



TYLin

May 19th, 2023

NHERI at UC San Diego

Seismic Testing for Transportation Infrastructure

Dr. Tim Ingham, PhD, PE, SE



Slide 2

CC0 Please check transition between slides. I personally prefer no effect.
Carol Choi, 2023-05-04T23:35:24.733



Agenda

- Introduction
- Golden Gate Bridge
 - Laced members, dampers, stiffener Retrofit, expansion Joints
- San Francisco-Oakland Bay Bridge
 - Shear link, W2 Bent, and orthotropic deck testing at UCSD
- Aurora Avenue Bridge
 - Fiber wrap of columns
- Bataan-Cavite Interlink Bridge
 - Unloading of cables, allowable strains
- Closing Remarks

TYLin Legacy

1946 Tung Yen Lin joins the faculty at UC Berkeley and begins his innovative research in pre-stressed concrete

1954 T.Y. Lin founds T.Y. Lin Associates in Los Angeles, which later becomes T.Y. Lin International, now TYLin

1960 The firm relocates to San Francisco, expanding its specialty in pre-stressed concrete



TYLin Facts and Figures

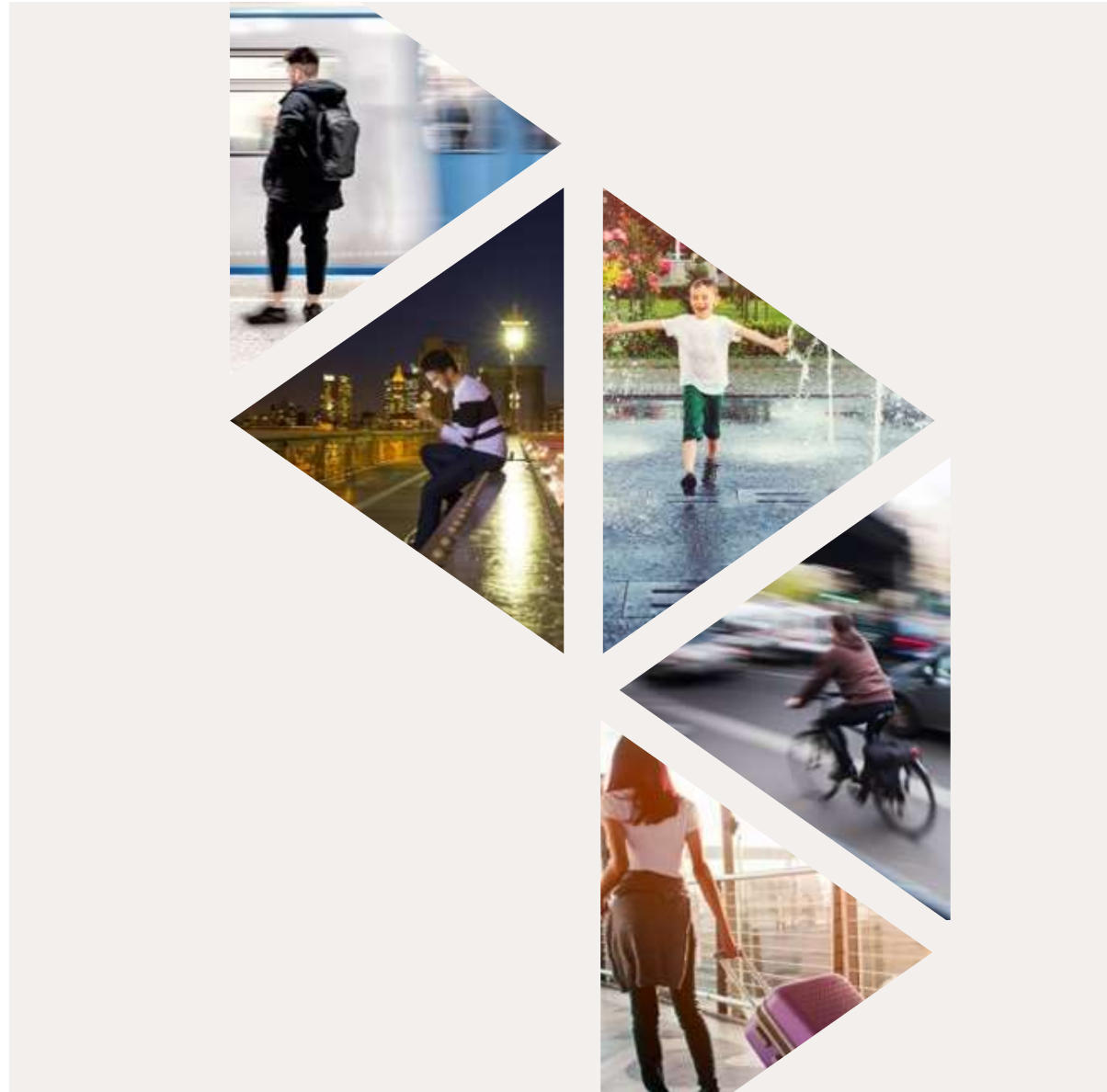
Established **1954**

People **5,000**

Locations **146**

Calif. Offices **8**

TYLin



TYLin Group

Key Market Sectors

Transportation

- Aviation
- Bridge
- Rail + Transit
- Roads + Highways
- Ports + Marine

Buildings

- Commercial
- Education
- Government
- Healthcare
- Science + Technology

Water

- Drinking Water
- Wastewater
- Water Resources

TYLin



Top Left: New Champlain Bridge (Montreal, Quebec Canada). Top Right: California High Speed Rail (California, USA) Middle Right: New Runway Fort Lauderdale/Hollywood International Airport (Florida, USA). Bottom Left: Hoover Dam Bypass (Clark County, NV & Mohave County AZ). Bottom Right: Marina Bay Sands Integrated Resort (Singapore).

Slide 6

CC0 Dear Taylor, please put "Transportation" first at the top.

Carol Choi, 2023-05-04T23:18:49.137

CC1 Please check website to confirm sectors.

Carol Choi, 2023-05-04T23:30:39.567

Worldwide Experience

North America

- CANADA**
 British Columbia Ontario
 Quebec
- UNITED STATES**
 Arizona New Mexico
 California New York
 Colorado North Carolina
 District of Columbia Ohio
 Delaware Oregon
 Pennsylvania
 Florida Rhode Island
 Georgia South Carolina
 Illinois Texas
 Maine Utah
 Maryland Virginia
 Michigan Washington
 Nevada West Virginia
 New Jersey

Latin America

- ARGENTINA**
BRAZIL
 Salvador de Bahia
 Minas Gerais
 Sao Paulo
 Rio de Janeiro
CHILE
- COLOMBIA**
 Bogotá
 Barranquilla
 Medellín
 Many Cities
PANAMÁ
 Panamá
PERU
 Chimbote
- MEXICO**
 Atizapan
 Boca del Cerro
 Chiapas
 Ecatepec
 Guadalajara
 Mexico City
 Puebla
 Toluca

Europe

- AUSTRIA**
CZECH REPUBLIC
HUNGARY
 Pecs
- ITALY**
 Florence
 Lucca
 Rosignano Marittimo
 Sondrio
- IRELAND**
- PORTUGAL**
 Lisbon
 Porto
- TURKEY**
 Istanbul
 Marmaray
- UNITED KINGDOM**
 Runcorn
- SPAIN**
 Alicante
 Asturias
 Badajoz
 Barcelona
 Castellón
 Catoira-Rianxo
 Córdoba
 Gerona
 Guipúzcoa
- Huesca
 La Rioja
 Logroño
 Madrid
 Malaga
 Pontevedra
 Saragossa
 Seville
 Toledo
 Valencia

China | Asia

- CHINA**
 Beijing
 Chongqing
 Fujian
 Guangxi
- Guangzhou
 Kunming
 Nanjing
 Qingdao
 Shanghai
- Shenyang
 Shenzhen
 Sichuan
 Wuhan

