Damage of Bridges Resulted from March 11, 2011 East-Japan Earthquake

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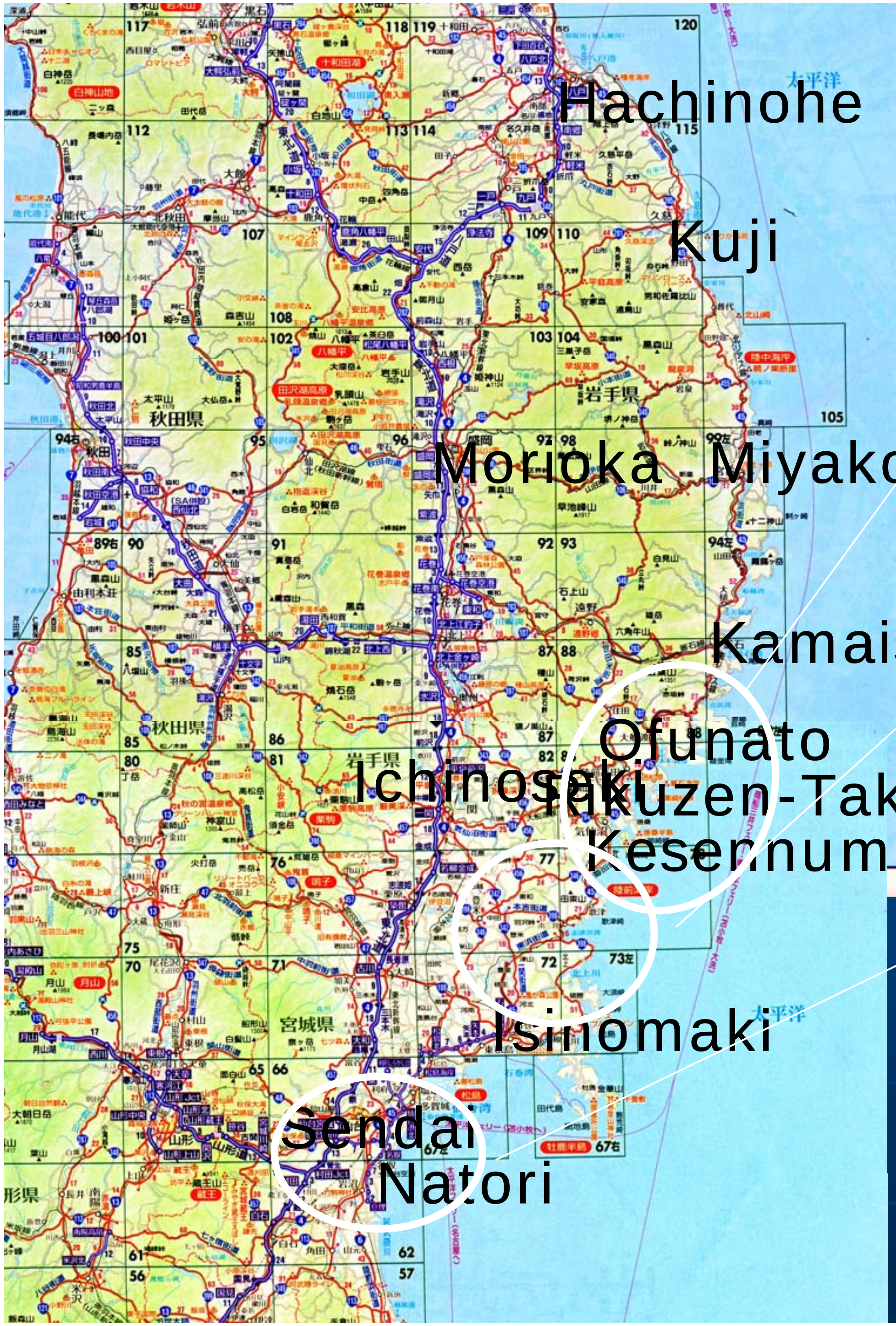
Introduction

This slide set shows damage of transportation facility due to the East-Japan earthquake, March 11, 2011. The field damage investigation was conducted on March 29-Arpril 3, 2011 by the author with other 12 members of the Japan Society of Civil Engineers’ reconnaissance damage investigation team. The cooperation of the team members is greatly acknowledged. The view shown here is that of the author, and does not necessarily represent the view of Japan Society of Civil Engineers.

JSCE Reconnaissance Site damage Investigation



Kesennuma, Rikuzen-Takada, Ofunato

Ishinomaki, Furukawa, Wakuya, Tukudate

Sendai, Yuriage

Preliminary Report on the Damage of Civil Engineering Structures Resulted from March 11, 2011 East-Japan Earthquake

http://committees.jsce.or.jp/report/node/40

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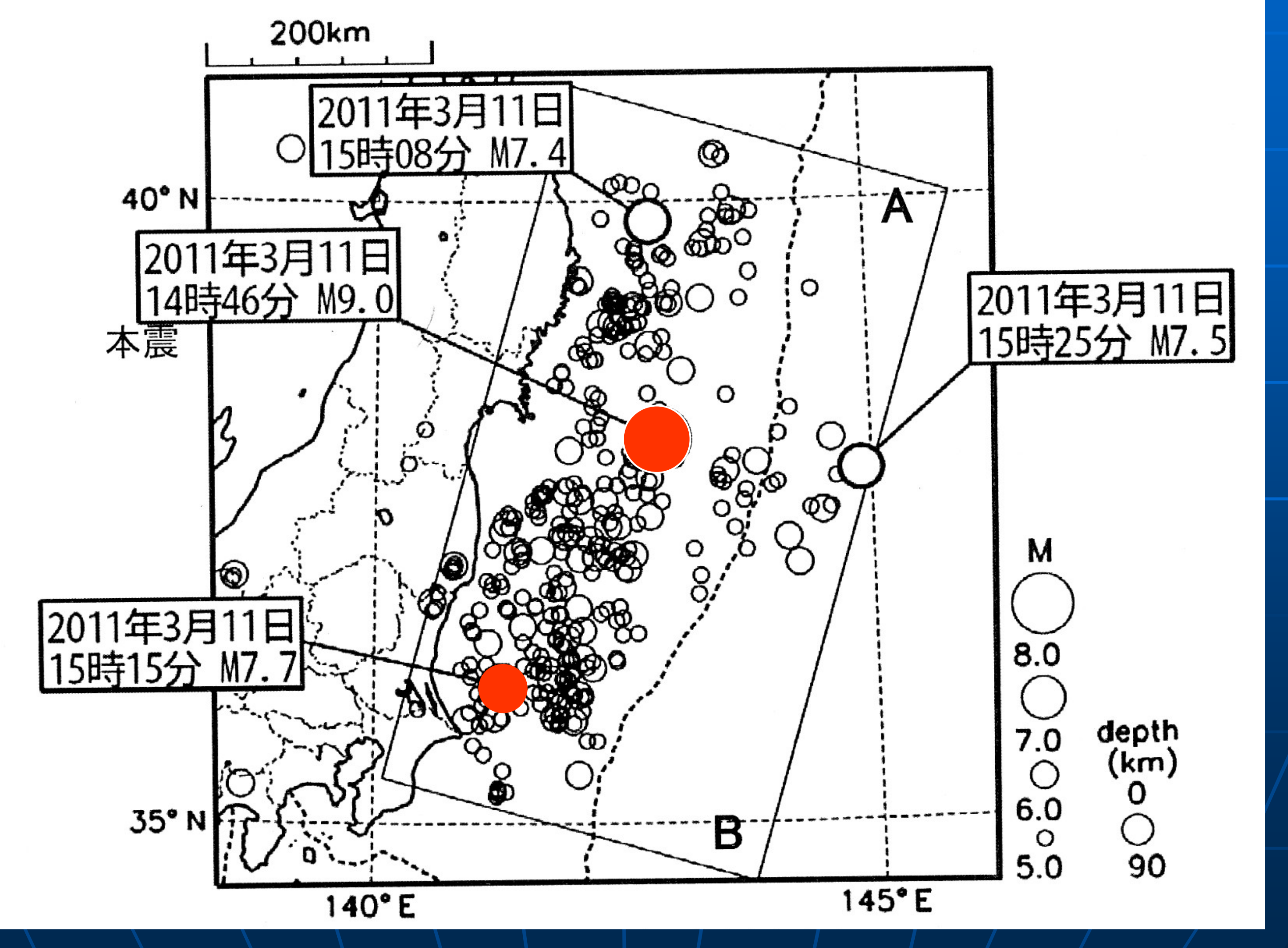
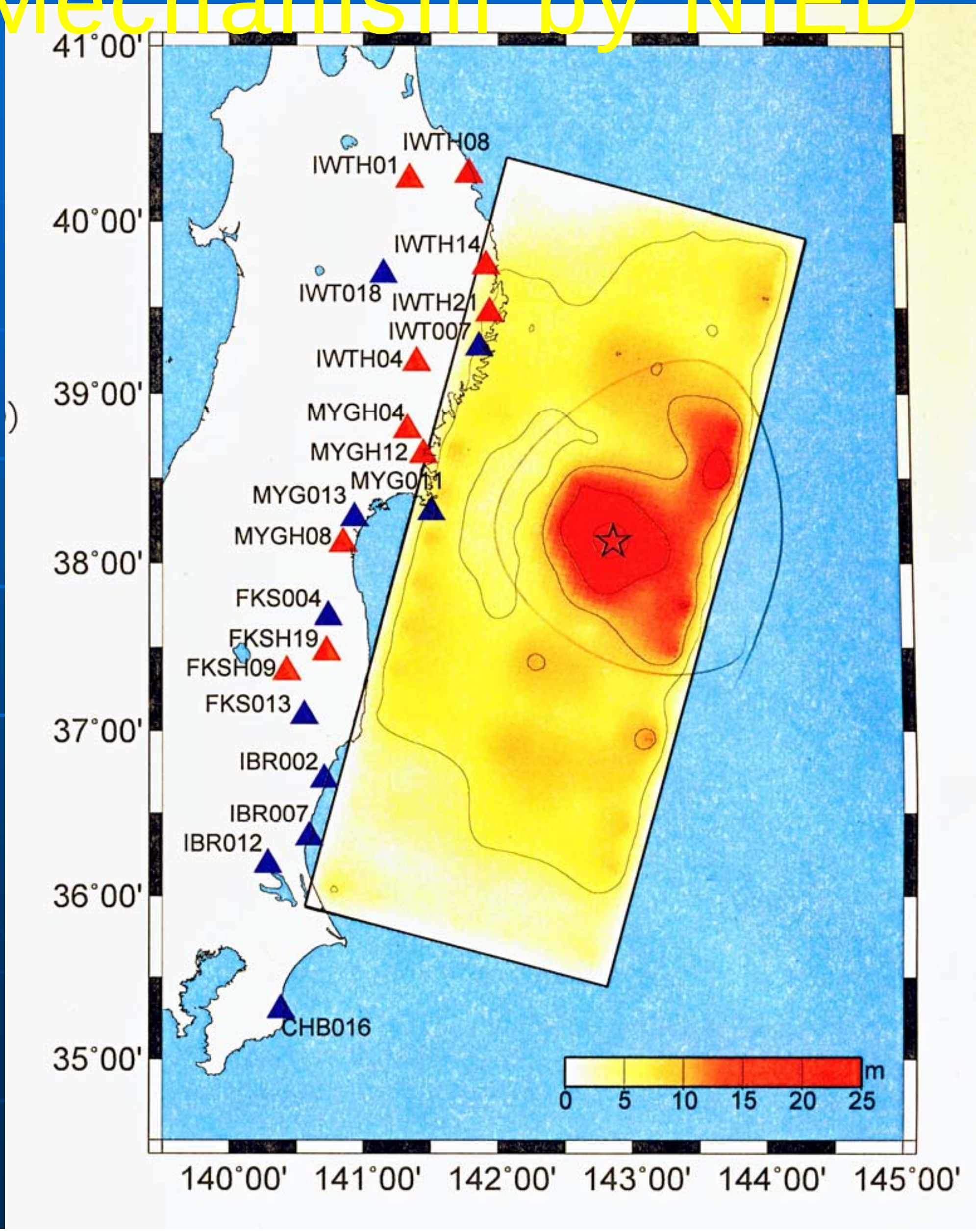
After-shock Area

