1.2 Damage Resulting from Deformation and Failure of Soils
地盤の変形や破壊によって生じる被害

1.2.1 Damage Resulting from Ground Deformation
地盤の変形によって生じる被害

- Ground deformation in this section implies the deformation due to seismic response of ground. Ground deformation due to surface ruptures of ground is treated separately.

- Since foundations and underground structures are subjected to earthquake ground deformation, this effect is important for foundations and underground structures.

(1) 1985 Mexico Earthquake

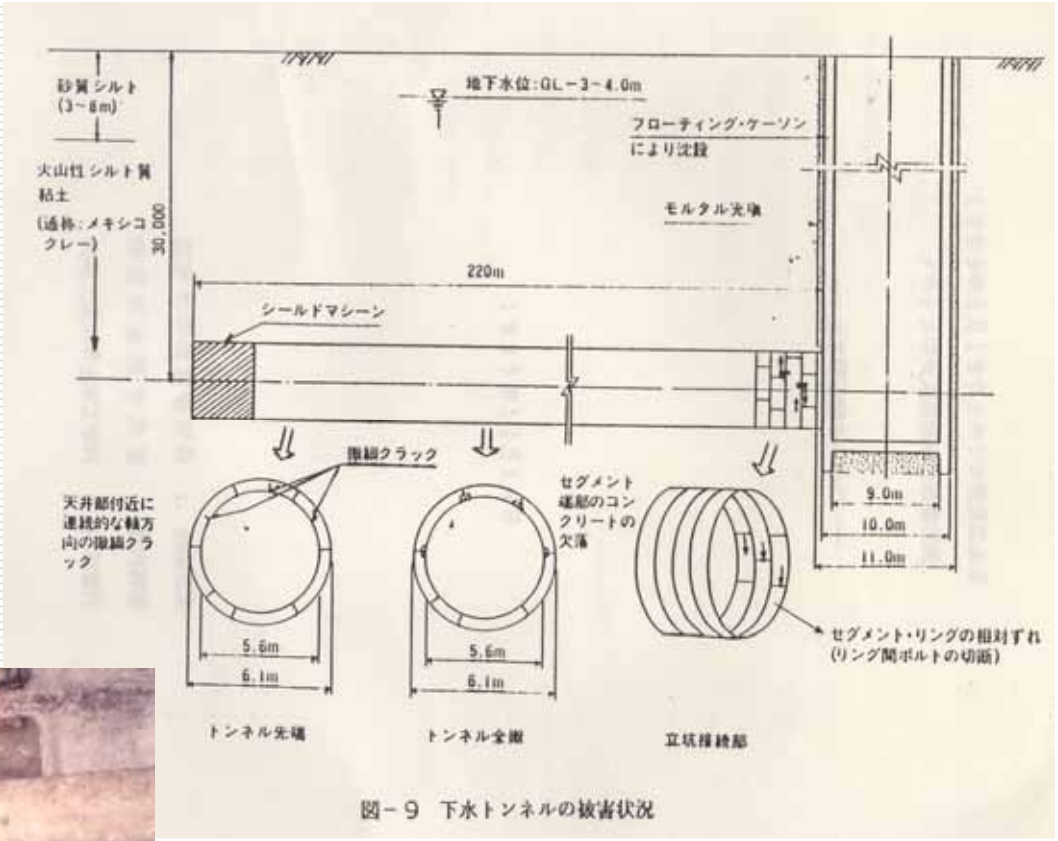


図-9 下水トンネルの被害状況

Failure of a sewer shield tunnel was resulted from torsion due to different response of a tunnel and a ventilation tower

(2) 1994 Northridge Earthquake, USA

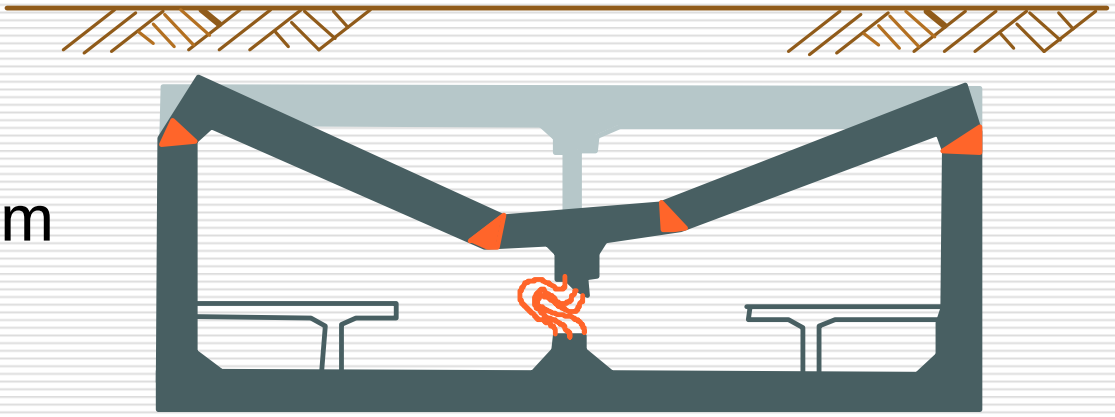
Failure of Water Pipes Resulting from Ground Motion Effects

(3) 1995 Kobe Earthquake, Japan

Collapse of Daikai Subway Station

Subsidence of Road Surface

Failure Mechanism



1.2.2 Damage resulting from Slope Failure and Rock Falls

(1) 1984 Nagano-ken-seibu Earthquake, Japan (M6.8)

Failure Resulting from Slope Failure

(2) 2008 Iwate-Miyagi, Japan, Earthquake

Damage Resulting from Failure of Mountains

(3) 2008 Wenchuan, China, Earthquake

Wenchuan Earthquake in China, **中国上海文化出版社**, 200

1.2.3 Damage Resulting from Soil Liquefaction

(1) 1964 Niigata, Japan, Earthquake

Showa Bridge

Unseating prevention system was first developed based on the damage

(2) 1983 Nihon-kai-chubu, Japan, Earthquake

Damage of back soils

Extensive pavement failure due to shallow liquefaction

Damage of a pile head

Gomyoko bridge suffered limited damage

1983 Nihon-kai-chubu, Japan, Earthquake (2)

Uplift of a gas storage tank at a gas station

Settlement of an electric pole

Failure of road pavement resulting from lateral spreading 1983 Nihon-kai-chubu, Japan, Earthquake

(3) 1992 Cairo, Egypt, Earthquake

A large sand bulb developed at Nile River Delta

(4) 2011 Christchurch Earthquake, New Zealand

(5) 2011 Great East Japan Earthquake, Japan

Urayasu city, Chiba-ken

NHK

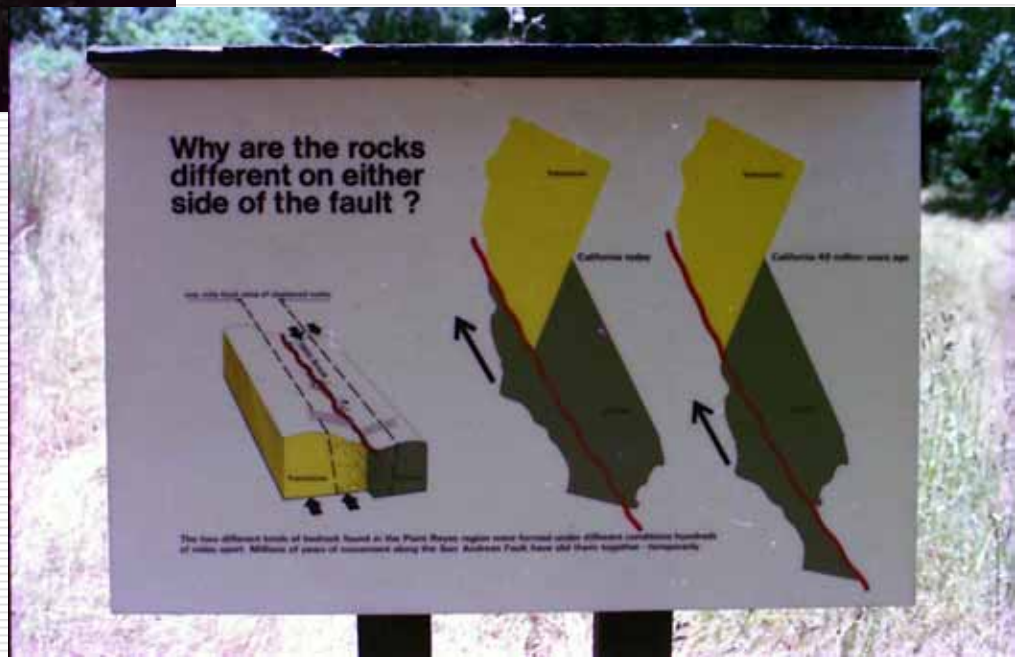
1.3 Damage Resulting from Fault Displacement

