Disasters of port facilities due to 2011 Great East Japan Earthquake

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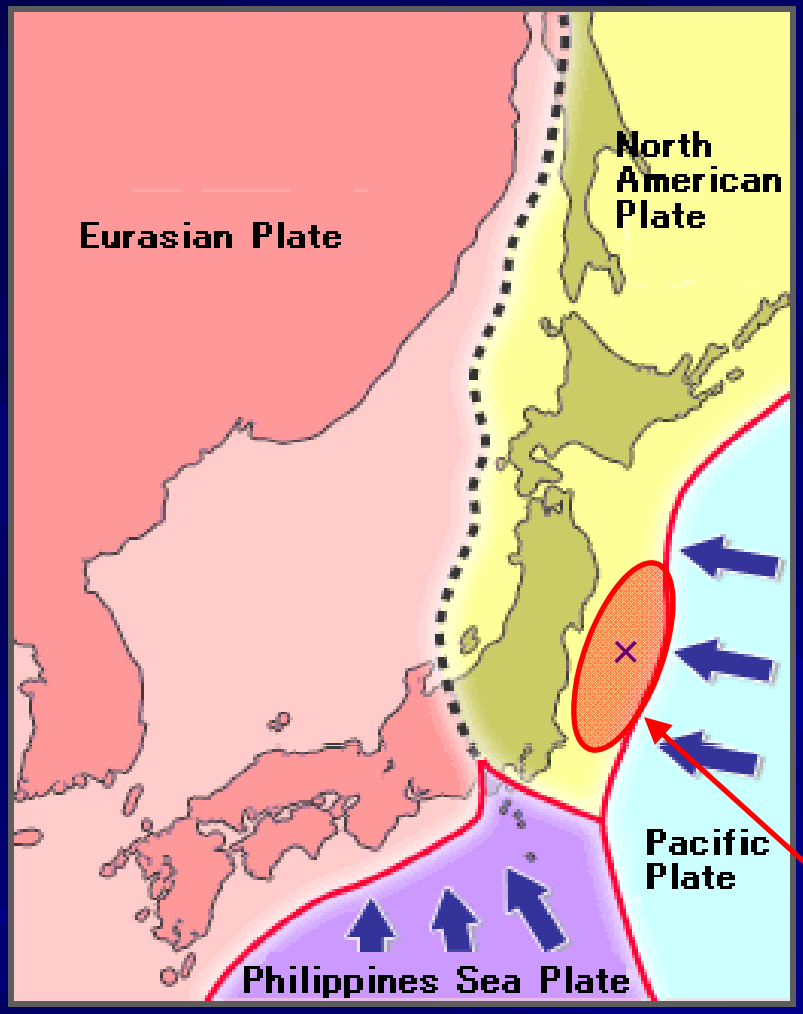
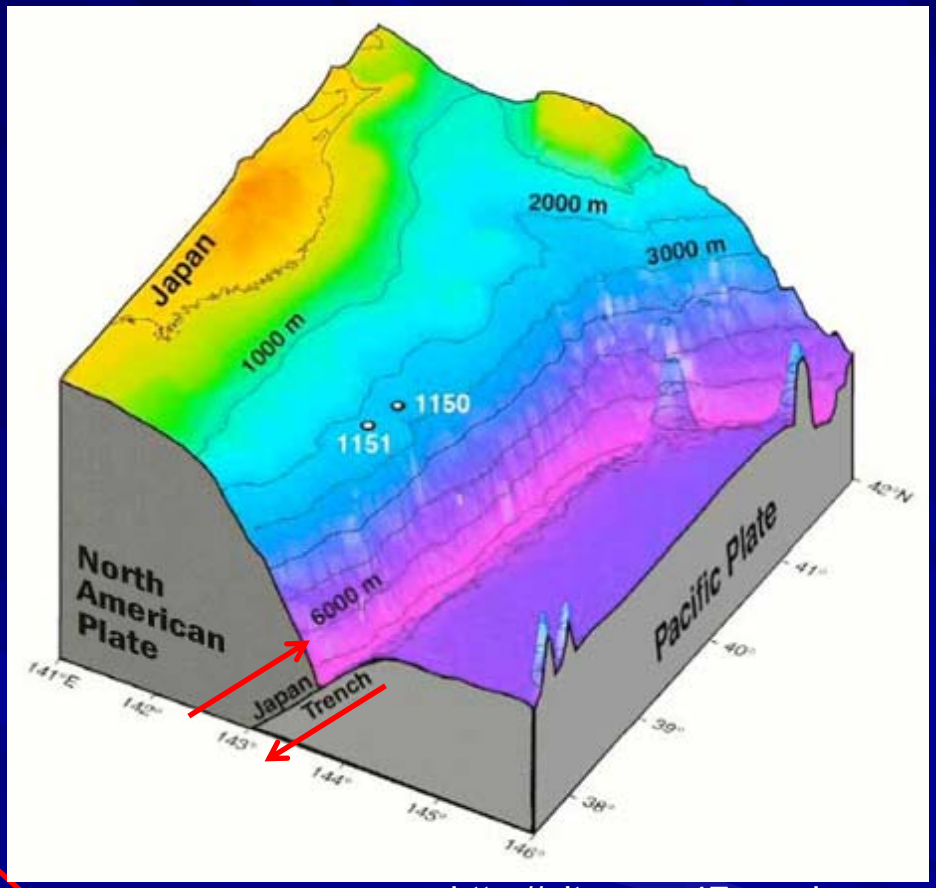
Source region of the earthquake



