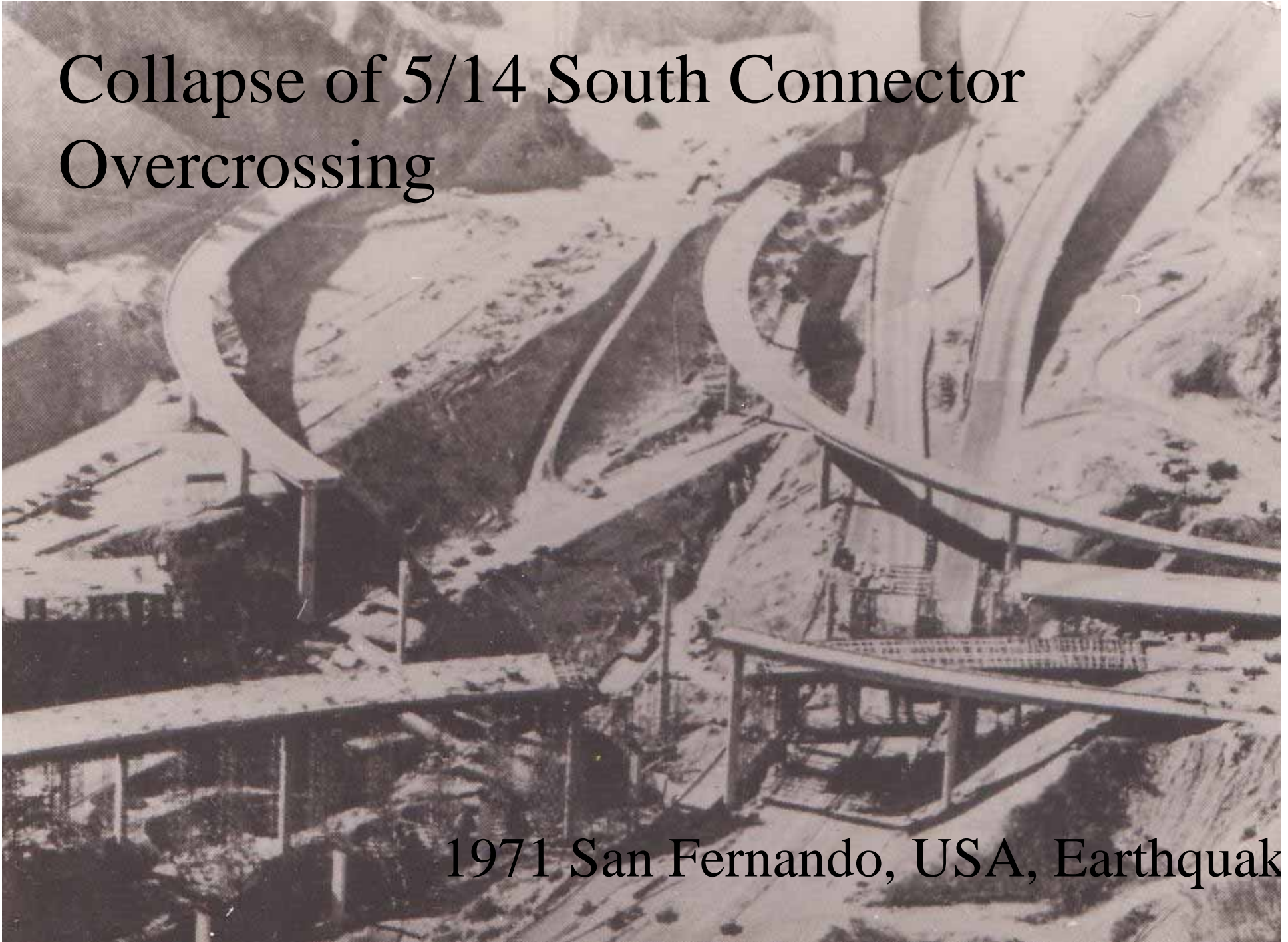


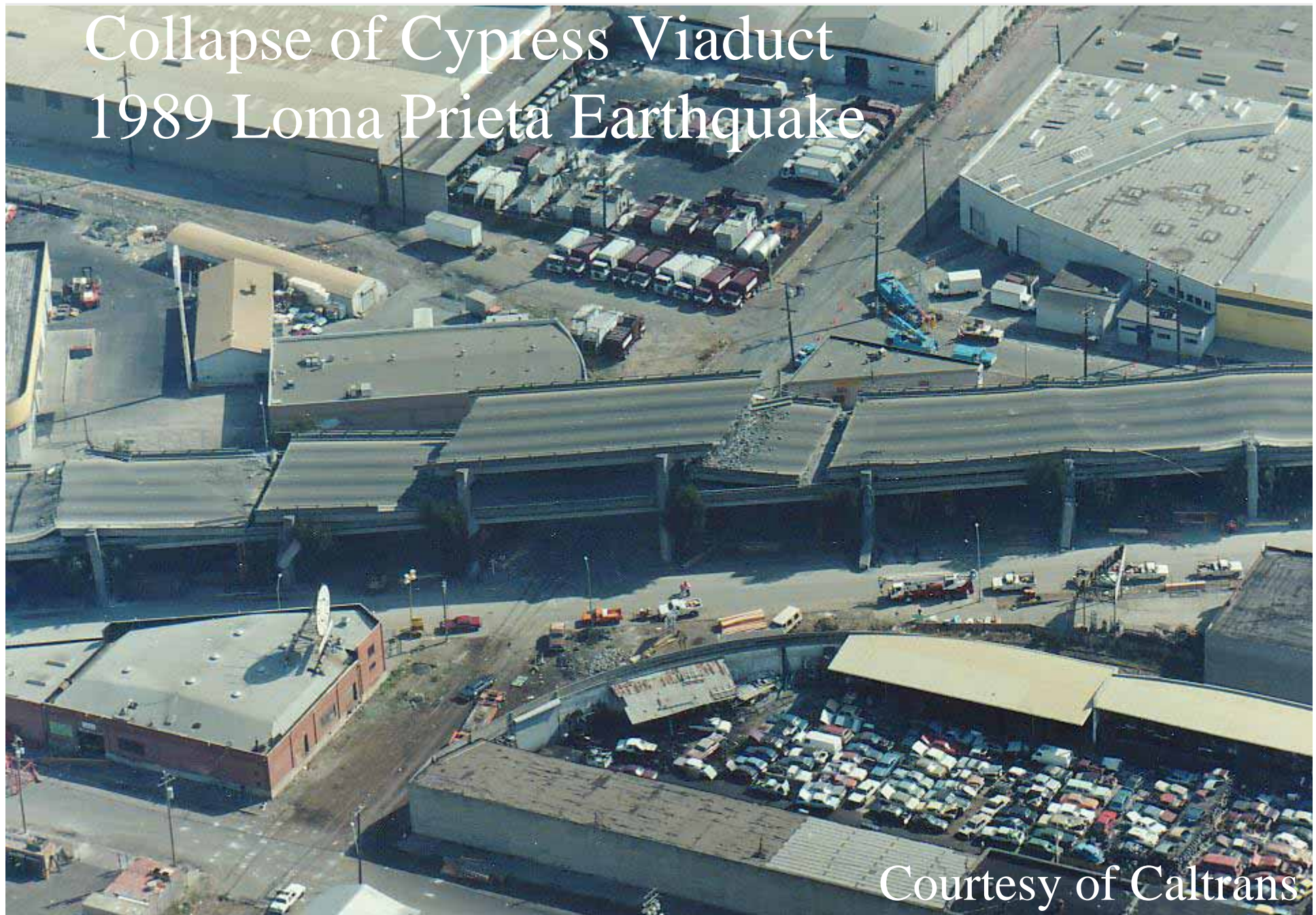
2.3 Seismic Damage of Bridges in USA

Collapse of 5/14 South Connector Overcrossing

1971 San Fernando, USA, Earthquake