(1) 1888 Nobi, Japan Earthquake

Midori Fault

2002

(2) 1906 San Francisco Earthquake, USA



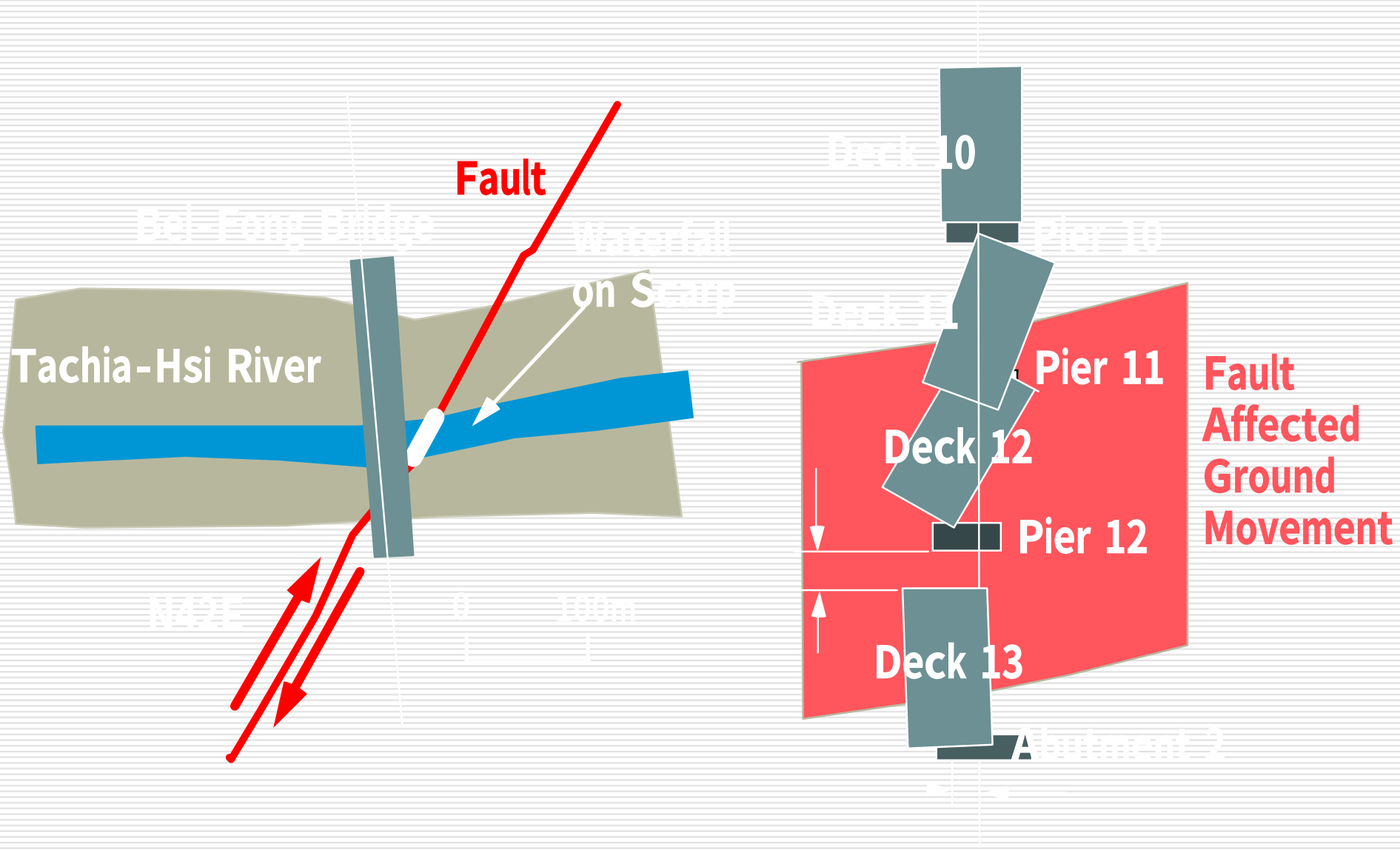
(3) 1999 Dutze, Turkey Earthquake

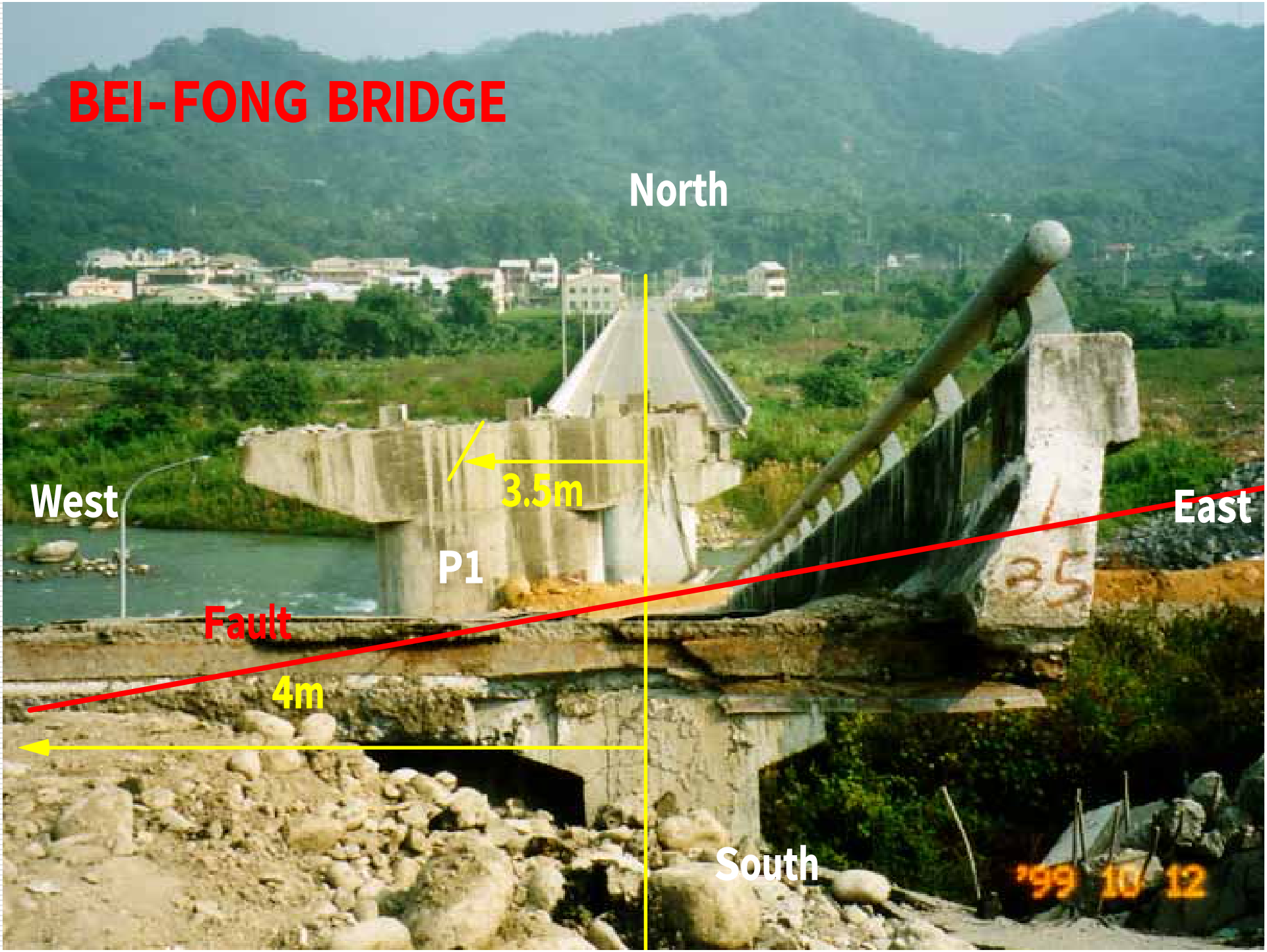
Nearly 6 m right lateral slip

Collapse of Arifiye Overcrossing

(4) 1999 Chi Chi Earthquake, Taiwan

Fault Dislocation around Bei-Fong Bridge




BEI-FONG BRIDGE
North
West
East
3.5m
P1
Fault
4m
South
'99 10 12


Wu-Shi Bridge
North
South
Up-stream
Down-stream
P1
P2
P3
P4

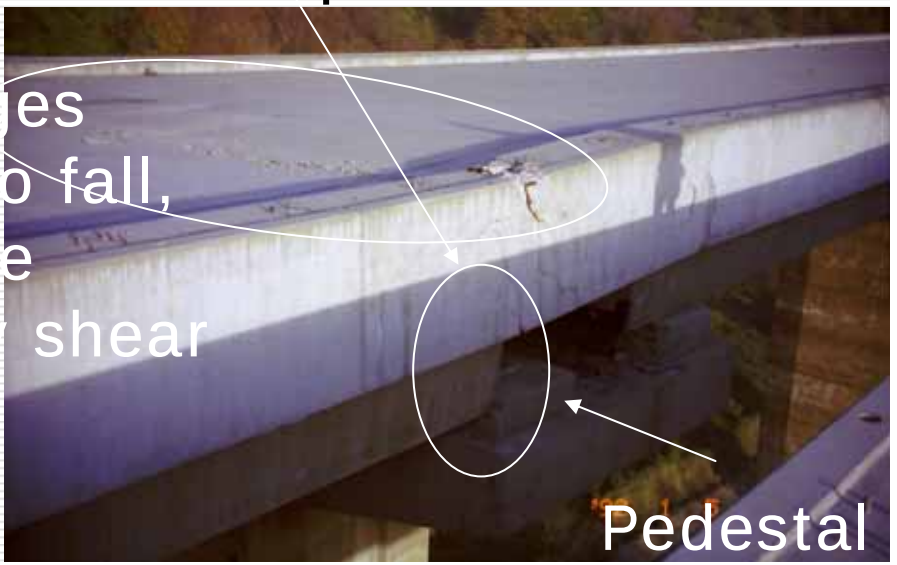

P1
P2