Between 12:00, March 11 and 12:00, March 23 by JMA



Preliminary Analysis of the Fault Mechanism by NIED



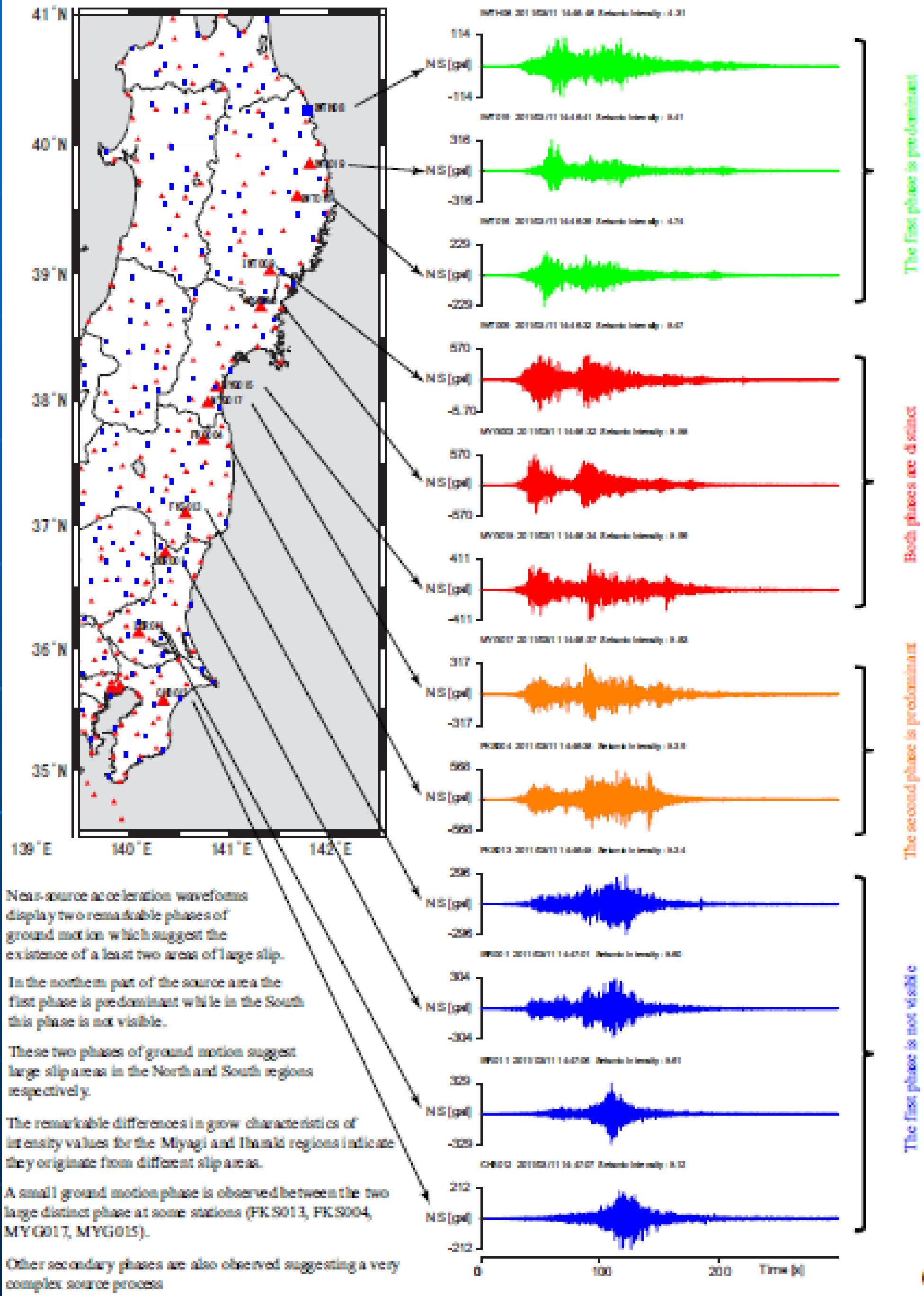
- Direction: 195 degree
- Dip: 13 degree
- Size: 501kmX210km
- Maximum slip: 23m
- M_w=8.9

NIED

K-NET Strong Motion Records

Characteristics of near-source ground motions

National Research Institute for Earth Science and Disaster Prevention



Near-source acceleration waveforms display two remarkable phases of ground motion which suggest the existence of a least two areas of large slip.

In the northern part of the source area the first phase is predominant while in the South this phase is not visible.

These two phases of ground motion suggest large slip areas in the North and South regions respectively.

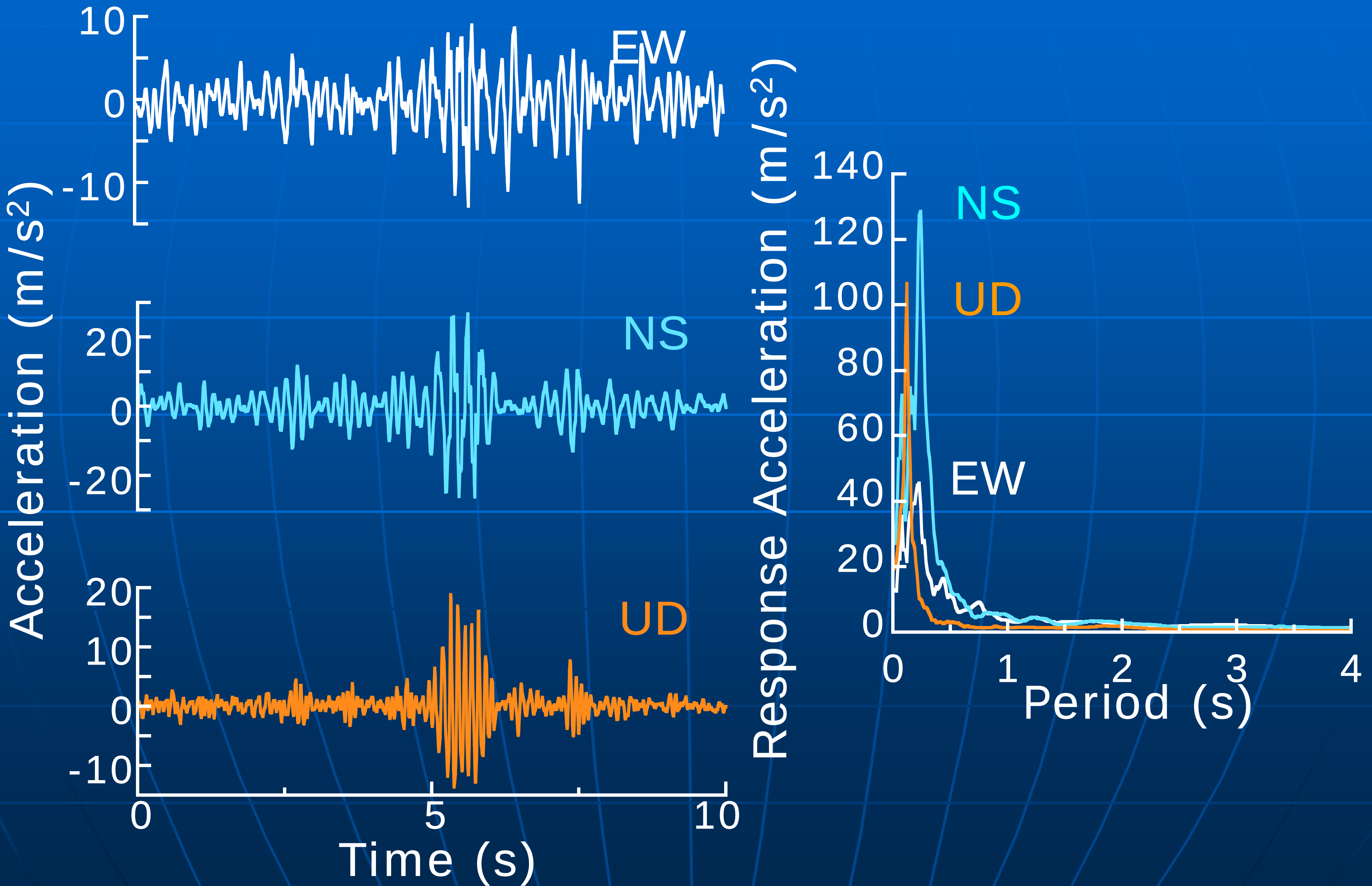
The remarkable differences in grow characteristics of intensity values for the Miyagi and Ibaraki regions indicate they originate from different slip areas.

A small ground motion phase is observed between the two large distinct phase at some stations (FKS013, FKS004, MYG017, MYG015).

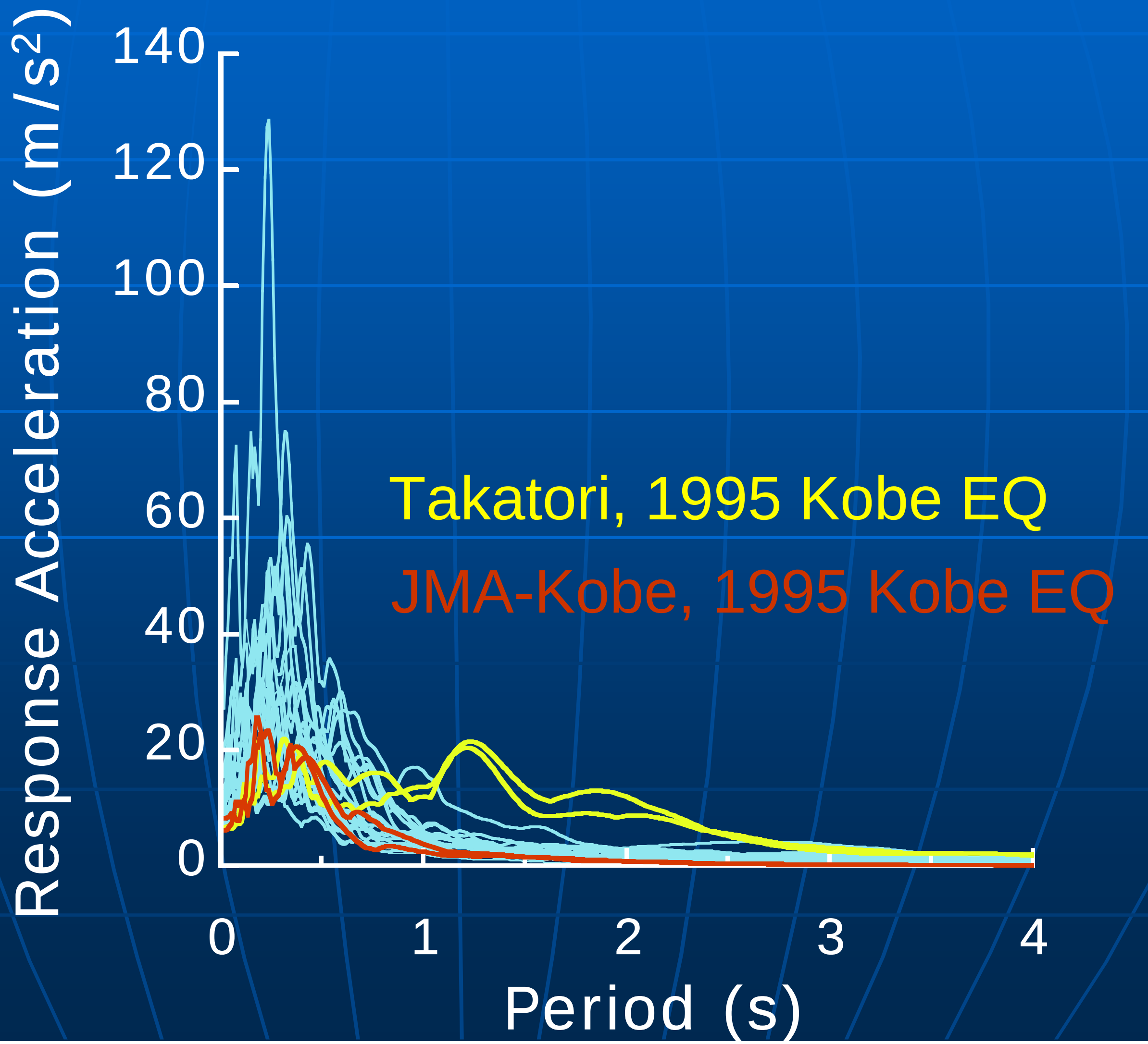
Other secondary phases are also observed suggesting a very complex source process