Collapse of Cypress Viaduct 1989 Loma Prieta Earthquake



Courtesy of Caltrans

Collapse of Cypress Viaduct 1989 Loma Prieta Earthquake



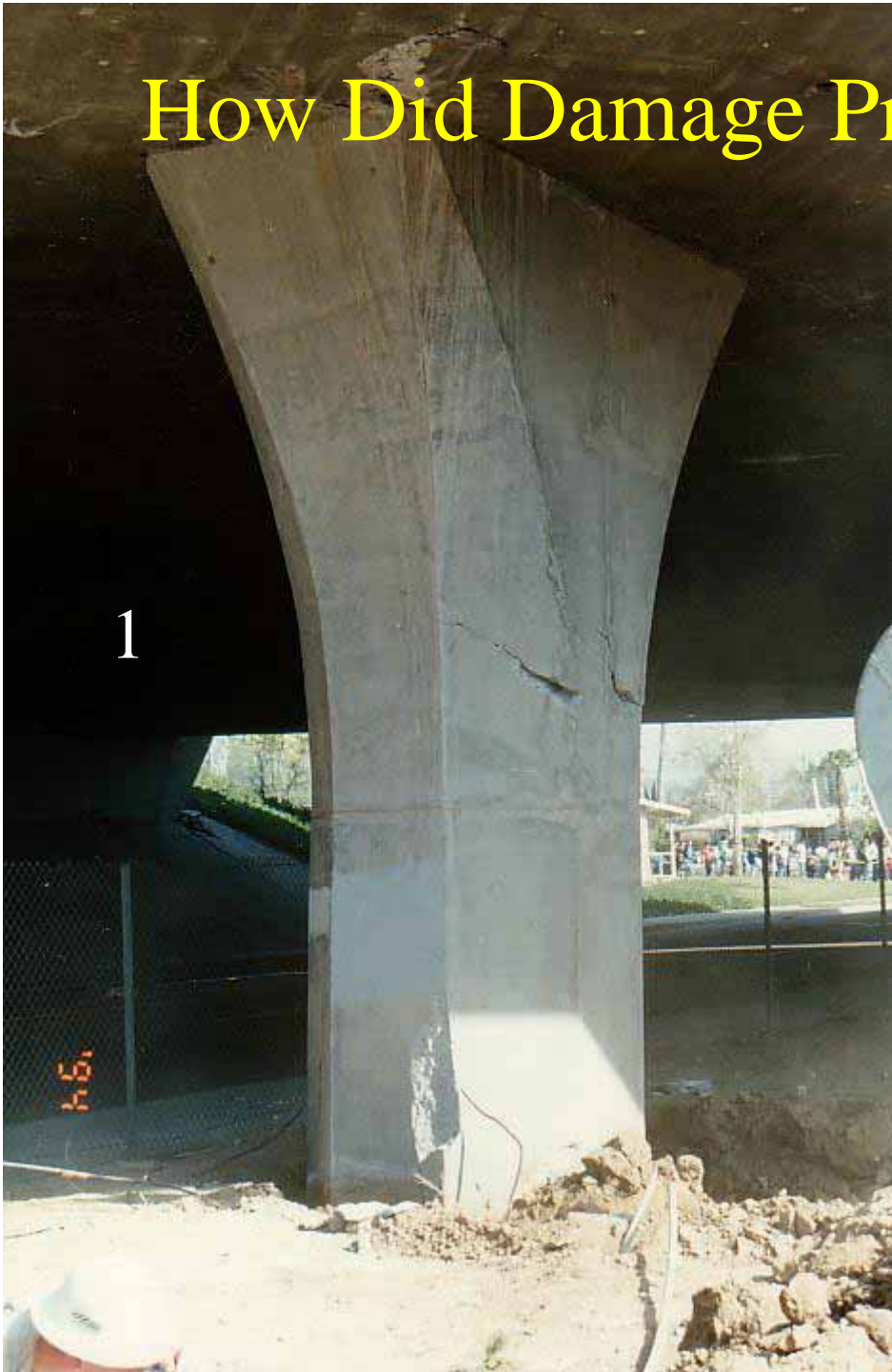
Courtesy of Caltrans

1989 Loma Prieta Earthquake



How Did Damage Progress?