http://www.sonpo.or.jp

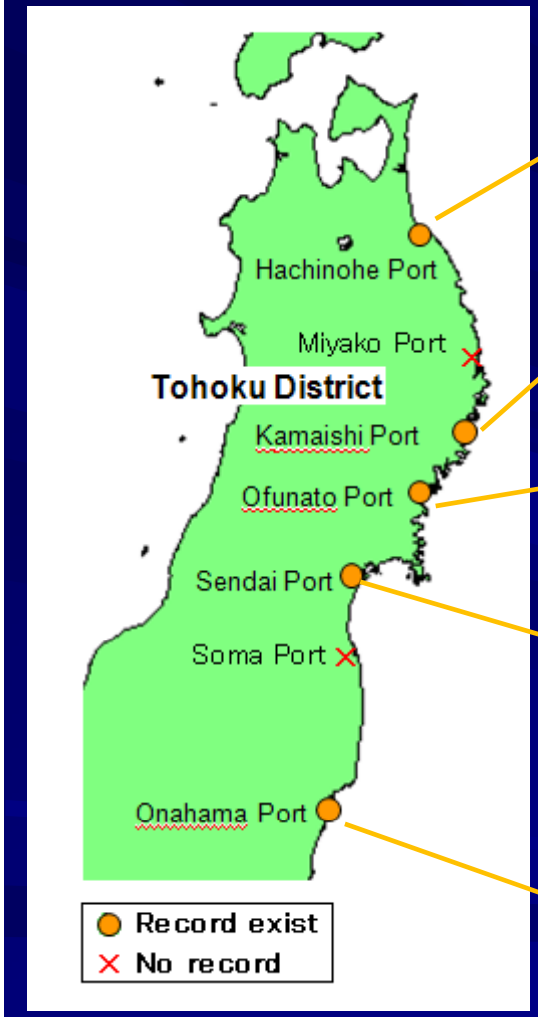


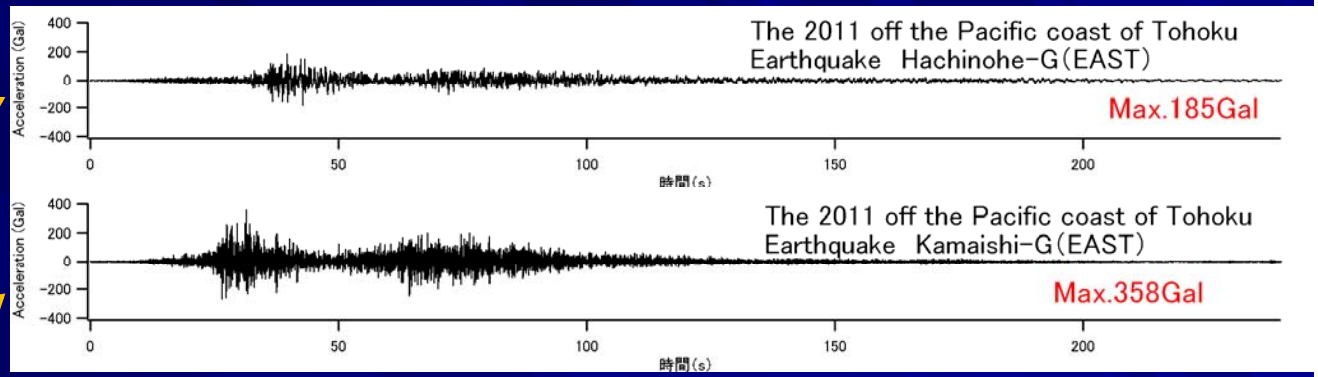
http://alterman47.wordpress.com

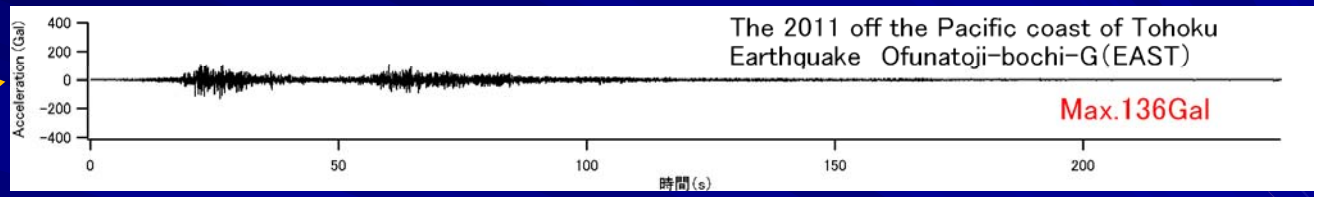
Approximate source region of the earthquake. “X” denotes the epicenter.

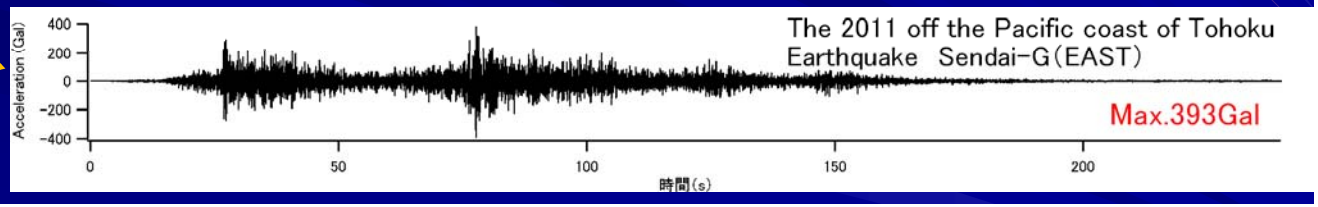
The pacific plate is subducting beneath the continental plate at the Japan trench. The earthquake occurred between the two plates.

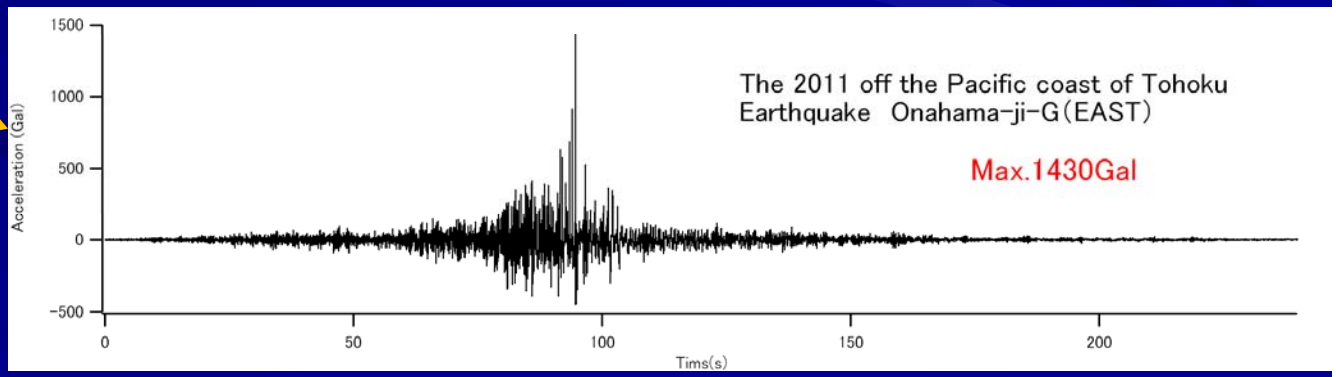
Strong motion data observed in the earthquake









