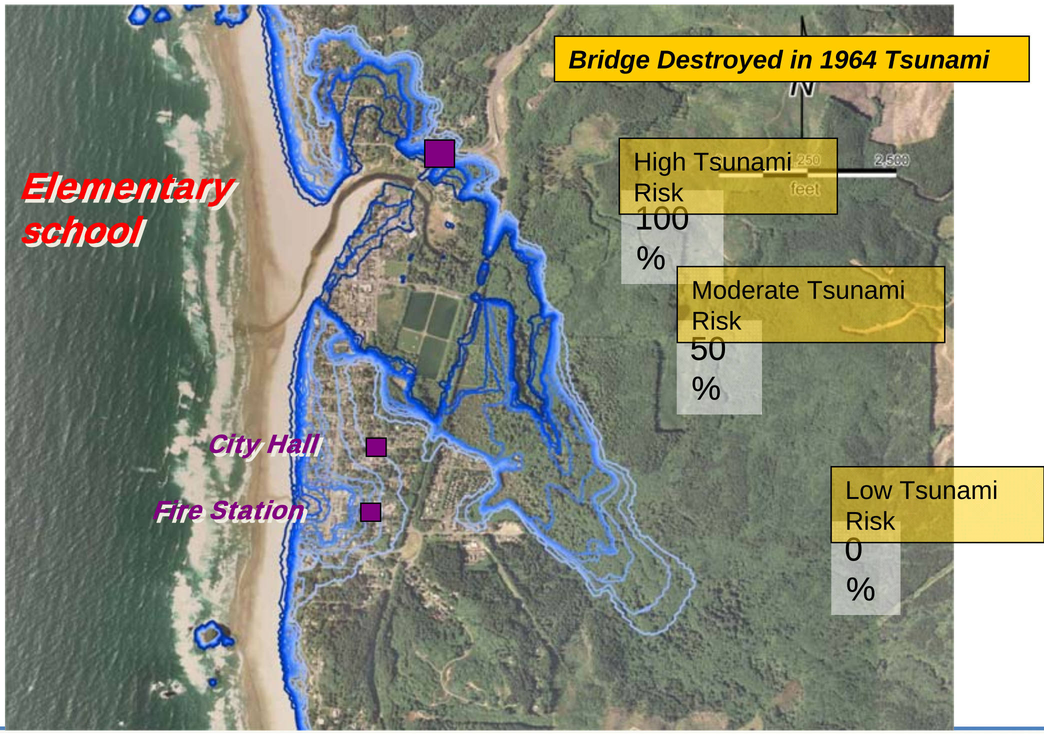
Japan

FEMA Guidelines (646/646A)





New Tsunami Hazard Map of Cannon Beach



Proposed Tsunami Refuge: Reinforced Concrete, Earthquake & Scour Resistant, Vertical Evacuation

Ecola Architects, PC (2008)

Electric Power

KEY OBSERVATIONS:

1.Recovery of the Electric Power grid access was timely (6 days, 90% – 10 days, 95%)
2.Significant percentage of damage was caused by the Tsunami
3.Transmission line tower performance was typical to other earthquakes (Liquefaction and Landslides)
4.Nearly IMPOSSIBLE to protect open air, ground level, substations against a Tsunami (Water & Tsunami impact)
5.High level of shaking damage to High Voltage Electric Power Transformers
6.Distribution System Failures: Tsunami impact, and typical failures from Landslides, Liquefaction, Pole mounted transformers, Unanchored equipment
7.Power Plant Problems (along the coast) Tsunami related, no/to very little information on actual failures of components from ground shaking (e.g. Soil failure of penstock)

POWER TRANSFORMER FAILURES: Significant issue for transmission line system

Reported Failures

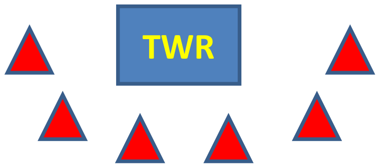
M9 (3/11/11)	**M7.2 (4/7/11)**	**M7.1/M6.3 (4/11-12/11)**
47 Shaking 23 Tsunami	15 Shaking	1 Shaking

SUBSTATIONS

INSIDE BUILDING

GAS INSULATED SUBSTATION

TRANSMISSION LINE TOWER



BARRIERS

SUMMARY

GAP #1

MORE INFORMATION ON ELECTRIC POWER COMPONENT FAILURES (TRANSMISSION, DISTRIBUTION, AND GENERATION) IS NEEDED TO IMPROVE THE INDUSTRY STANDARDS FOR THE SEISMIC DESIGN OF POWER SYSTEMS

GAP #2

THE PERFORMANCE OF THE TEPCO ELECTRIC POWER SYSTEM IS IMPORTANT TO THE SUCCESS OF LEARNING FROM THIS EARTHQUAKE

TCLEE TEAM WANTS TO THANK TOHOKU ELECTRIC POWER FOR THEIR PARTICIPATION IN THIS RECONNAISSANCE EFFORT

Gas & Liquid Fuel

Observations:

1. Information from Prof. Konagai from Petroleum Association of Japan (PAJ):
    1. 15 terminals & 3 refineries closed 3/12
    2. Emergency response by PAJ
    3. Tsunami, fire, leaks, sloshing
2. Did not obtain detailed information on shaking damage to facilities, liquefaction, settlement, sloshing, fire, tsunami, e-generators, spill
    1. No meetings w/PAJ or companies.
3. Sendai City claimed #1 problem was lack of fuel for emergency response

Gas & Liquid Fuel

Limited Recommendations:

1. Improved earthquake, tsunami and fire protection
2. Provide reliable emergency fuel supply and rapid distribution to Sendai and impacted areas

Gas & Liquid Fuel

Future Needs:

1. PAJ/companies to provide information on performance to share lessons learned and avoid repeating mistakes:

Shaking damage to facilities-type of pipes, pipe configuration (loops), pipe connections, tank design, etc

Liquefaction, lateral spreading & settlement- ground improvement, ring wall foundations

Sloshing- how full were tanks, height of sloshing, tank anchorage

Also, Fire, tsunami , emergency generators, Hazmat spills, etc

Gas & Liquid Fuel

Observations:

1. Information from Profs Nojima and Maruyama
   1. 84 days for 100% restoration
2. Sendai Gas Bureau
   1. Sendai system: 60 seismometers, 11 blocks, 3 blocks manually closed after earthquake, all 11 blocks after tsunami
   2. Transmission & Distribution Pipe breaks: 20 DIP, 170 steel, **0 PE**
   3. Gas Holders (spherical tanks) bracing damage
   4. 30% (pre-3.11) to 100 % Niigata pipelines (and Tokyo Gas servicing)
   5. No fires
   6. Concentrated damage in cut and fill slope
3. Sendai LNG port facility:
   1. Good performance , except salt water damage & pipes/equipment
   2. Emergency generator waterproofed and reliable
   3. Restart Dec. 2011

Gas & Liquid Fuel

Recommendations:

1. Protect Important Equipment with waterproofing
2. Improve service line performance in cut/fill slopes
3. Improve bracing for gas holders (spherical tanks)

Gas & Liquid Fuel

Future Needs:

1. Share performance successes with other seismic regions (Tokai, Cascadia, etc)
    1. Real time Videos (earthquake & tsunami)
    2. In-ground LNG tank design
    3. Seismic monitoring system
    4. Waterproof emergency generator s to be operational

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Ports & Harbors

Observations:

1. Shaking caused significant damage, lateral spread, and settlement in areas of poor fill
2. Important Equipment kept in non-waterproof areas
3. Poor performance of Fill Areas and Slopes
4. Significant losses due to tsunami damage
5. Lack of electricity is a major setback

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Recommendations:

1. Protect important equipment in watertight areas.
2. Test Important Equipment
3. Consider Ground Improvement in Fill Areas
4. Significant losses due to tsunami damage

Future Needs:

1. Data on Speed of Recovery
2. Data on Lost Revenue/Clients
3. Data on Recovery Costs

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Sendai Airport

Observations:
1.Good Performance
2.Ground Improvement Worked Well
3.Electricity Loss Paramount

Recommendations:

1. Protect Emergency Generators from Water Damage
2. Consider Ground Improvement for Rehabilitated Areas to prevent repeat liquefaction damage

Telecommunication

- Maximum number of land-lines affected: 1.5 Million circuits. 93% recovered by March 28th.
- Maximum number of base stations affected: 6,700 (Aprox.), many due to power issues. 90 % recovered by March 28th.
- Maximum number of affected buildings: 1,000 (Aprox.) out of 1,800 in the area.
- Traffic increased 8 to 10 times from normal. “171” messaging system used to reduce network congestion.
- Transmission links severed in 90 routes (not counting Fukushima-Daiichi Nuclear Power Plant area). One of three links to Hokkaido were damaged.
- 65,000 Poles and 6,300 km of cable destroyed in coastal area
- 9 COs near the Fukushima-Daiichi Nuclear Power Plant area lost service

Telecommunication

KDDI COW

KDDI Cell Site Rebuilt

Telecommunication

- 16 Buildings had minor damage to its building but power facilities were lost due to water damage.
- Restored with mobile power plants.

Miyako

Ofunato

Telecommunication

- 4 central offices lost service due to isolation from the rest of the network caused by severed transmission links caused by destroyed bridges.
- Restored with new by-pass transmission routes.

Sanriku

Telecommunication

- 26 Buildings were damaged by the tsunami and all of its equipment in its interior was destroyed..
- Restored with switches in shelters located at the location of the destroyed central office building, or remote subscriber line modules (RSBM) small cabinets (also called digital loop carrier or fiber to the curb systems) distributed along the destroyed central office service area.

Shichigahama CO

Shichigahama CO building carried away 500 m by the tsunami

Telecommunication

- Almost 1,500 satellite terminals were deployed by a telecommunications service provider.
- Service restoration to wireless networks included 30 cell on wheels by one of the network operators.

Rikuzentakata

Osawa

Transportation (Bridges & Railway)

Teach people to stop their car at the first indication of an earthquake.

