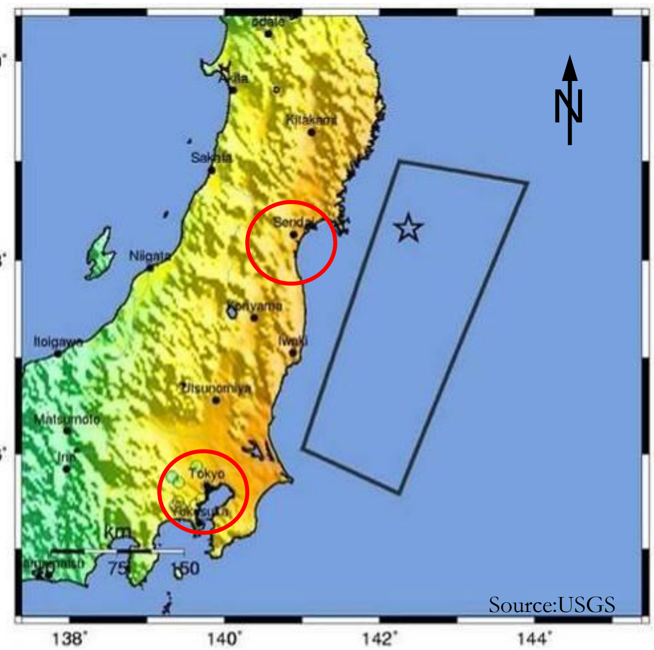
M9.0 GREAT EAST JAPAN EARTHQUAKE & TSUNAMI
March 11, 2011

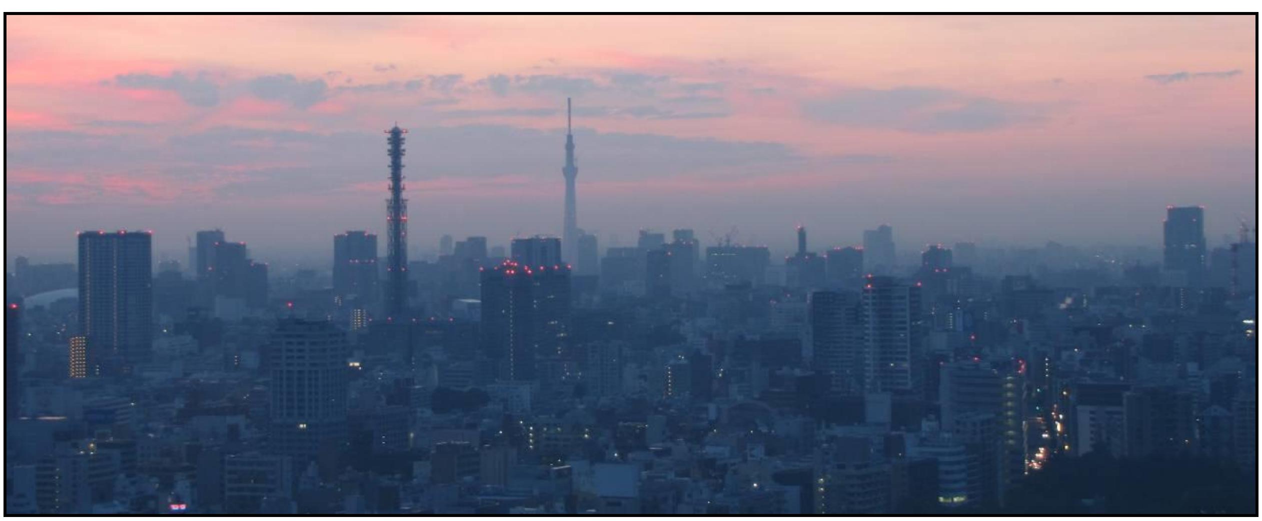
MRP Engineering Summary Report — **August 2011**

The recent March 11, 2011, M9.0 Great East Japan Earthquake and Tsunami caused widespread losses affecting many communities and businesses throughout Japan and beyond. Overall losses and reconstruction costs from the 2011 event are estimated to exceed US $200 billion. MRP Engineering visited Japan in June 2011 as part of the Structural Engineers Association of Washington (SEAW) reconnaissance team to observe the earthquake impacts and recovery efforts in Miyagi prefecture and Tokyo metropolitan areas. We observed impacts on communities, businesses, and critical lifelines throughout these regions. This event and its aftermath offer many lessons to better manage seismic risks in the future in Japan and elsewhere. The following observations represent opinions of MRP Engineering. All photographs are by Mark Pierepiekarz of MRP Engineering.