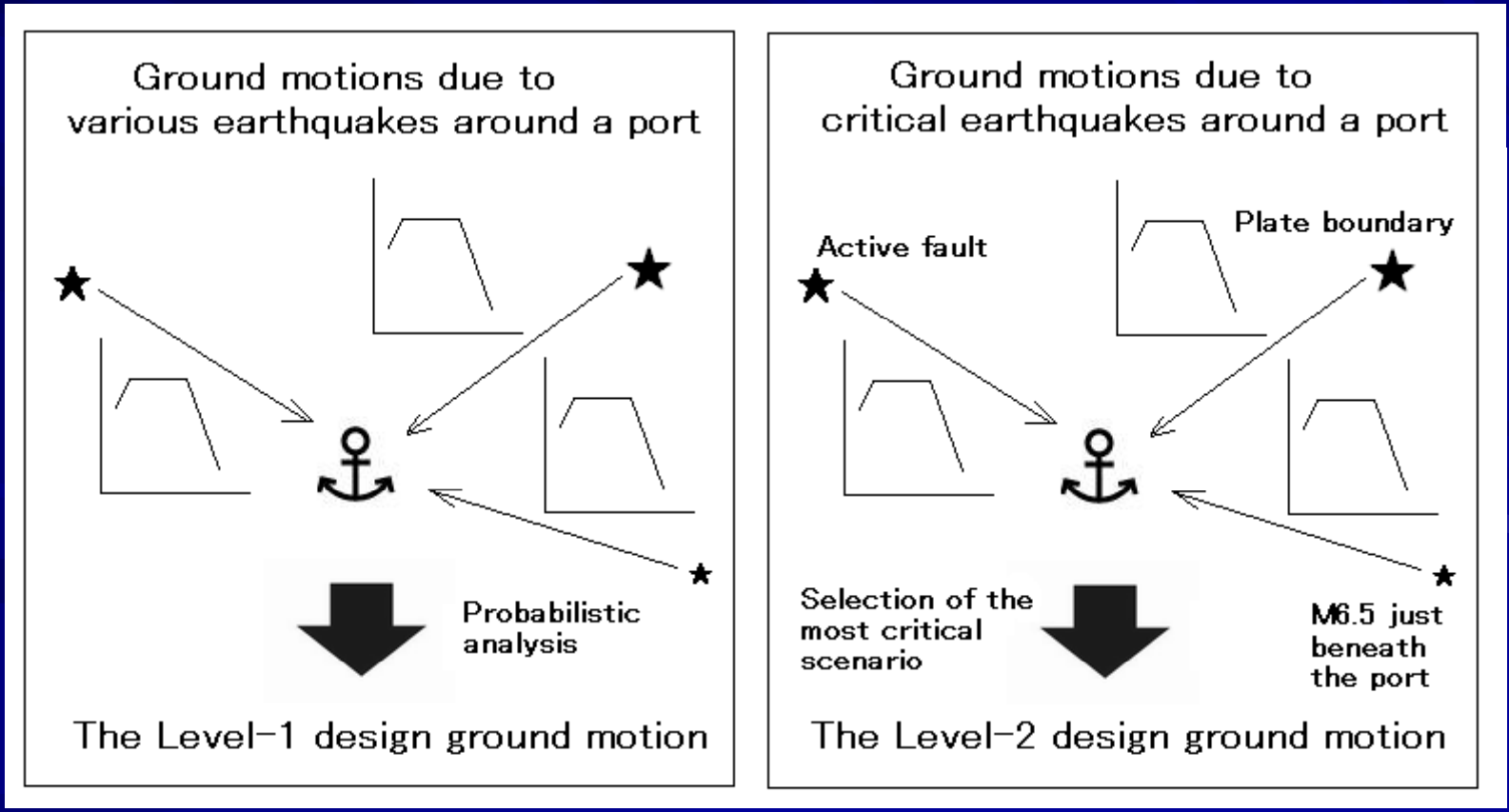


PARI

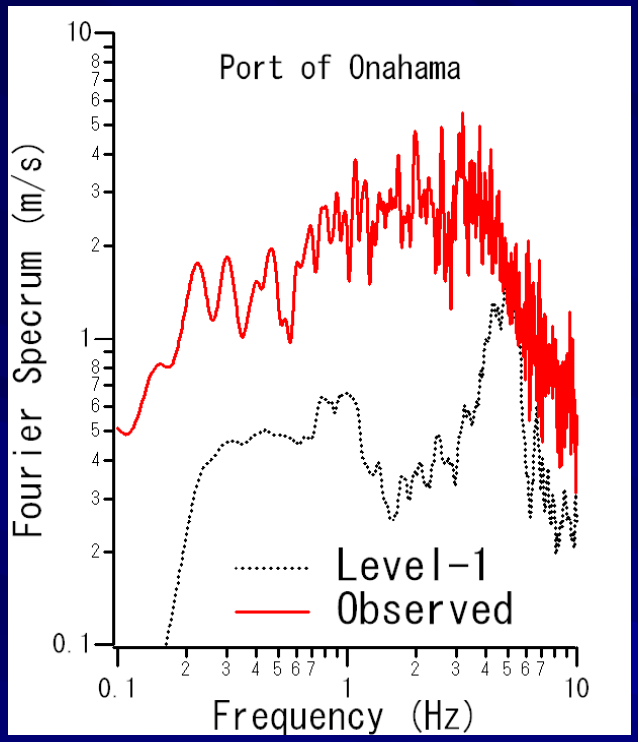
Design ground motions for Japanese Ports

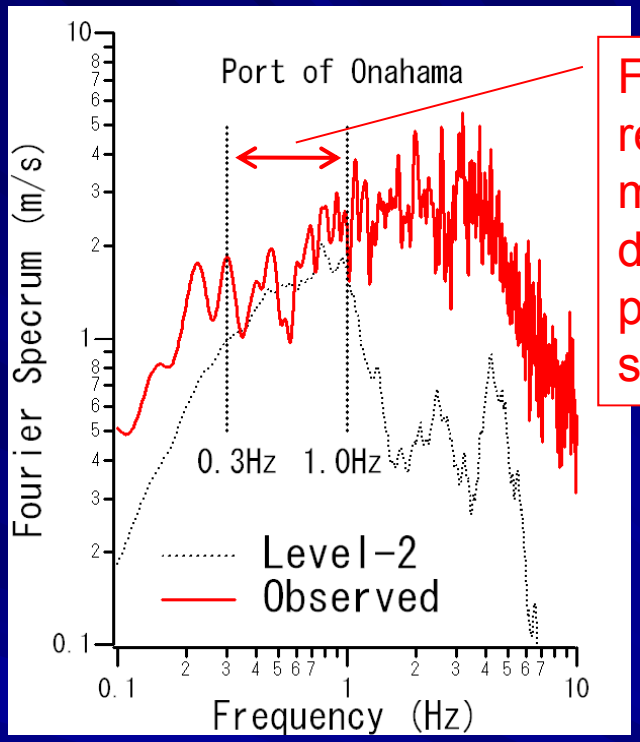
Two kinds of design ground motions are considered in the seismic design of Japanese port structures.

The Level-1 design ground motion is defined as a ground motion with the annual probability of exceedance of 1/75.
The Level-2 design ground motion is so called “the worst case scenario” ground motion.



Comparison of design and observed seismic motions --The case of Onahama Port



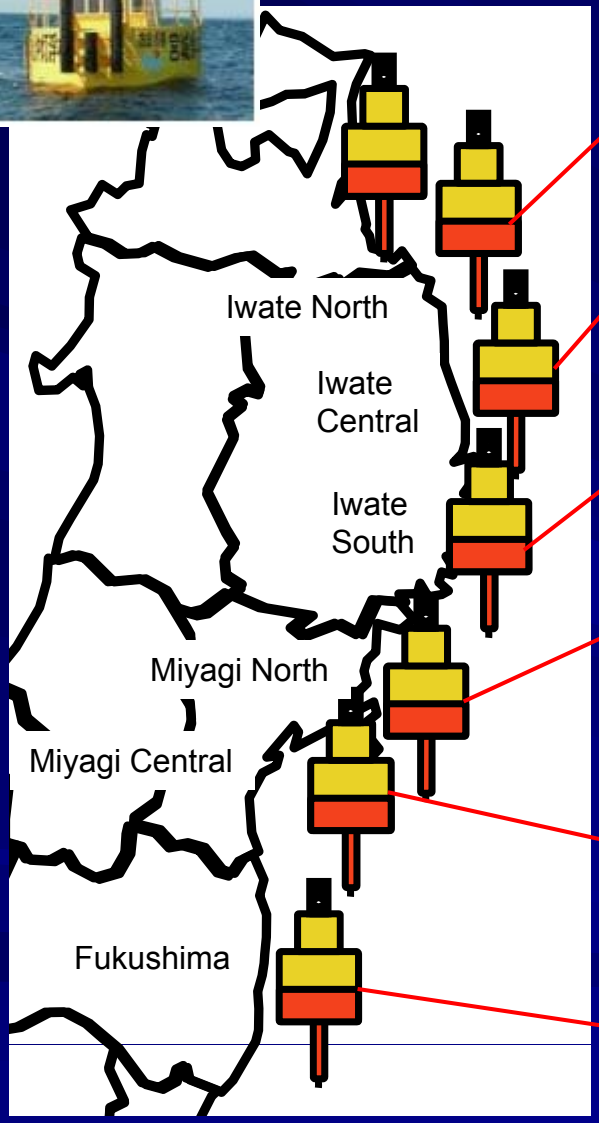


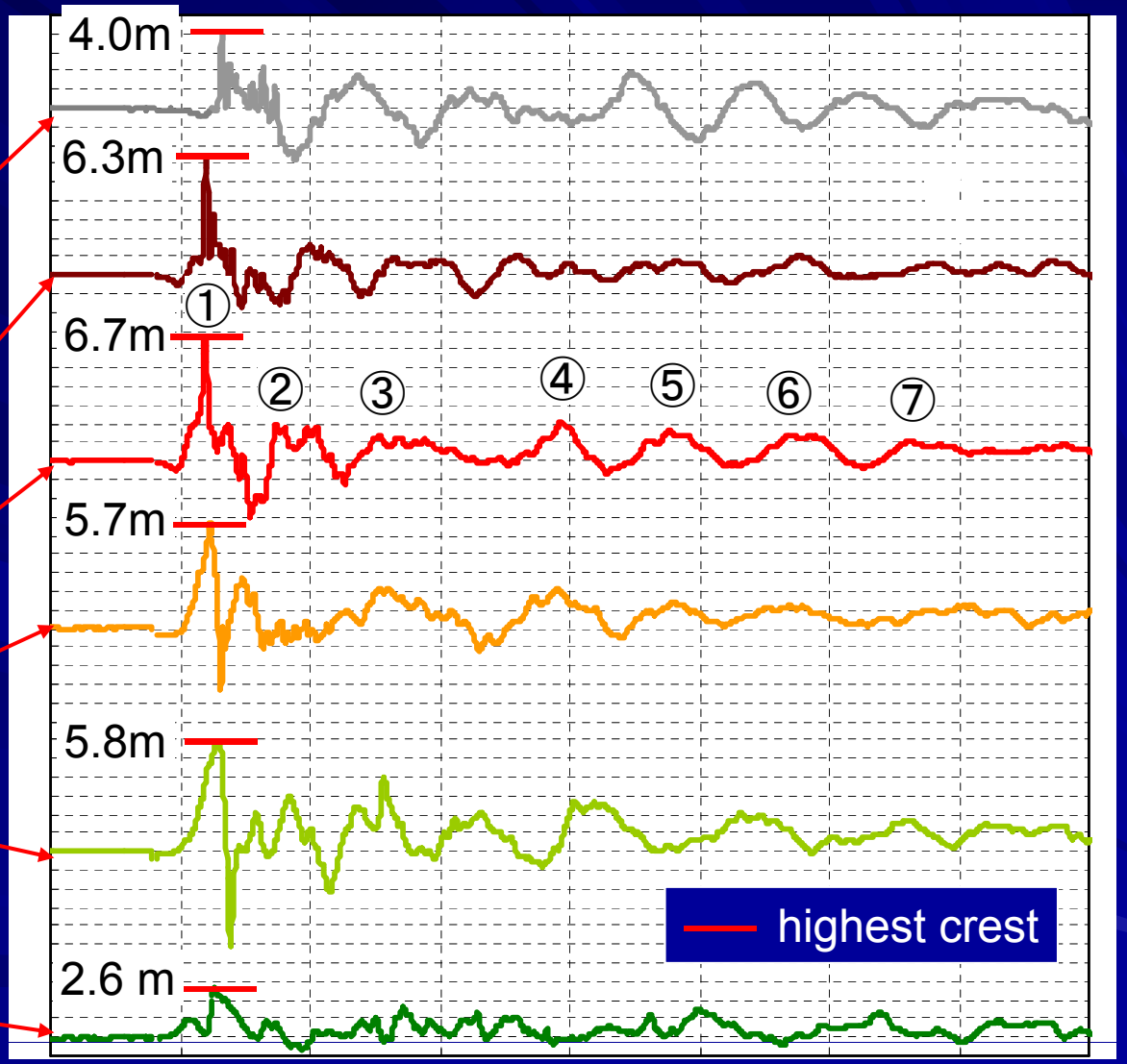
Frequencies relevant to major damage to port structures