During tsunami why do a few spans get knocked off bridges but most spans stay on bridges?

Is it better to tie the girders to the piers or will that just cause the piers to be damaged during tsunami ?

Is it better to retrofit Shinkansen viaducts or just repair them after each earthquake?

What are the consequences of designing tall columns and short columns on the same bridge?

Water System

Observations

- After Kobe 1995, most Japanese water utilities began various seismic mitigation and preparedness actions.
- These actions included installation of new "Seismic proof" pipe ($$$$$); installation of local small water tanks for consumption ($$); better repair and restoration procedures ($)

Water System

Pipe Performance

- Between 75% to 99% of water pipe in the affected areas remain “non-seismic”, include the largest pipes (up to 2.4 meter diameter)
- Where non-seismic pipes were exposed to liquefaction or road-fill slumps, they broke. Final tally will be in the several thousands of water pipes that needed to be repaired

Water System

Special Water Issues for this Earthquake

- Tsunami: little direct impact on water systems
- Liquefaction: much MORE will occur in future earthquakes.
- Power supply: loss of TEPCO and TOHOKU power to water treatment plants and pump stations had some impacts.
- Fire Following. 345 Fire Ignitions Reported. Failure of water supply might have led to conflagration in Kesennuma.

Water System

Observations

- Japan should continue to replace 50mm - 300 mm water pipes with HDPE or Welded Steel or ER-DIP (or similar) on a 100-year cycle. For non-redundant 600 mm+ pipes, use a 50-year cycle.
- Seismic design for transmission pipes must include earthquake-generated hydrodynamic forces.
- FFE remains a SERIOUS threat!

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Kesennuma Fire

- 300 miles Northeast of Tokyo
- Pre-earthquake population 74,000 people

Video: Night of 3/11/2011 - 3/12/2011

Wastewater System

- Collection Pipelines
  - Most damage by liquefaction and land movement
    - Joint separations and floatation (manholes and pipelines)
    - Noted increases in WWTP flows and sand content
    - Pipelines only 30% to 40% inspected at this time
    - Temporary systems include pumping to sewers from each house
  - Need to improve post earthquake inspections to eliminate infiltration/inflow before rainy season

Wastewater System

- Treatment plants in inundation zone
  - Impacted by flooding, debris, horizontal forces, electrical/control failures
  - Structural damage to buildings and equipment due to impact forces
  - Limited shaking damage inspection due to tsunami warning
  - Able to provide some levels of treatment with gravity settling and chlorination

Wastewater System

Wastewater System

Observations, Comments

- At Minami Gamou, decided to demolish 40+ year old structures and replace with higher structures to be above tsunami. Cost = 100 billion Yen and 3 years
- May be more cost effective to rehabilitate and provide electrical and impact protection
- Result – full treatment capacity sooner, less pollution
- Increase speed of collection system inspections to reduce flows and treatment demands and reduce potential for sinkholes

Hospital

- Passed by one hospital totally gutted by tsunami,
- Hospital in Onagawa – ground floor inundated, back to operation
- How can we get more information
  - Hospitals not in tsunami zone (within 0.3g PGA zone)
  - Performance of lifelines within the hospital
  - Total number of hospitals within the impacted area
  - Total capacity

Hospital

Debris Management

- Debris removal delayed by missing people
- Handling of family items with sentimental values
- Separating material – plastics, metals, appliances, cars, wood, concrete, etc.
- Iwate Prefecture requires more than 300 hectares of land to dump the debris
- Debris in the coastal water is the most difficult to remove – cars, boats, etc.
- Debris removal hired many unemployed temporarily
- Estimate complete removal of debris will take 3 to 5 years
- Local Government working with insurance companies to speed up the rpocess


Emergency Response & Social Impact

- Mutual aid agreements worked very well to mobilize repair teams and improve recovery
- Pre-selected contractors and reduced “red tape” allow for rapid response for debris removal and reconstruction
- Need to consider public notification of water contamination by sewage
- Improve fuel storage and delivery systems to assure pumps and treatment components can run for extended power outages

Emergency Response & Social Impact

• Logistics to support people's services are essential to restore and repair lifelines.

• Problems for emergency response:
  • Downed communications
  • Oil shortages

• Most of the funds for reconstruction comes from the central government but many decisions are made at a local level.

• Total number of troops deployed by the central government in the entire affected area: 100,000

Emergency Response & Social Impact

• Key point in regional and local recovery plans: avoid repeating the effects of this disaster.

• At least two towns in Iwate Prefecture had approximately 10% of their population missing or dead.

• Current needs: health care (including mental care) and food. Health services in towns with destroyed hospitals being transferred to less affected towns.

• Due to damage to local industries, unemployment rate in towns affected by the tsunami is high (e.g. in Ofunato is 25%).

• In Ofunato about 50 % of the evacuation centers still have evacuees. In Ofunato 1732 temporary housing units have been constructed. In Iwate Prefecture almost 24,000 homes were destroyed.

Emergency Response & Social Impact

THANK YOU

DISCUSSIONS AND EXCHANGES