Africa

- ALGERIA**
 Mostaganem
GUINEA
 Bissau

Middle East

- SAUDI ARABIA**
 Farasan Island
 Mina
- QATAR**
 Doha

Central Asia

- INDIA**
 Farakka

Australia | South Pacific

- AUSTRALIA**

INDONESIA

- Jakarta

MALAYSIA

- Kuala Lumpur

PHILIPPINES

- Manilla

SINGAPORE

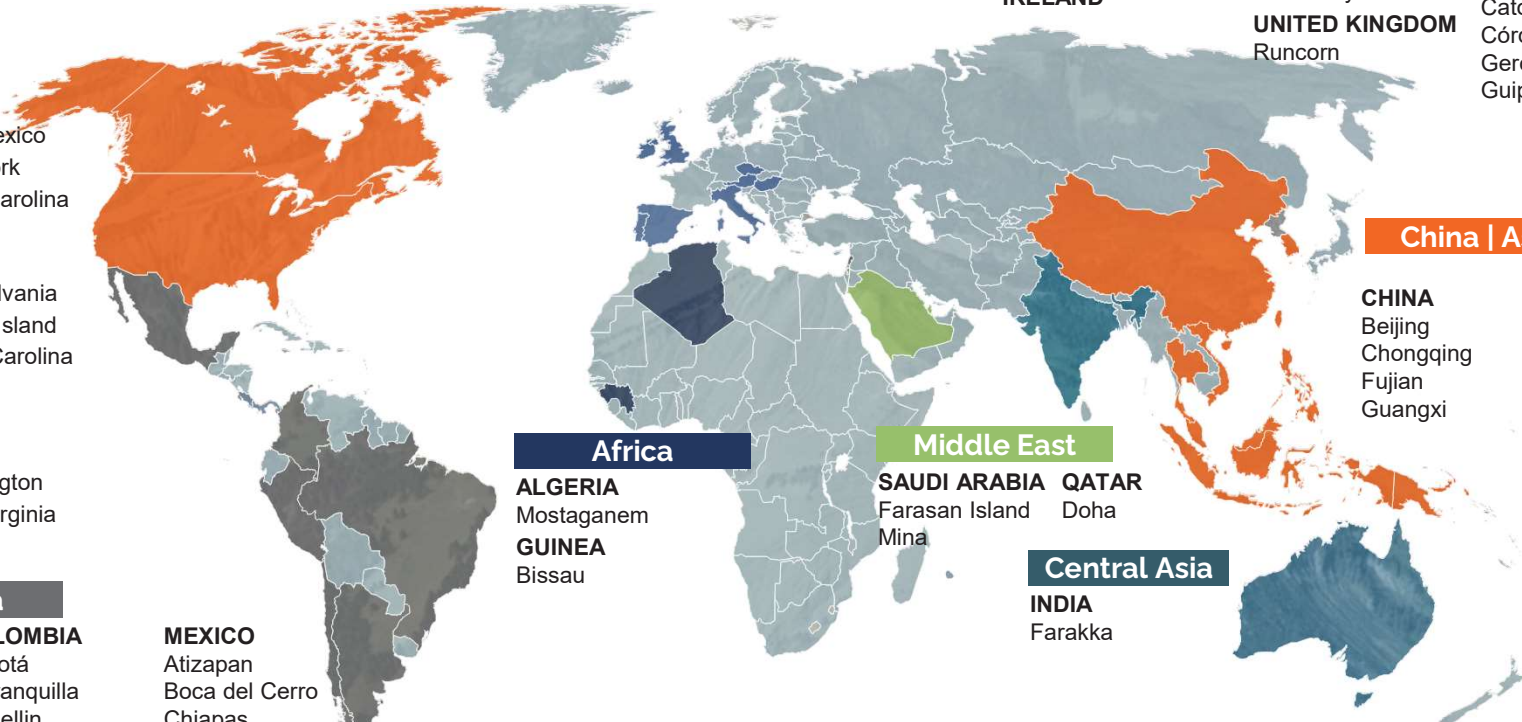
- Singapore

TAIWAN

- Taipei

VIETNAM

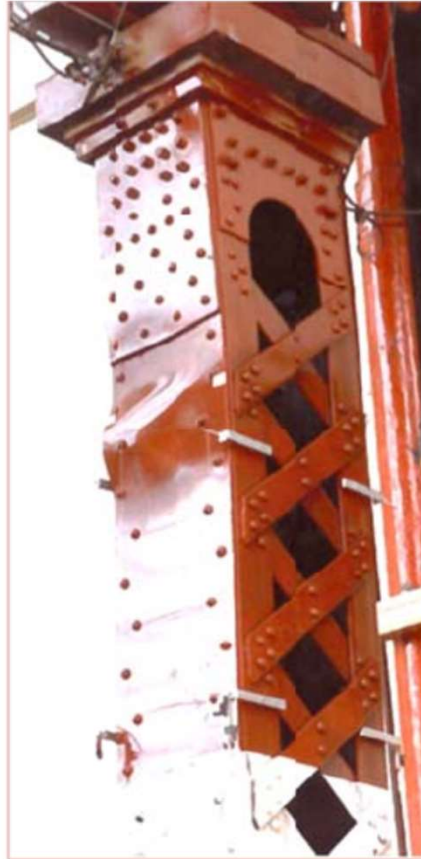
- Hanoi



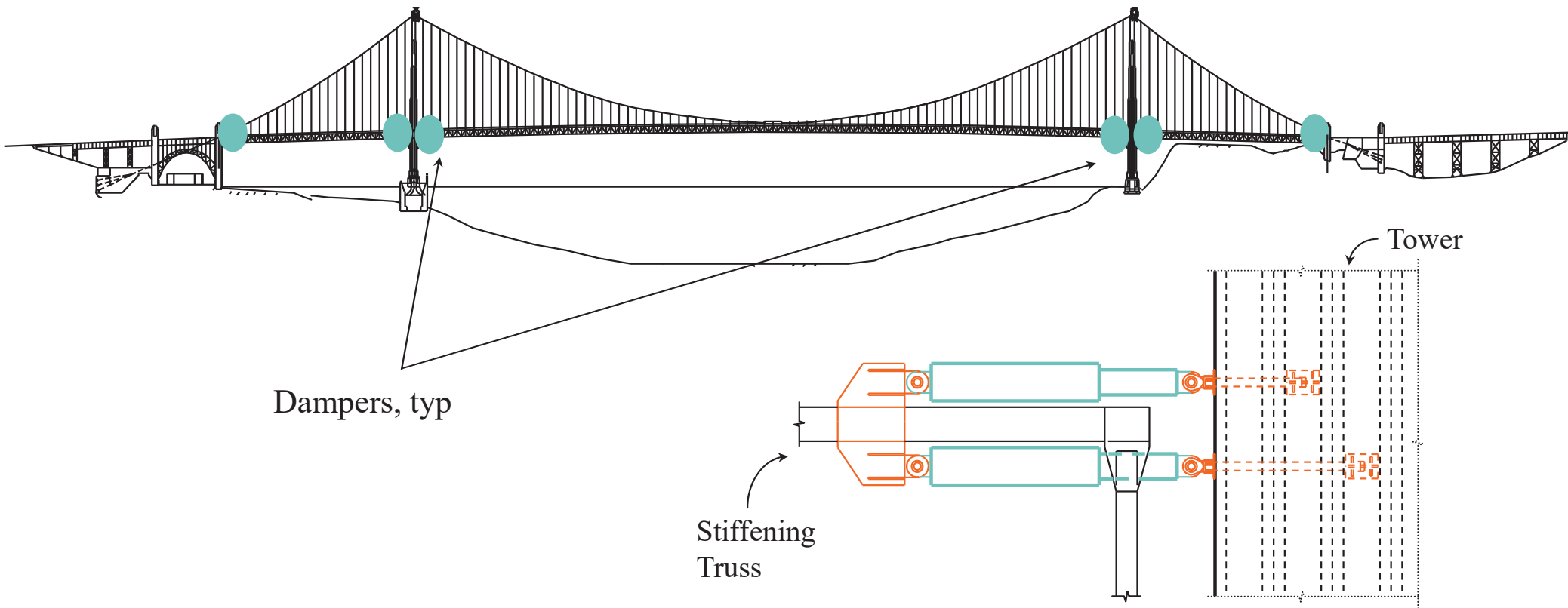


Golden Gate Bridge, San Francisco

Testing of Laced Members – UC Berkeley

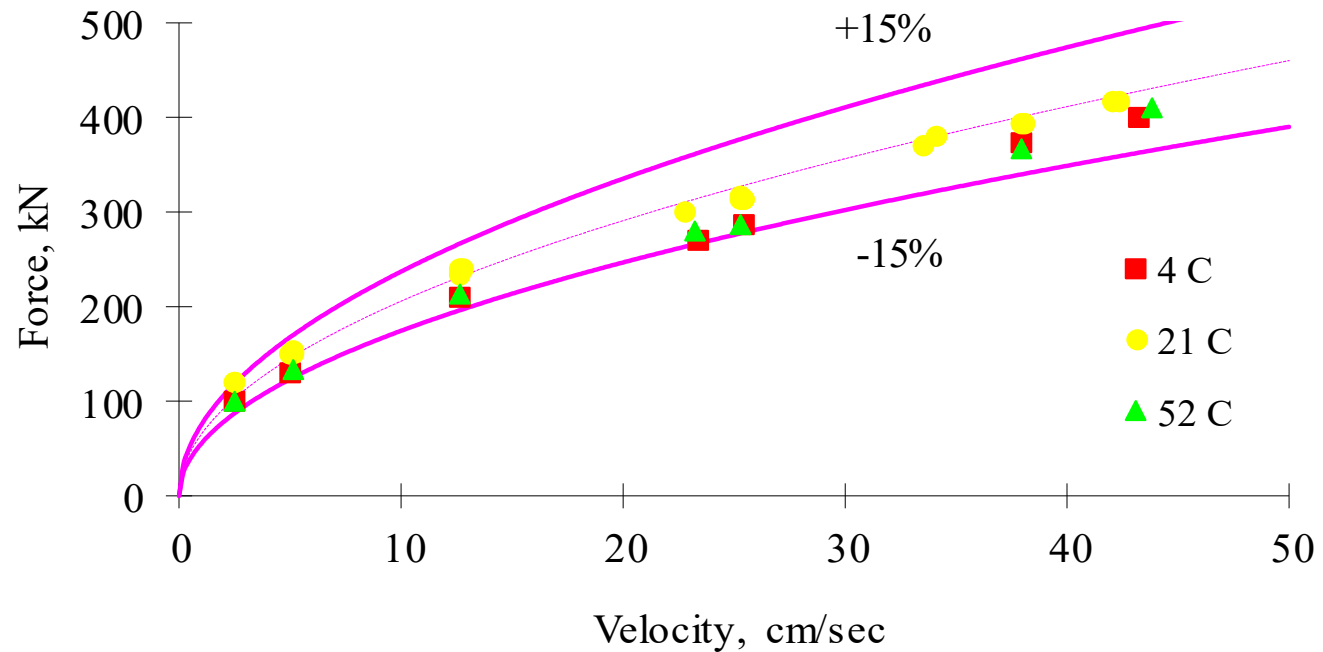


Viscous Dampers to Reduce Seismic Response

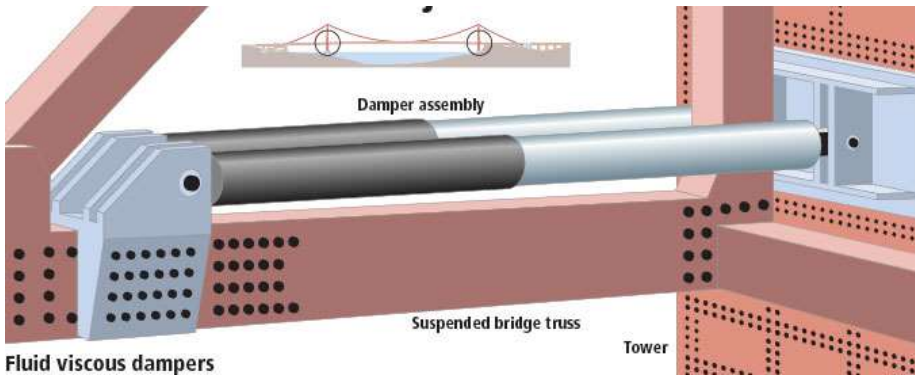


Testing at UC Berkeley

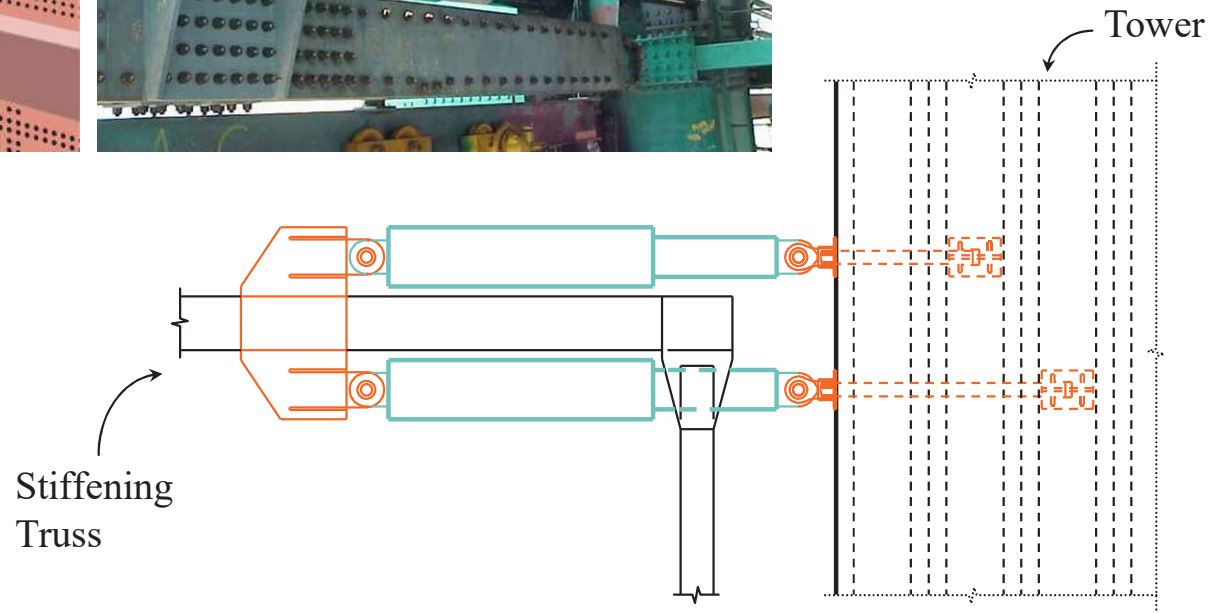
– Four submissions: Enidine, FIP, Liseqa, Taylor Devices