NIED

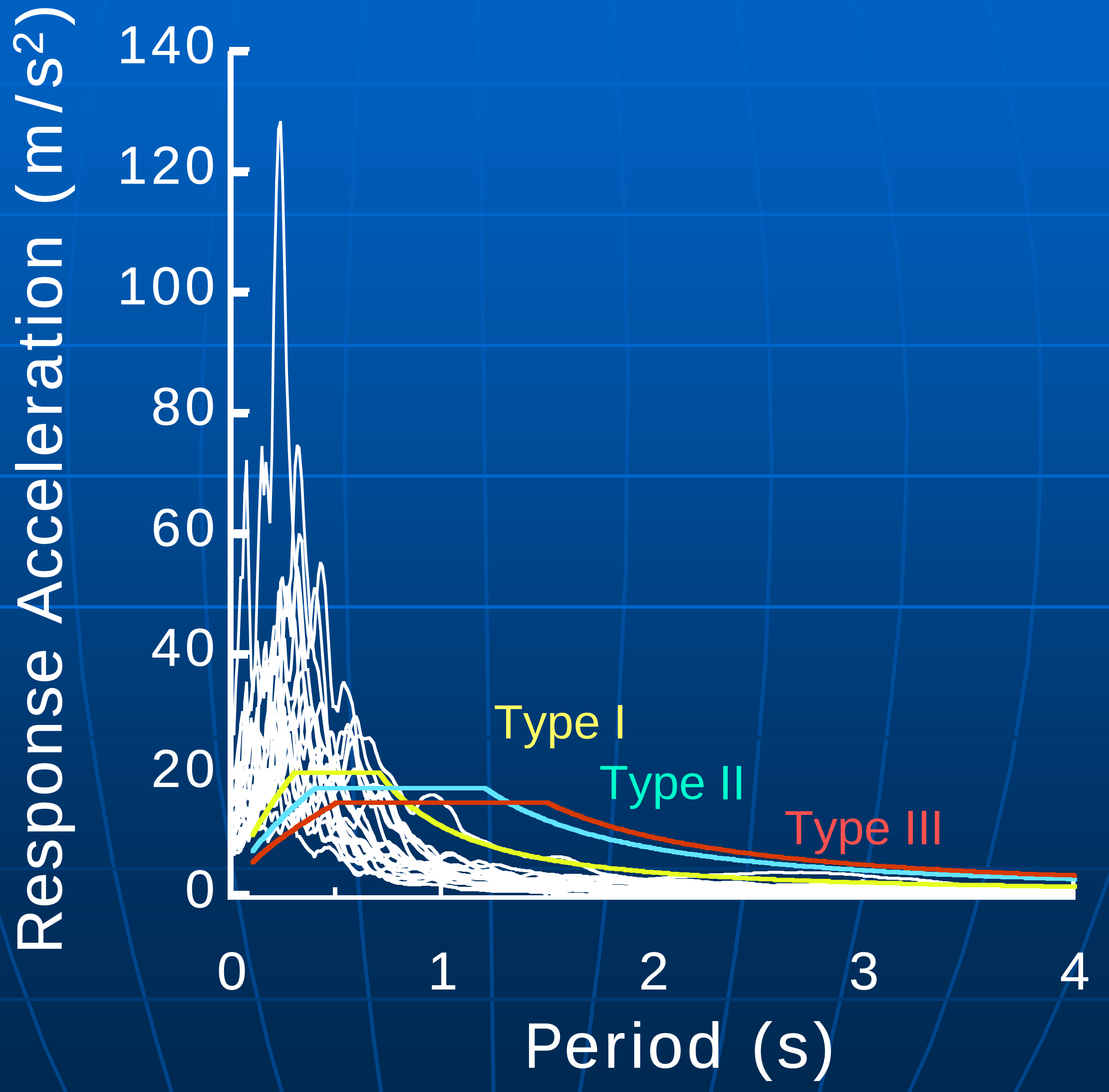
Response Spectrum at Tsukudate where Response Spectrum was the highest



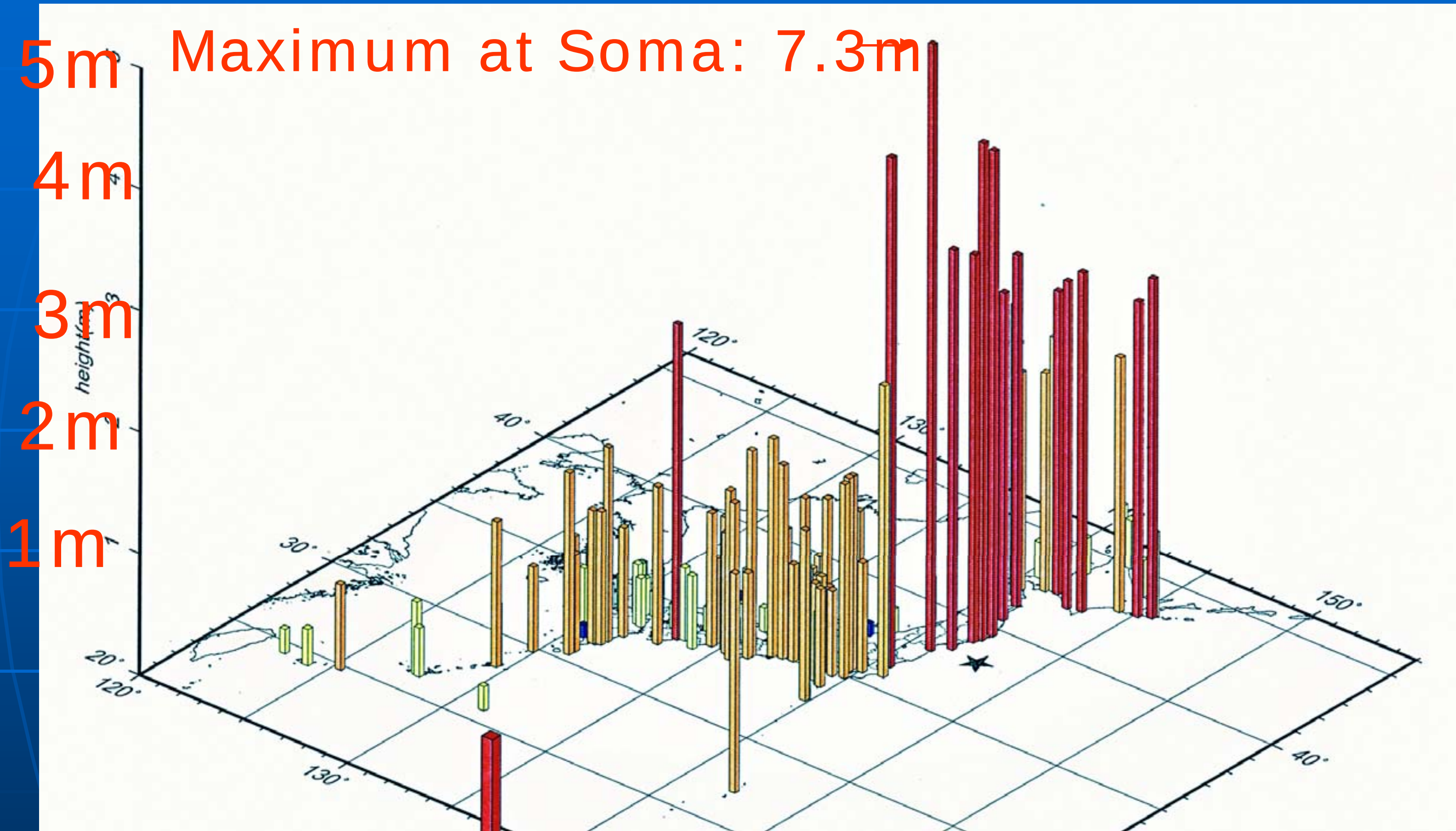
Comparison with 2 typical near-field ground motions during the 1995 Kobe, Japan earthquake JMA Kobe & JR Takatori Station



Comparison with Type II Design Spectra, JRA Design Specifications of Bridges



Tsunami Height measured by JMA



- Local tsunami height is being investigated. It is reported that tsunami run up 23 m at a site in Ofunato City.