About 2m


P3
West
Downstream
East
Upstream

Shikang Dam
1999 Chi Chi, Taiwan, Earthquake

(5) 1999 Bolu Earthquake, Turkey

Bearings already drifted from their pedestals



Residual lateral drift of a deck

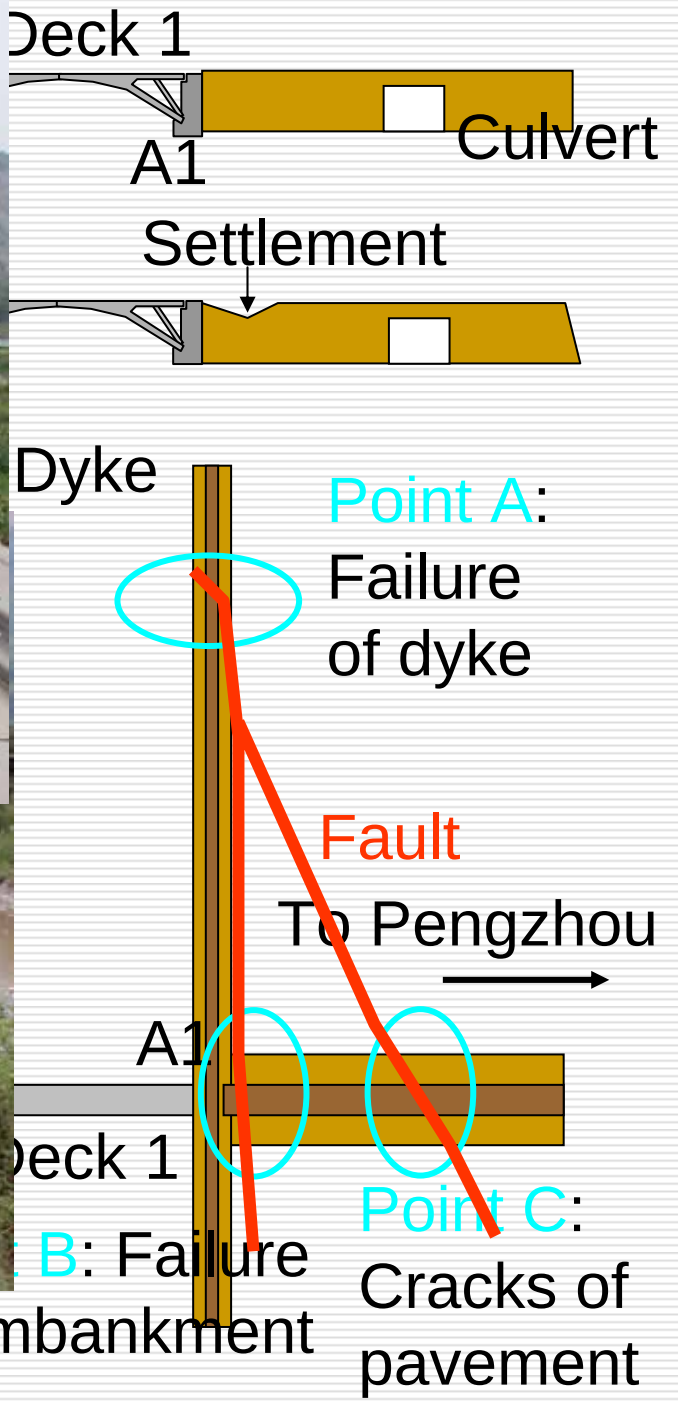
Dislodgement of bearings from pedestal

Column Rotation

Damage of a tunnel
1999 Bolu, Turkey earthquake

(6) Wenchuan, China Earthquake

Xiaoyudong Bridge


Deck 1
A1
Culvert
Settlement
Dyke
Point A:
Failure
of dyke
Fault
To Pengzhou
A1
Deck 1
B: Failure
embankment
Point C:
Cracks of
pavement