It is quite natural that the observed ground motion exceeded the Level-1 design ground motion. The observed ground motion was close to the Level-2 design ground motion at frequencies relevant to major damage to port structures (0.3 – 1 Hz). But at higher frequencies, the observed ground motion exceeded the Level-2 design ground motion. In the case of Onahama, the Level-2 design ground motion was based on a scenario earthquake with magnitude 6.5 (but just beneath the port). The appropriateness of the scenario should be investigated once more.

PARI

Observation by GPS- mounted wave buoy





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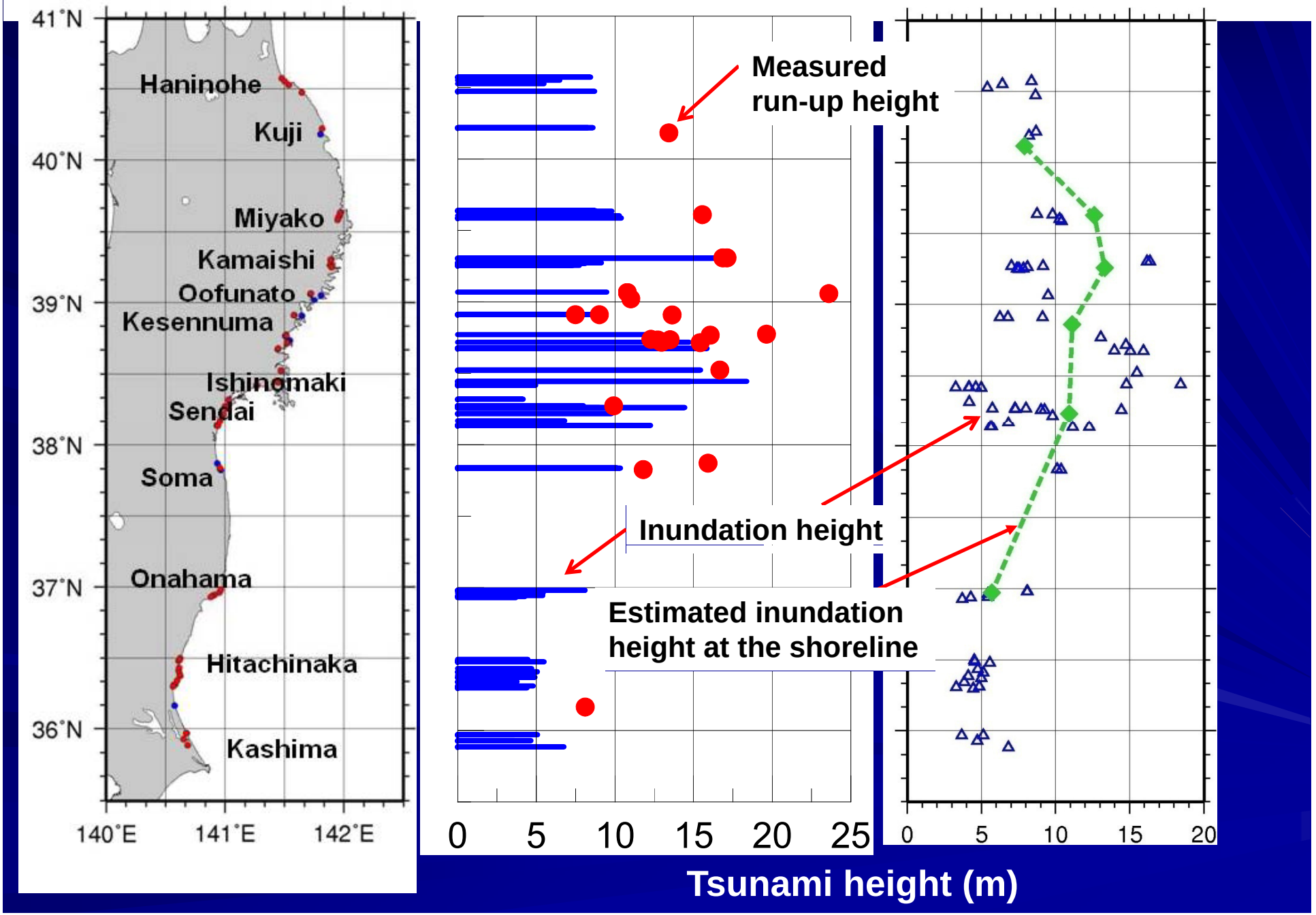
Observed and estimated tsunami height