Kesen-numa City

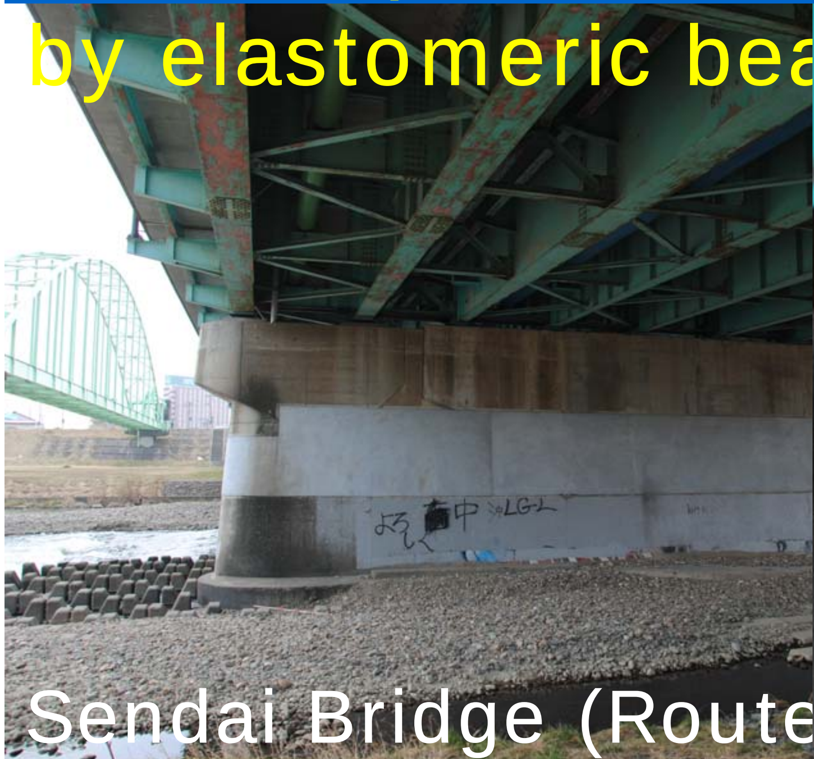
From Kesen-numa Junior High School

Kesen-numa City

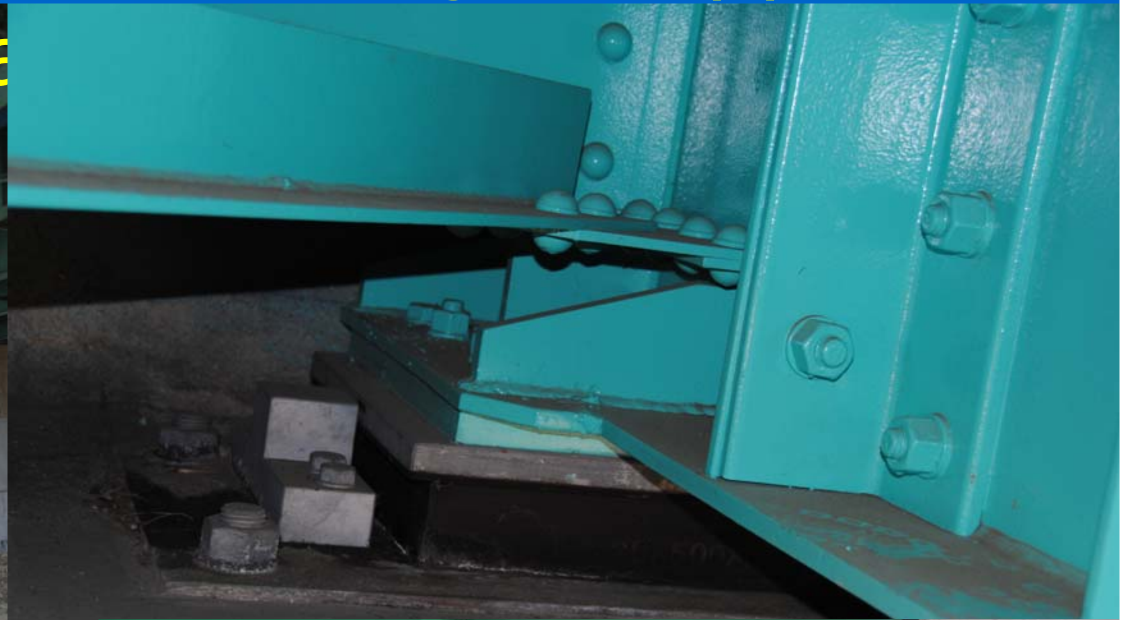
Field damage investigation for bridges was conducted focusing on the following issues:

- Was the ductility capacity method which was enforced in design of road bridges since 1990 effective for mitigating damage?
- Was the extensive use of elastomeric bearings since 1995 Kobe earthquake effective for mitigating damage of bearings?
- What types of damage occurred to bridges due to tsunami?

Seismic performance of bridges supported by elastomeric bea



Sendai Bridge (Route



Shin-Tenno Bridge (Sar

Bridges supported by elastomeric bearings did not suffer damage

Iinogawa Bridge, Route 45

Higashi Matsuyama Bridge, Route 45

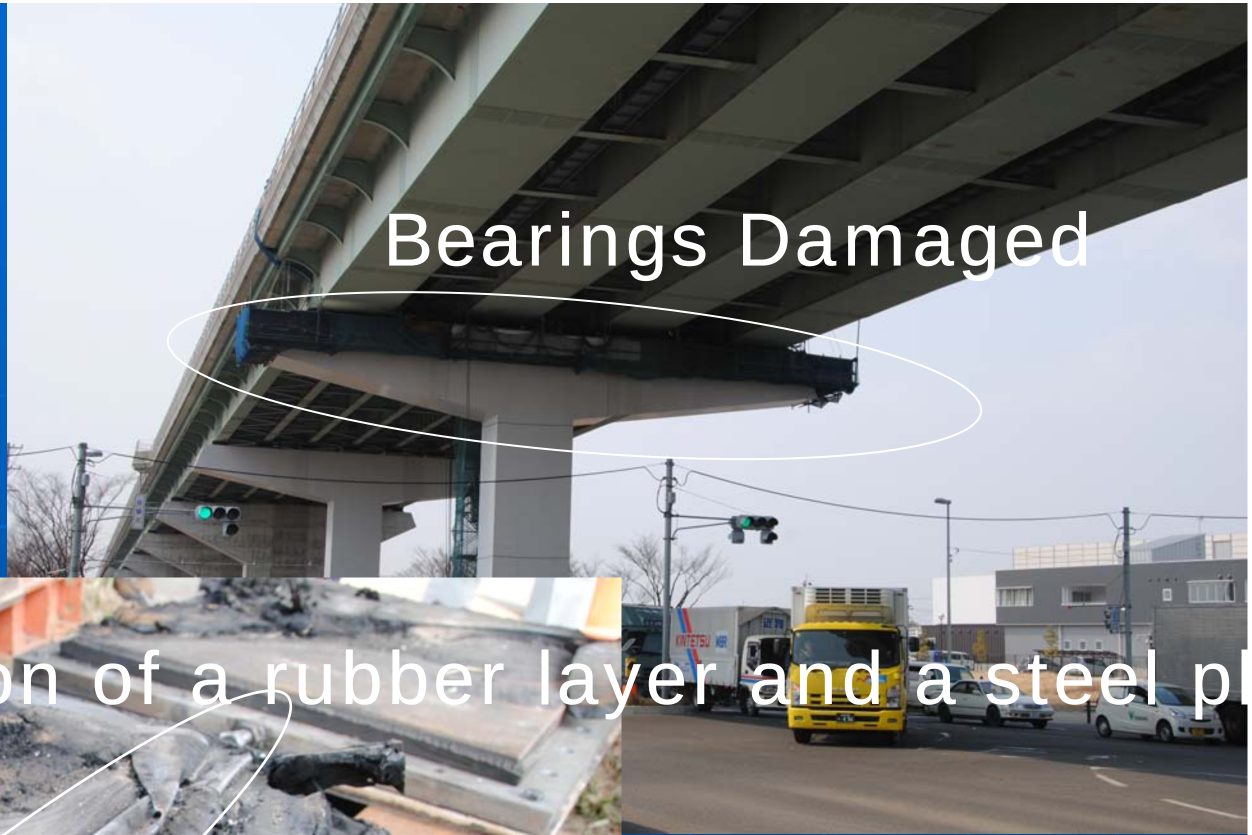
Existing damage still continued to occur in the bridges supported by existing steel bearings

Tenno Bridge
Route 45

Rupture of Elastomeric Bearings Occurred at Two Locations Close Each Other

East Sendai Road、NEXCO-East

NEXCO-East



Bearings Damaged

Separation of a rubber layer and a steel pl

The steel plate bent in double in a complex manner

Separation of rubber layers from steel plates did not occur in the past

- How large shear strain was induced in the rubber layers?
- Was the bearing properly fabricated?

Unretrofitted Shinkansen columns suffered extensive damage

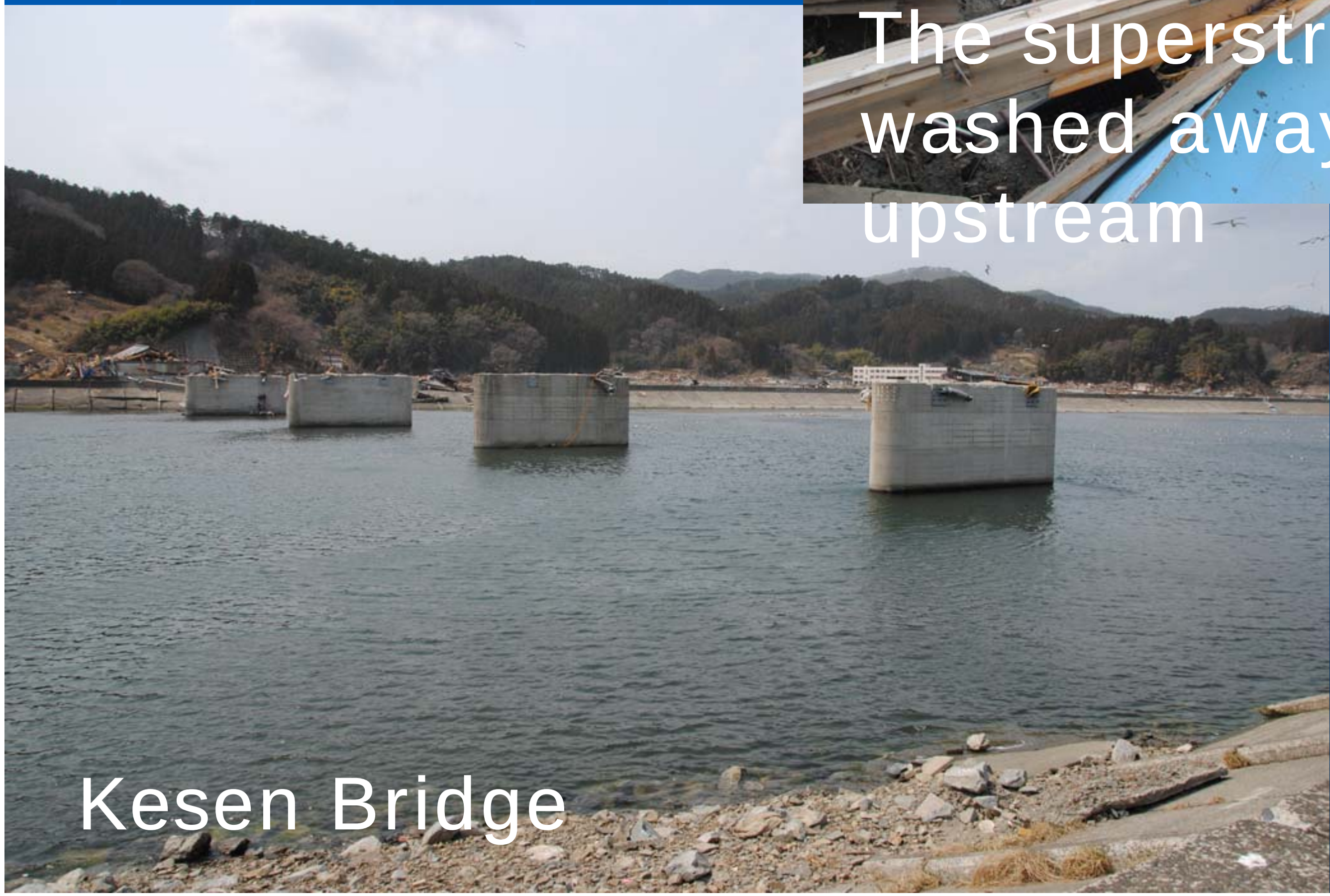
Extensive Damage of Shinkansen Viaduct during 2003 Miyagi-ken-oki earthquake