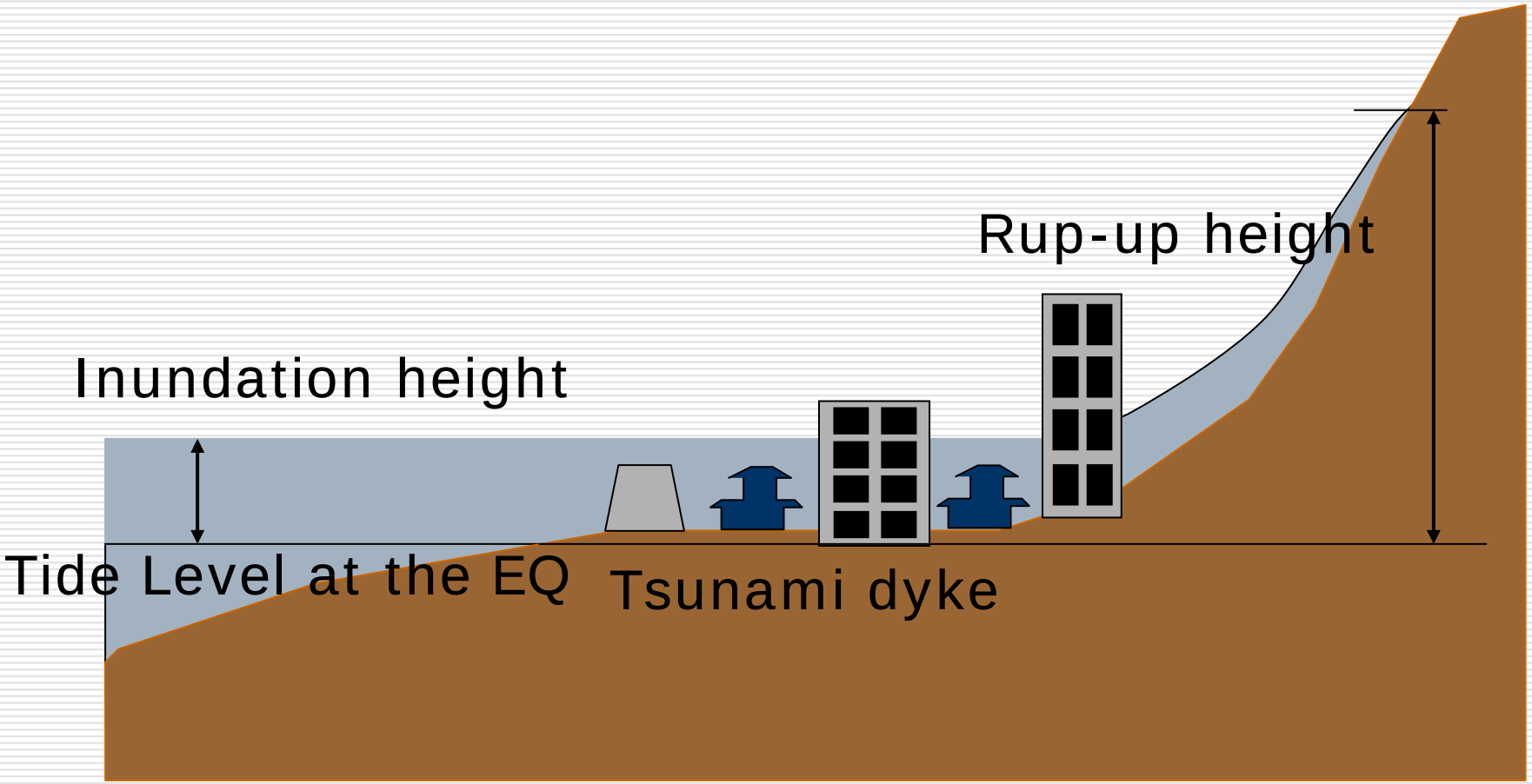
1.4 Damage Resulted from Tsunami

(1) 1992 East Flores Island Earthquake, Indonesia

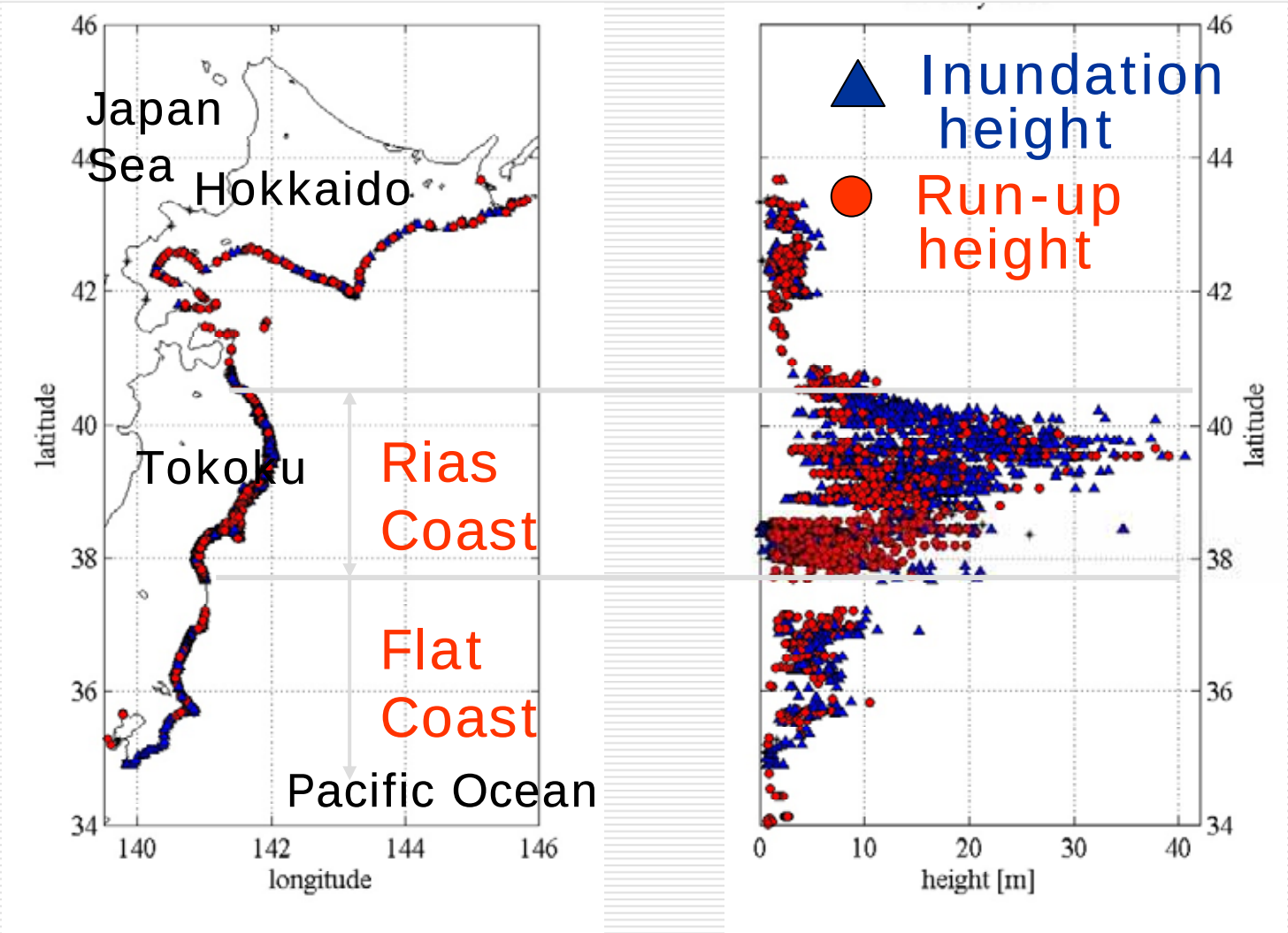
(2) 2010 Maule, Chile Earthquake

(3) 2011 Geat East Japan Earthquake

Inundation Height vs. Run-up Height



Measured Inundation & Run-up Height

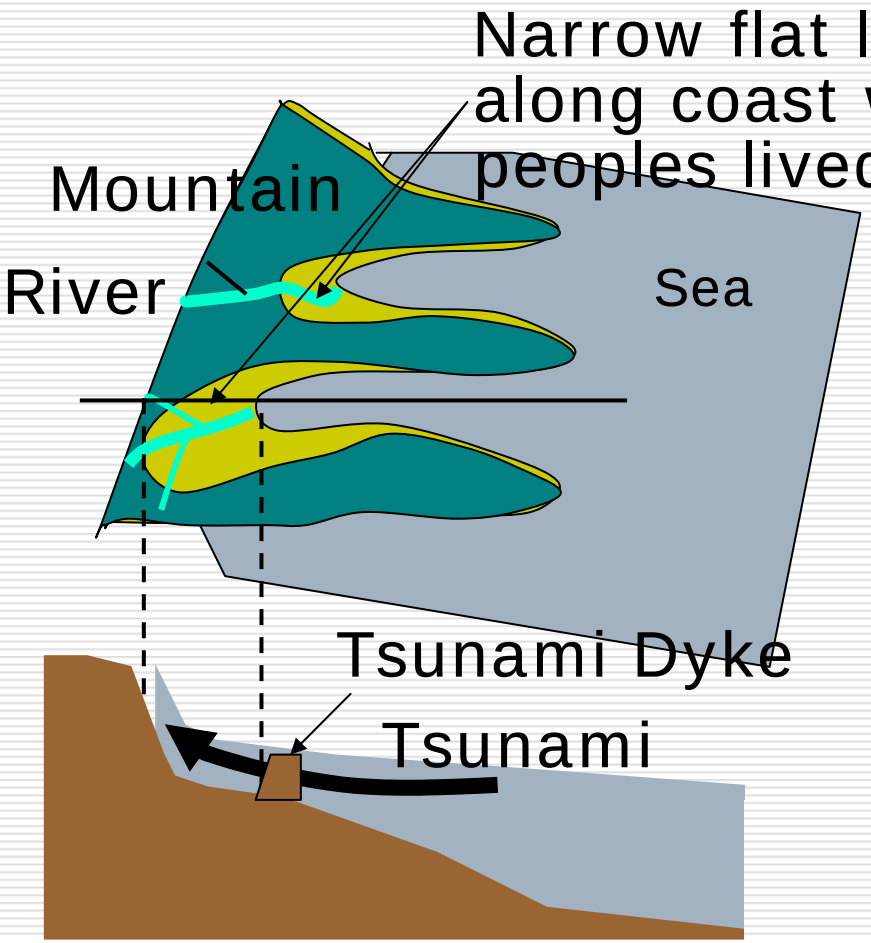


Tsunami Joint Survey Group The 2011 Tohoku Earthquake (2011). "NATIONWIDE FIELD SURVEY OF THE 2011 OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE TSUNAMI", Journal of JSCE, B2, 67(1), 63-66

Only Tidal Wave Protection Dykes were Available at the Coast South of Sendai

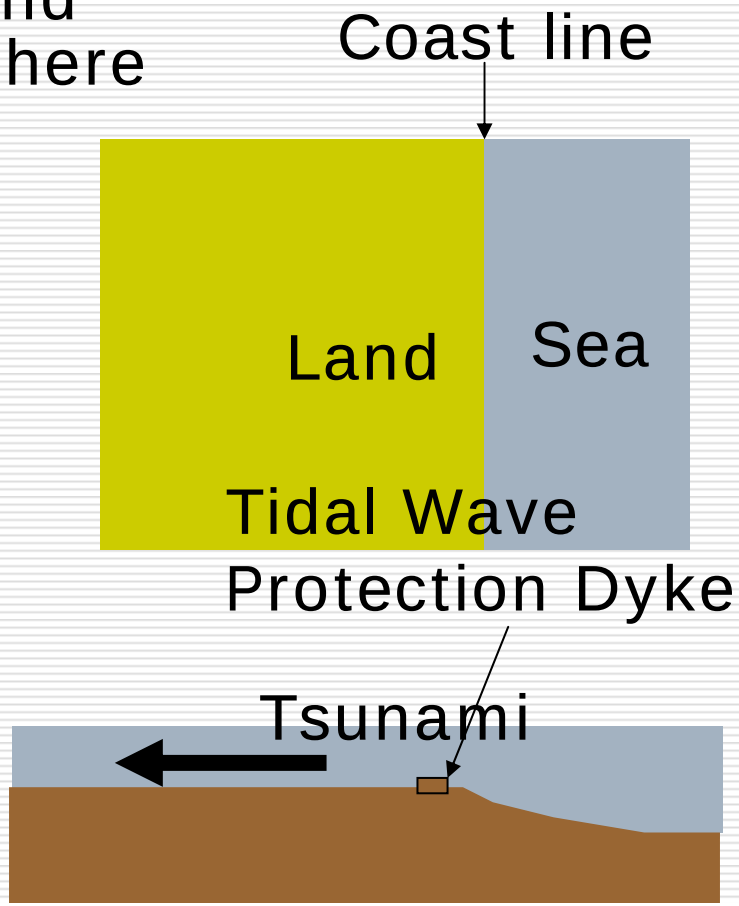
North Coast

Drowned River Valley that remains open to sea (Rias)