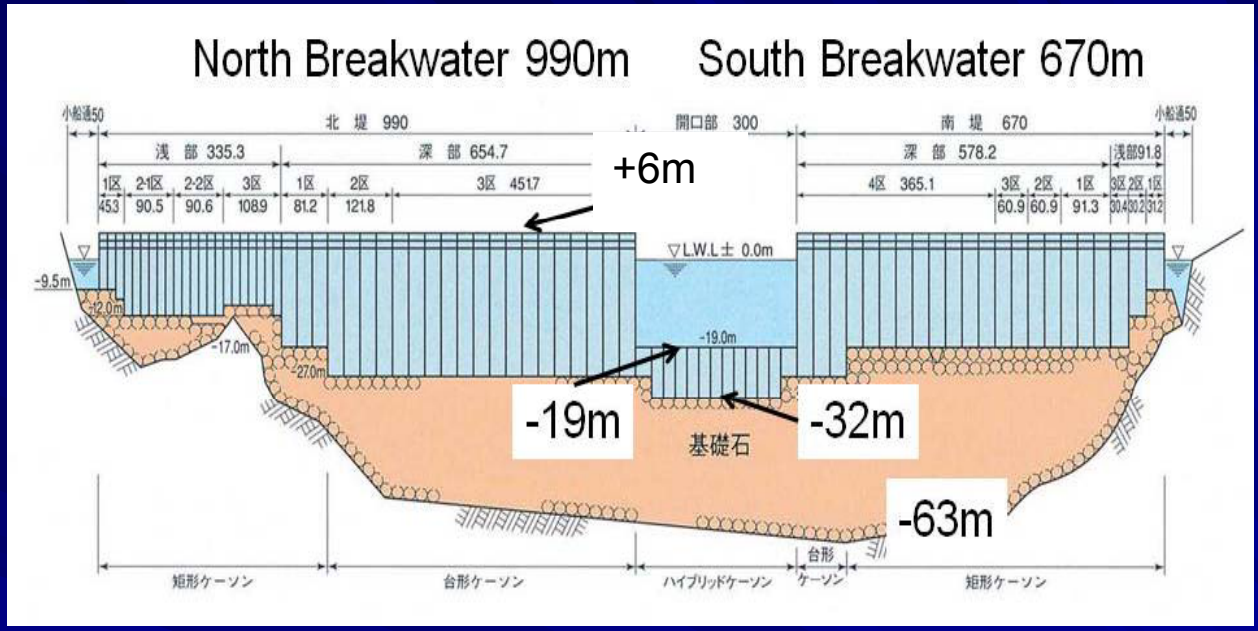
Breakwater disaster －Kamaishi Port

MLITT Tohoku regional Construction Bureau Kamaishi Office

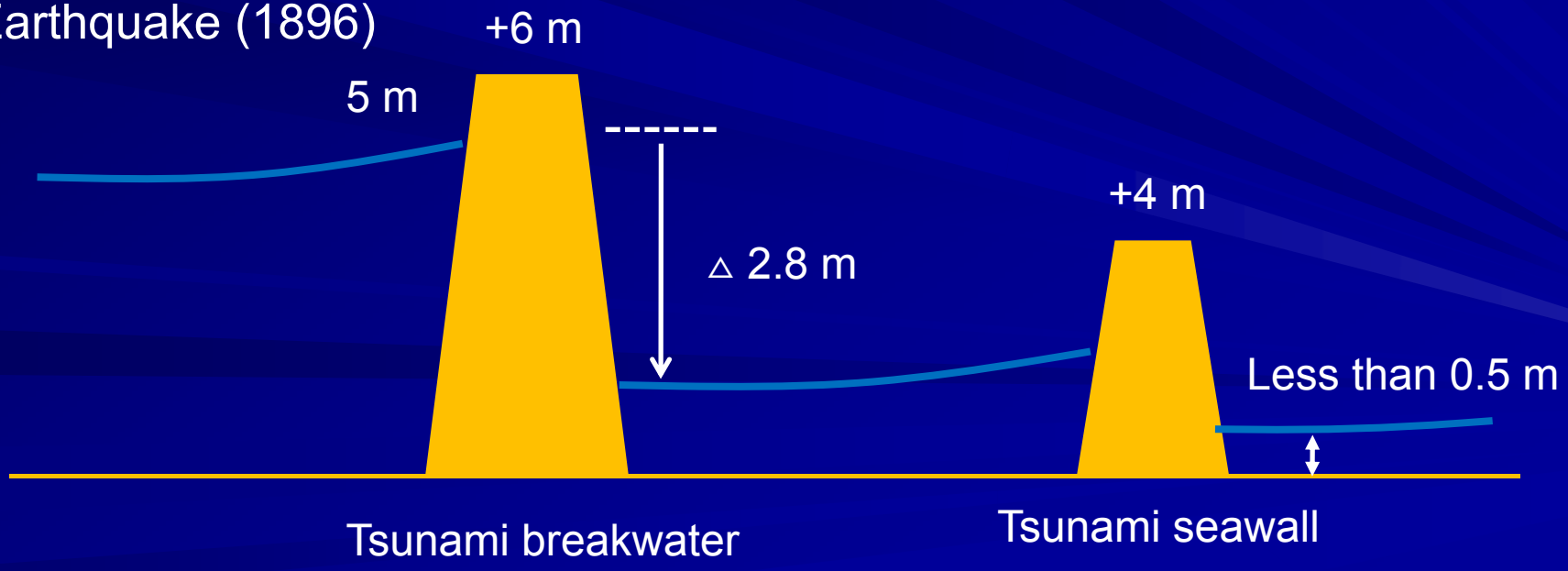
- Protection scheme ：Breakwater and coastal barrier
- Expected tsunami were Meiji and Showa Sanriku tsunami

Kamaishi Tsunami Breakwater

Construction:
1982-2008



Meiji Sanriku
Earthquake (1896)