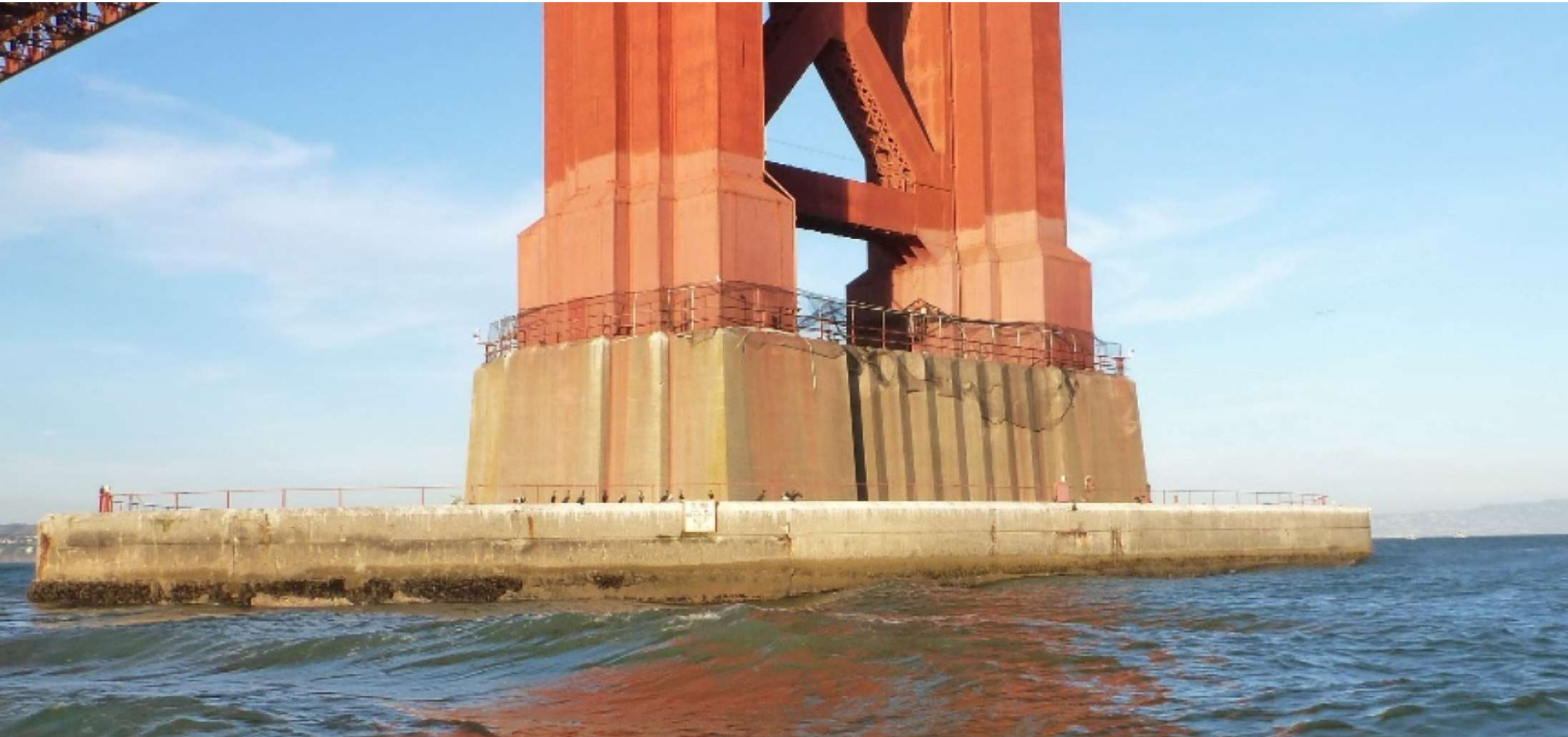
Viscous Damper Installation



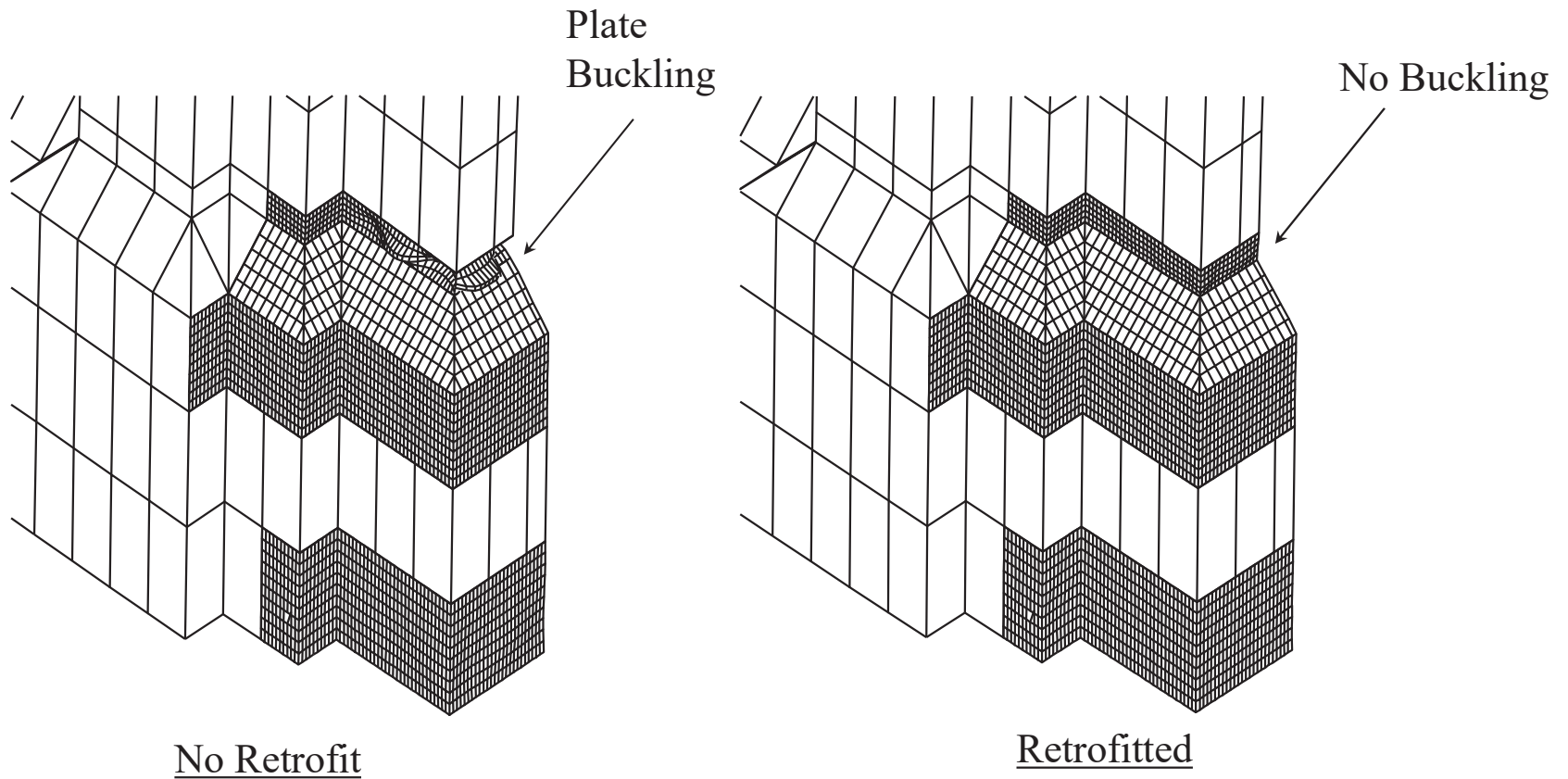
Fluid viscous dampers



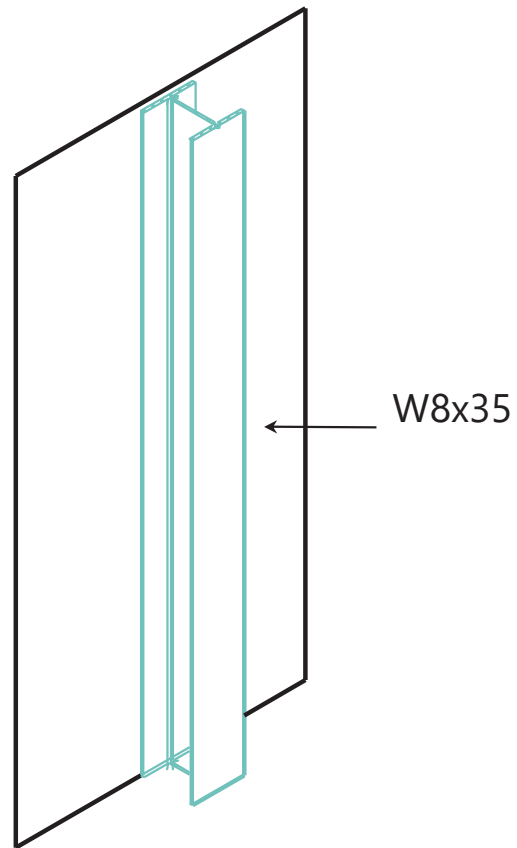
Tower Base Retrofit – Buckling Prevention