South Coast

Flat Coast



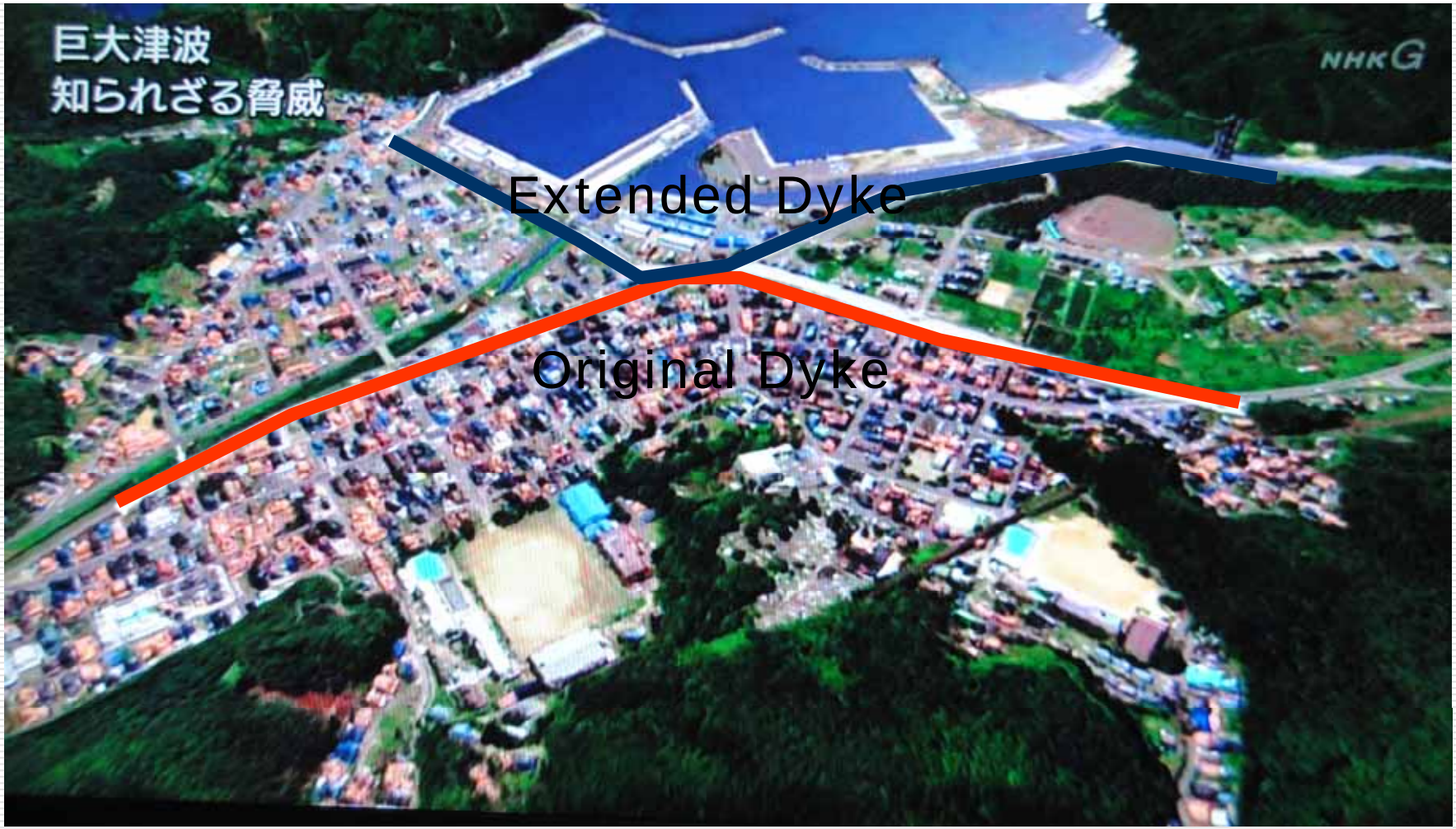
North Area repeatedly suffered damage from tsunami

History of Taro Village is a history fighting with tsunami

- By 1611 Keicho earthquake (M8.1), the village was almost all collapsed
- By 1896 Meiji earthquake (M8.2-8.5), 83% peoples (1867 among 2248) was killed
- By 1933 Syowa earthquake, 32% (911 among 2773) was killed

Taro Town

Long history for competing with tsunami



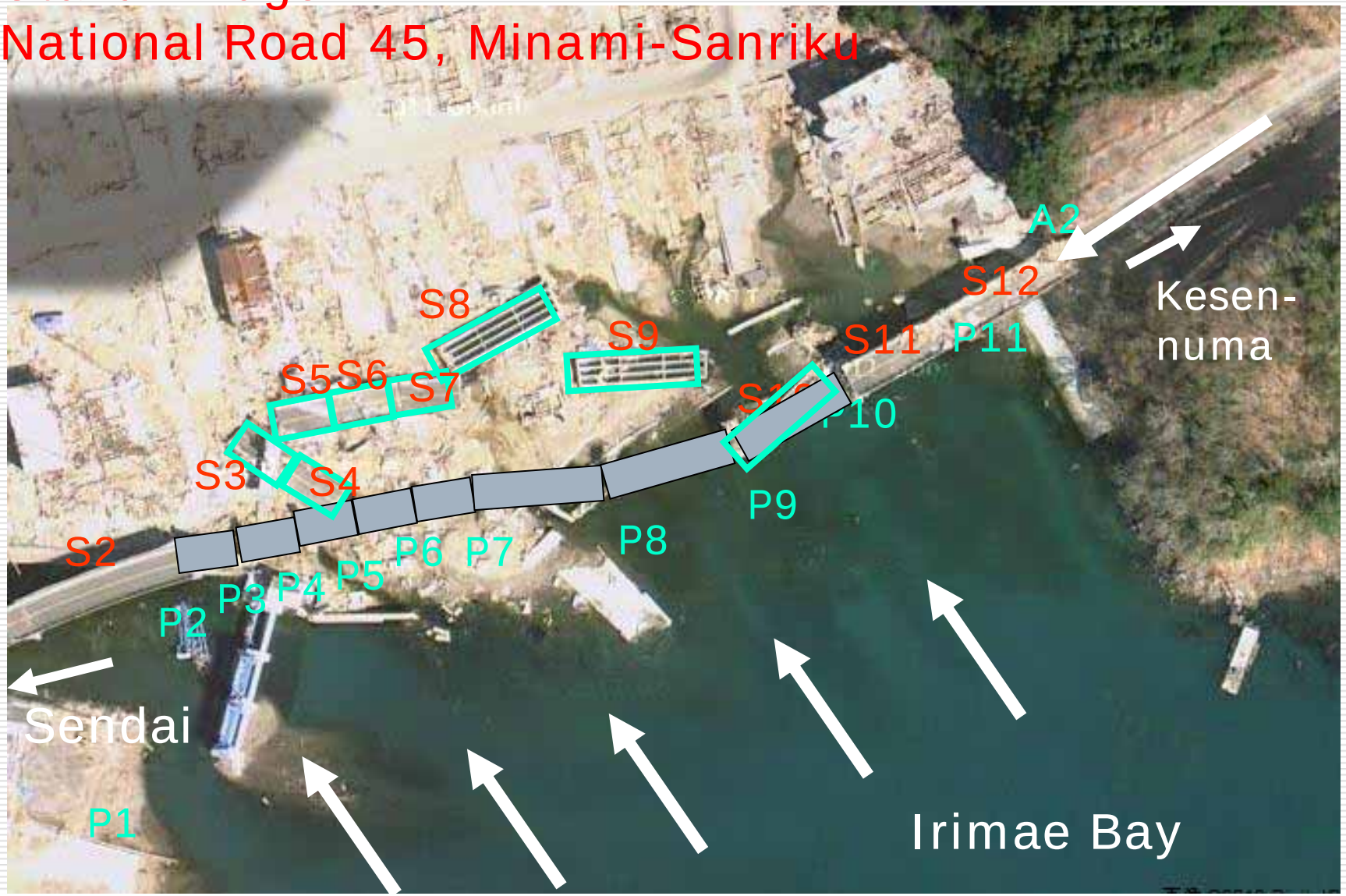
NHK


大津波
の脱出
撮影 海上


10 m Tall Original Dyke

No single word about “Tsunami” was provided in the seismic design codes of bridges