Kesen Bridge

Route 45

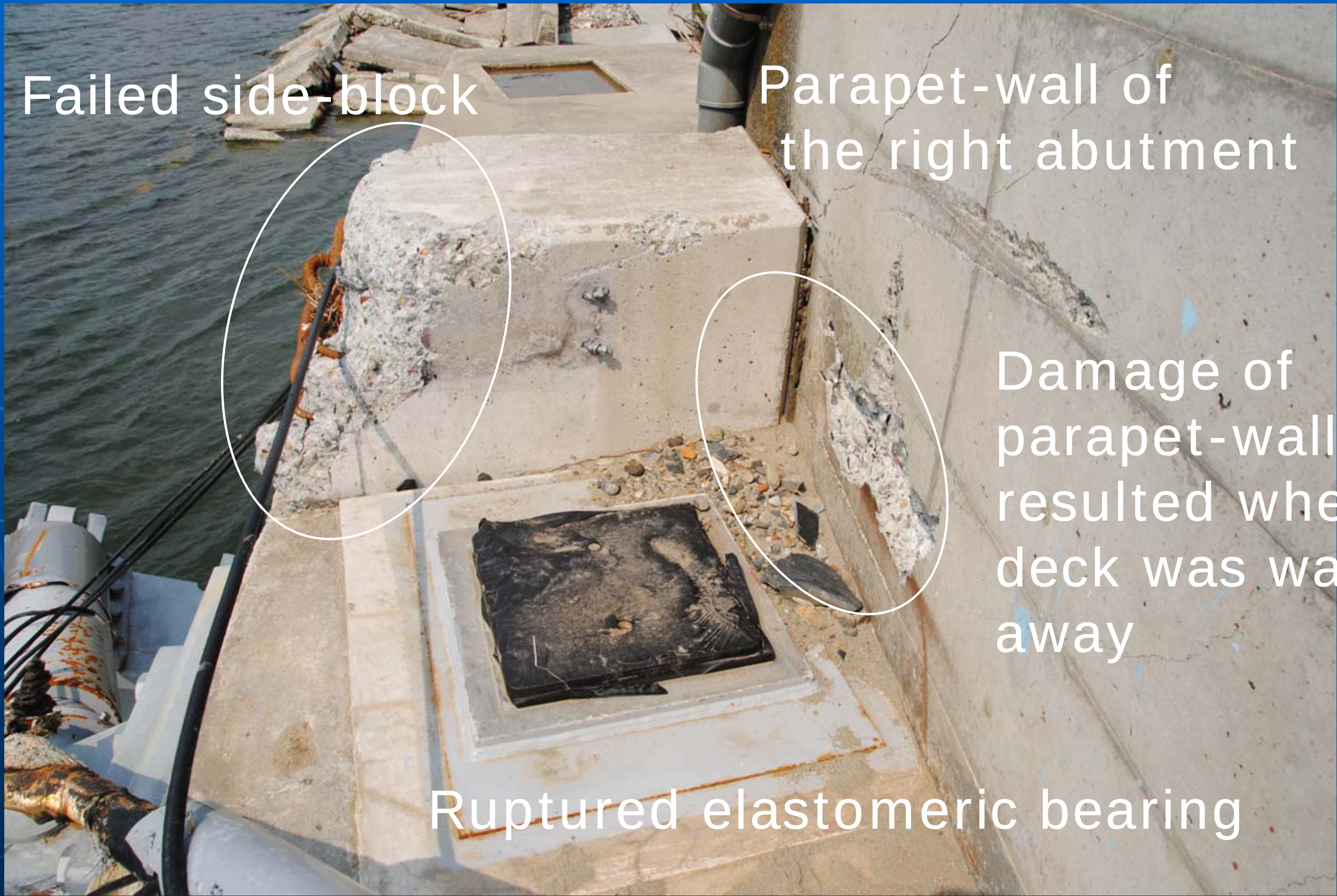
Rikuzen-Takada City

The superstructure was washed away 310 m upstream

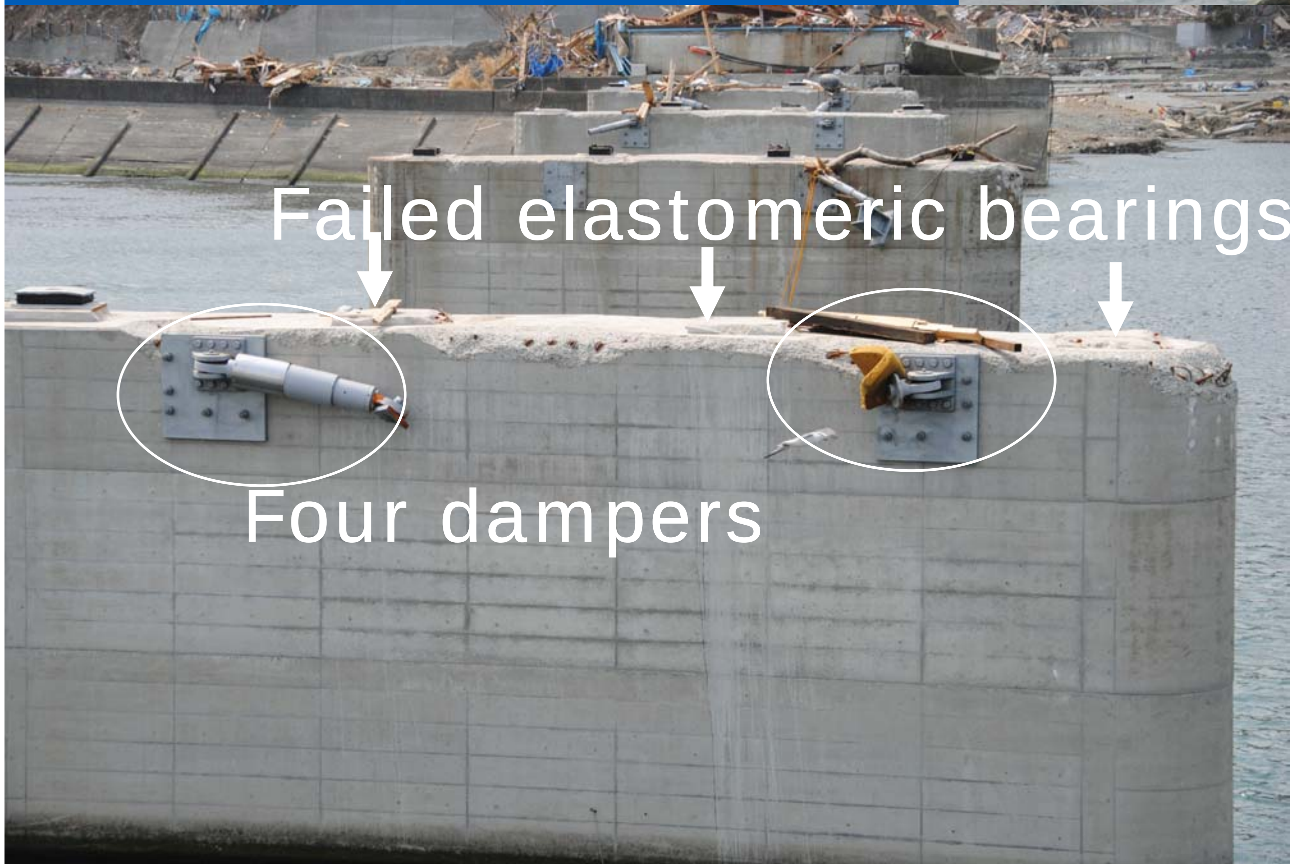


Kesen Bridge

Damage of Bearings and Side-Blocks at the Right Abutment



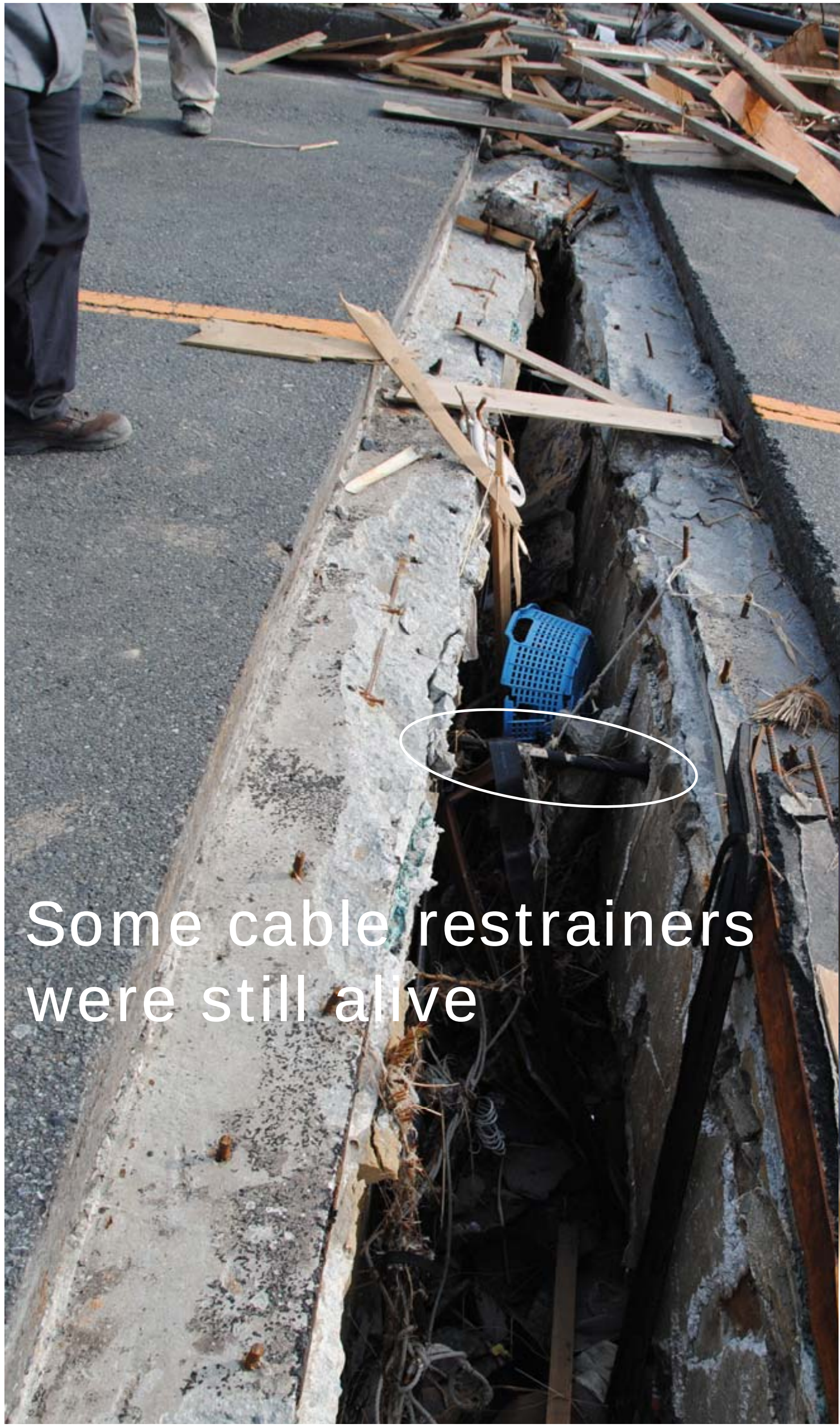
Damage of Dampers Installed for Seismic Retrofit