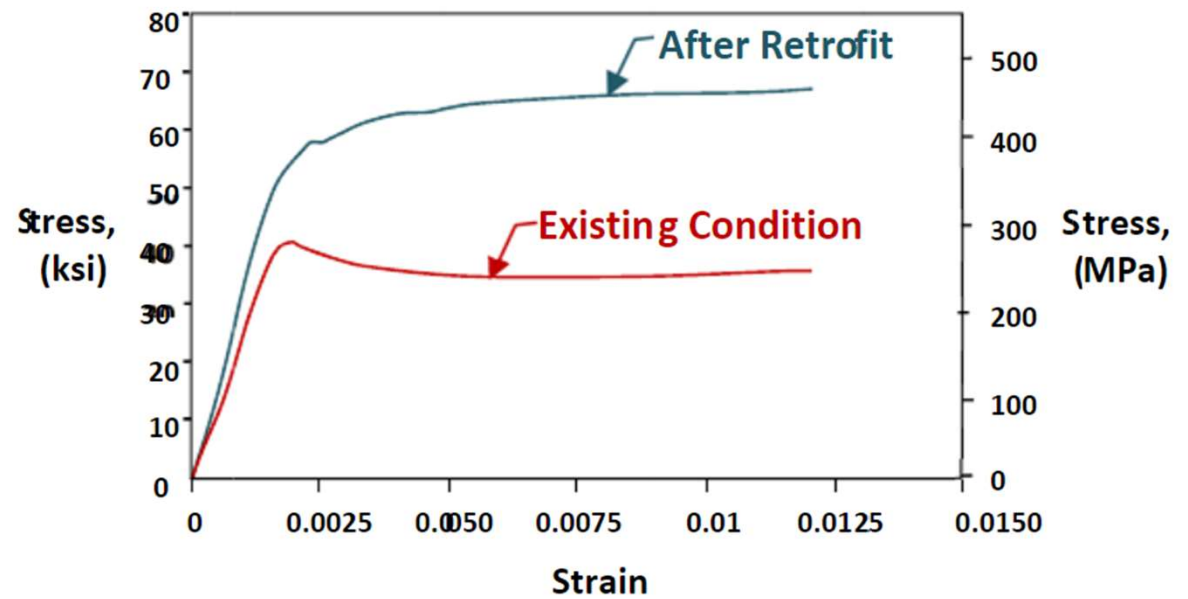
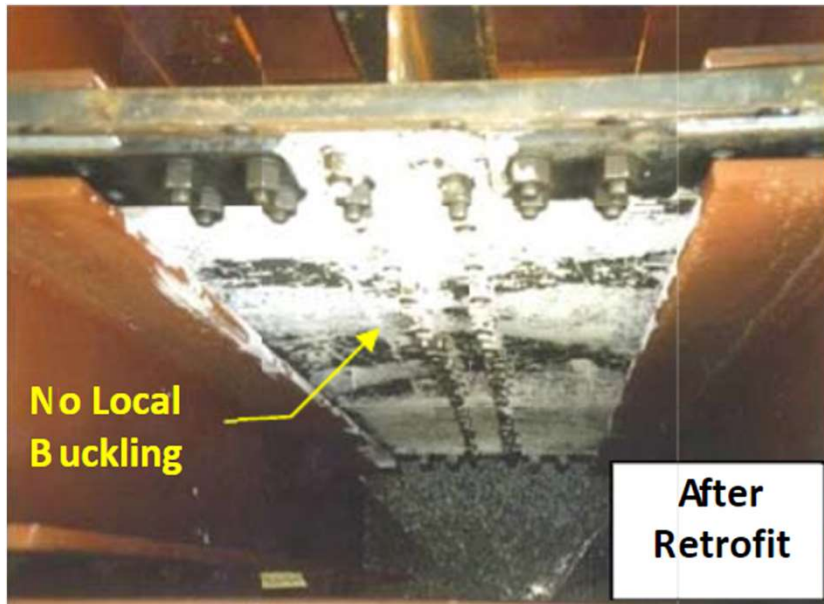
Tower Base — Before and After Retrofit



Stiffener Retrofit & Testing at UC Berkeley



Testing at UC Berkeley



Swivel Expansion Joint & Testing at UCB

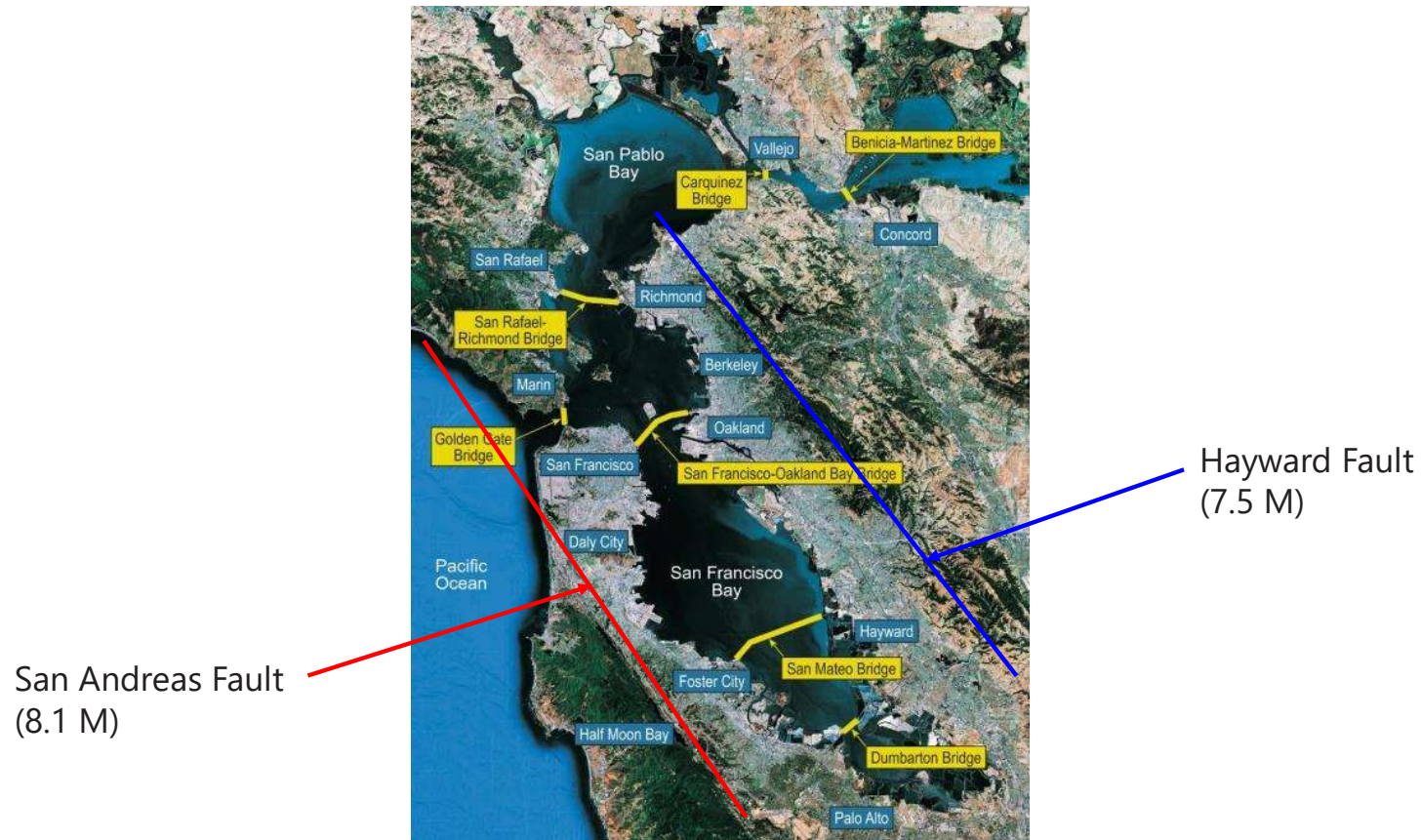
– Specimen subjected to full scale seismic displacement and velocity