Utazu Bridge
National Road 45, Minami-Sanriku



Video showing submerging of Utatsu Bridge

Before Tsunami Attack

Center of Utatsu Town

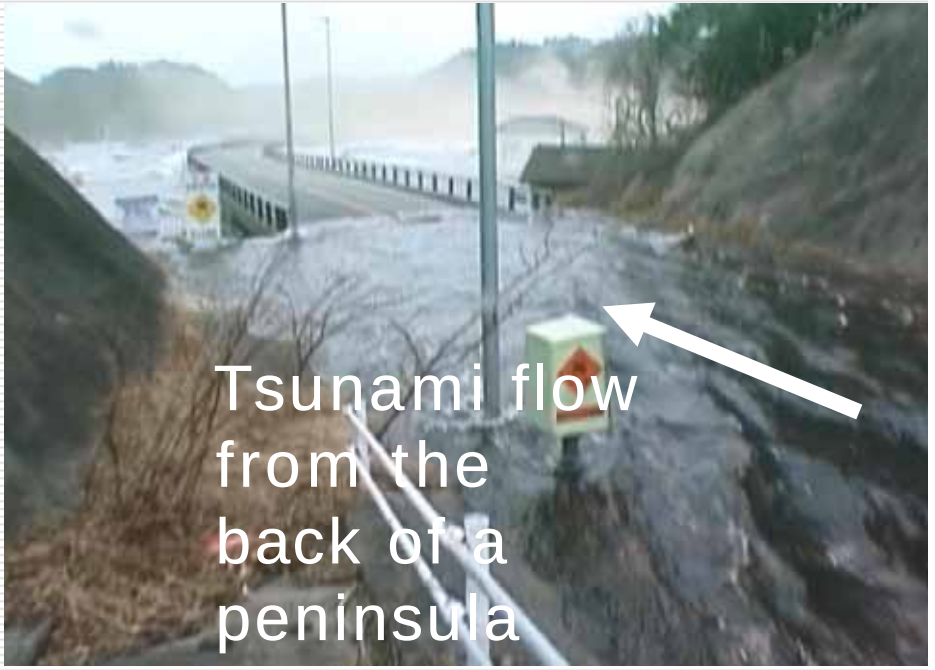
Still peoples were chatting & watching see