TOKYO AREA

Metropolitan Tokyo is located about 400 kilometers southwest of the earthquake's epicenter. The capital experienced relatively lower ground-shaking levels as compared to the areas along the northeast coast. However, long-duration ground shaking and soil-related impacts (liquefaction, lateral spreading, and settlement) affected some sites along the Tokyo Bay.



Sunrise above Tokyo skyline with reduced building lights in July 2011. Electrical power supply restrictions led to reductions in nonessential lighting. Many businesses adjusted operations or installed additional backup generators to cope in the aftermath.

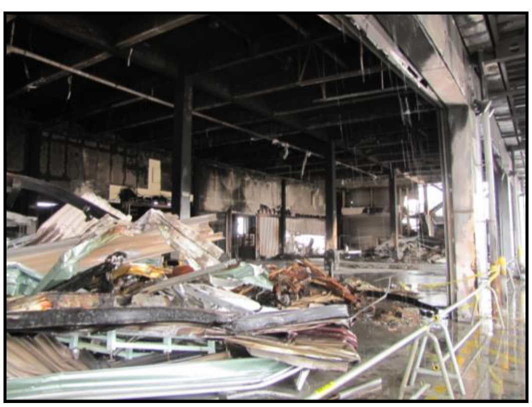
Chiba (Tokyo metro): Areas built on reclaimed land along Tokyo Bay experienced soil liquefaction which induced buoyant forces on a pipeline beneath this sidewalk.

Urayasu (Tokyo area): The community was developed on reclaimed landfill along Tokyo Bay and experienced extensive soil liquefaction (see uplifted manholes). The hotel in the background was developed on a seismically improved (densified) site which performed well during the earthquake.

EXAMPLES OF EARTHQUAKE AND TSUNAMI IMPACTS

Ishinomaki (Miyagi): Damaged tanks at Port of Ishinomaki. Displaced or overturned steel tanks were a common occurrence in tsunami inundated areas.

Ishinomaki (Miyagi): Tsunami erosion and damage around gas storage facility near the waterfront. Wood-framed structures (foreground) were wiped out by the tsunami forces.



Sendai Airport (Miyagi): A cargo warehouse was damaged by fire that initiated from a vehicle (battery) displaced by the tsunami.

Port of Sendai: Tsunami erosion behind a ship berth and a fuel storage facility (background) damaged by fire.

SEISMIC MITIGATION AND PREPAREDNESS

Japan has been aggressive in applying lessons learned from previous earthquakes. The following are examples of seismic mitigation projects that proved invaluable in preventing an even bigger disaster.

- Following the 1995 Kobe earthquake, the country embarked on a seismic retrofit program for bridges as well as elevated roadways and rail viaducts (see photo below). Much of this program was completed by 2011.
- In 1978 Sendai area experienced an earthquake that caused extensive damage to many buildings. Seismic retrofits in the city core were evident and the extent of structural damage in the 2011 event was significantly lower.
- Along the Miyagi coast many hospital and school buildings (see photo below) were also seismically retrofitted. The upgraded structures survived the strong shaking and provided vertical evacuation shelters during the ensuing tsunamis.
- Many commercial structures in Japan include advanced seismic protection structural systems (base-isolation and damping systems). These structural solutions are effective in lessening both structural and contents damage.
- Early warning systems for both ground shaking and tsunamis saved many lives in the 2011 event. Earthquake and tsunami drills are a routine occurrence.

Tokyo: Seismic retrofits of elevated railways and highways (column steel jackets) were a common sight in the region.