1



2



3



4



5



6



Pounding of Decks at Intermediate Hinge



History of Seismic Design of Bridges in USA

1776 Independence

1830-1840 Gold Rush

1850 California became a part of US territory

1906 San Francisco Earthquake

1933 Long Beach Earthquake

Field Act (0.1 Seismic coefficient for school
buildings, and 0.02-0.05 seismic coefficient
or other structures) & Riley Act

1936 Construction of San Francisco Oakland
Bay Bridge

1957 Construction of Cypress Viaduct

1961 First Stipulation for Seismic Effects in AASHO

1961 First Stipulation for Seismic Effect in
California Department of Transportation

History of Seismic Design of Bridges in USA (continued)

1971	San Fernando Earthquake Damage of bridges during 11 earthquakes with magnitude of 5.4-7.7 between 1933 and 1971 was only \$100,000
1973	New Caltrans Seismic Design (Incorporated into AASHTO in 1975)
1981	New FHWA Seismic Design Code
1989	Loma Prieta EQ
1994	Northridge EQ

History of Seismic Design of Bridges in Japan

1923 Kanto EQ

1925 First Design Code for Bridges including Seismic Effects

1964 Design Specifications (2 pages)

$k_h=0.2$, $k_v=0.1$

1971 First Independent Seismic Design Specifications (30 pages)

Unseating prevention devices, Evaluation for liquefaction potential

1980 Design Specifications (50 pages)

Updated Evaluation for Liquefaction

History of Seismic Design of Bridges in Japan (continued)

1990 Design Specifications (100 pages)

Check for Ductility, Lateral Force for Multi-span
Bridges, Standard Ground Motions for Dynamic
Analysis