Tsunami rose up to the bottom of the bridge

Houses are being floated

Courtesy of Mr. Katsuya Oikawa

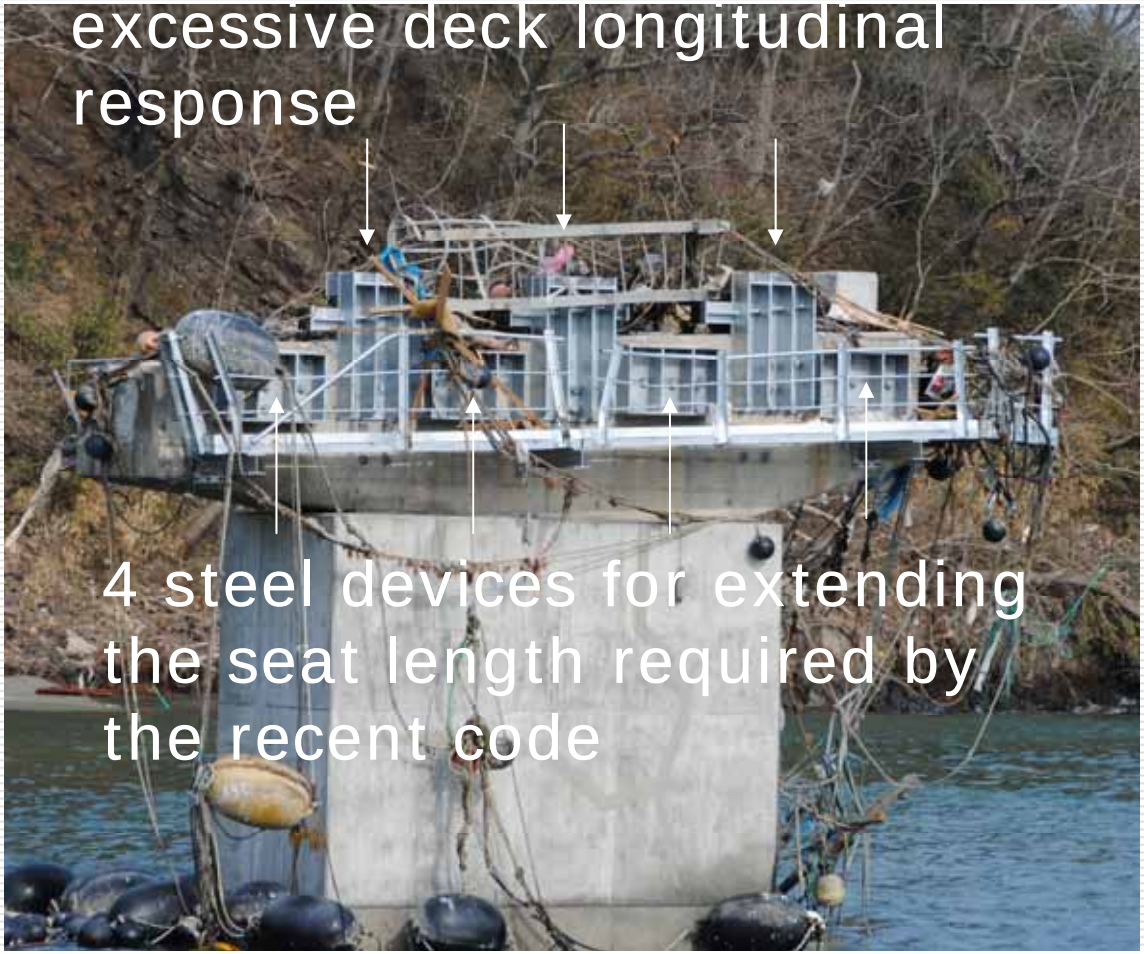
Rising Up of Tsunami



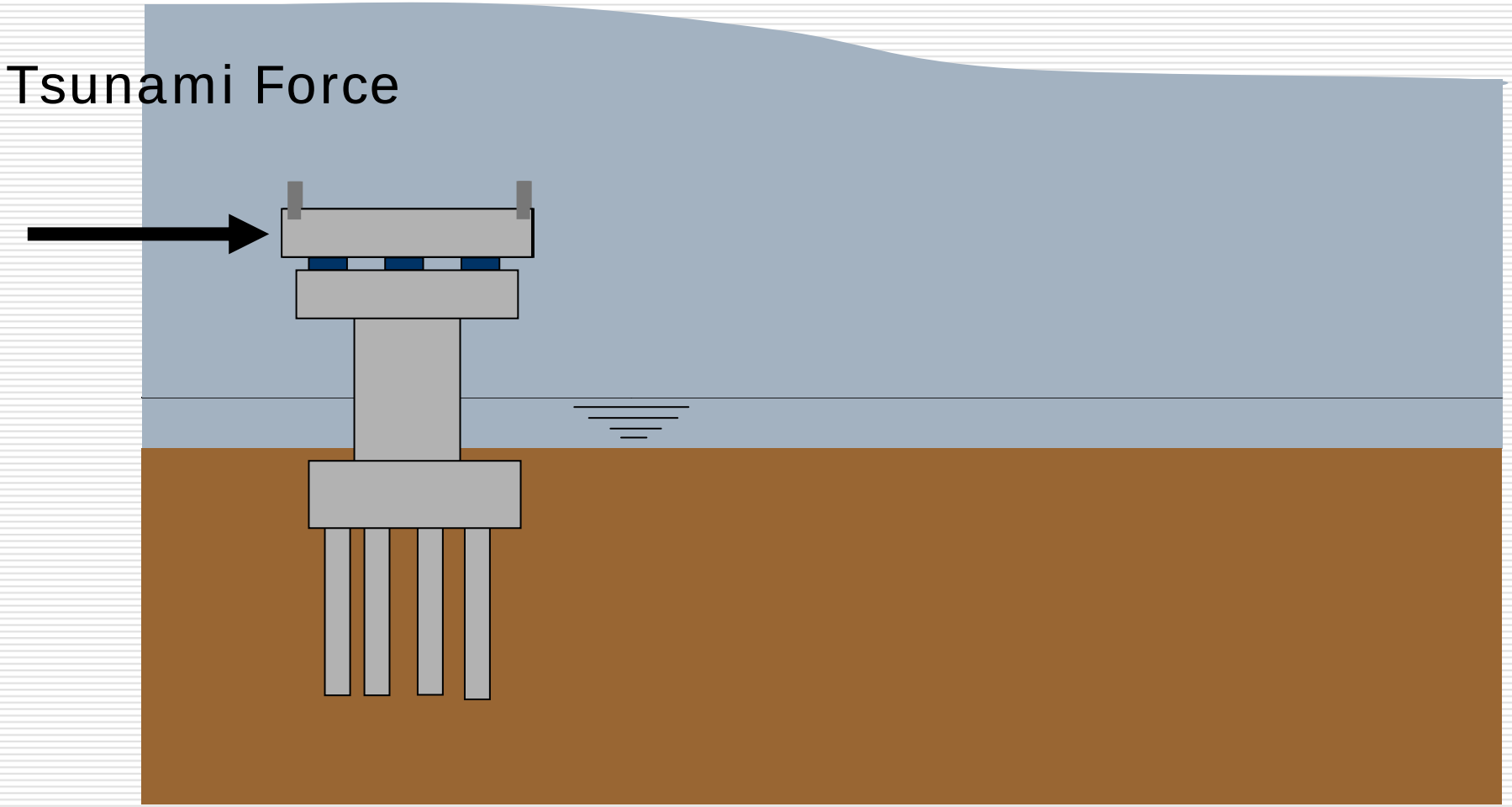
Collapse of a bridge by tsunami

Utazu Bridge, Route 45, Rikuzen-Takada City

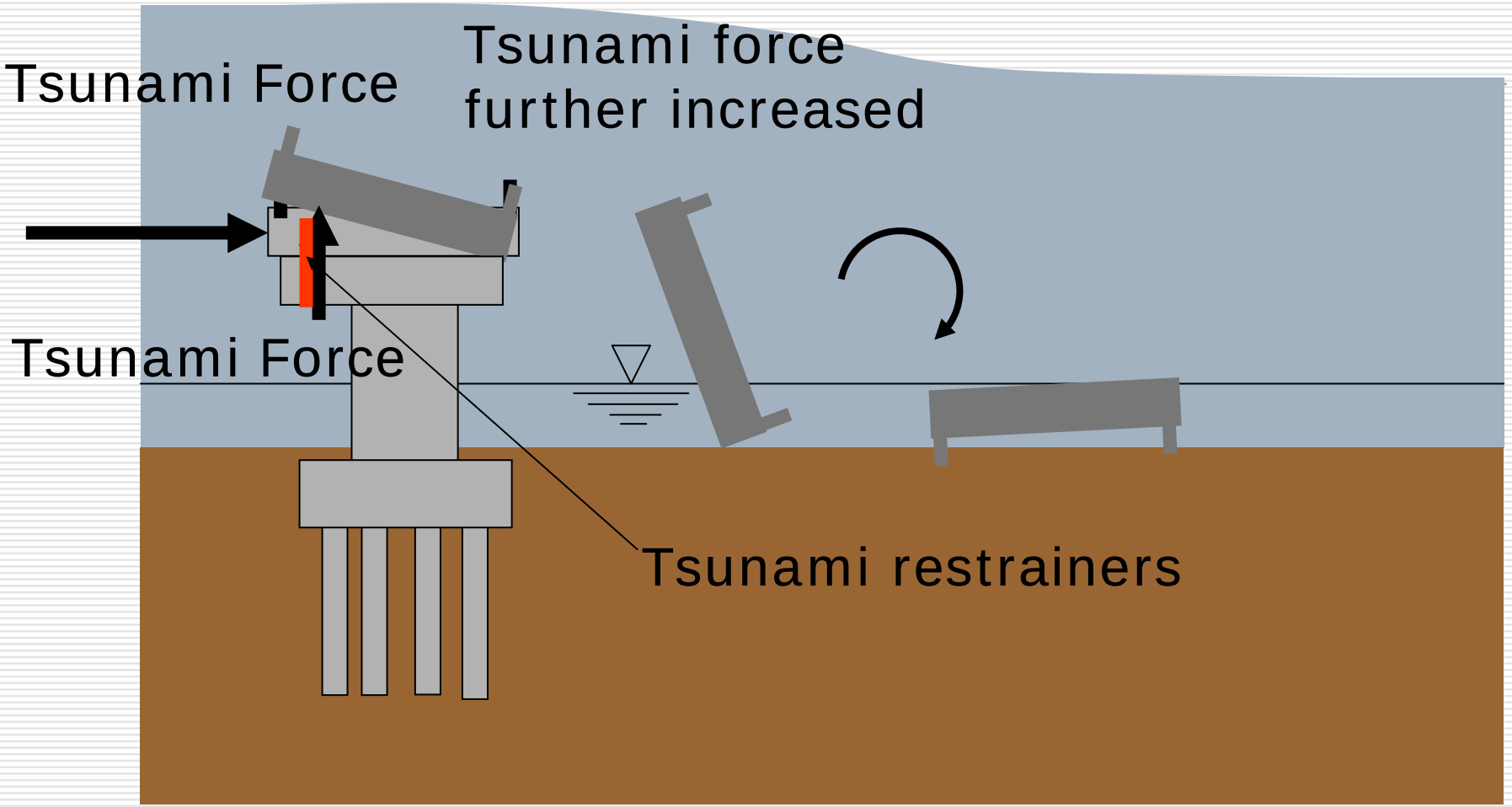
Steel stoppers were provided, but they were ineffective for preventing transverse deck movement & uplift by tsunami



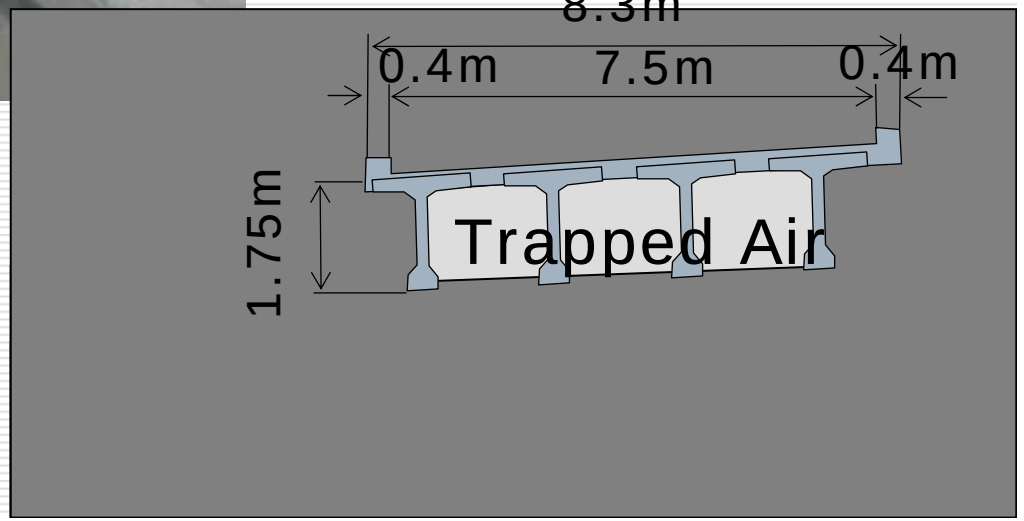
A possible Failure Mechanism of Bridges due to Tsunami