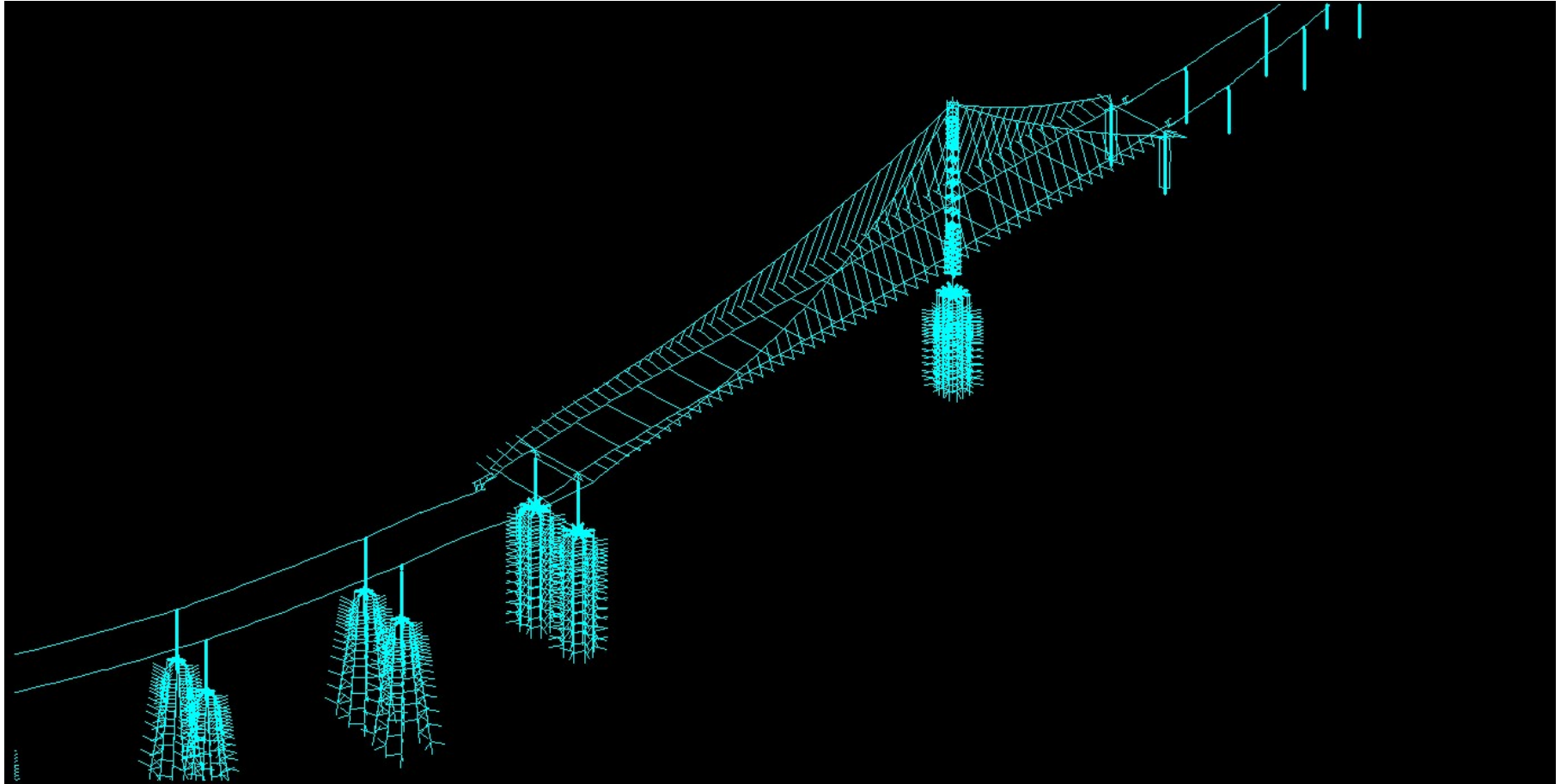


San Francisco-Oakland Bay Bridge, San Francisco

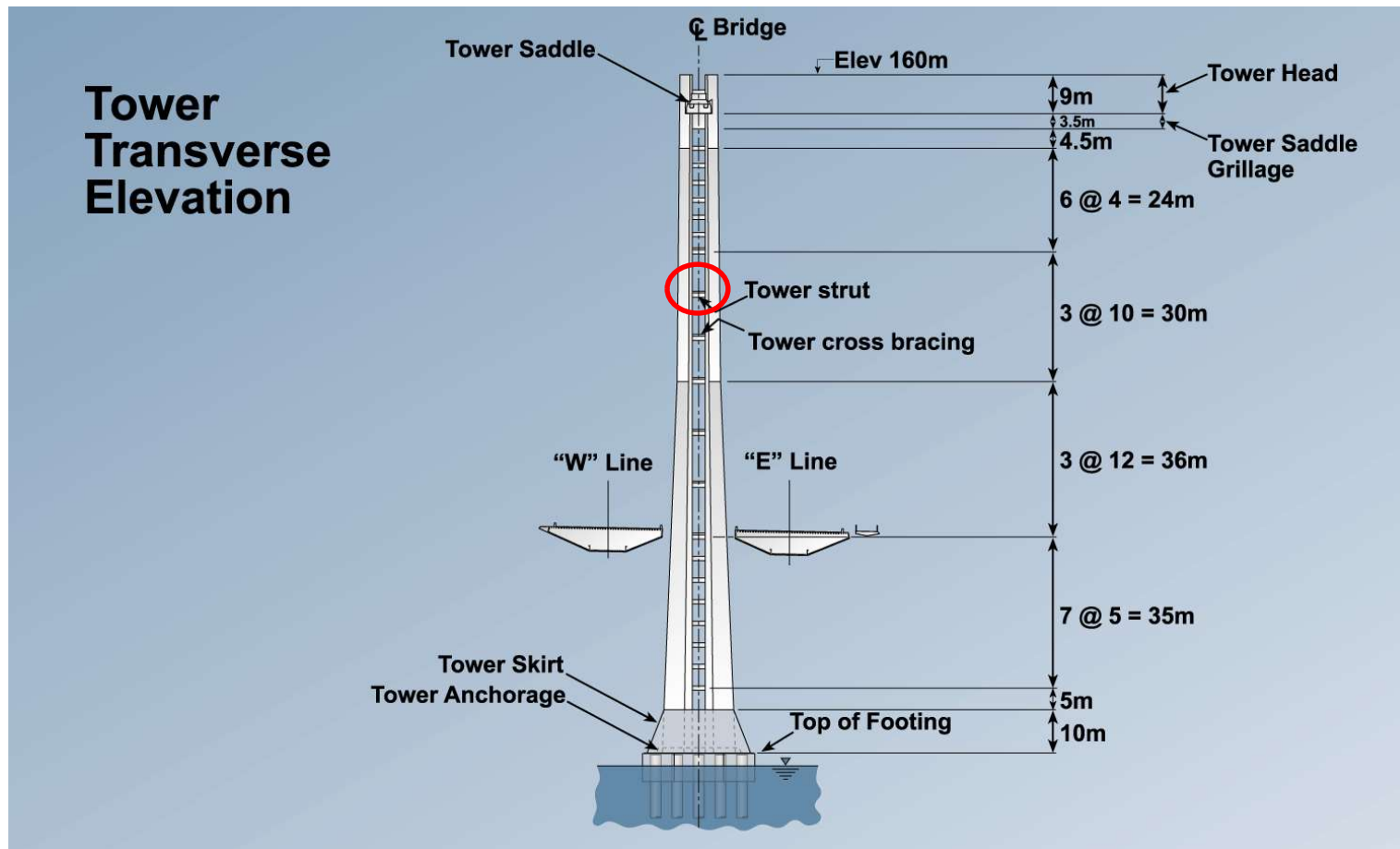
The SF Bay Area Challenge — Seismicity!