1995 Kobe EQ

1996 Design Specifications (200 pages)

Ductility Design, Near-Field Ground Motions

2002 Design Specifications (240 pages)

2012 Design Specifications of Highway Bridges

2.4 Damage of Bridges Due to Fault Displacement

2.4.1 1999 Kocaeli & Duzce, Turkey, EQs

August 17 Kocaeli EQ & November 12 Duzce EQ, 1999

North Anatorian Fault System



Arifiye Overbridge



Evidences of Fault Dislocation around Arifye



Offset of a Concrete Fence by a Fault Dislocation



Offset of an Irrigation Pipe along the Motorway



Bolu Viaduct

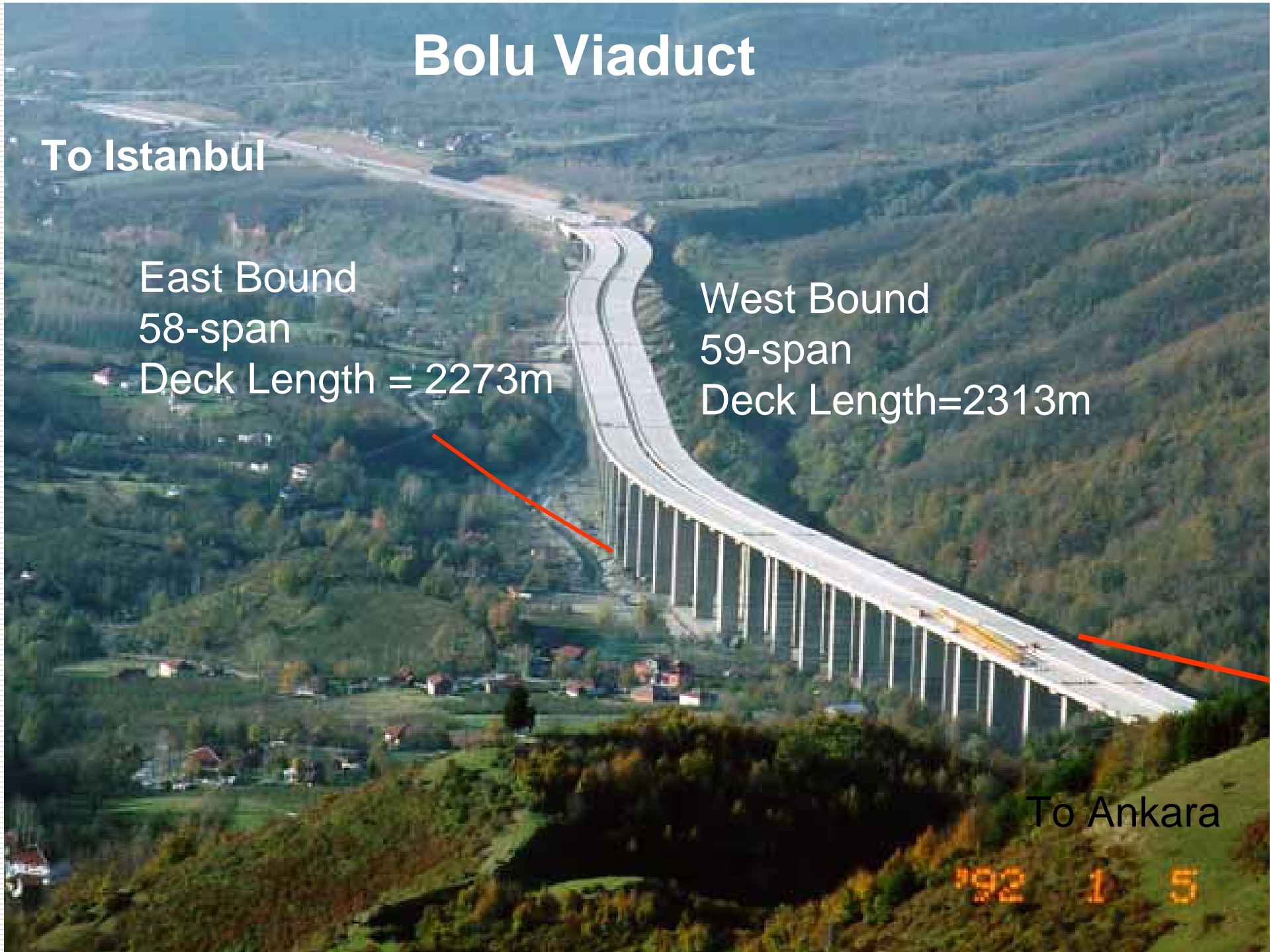
To Istanbul

East Bound
58-span
Deck Length = 2273m

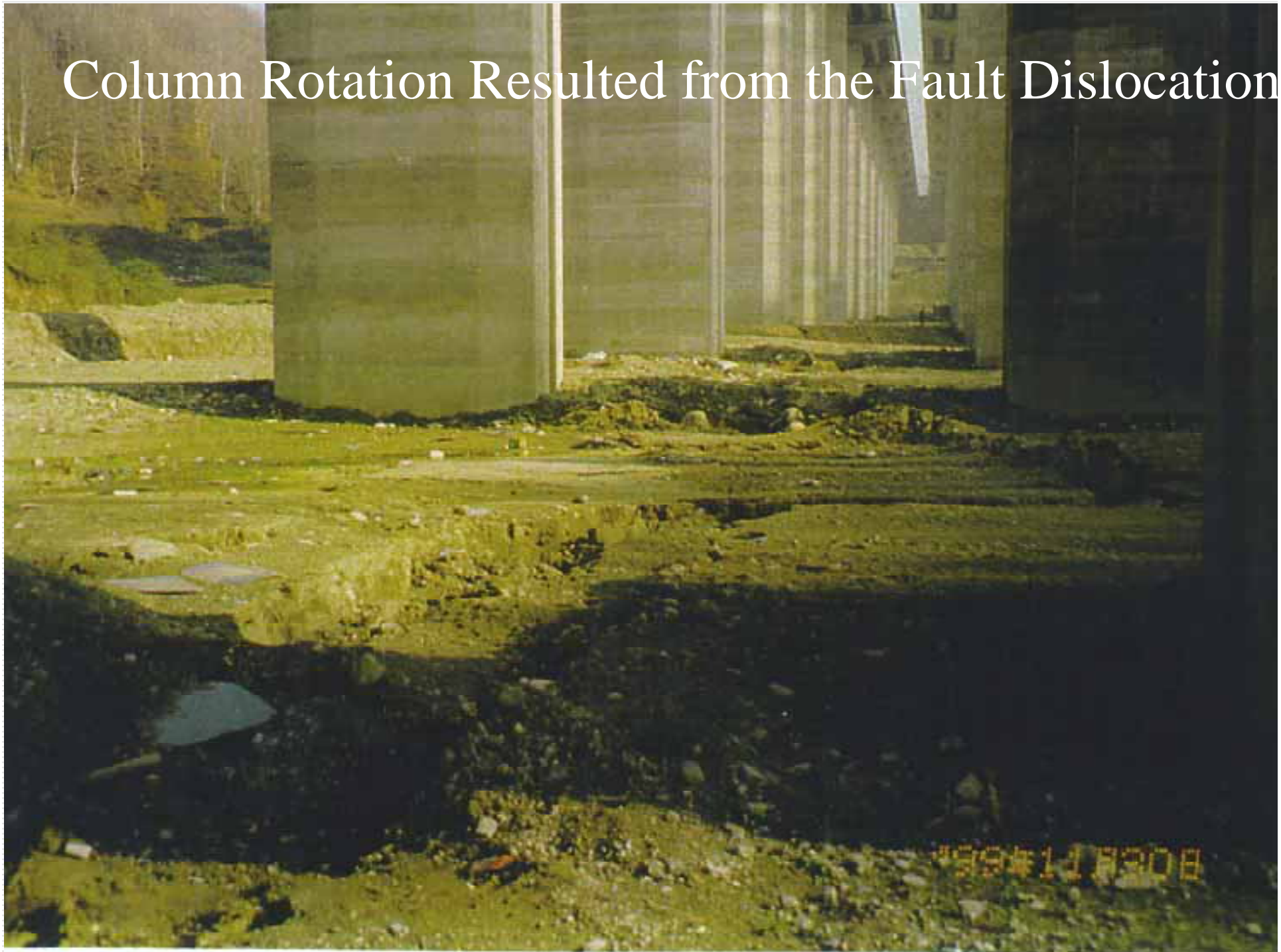
West Bound
59-span
Deck Length=2313m

To Ankara

'92 1 5



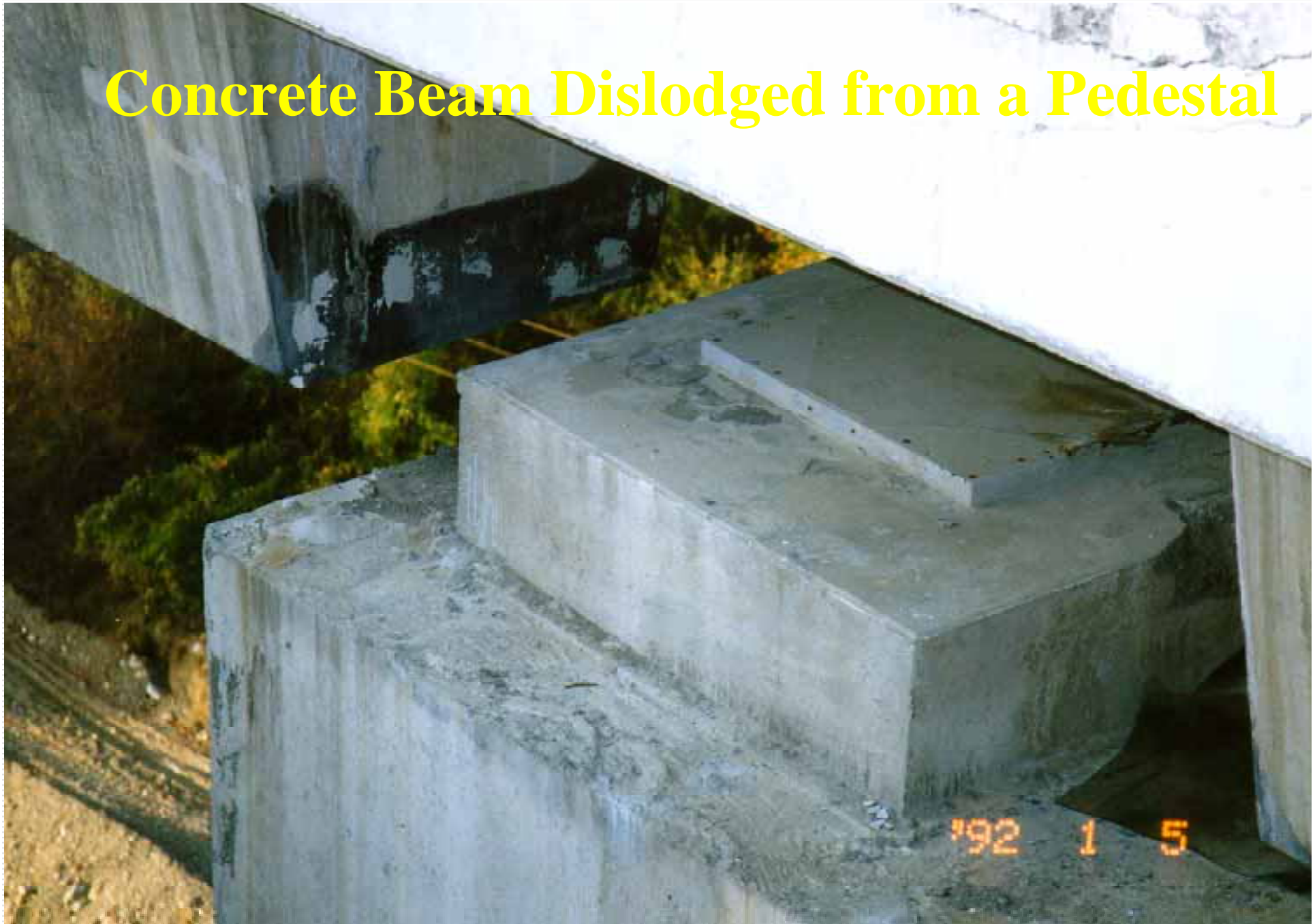
Column Rotation Resulted from the Fault Dislocation