Utazu Bridge

Route 45

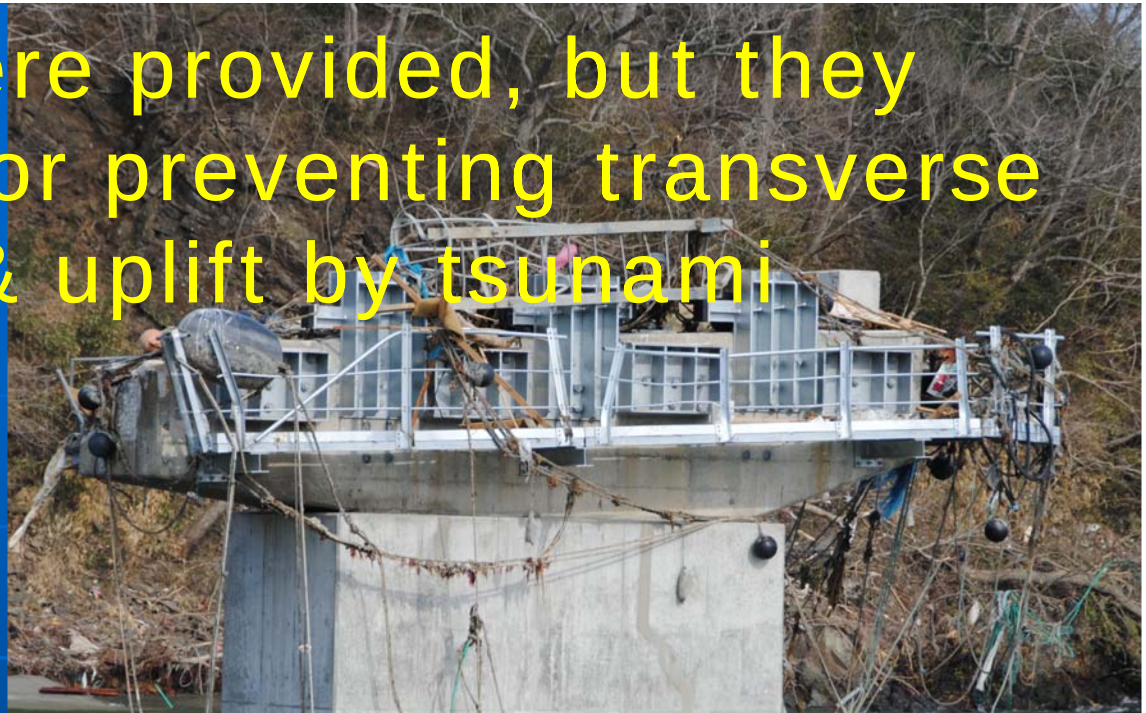
Rikuzen-Takada City



Some cable restrainers were still alive

Installed in 2005 for seismic retrofit

Steel stoppers were provided, but they were ineffective for preventing transverse deck movement & uplift by tsunami



There was an end-block here, but it was insufficie for preventing transverse deck movement

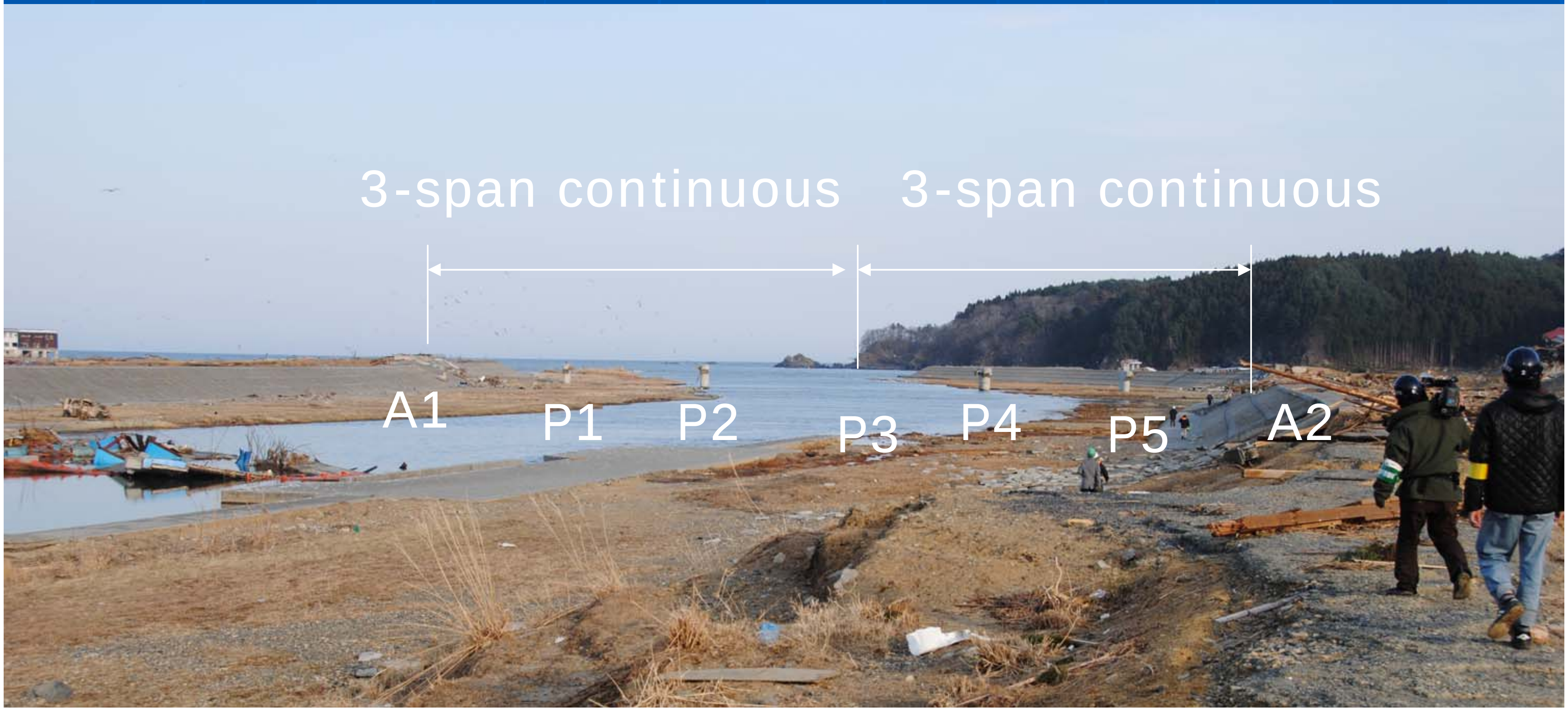
RC side blocks were used, but they were also insufficient

Koizumi Bridge

Route 45

Rikuzen-Koizumi

- Two 3-span continuous plate girder bridges
- P3 was washed away



Two 3-span continuous superstructures were washed away upstream

Superstructure 1

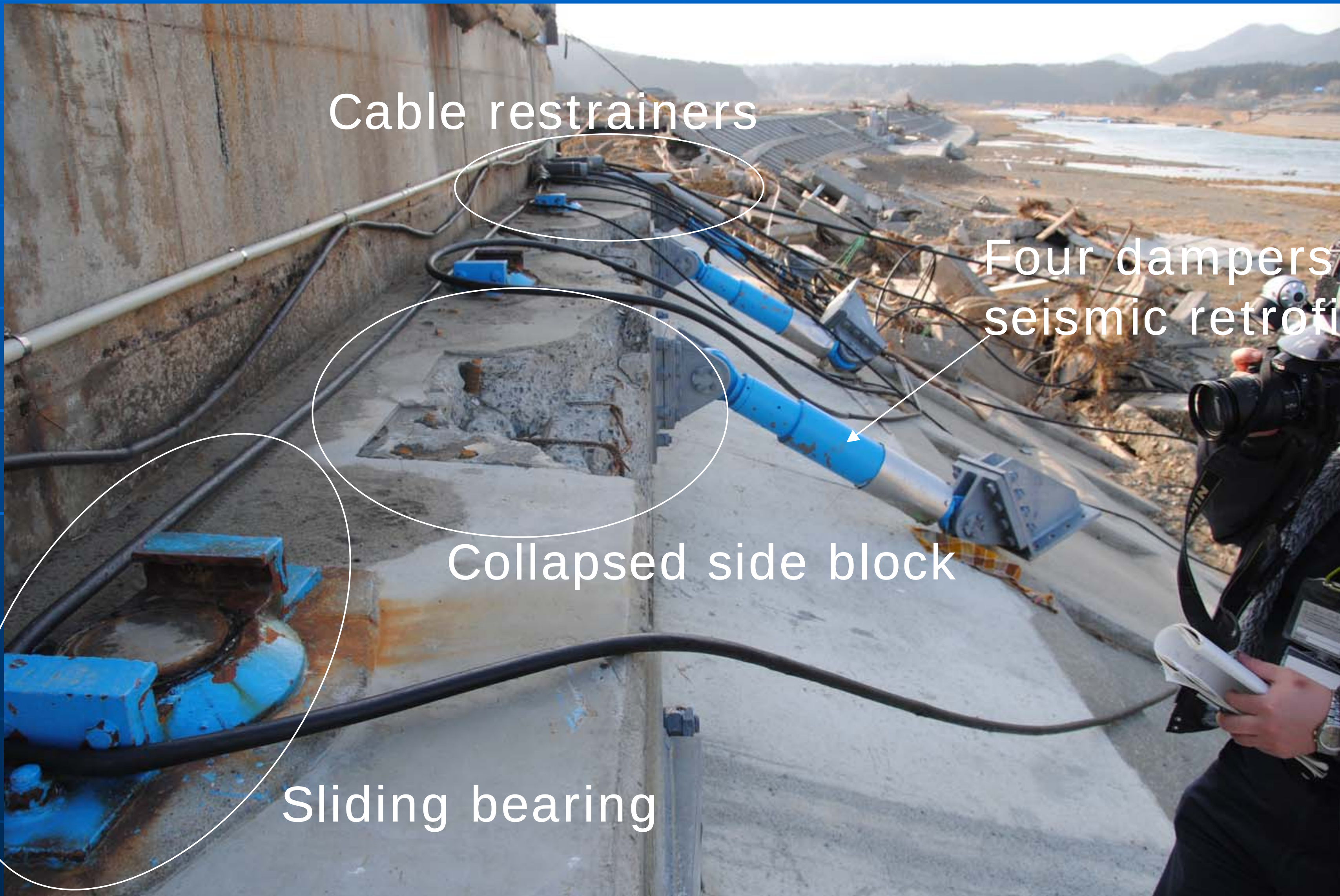
350 m upstream

Another superstructure was washed away 450m upstream at the left side bank

Trace left on the left dyke showing that the bridge was [illegible]d along [illegible]e

Damaged steel bearings on P2

Support condition of a bridge on A2 abutment



Shin-Kitakami Bridge

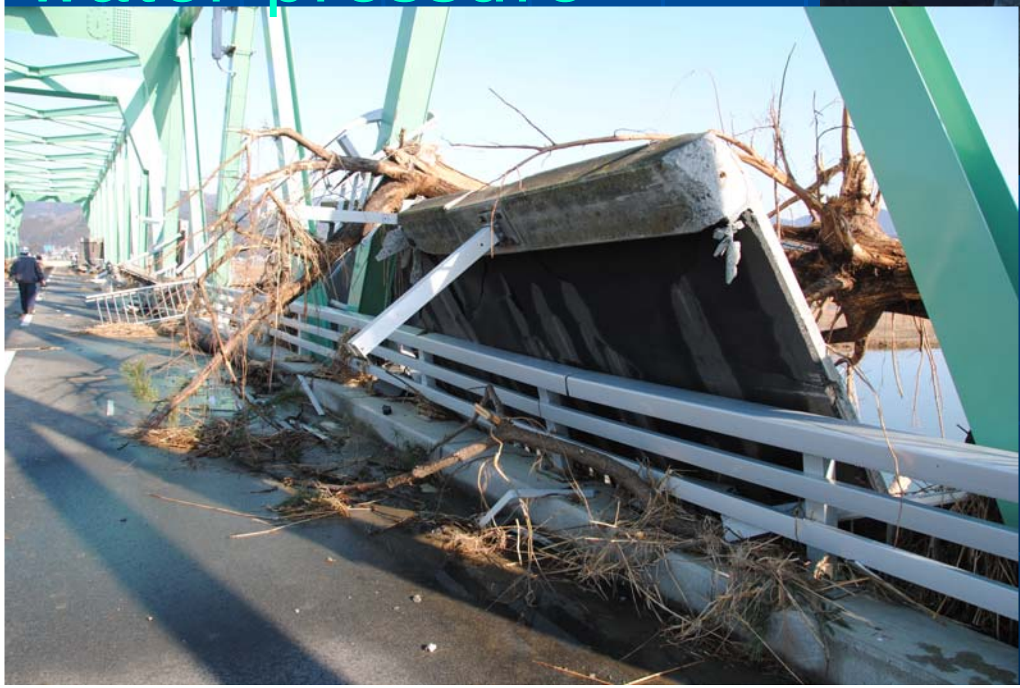
Regional Road over Kitakami River

Two spans were washed away several hundreds meters upstream

Full of Debris on the Deck

Deck floors of a side pedestrian bridge (upstream side) uplifted to rotate by 90 degree from the girders