Movement of the caissons and deformation of the mounds

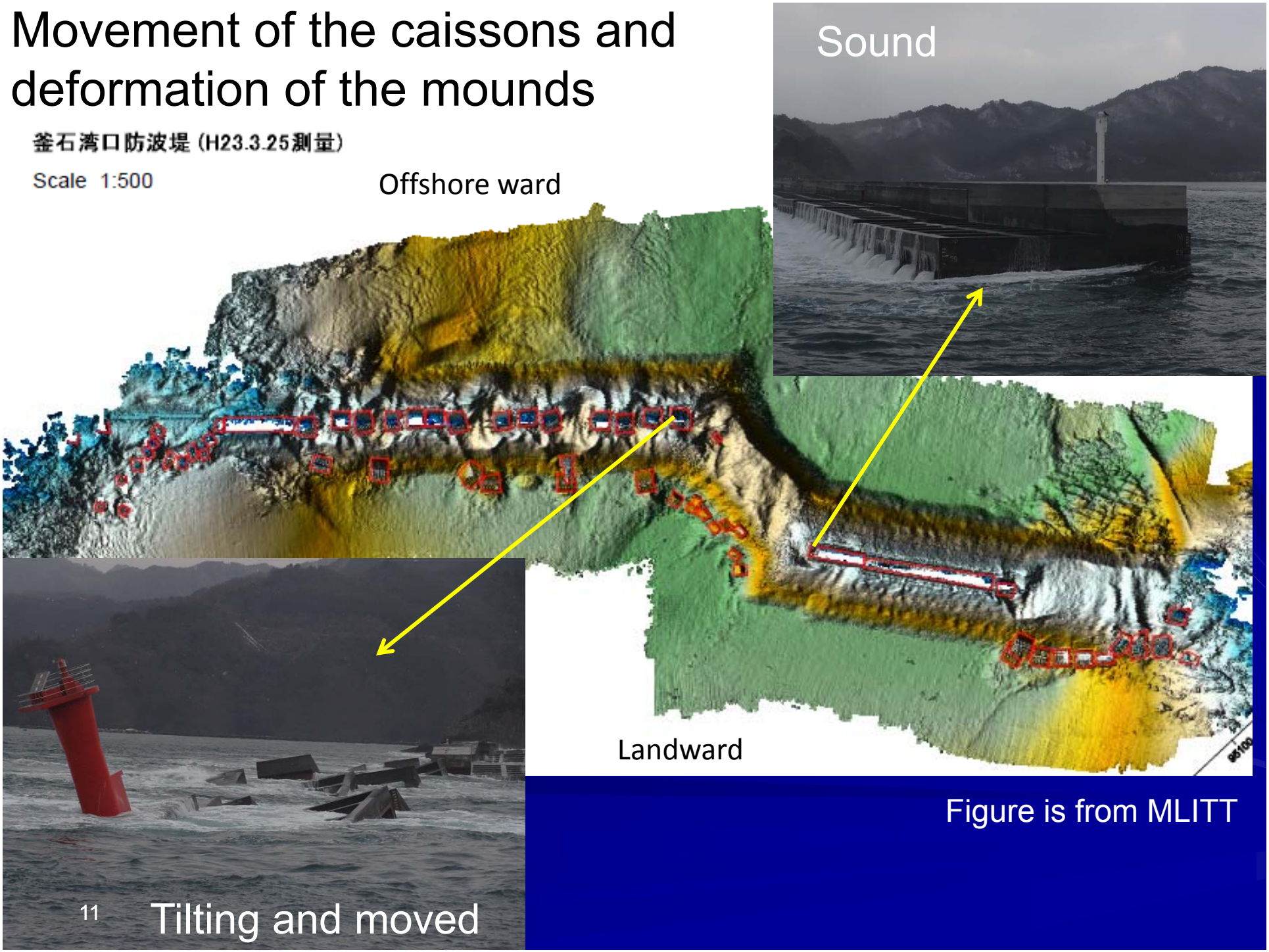


Figure is from MLITT

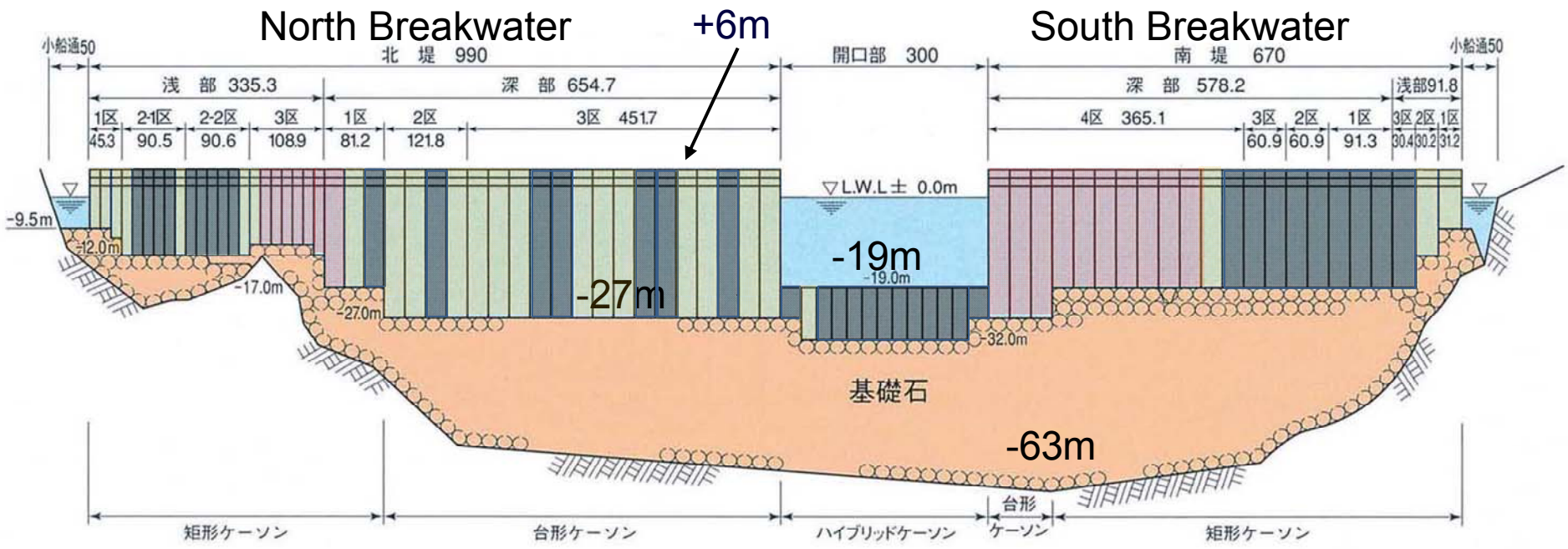
The earthquake occurred at 14:46

Kamaishi Office, MLITT

MLITT Tohoku regional Construction Bureau Kamaishi Office

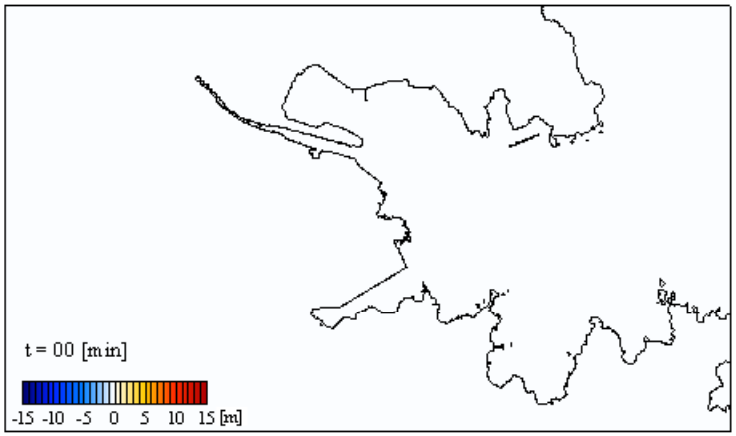
After the first tsunami

Kamaishi Tsunami Breakwater

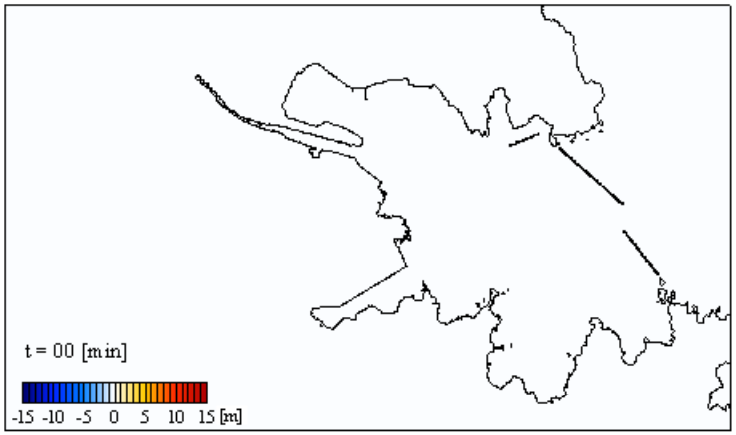


MLITT, Tohoku Regional Construction Bureau
Kamaishi Office

Simulation results for the ToHoku Earthquake in 2011



Without Breakwater

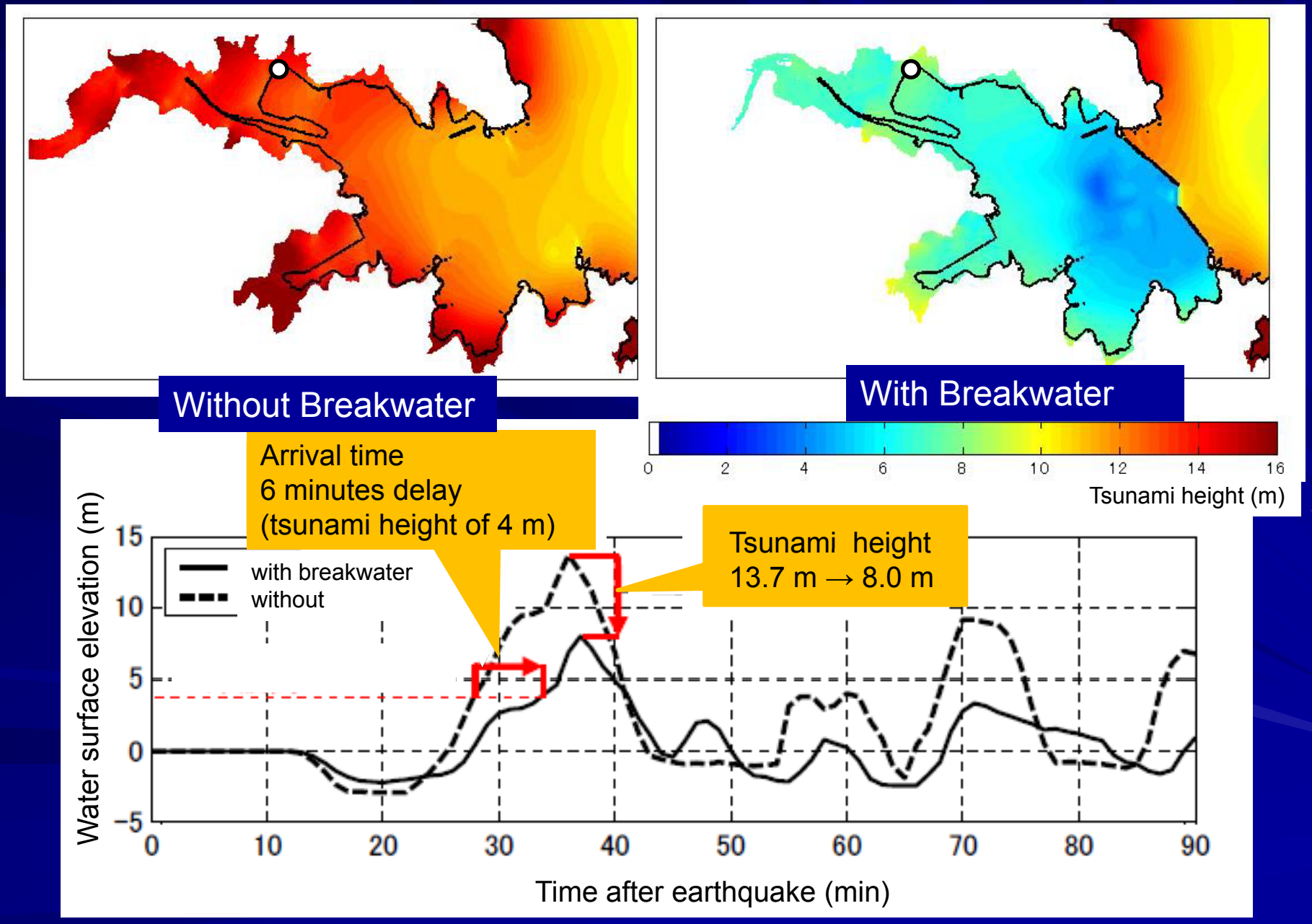


With Breakwater

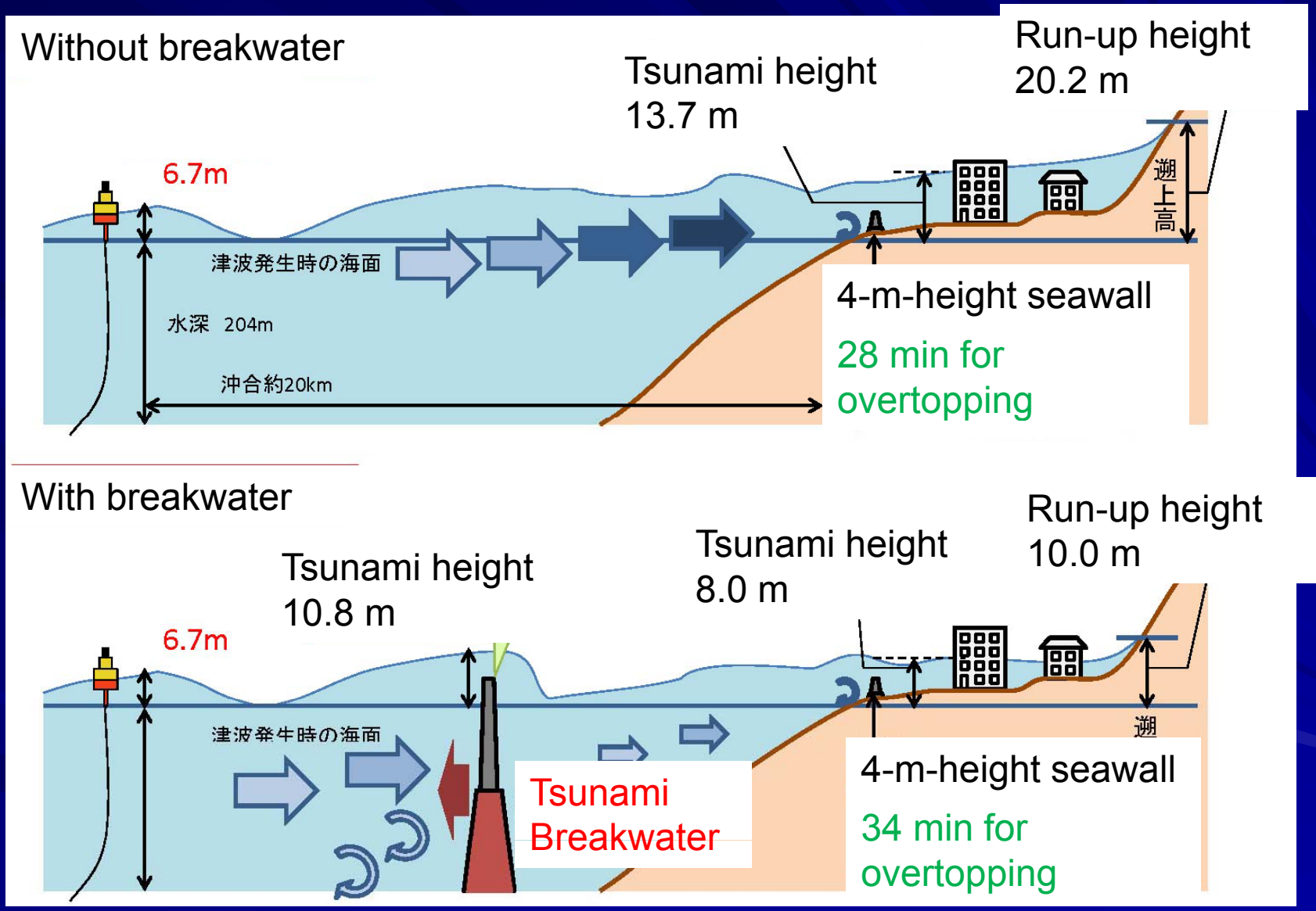
The 2011 off the Pacific Coast of Tohoku Earthquake (2011)

This tsunami simulation is conducted by ‘Storm Surge and Tsunami Simulator in Oceans and Coastal Areas (STOC)’, which is developed by PARI.