Extensive Deck Displacement



Concrete Beam Dislodged from a Pedestal

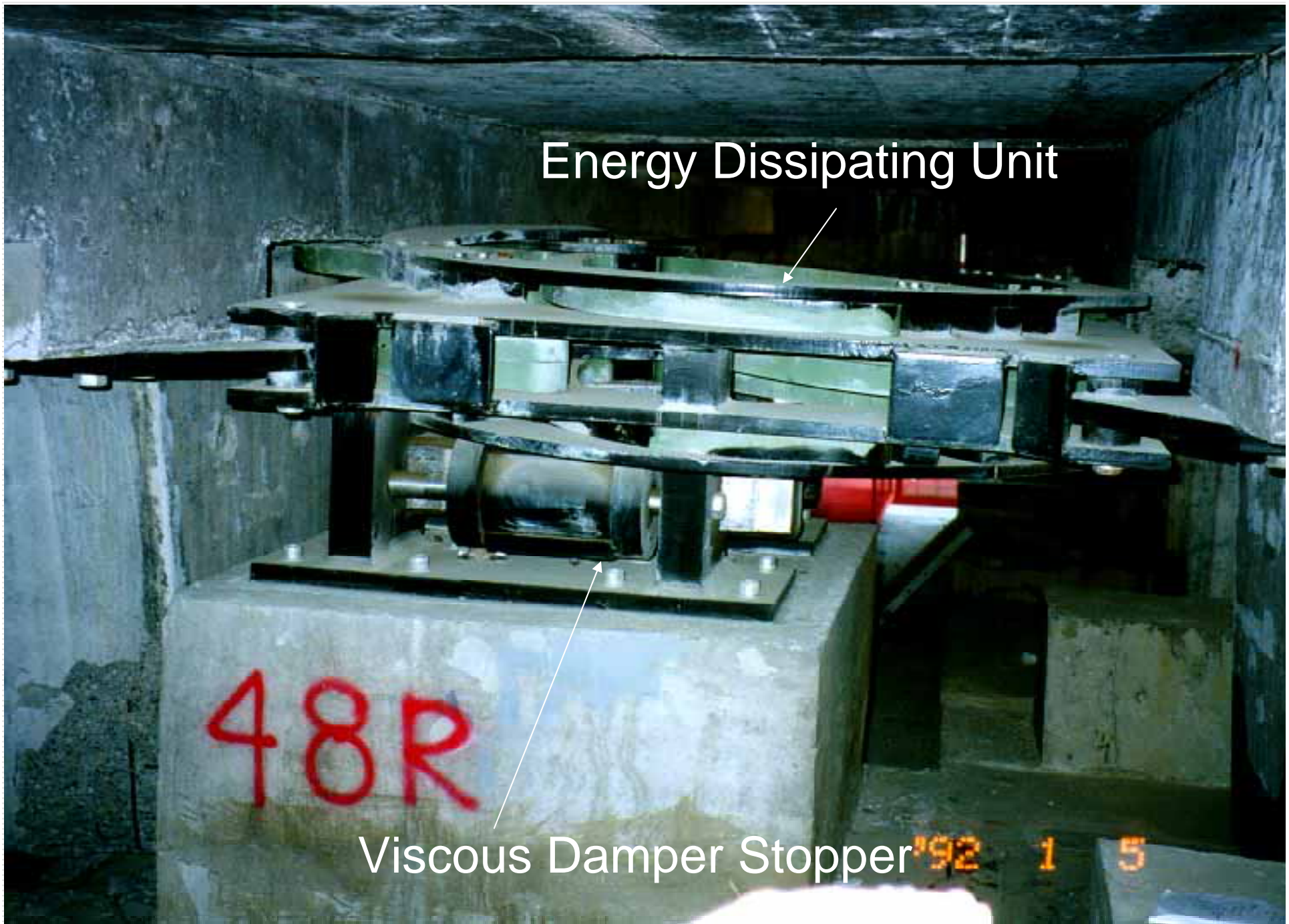


Energy Dissipating Unit

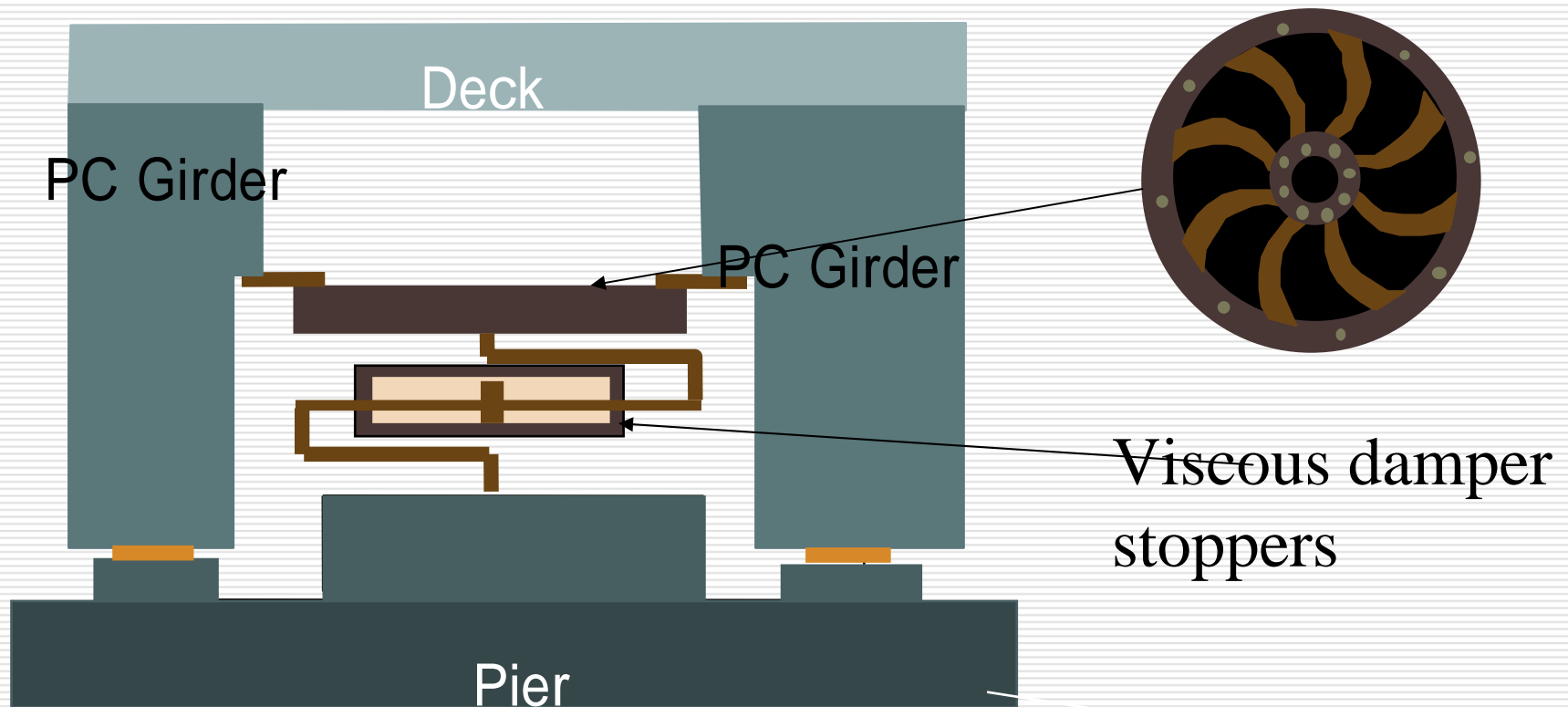
48R

Viscous Damper Stopper

'92 1 5



Combination of Energy Dissipating Unit and Viscous Damper Stopper



Energy Dissipating Unit Damaged

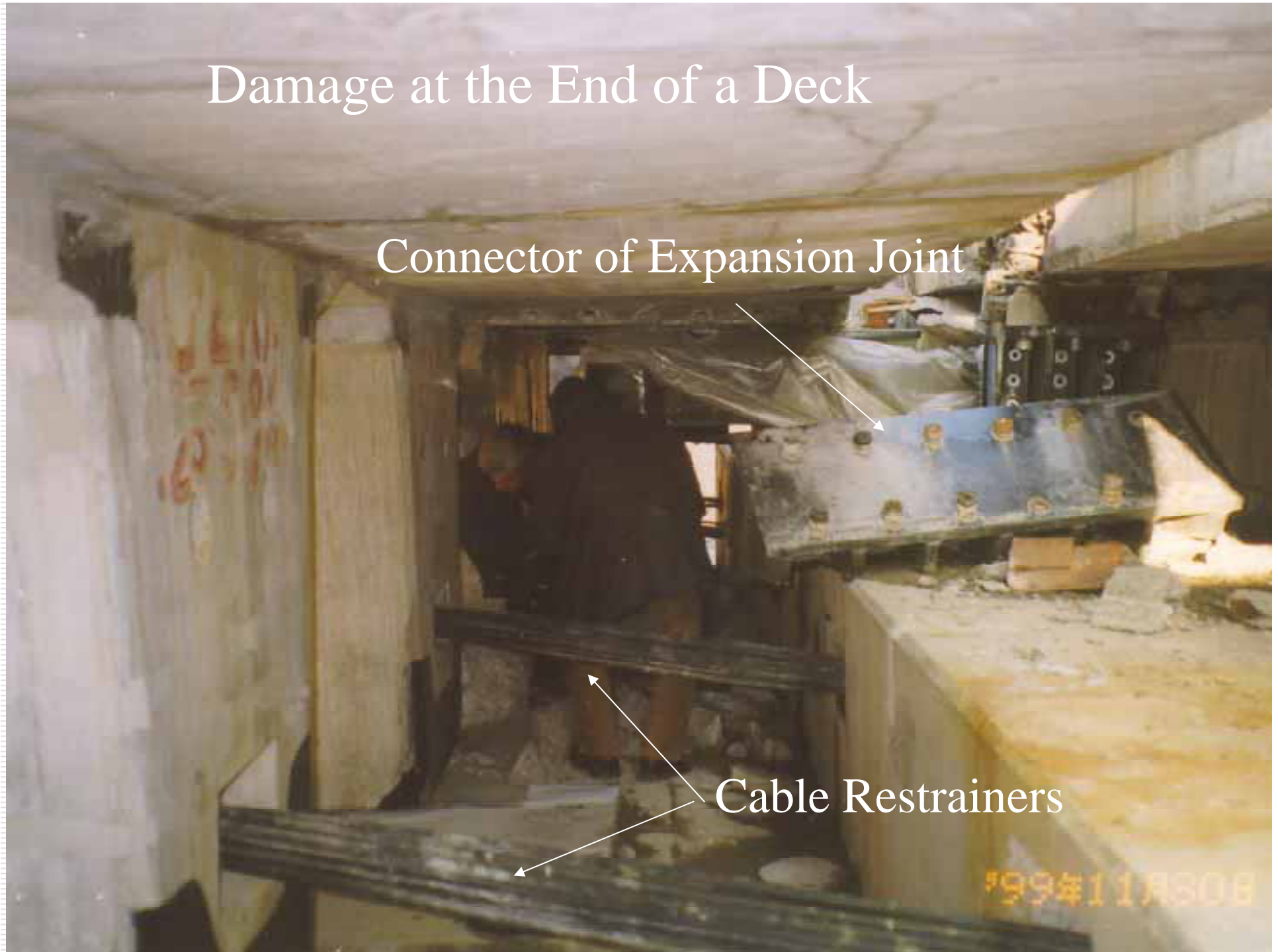