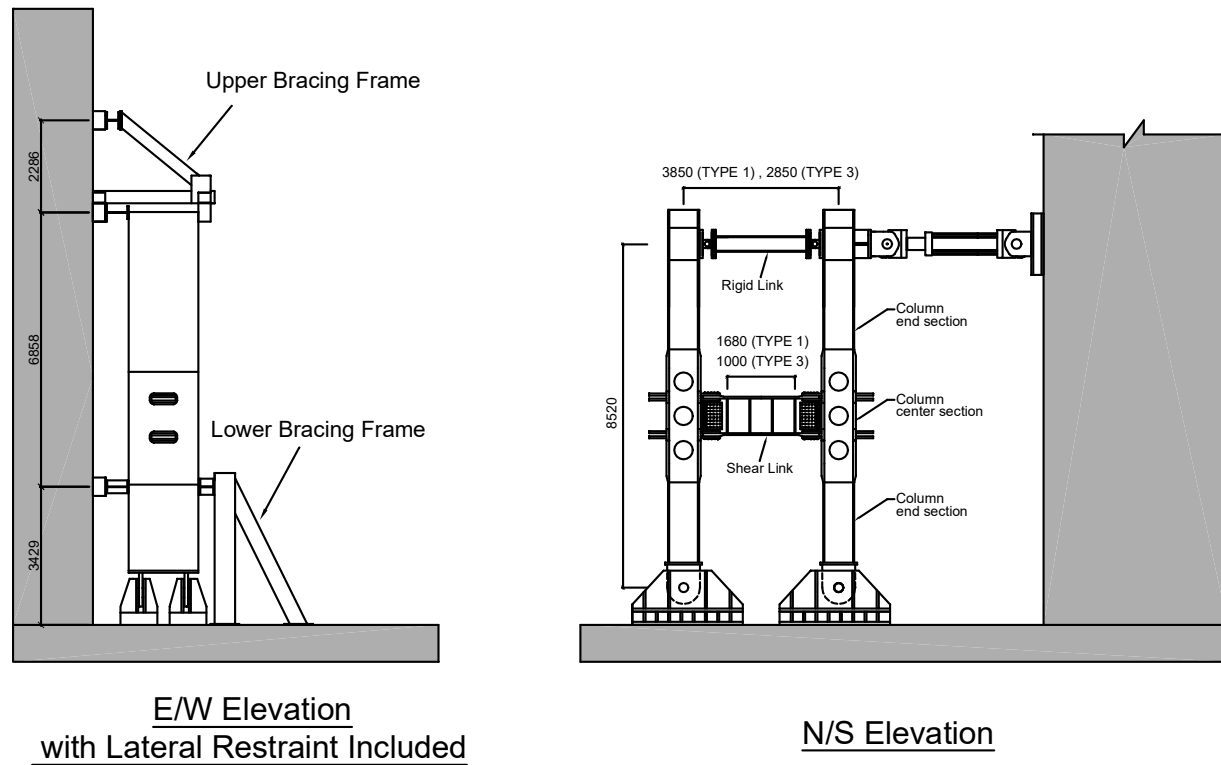
Seismic Analysis – Response Animation



Tower Shear Link Test



Tower Shear Link Test Set-up at UCSD

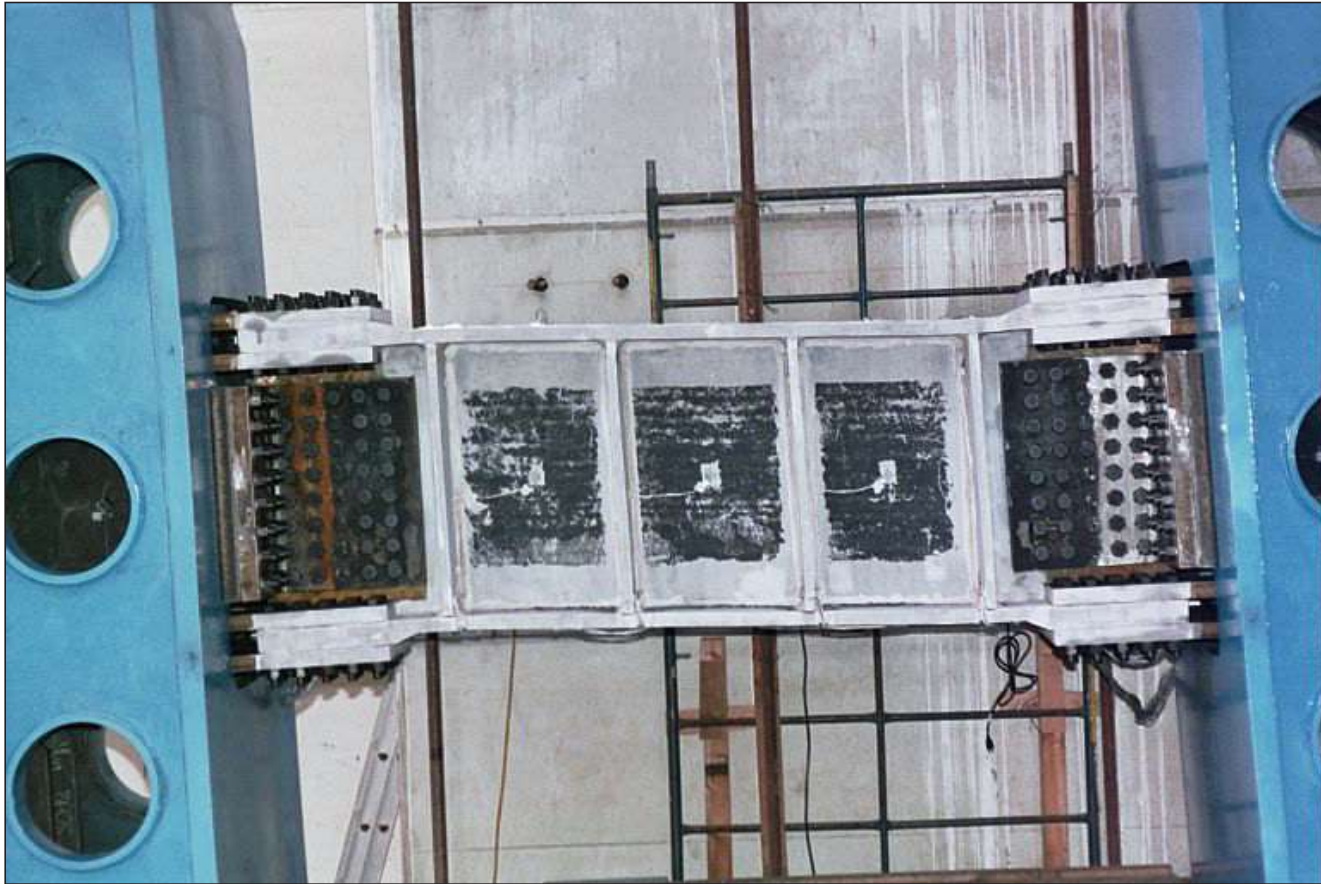


E/W Elevation
with Lateral Restraint Included

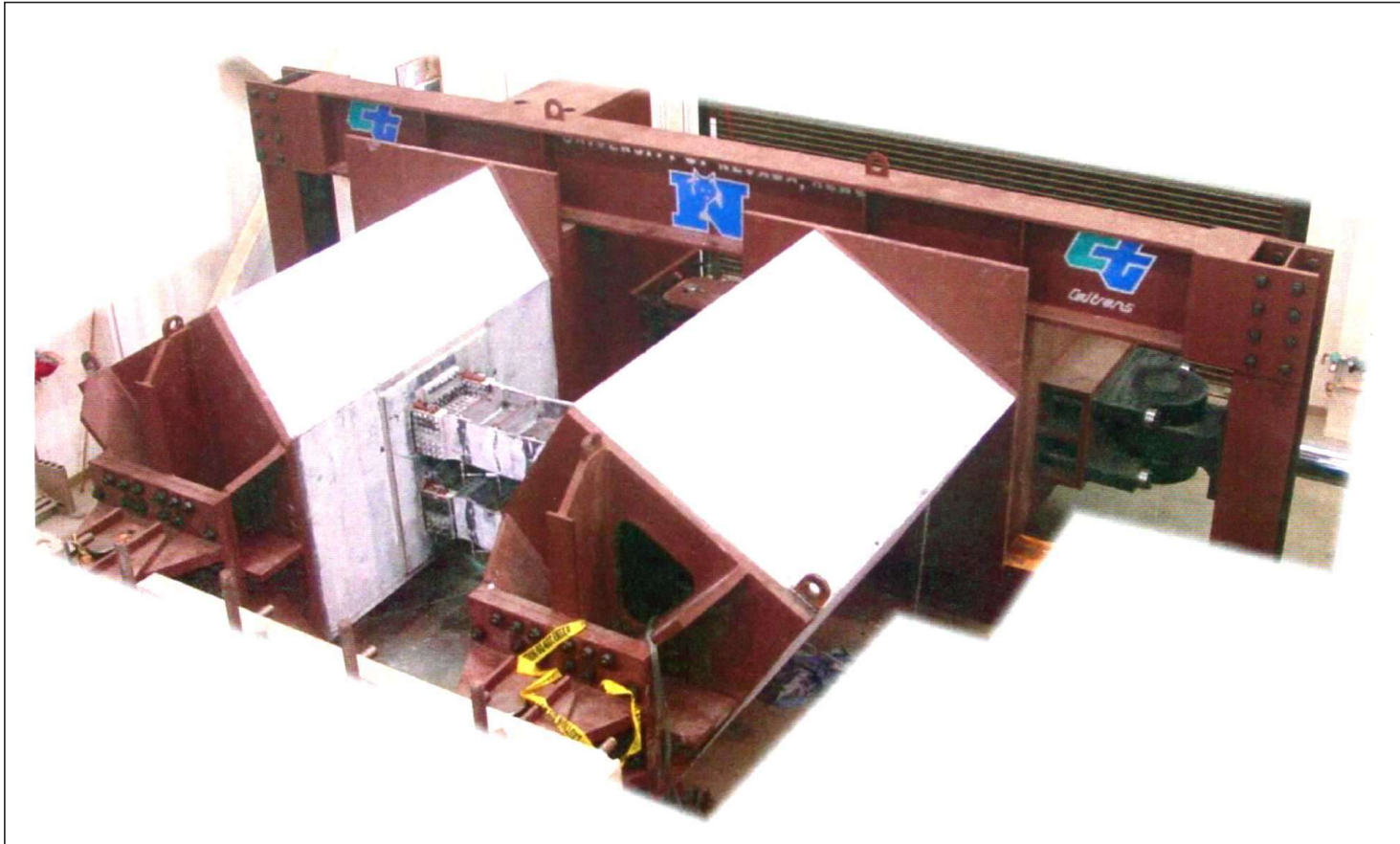
N/S Elevation

UCSD Test Set-Up

Shear Link at 0.07 rad Rotation



Tower Shear Link Test Set-up at UNR

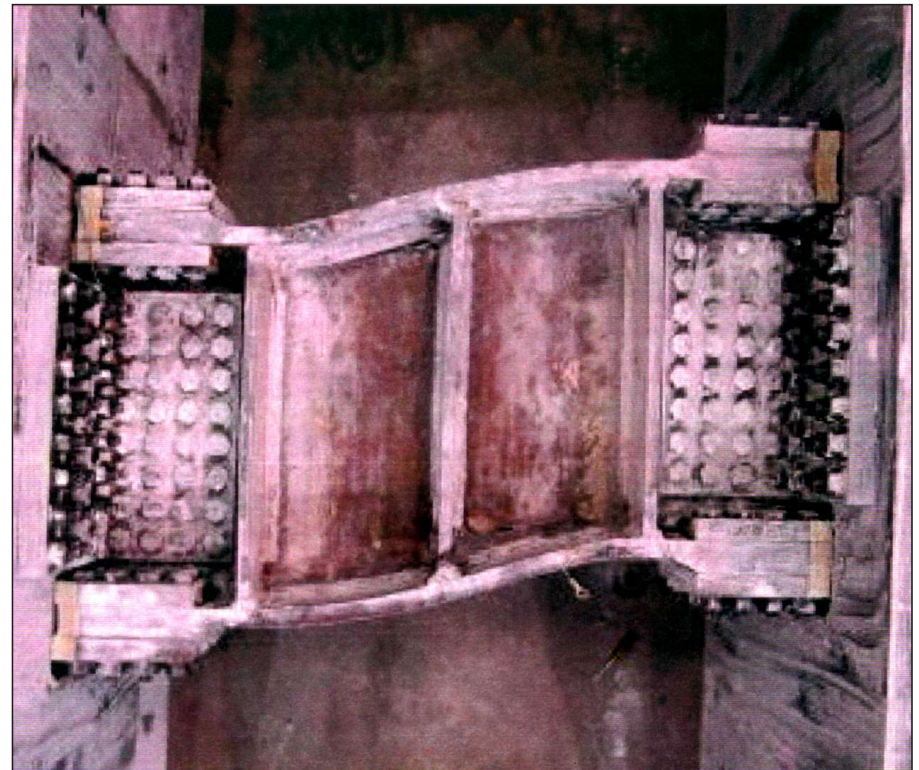