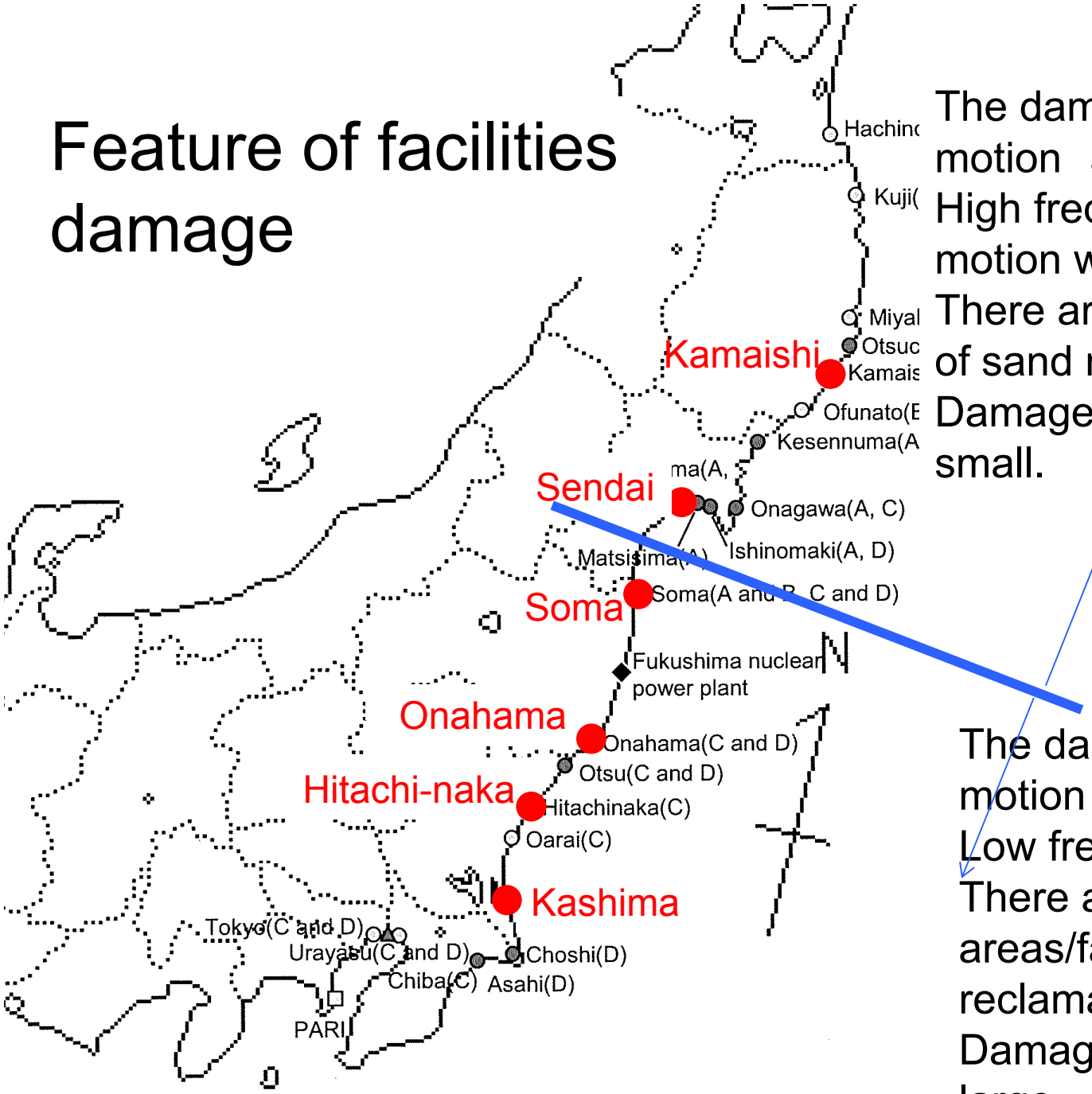
Effect of breakwater



Effect of breakwater



Feature of facilities damage



The damages due to seismic motion are slight.
High frequency seismic motion was observed.
There are few areas/facilities of sand reclamation.
Damage by liquefaction was small.

The damages due to seismic motion are relatively sever.
Low frequency
There are a lot of areas/facilities of sand reclamation.
Damage of liquefaction was large.

High earthquake-resistance quay wall

Central Wharf, Hitachi-naka District, Ibaraki Port

- Little lateral displacement of the quay wall.
- Liquefaction evidence was not recognized since un-sieved crushed stone is filled as liquefaction countermeasure.
- The high earthquake resistance quay wall showed good seismic performance. The quay went into service on March 15 after checking the burying of navigation channel by tsunami.