Damage at the End of a Deck

Connector of Expansion Joint

Cable Restrainers

1999年11月30日



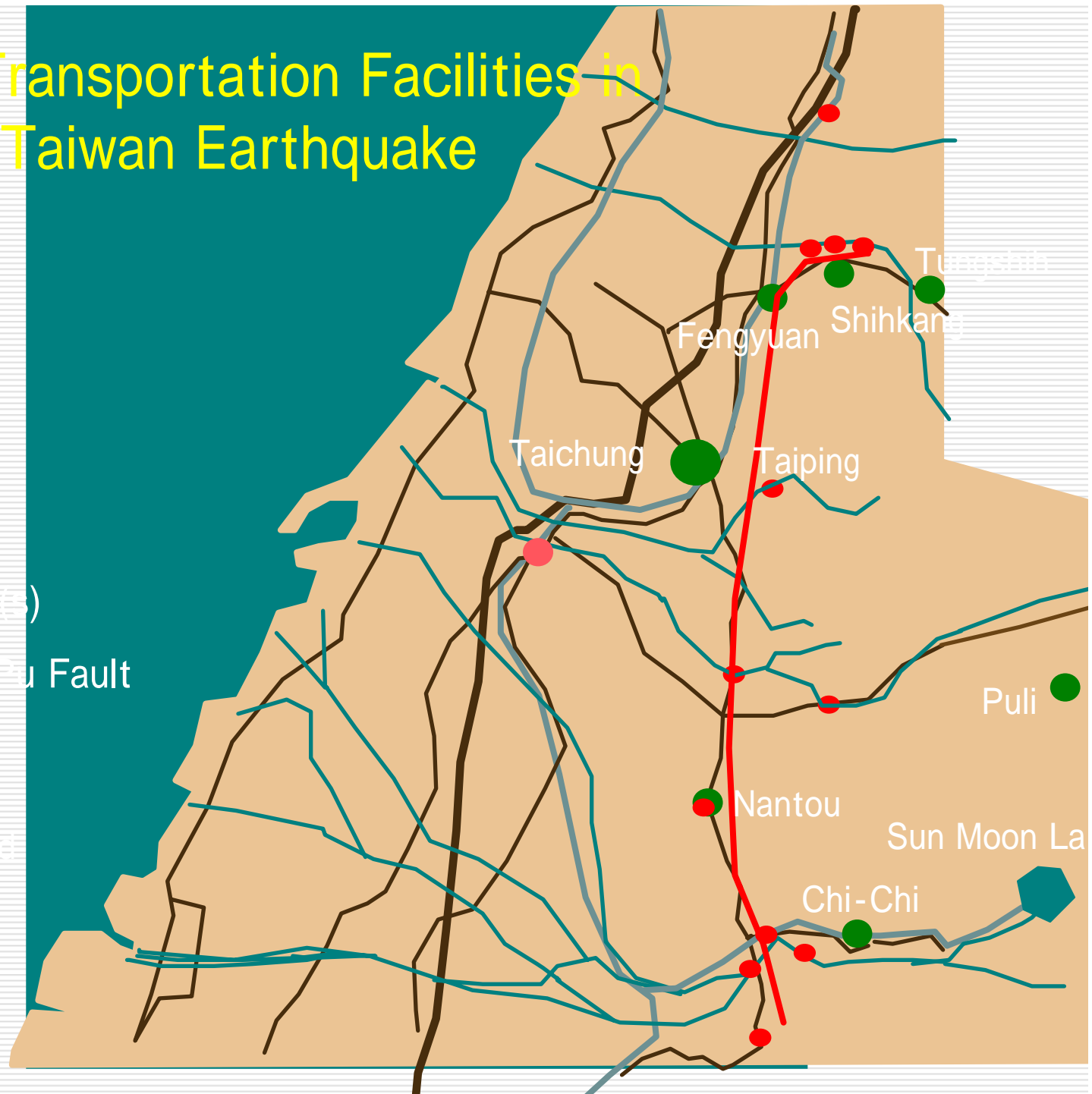
Pile Foundation Damaged by Fault Displacement



2.4.2 1999 Chi Chi, Taiwan, EQ

Damage of Transportation Facilities in the Chi Chi, Taiwan Earthquake

- Major City
- Damage of Bridge(s)
- Che-Long-Pu Fault
- River
- Expressway
- National Road
- Railways