Shear Link Testing

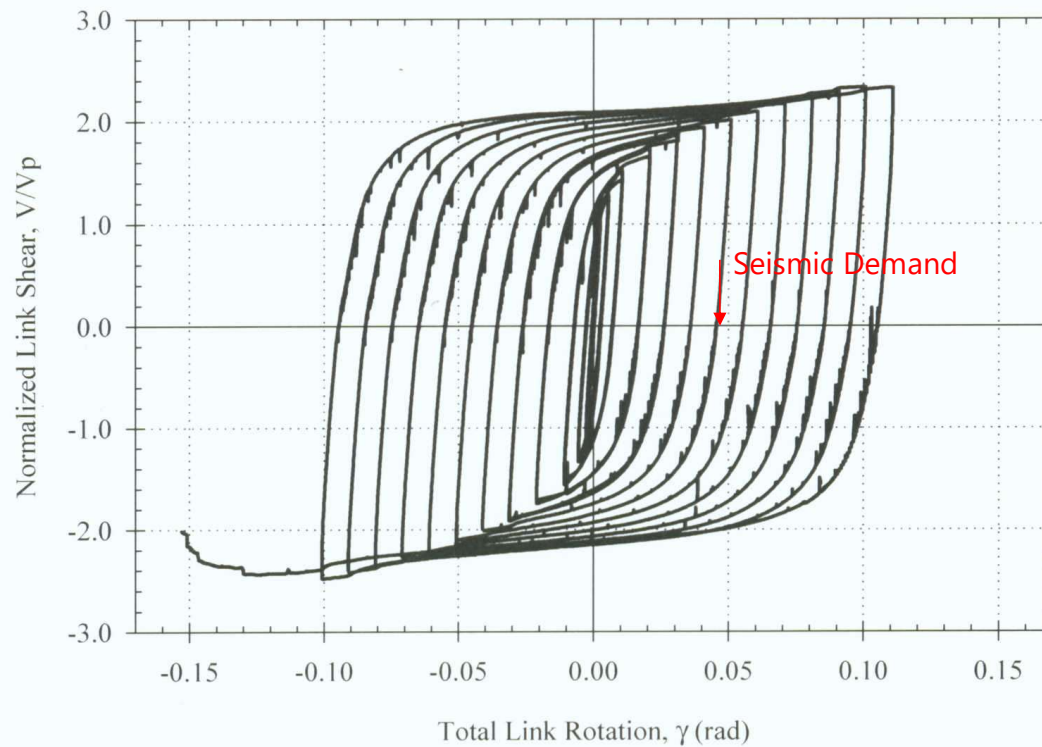
Web Fracture of Shear Link at 0.15 rad



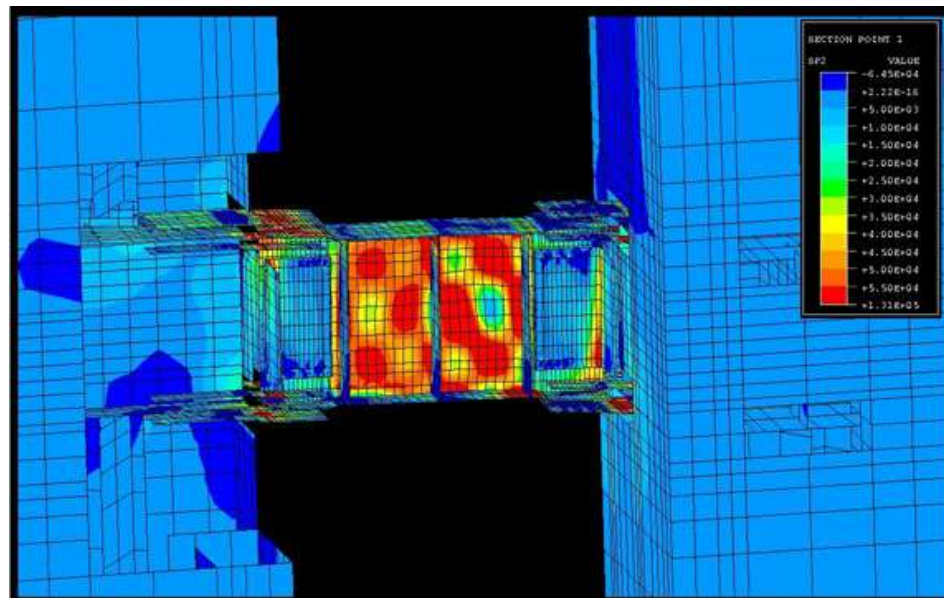
Deformed Shear Link at 0.12 rad



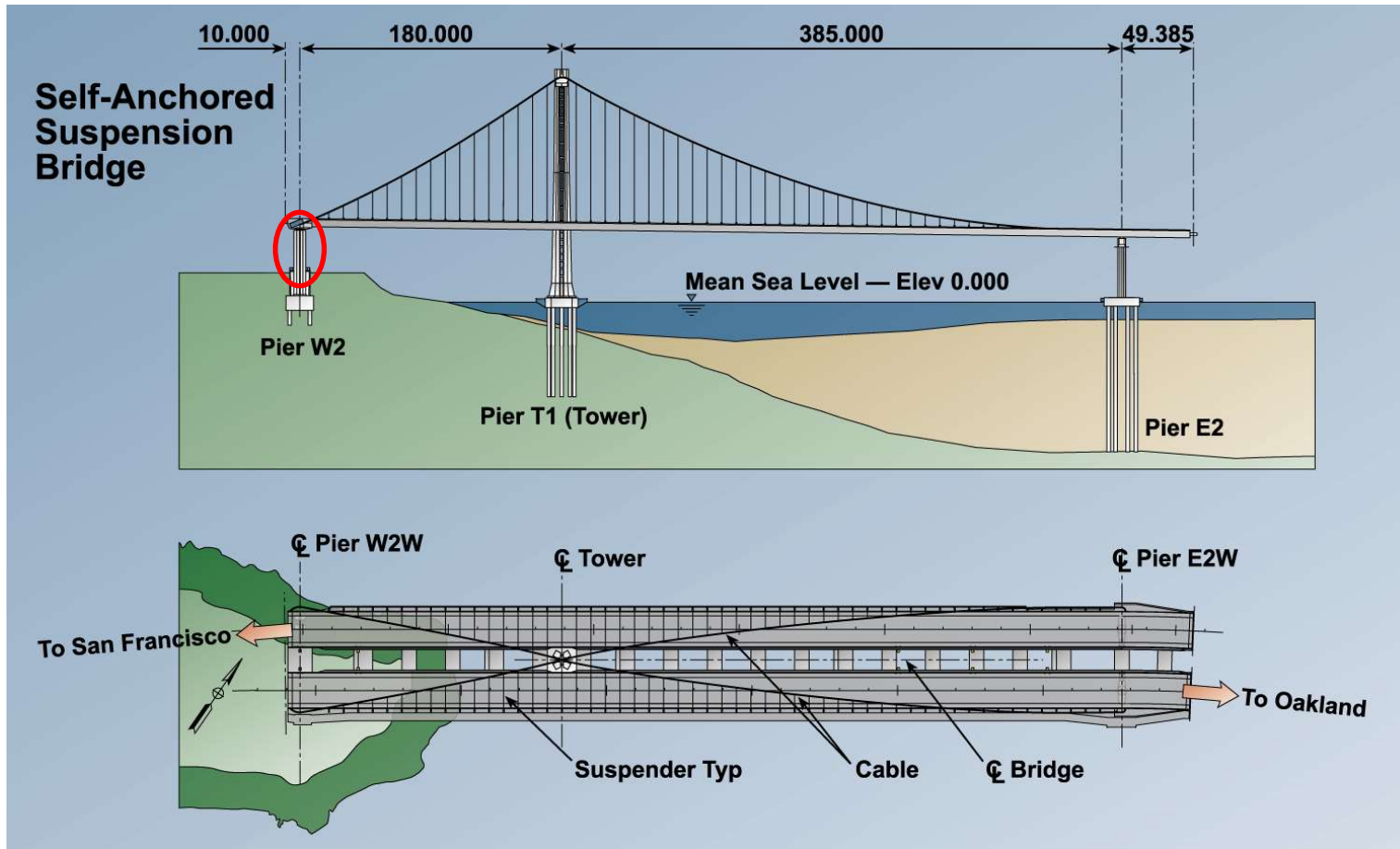
Cyclic Behavior of Shear Link



Shear Link Seismic Behavior - Animation

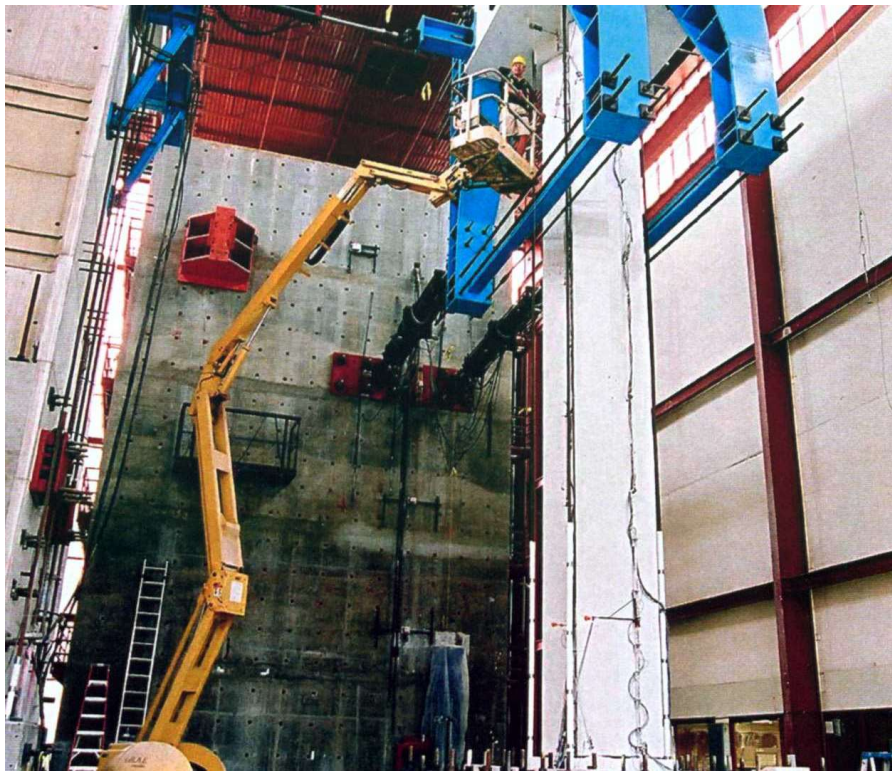


Pier W2 Test



Pier W2 Test Set-up

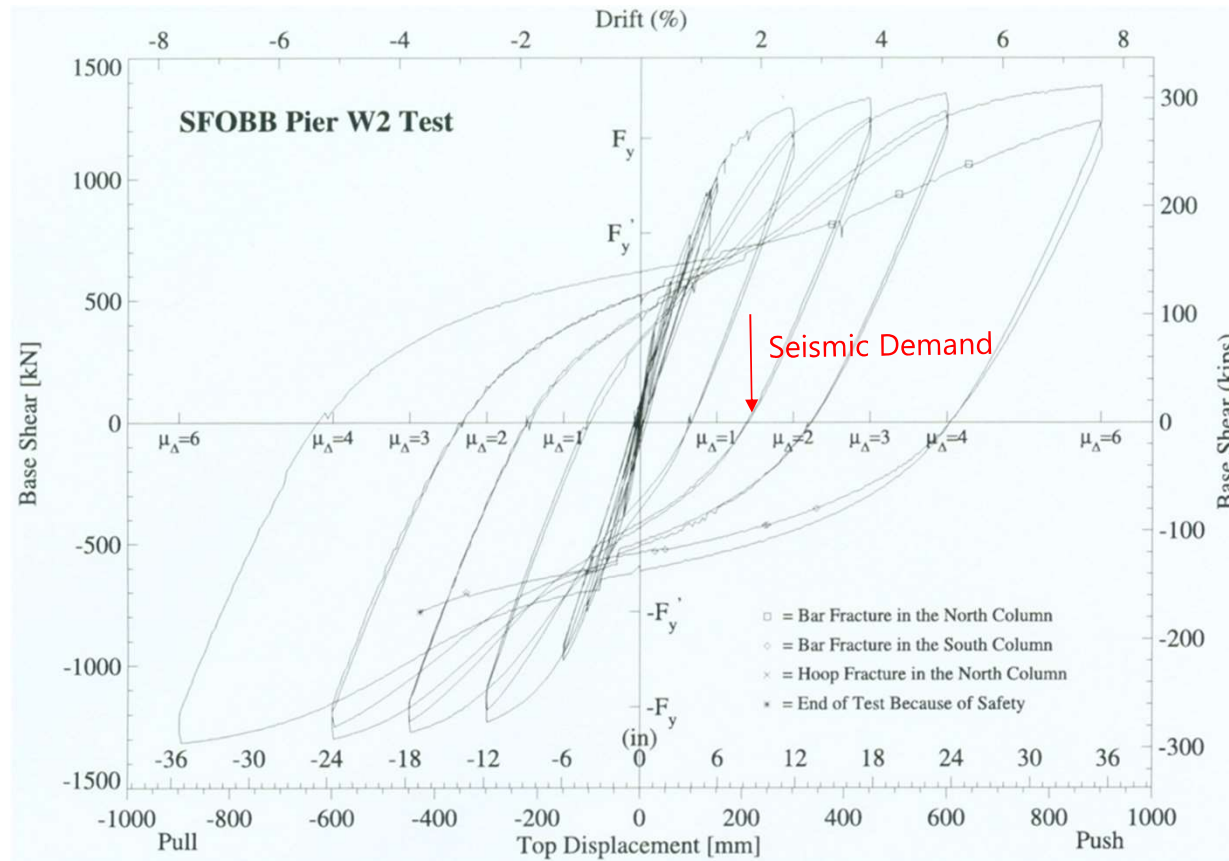