They contributed to increasing of water pressure



Jibbers for connection

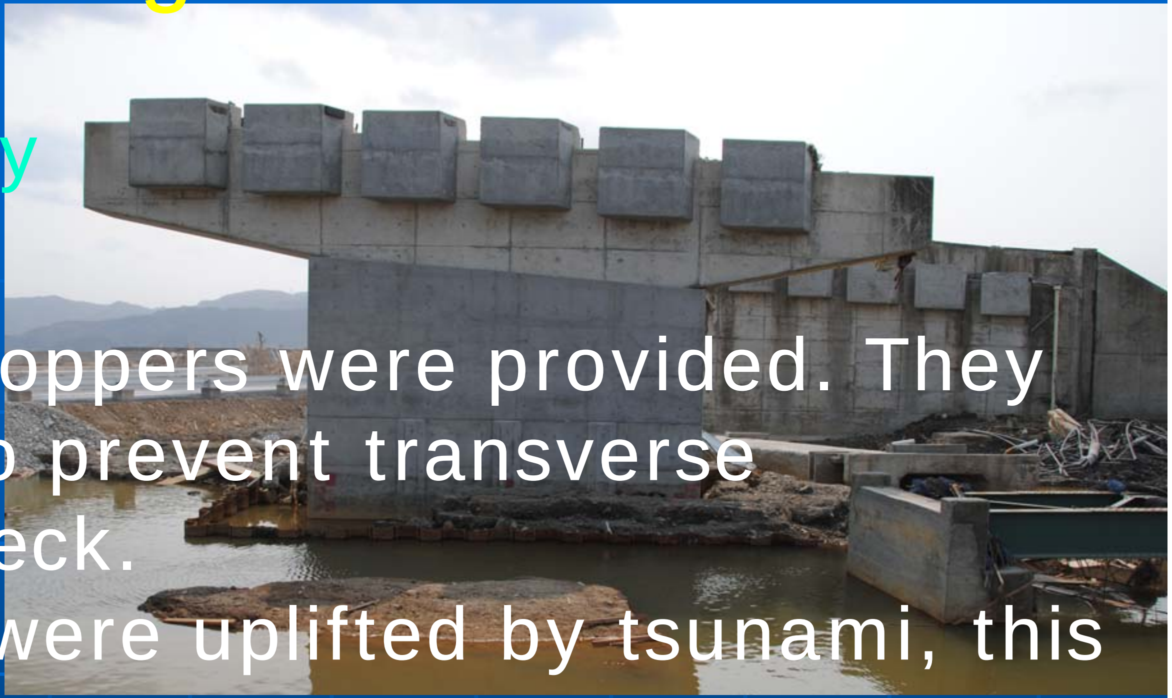
Abutment seat from where the span felt

Two piers and the left side abutment did not suffered damage

Numata Over Bridge

Ropute 45

Rikuzen-Takada City



●Six longitudinal stoppers were provided. They must be effective to prevent transverse movement of the deck.

●Unless the decks were uplifted by tsunami, this failure could not happen.

Embankment was completely washed away, and an abutment was left alone

There were a number of bridges which did not suffer damage by tsunami, but back soils & embankment were washed away