Minamisanriku (Miyagi): The seismically retrofitted hospital (with external inverted "V" braced frames) survived three minutes of strong ground shaking, followed by a tsunami that reached the upper level. The four-story structure was barely tall enough to serve as tsunami vertical evacuation shelter.

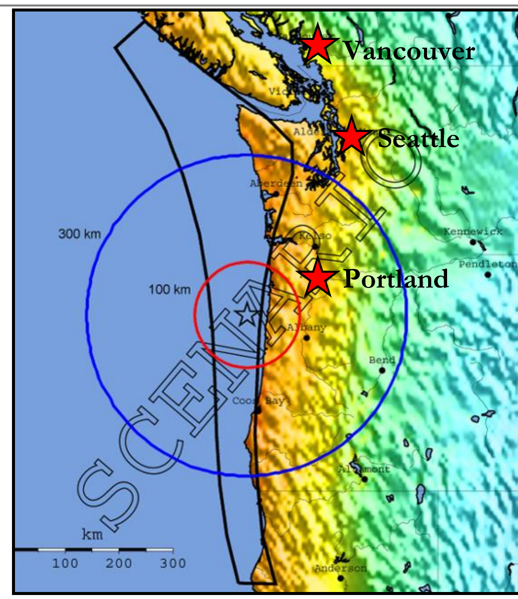
THE AFTERMATH AND LESSONS

Rebuilding of the most affected areas along the Tohoku coast will take a long time and the region's future will not be the same, but Japan will eventually recover. Risk of future earthquakes and tsunamis will require tough decisions on zoning and construction. In the meantime, industries such as manufacturing, high-tech, fishing, shipping, tourism, and agriculture are affected. This event and its aftermath offer the following lessons for other regions that may be impacted by similar events:

- Current building standards in Japan (and the U.S.) appear to adequately address "life-safety" performance for new construction in major earthquakes. However, "functional" performance (including building equipment and utilities) is often needed for high-rise structures, as well as commercial and industrial facilities.
- Seismic retrofits of vulnerable structures, early warning systems, and preparedness actions do work and save lives. Nonstructural upgrades enhance facility seismic resilience and operational impacts.
- In potential tsunami inundation zones, vertical evacuation structures must be sufficiently tall, strong, and accessible to provide reliable shelter for the local population.
- In subduction-type earthquakes, relatively distant areas may still be impacted (infrastructure, in-building contents, soil failures, and fires).

SUBDUCTION ZONE EARTHQUAKES COMPARED

The 2010 M8.8 Chile and the 2011 M9.0 Japan subduction earthquakes are particularly relevant to the Pacific Northwest. This region is also located along the boundary of two tectonic plates, a geological structure known as the Cascadia Subduction Zone. One of the tectonic plates, the Juan De Fuca plate, forms the ocean floor, slides beneath (subducts) the North American plate, and is slowly driven into the earth's mantle. This seismic source is considered capable of generating M9 events every 300 to 500 years (see map), with long duration ground shaking, multiple aftershocks, and tsunamis. The most recent event on this source occurred in 1700. In addition to affecting Pacific Northwest coastal communities, a M9 subduction zone earthquake would impact the metropolitan areas of Portland and Seattle, as well as Vancouver, British Columbia, Canada. Application of lessons from the recent Japan and Chile earthquakes will result in a more resilient Cascadia Region.



M9.0 Cascadia Subduction Zone Scenario

MRP ENGINEERING SERVICES

MRP Engineering is a structural engineering and risk analysis firm (based in metropolitan Seattle, Washington) and provides proactive risk analysis for natural hazards, damage investigation, and upgrade design. We assist clients to protect their business operations from risks to physical assets resulting from extreme events such as earthquakes and hurricanes. Our philosophy is to listen to your needs and then provide you with practical and cost-effective structural engineering-based risk reduction solutions. Services include:

- Earthquake and wind risk evaluation
- Structural benefit-cost analysis
- Upgrade design
- Independent design review
- Damage (root cause) investigation
- Expert witness and claim support

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