Most Probable Failure Mechanism of Bridges due to Tsunami



Possible Contribution of Uplifting Force due to Air Trapped under PC Spans

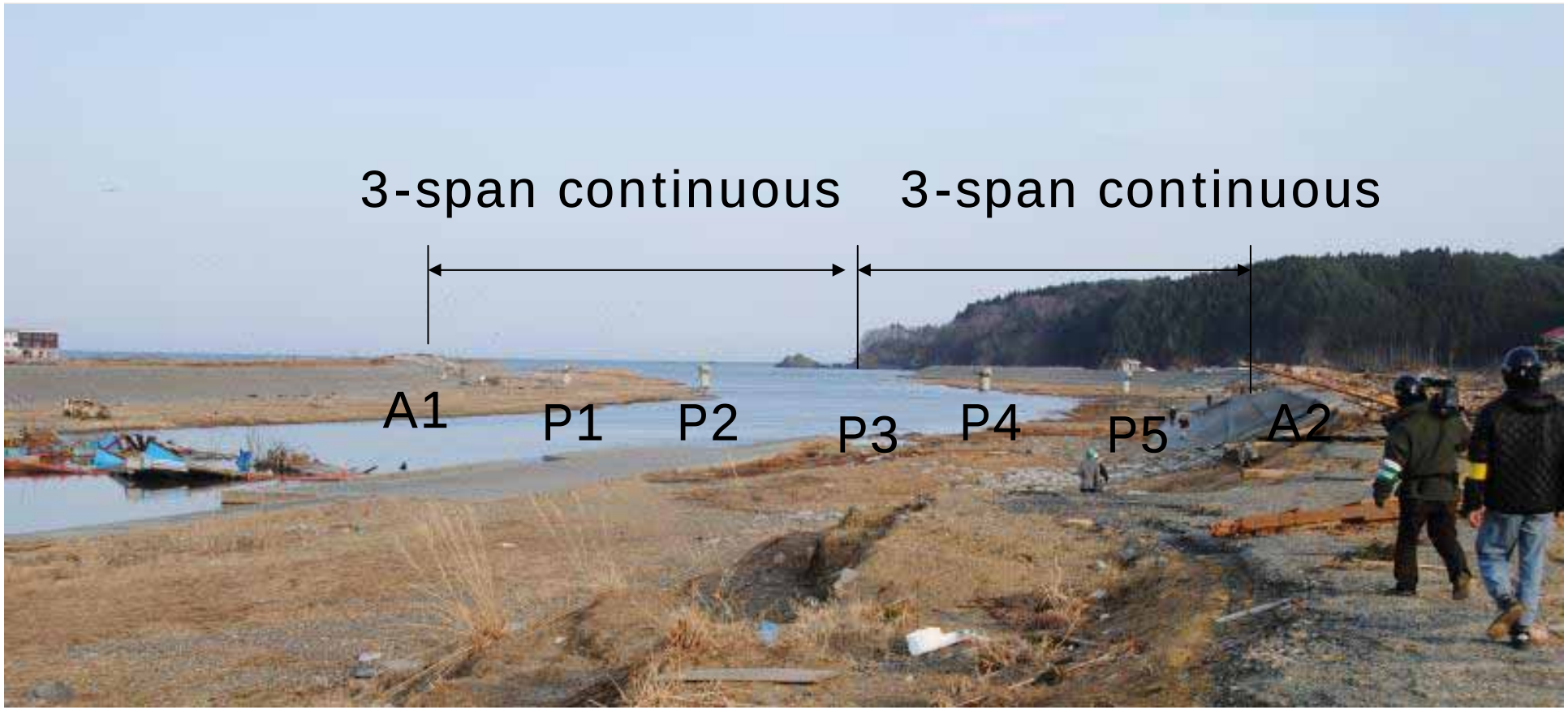


Koizumi Bridge

National Road Route 45

Rikuzen-Koizumi

- Two 3-span continuous plate girder bridges
- P3 overturned due to tsunami
- Built in 1974



Two 3-span continuous spans were floated upstream

The second 3-span continuous deck

The first 3-span continuous deck

Koizumi Bridge was submerged by 12m tall tsunami

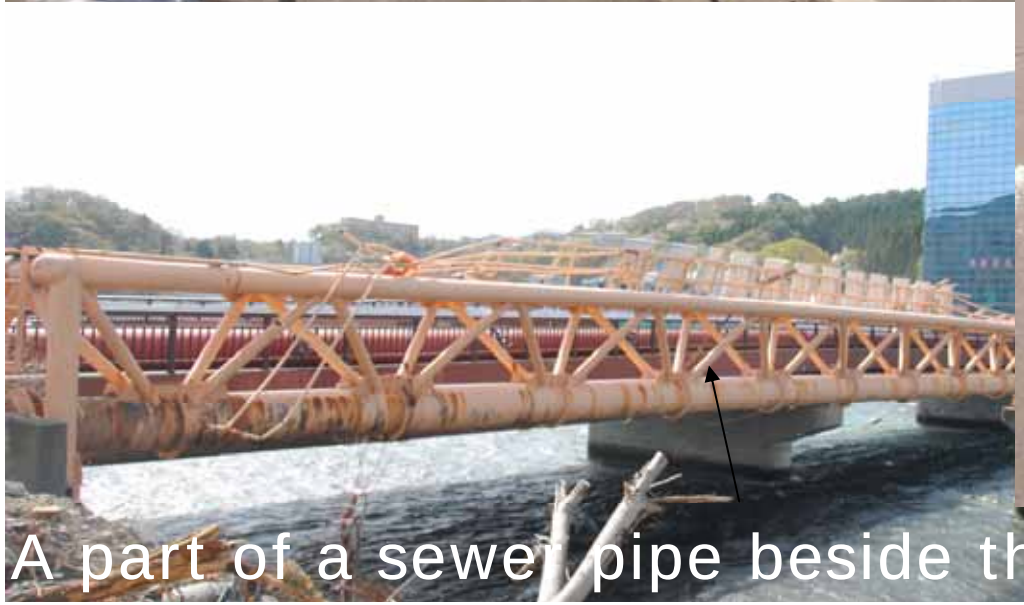
Tsunami rose up 6 m above the spans

Many bridges survived whereas they were at critical locations and were totally covered by tsunami (Yanoura Bridge,Kamaishi)

After Kozo Sawada, Sunday Maichi, Special Issue for E-J EQ, No.2

Yano-ura Bridg after the earthquake

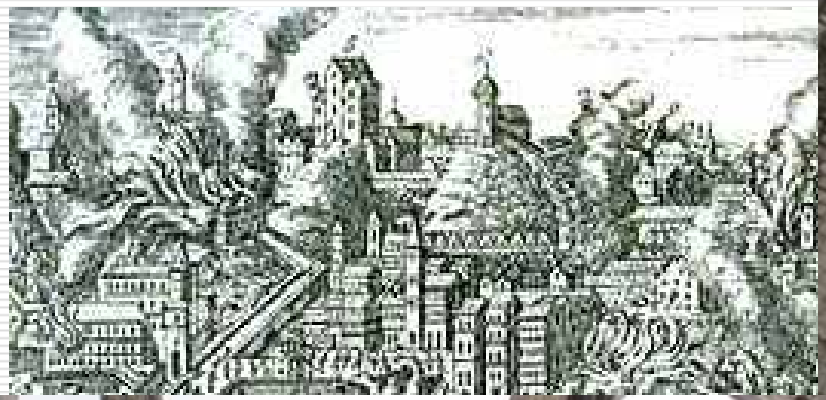
No residual dis



A part of a sewer pipe beside the bridge was w

1.5 Damage Resulted from Fire After an Earthquake

(1) 1755 Lisbon earthquake, Portugal



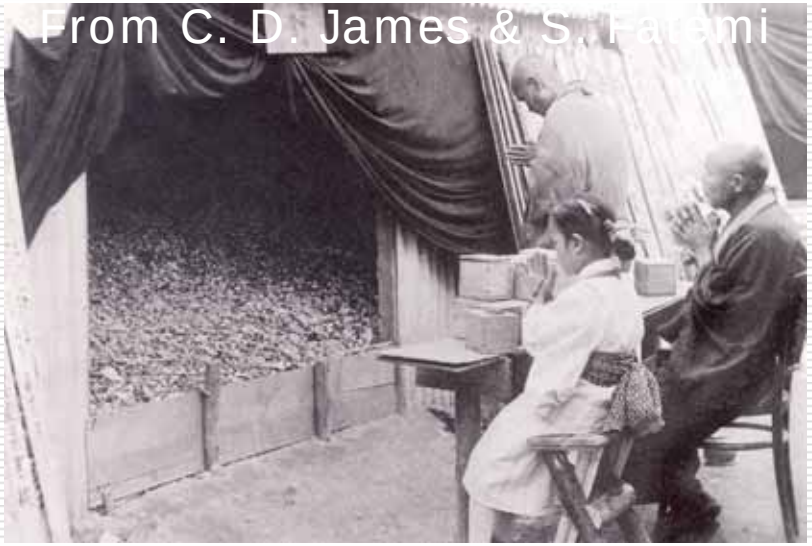
Carmo Church

(2) 1906 San Francisco, USA, Earthquake

(3) 1923 Kanto Earthquake, Japan

Victims at Hifuku-Sho

A priest praying at Hifuku-Sho
From C. D. James & S. Fatemi



Fire tornado火災旋風

(4) 1994 Northridge, USA, Earthquake

(5) 1995 Kobe, Japan, Earthquake

Summary of Chapter 1

1. Seismic effects include at least 1) ground vibration, 2) ground deformation, 3) fault displacement (**断層変位**), 4) tsunami and 5) fire.

2. In addition to the above five effects, there are many other effects, such as 1) generation and propagation of functional damage, economical effects, and mental damage. **機能喪失とこの連鎖、経済的損失、精神的ダメージ**

3. Because the five effects in 1. results in various damage in 2. it is essential to mitigate damage in 1.

4. Seismic isolation and response modification technology aim of mitigating damage due to ground vibration.