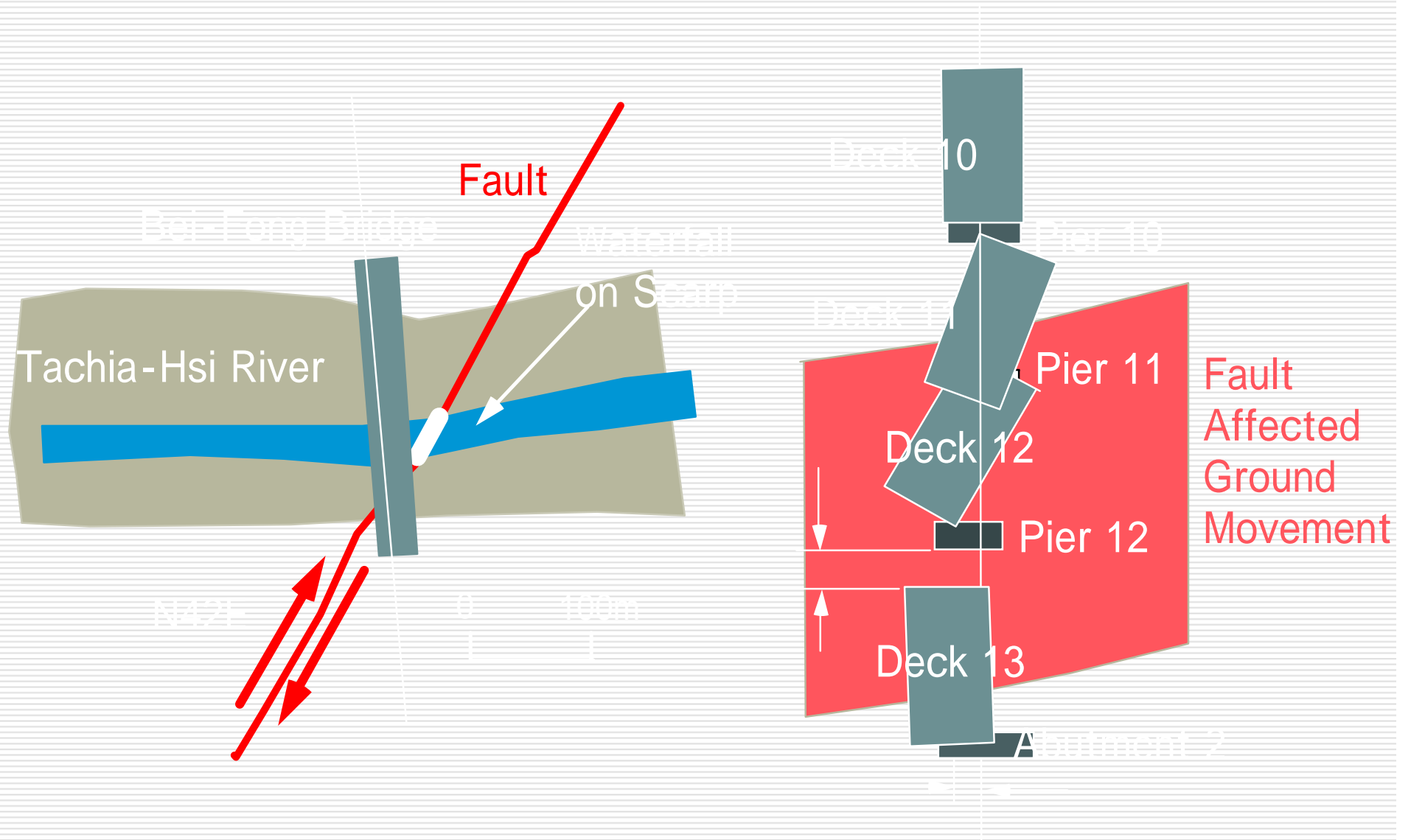
Bei-Fong Bridge

Fault

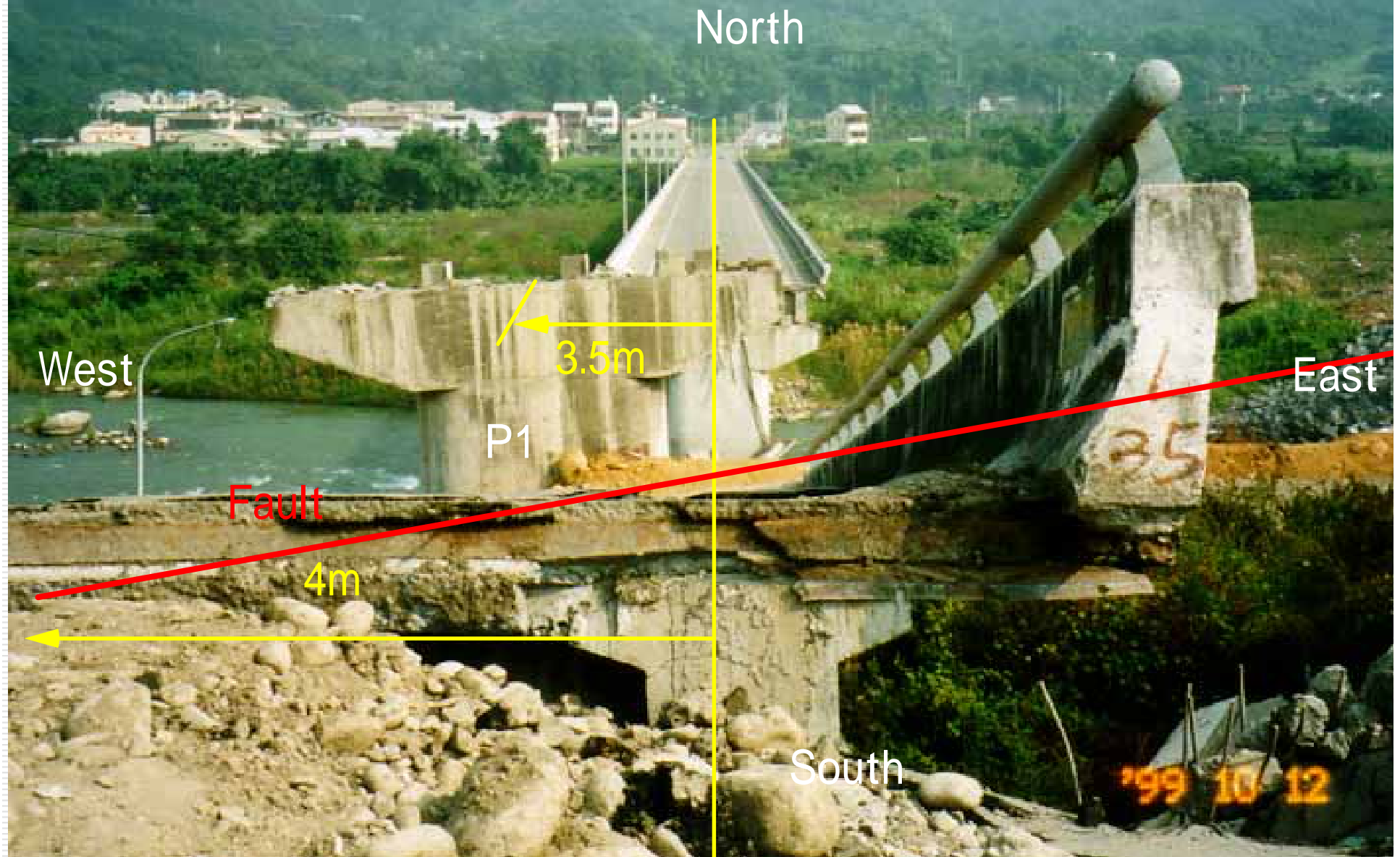


1995 10 12

Fault Dislocation around Bei-Fong Bridge



BEI-FONG BRIDGE



Wu-Shi Bridge

North

South

Up-stream

Down-stream

P1

P2

P3

P4