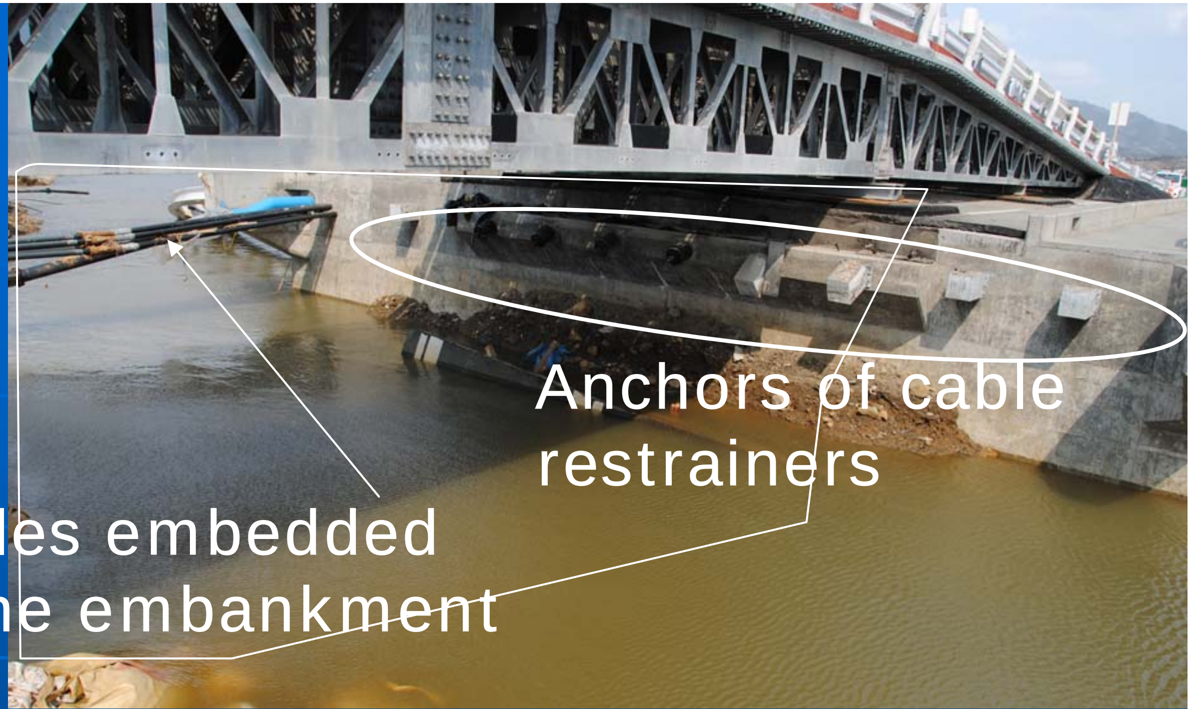
Kawahara River Bridge

Route 45

Rikuzen-Takada City

The two story building hit the bridge, but the bridge survived

Embankment was completely washed away



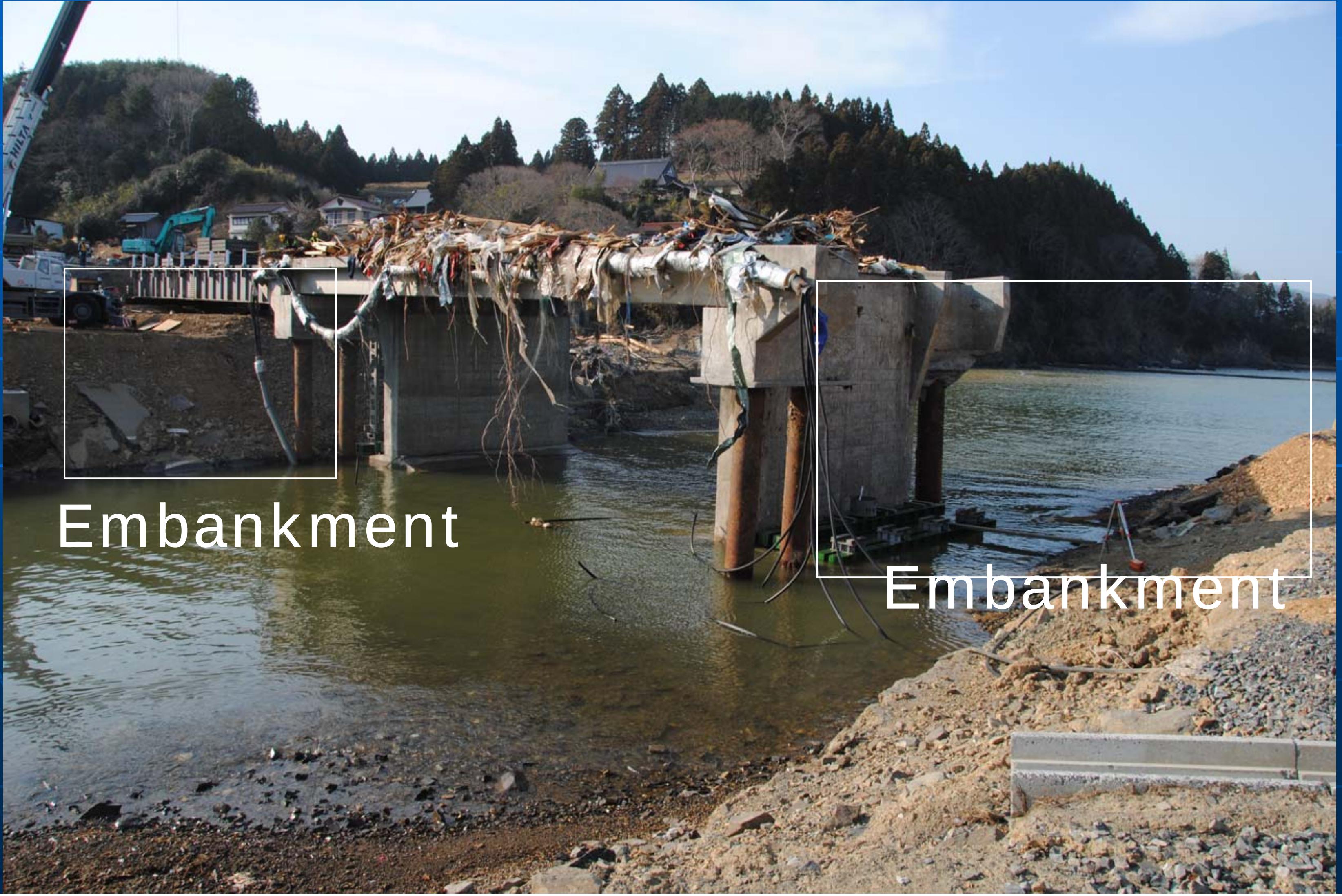
A two story building

Furukawa Bridge (Pedestrian Bridge)
Takada-no-matsubara Park
Rikuzen-takada City

Nijyu-ichi Hama Bridge

Route 45

Kesen-numa City



Many short bridges survived tsunami

A Bridge on
Route 45
Shizu-gawa town

Damage of the town around the bridge

Guard Rails were washed away

Minato Bridge

150 m downstream of the bridge in the previous slide

Shizu-gawa town

This bridge suffered minor damage

Sho-nin Bridge

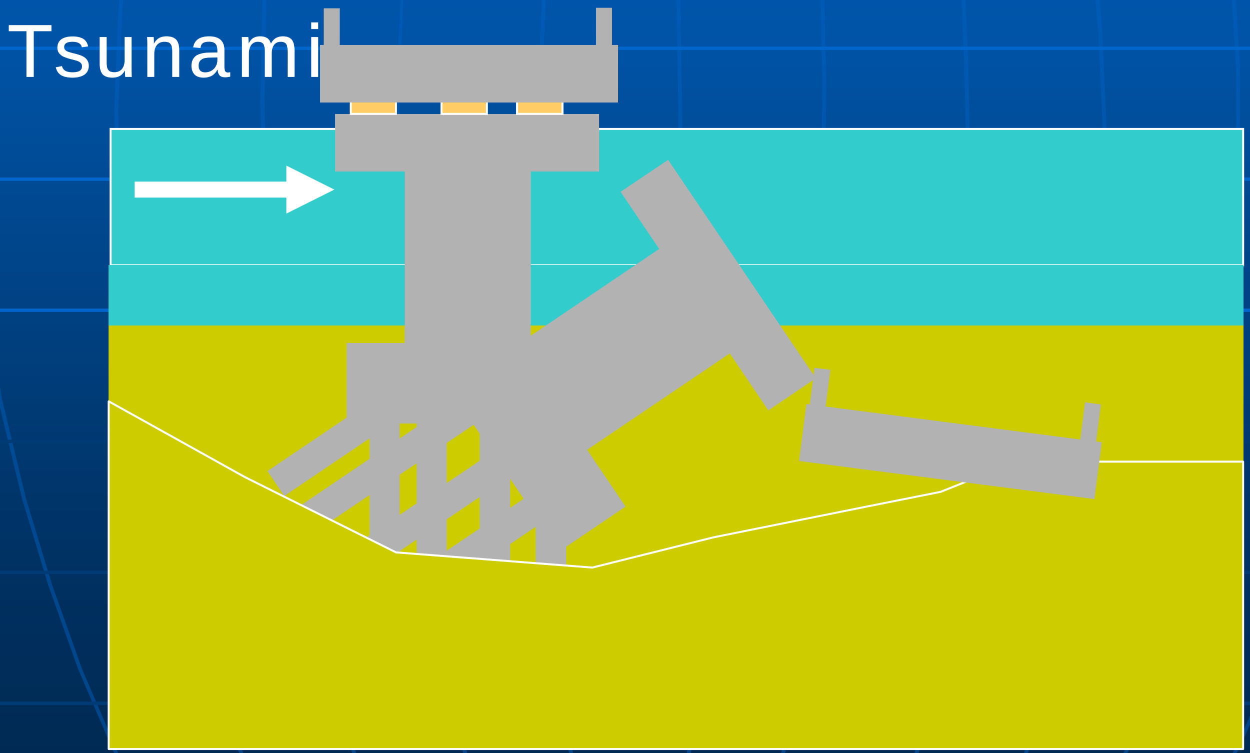
Route 45

Ofunato City

Damage of the city 100 m upstream the Sho-nin Bridge

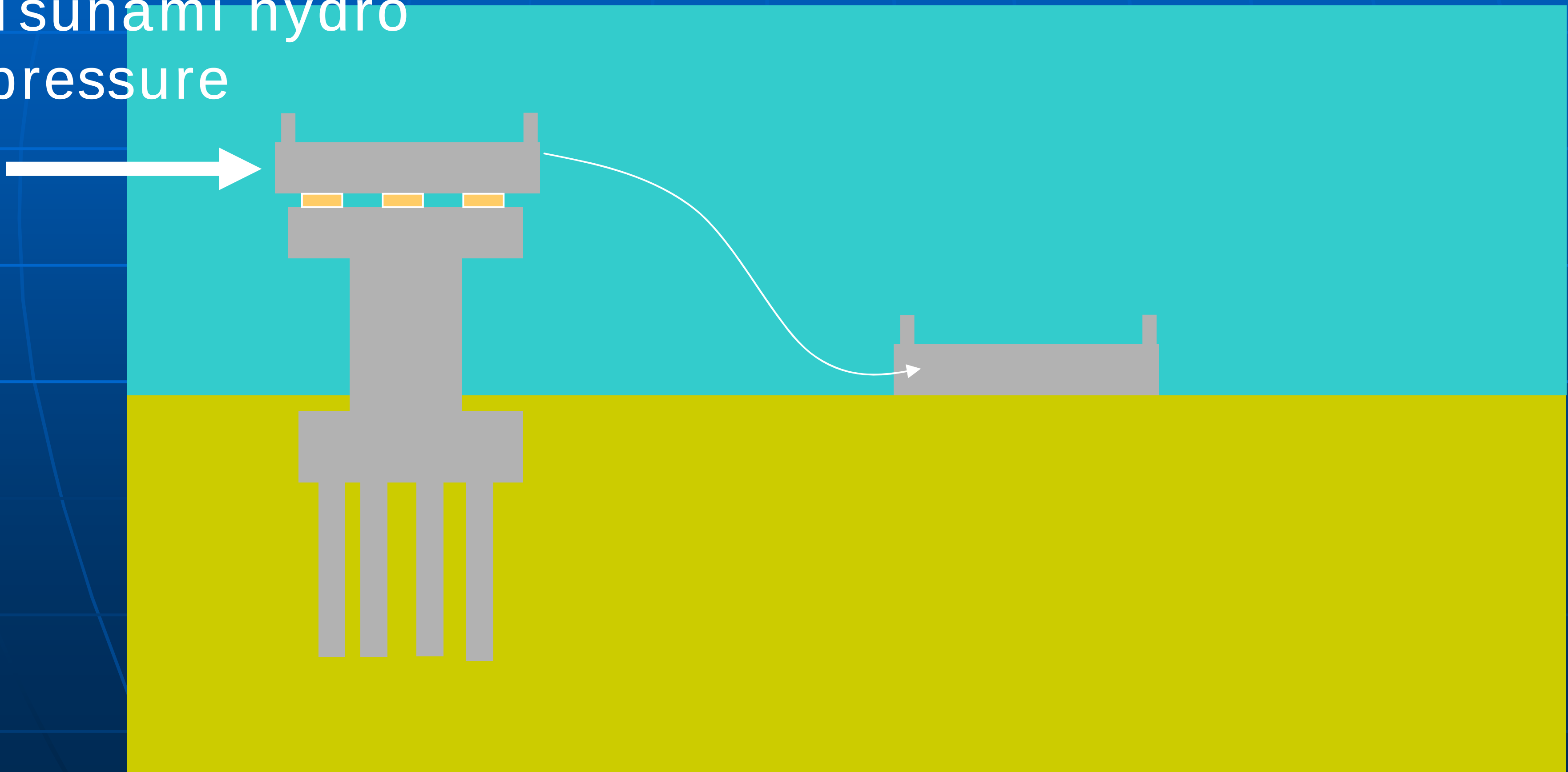
Failure Bridges due to Scouring

- This failure mode was not observed during the East-Japan earthquake since foundations were deep and well constructed

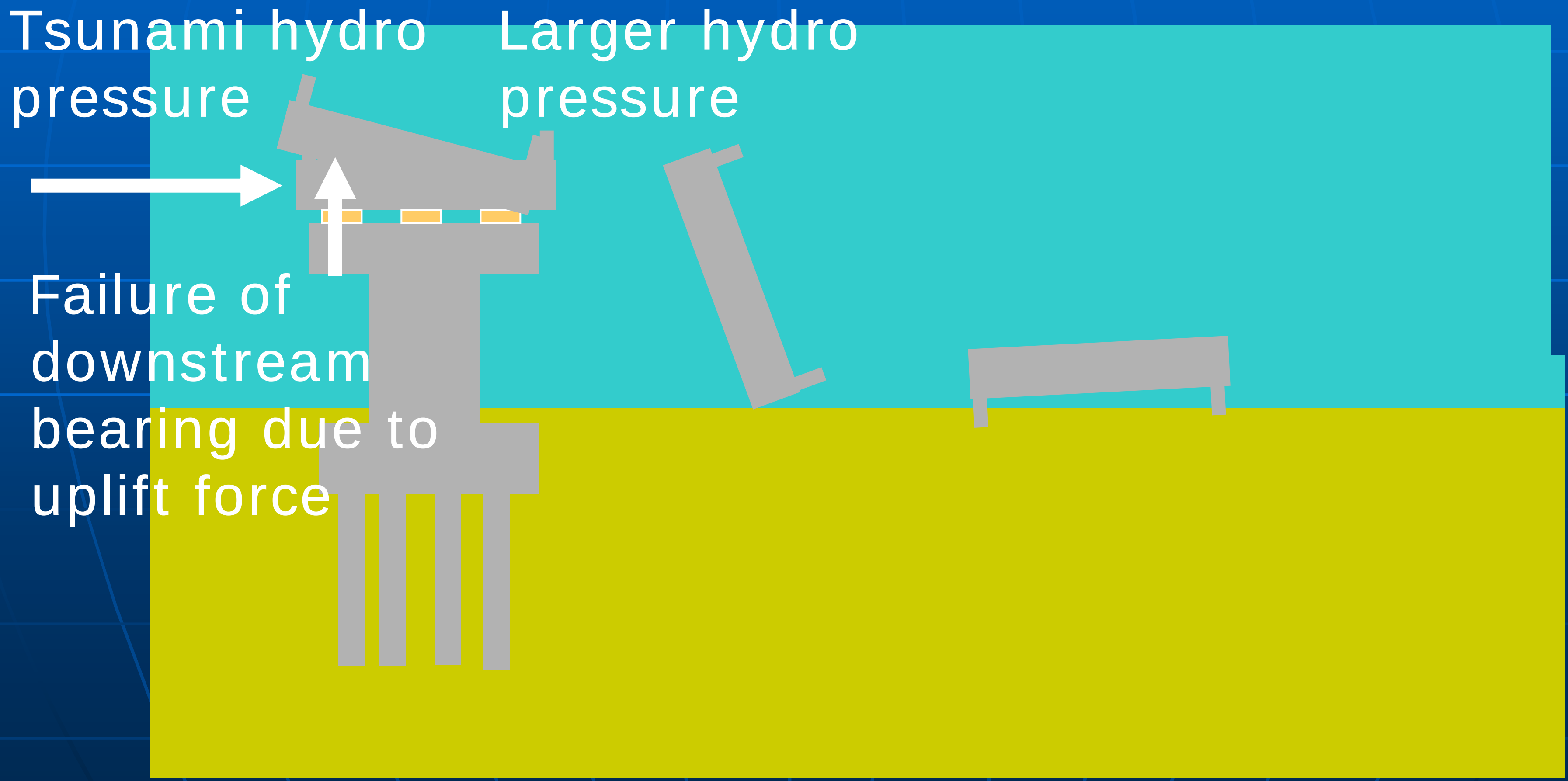


A possible Failure Mechanism of Bridges due to Tsunami

Tsunami hydro pressure



Most Probable Failure Mechanism of Bridges due to Tsunami



Preliminary Findings

- Bridges which were constructed or were retrofitted based on the ductility design method (enforced since the 1990 JRA Design Specifications) suffered almost no damage. It contributed to the enhancement of the seismic performance of bridges.

- Elastomeric bearings including lead rubber bearings and high damping rubber bearings which were introduced since 1990s mitigated damage of bearings. However several elastomeric bearings ruptured at two locations of East Sendai Expressway. Reason of the damage has to be clarified.

Preliminary Findings (2)

- A number of bridges suffered damage by tsunami. Damage was possibly developed by deck rotation toward upstream side, resulted from uplifting force. If failure of bearings (particularly downstream side bearings) due to uplifting force can be prevented, damage of tsunami may be mitigated.

- It is recommended to install “unseating prevention device for tsunami.” Restrainers which are widely used for unseating prevention device for earthquake may be effective if they are set in the vertical direction.

Acknowledgements

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