Damage by Liquefaction Onahama Port

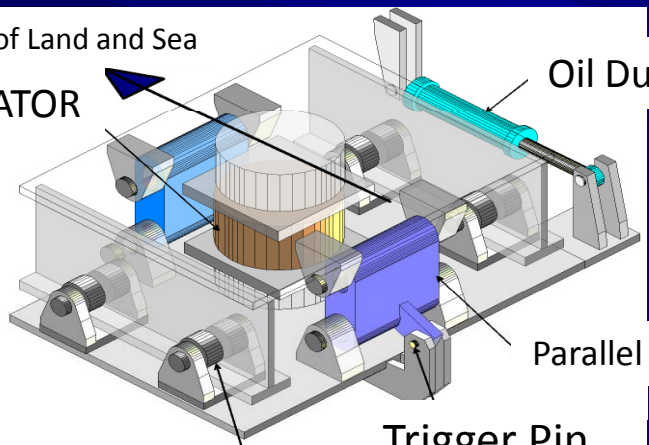
Because of liquefaction

Uneven settlement : pile supported crane rail and apron

Sendai Port: Base Isolated Gantry Crane

4 Gantry Cranes : 2 base-isolated cranes
2 non-base-isolated cranes

Damage occurred in one non-base-isolated crane

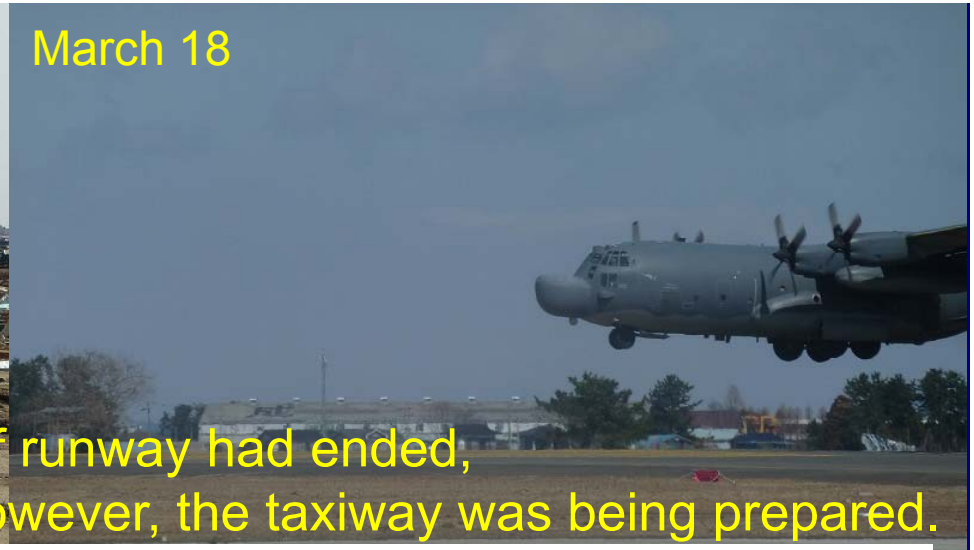


Base Isolation system

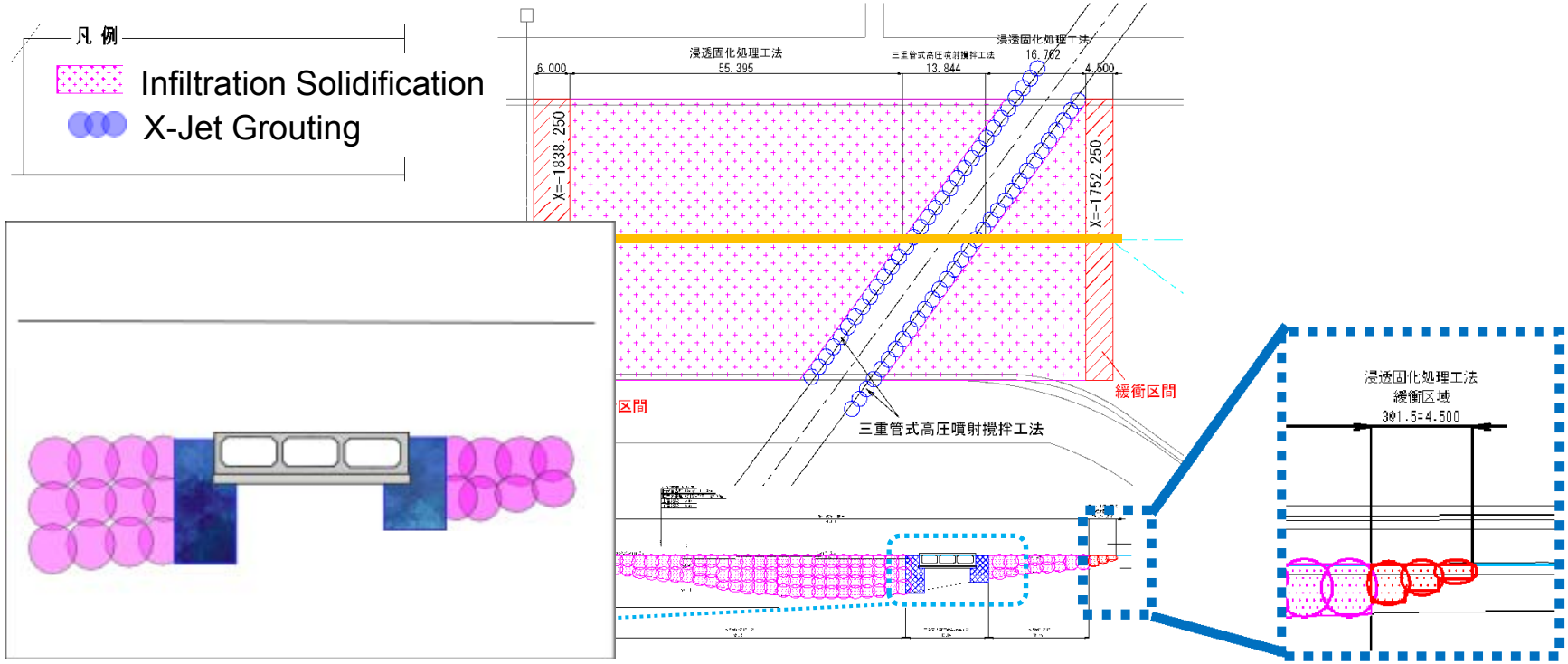
Patent holder : PARI and Mitsui Engineering & Shipbuilding Co, Ltd.

Base-isolated cranes: No structural damage

Liquefaction remediation Sendai Airport



The liquefaction counter measure of runway had ended,
however, the taxiway was being prepared.



Liquefaction remediation Sendai Airport

The runway keeps ‘Serviceability’ just after the Earthquake. However, It took one week to cleanup the debris due to Tsunami.

The operation of the passenger plane restarted on April 13.

There are serious subsidence, uneven settlements and clacks on the surface of un-improved taxiway.
It lost the ‘Serviceability’ and the ‘Reparability.’

Summary of disasters by EQ

- There are some relations between site characteristics and the level of damages of the structures.

Northern Tohoku: Seismic motion has high frequency, small damages were observed.
Southern Tohoku: Seismic motion has low frequency, large damages were observed.

- Liquefaction of reclaimed land

Northern Tohoku: a few reclaimed land
Excavated port: small damage
Long duration and long period seismic motion make liquefaction damage large.

- Effect of small landform

Reclaimed marsh made damage large.
Damage level was different between in sand dune and backswamp.

- Effect of liquefaction measurement

  Advantage of liquefaction measurement was proved.

- Aftershocks made damage extend.

- Design codes need to modify with performance based design concept considering the relation between seismic motion and damage level of the structures. High accuracy design verification method is required to improve the estimation of seismic motion and damage level relation.

Complex damage by both EQ and Tsunami

EQ		Tsunami		EQ + Tsunami damage
slight damage	+	slight damage	=	slight ? medium? extensive?
medium damage	+	slight damage	=	slight? medium? extensive?

Damage of sheet pile quay wall

Soma Port

Dimension of damaged zone was 30m×15m

Backrush flow was concentrated to a small area because of the structures.

Damage was observed only in a small area. This kind of things have never observed only by earthquake.

EQ ＞Liquefaction ＞ damage of pavement and sheet pile ＞ scouring of apron ＞Scouring of foundation of sheet pile ＞ Damage of the quay wall was extended by backrush

The messages “Make the best Nippon“, “Make the best Tohoku” were printed on the side of the Tohoku Shinkansen

Thank you for your kind attention!

March 18, 2011 Kamaishi Port