- Pier W2 Test Set-up



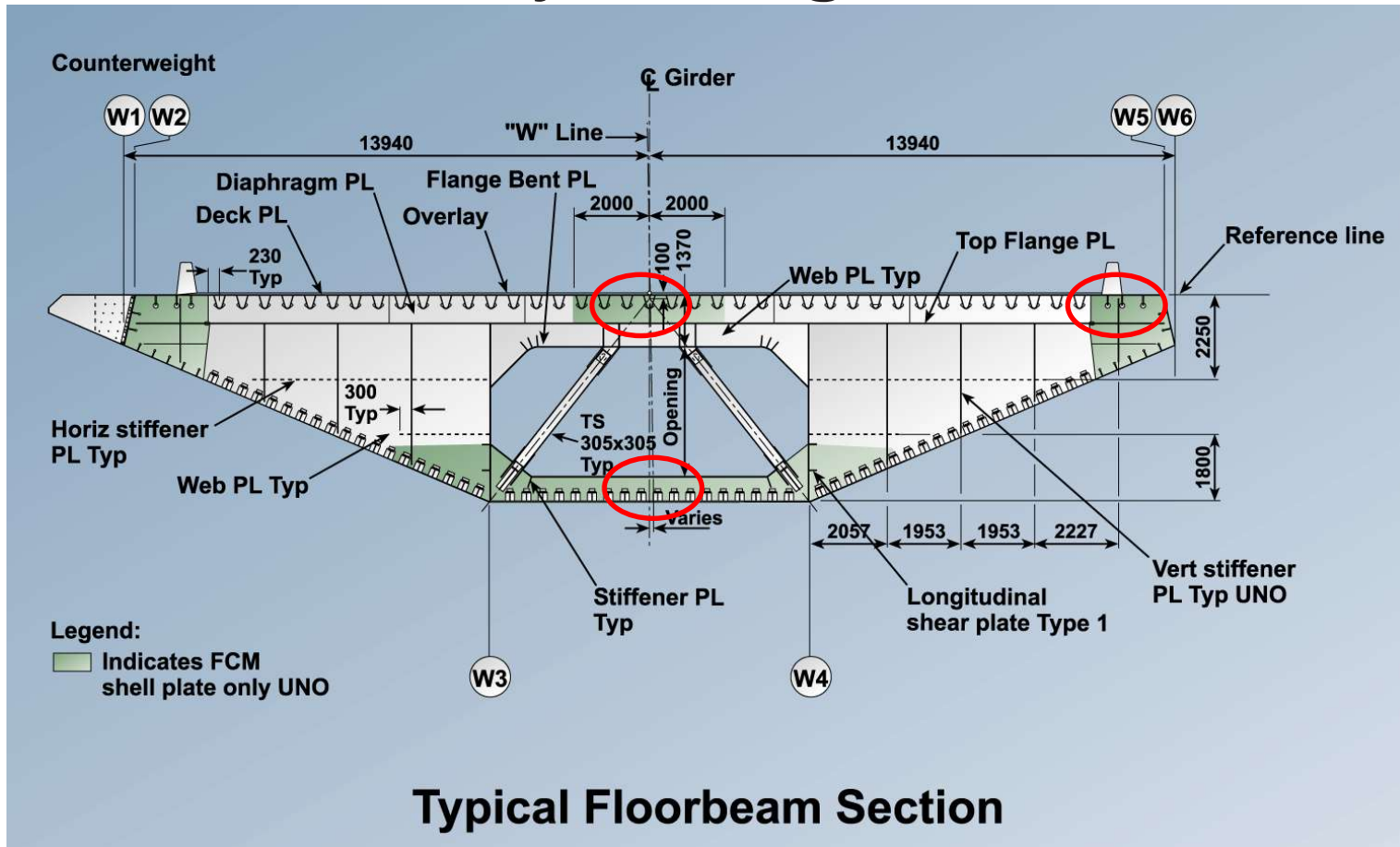
- Deformed Shape of Pier W2



Cyclic Behavior of Pier W2



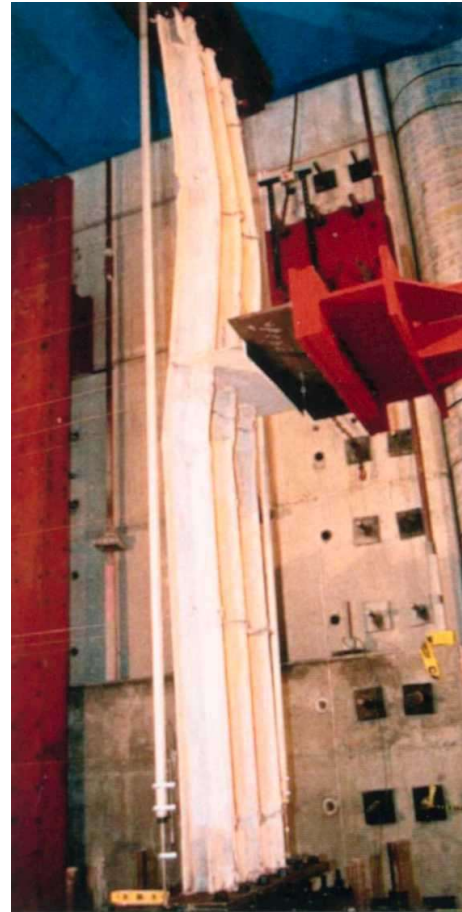
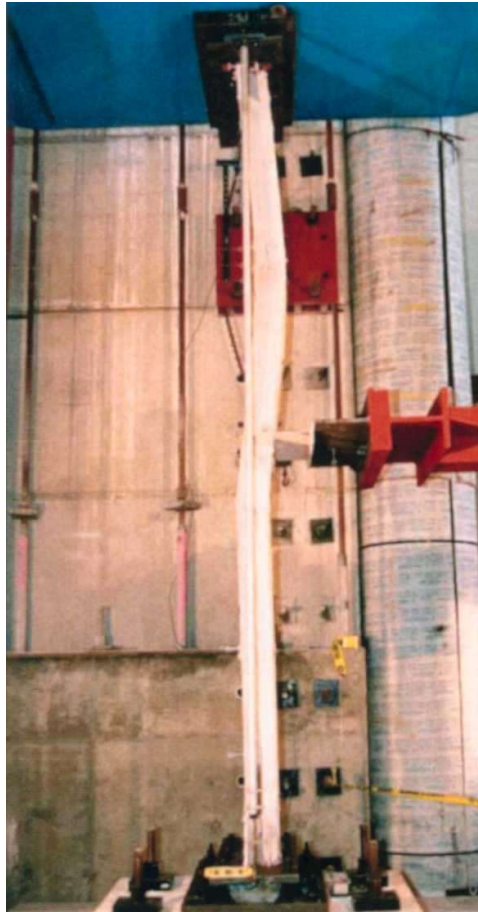
Box Girder Stability Testing



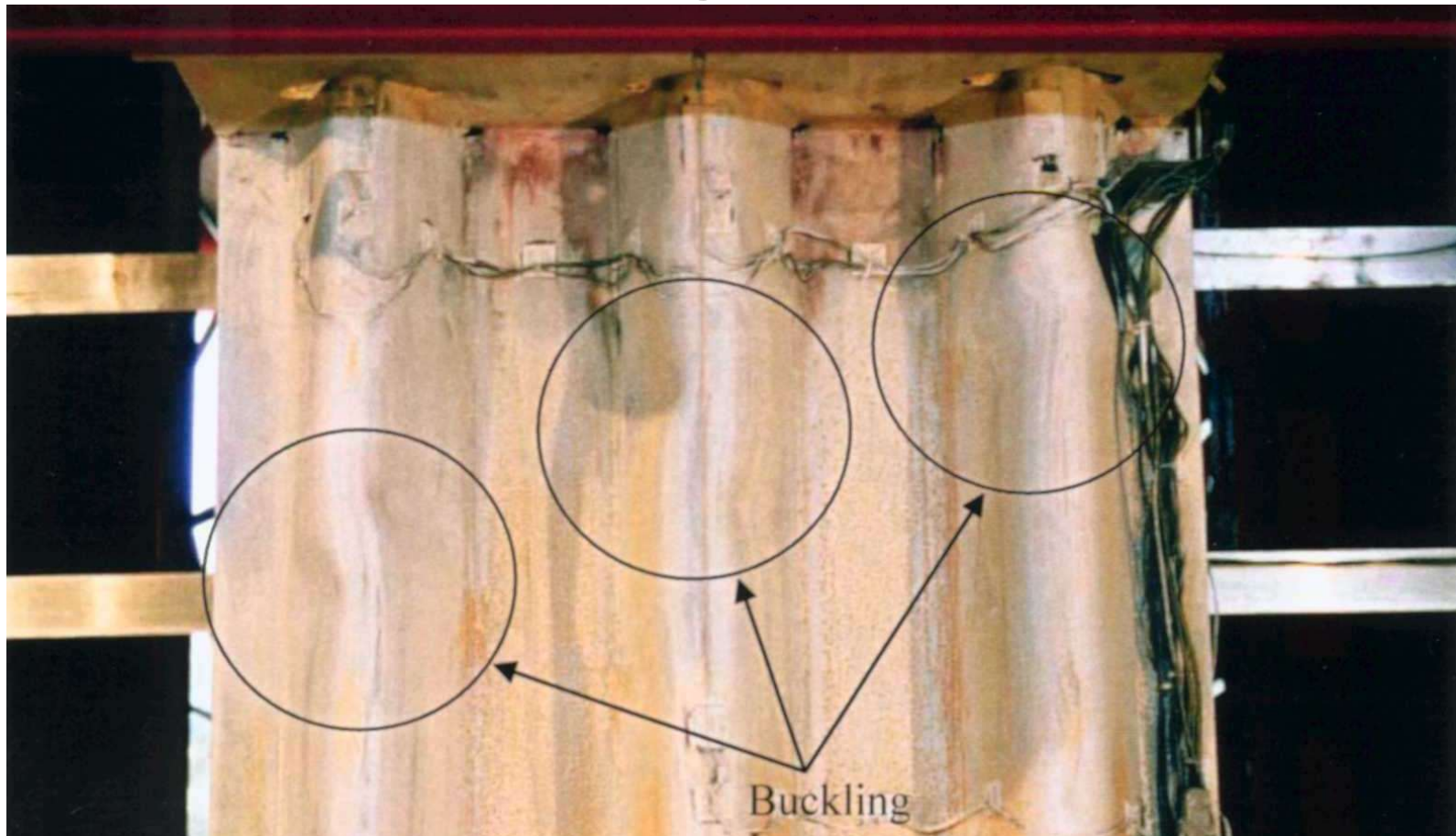
Orthotropic Deck Stability Test



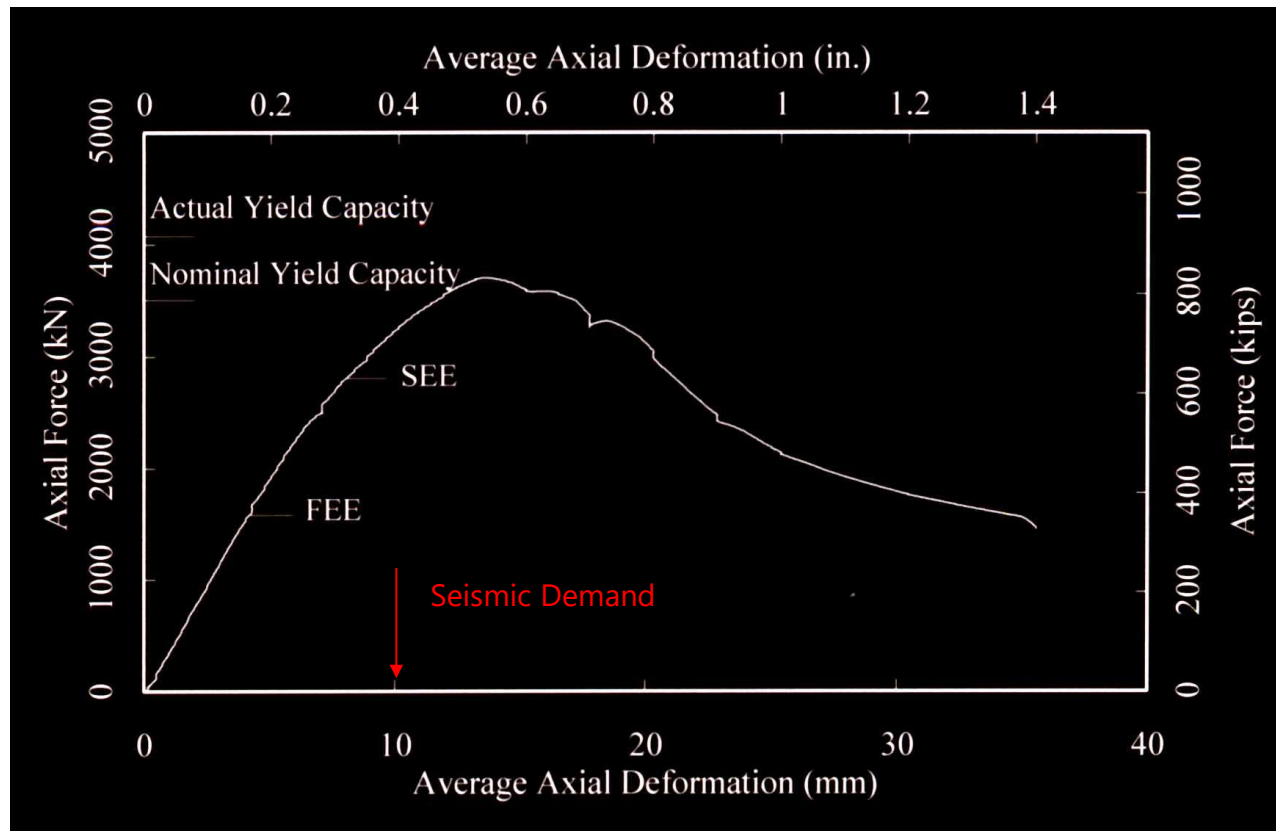
Panel Buckling



Local Rib Plate Buckling



Axial Load Displacement Behavior

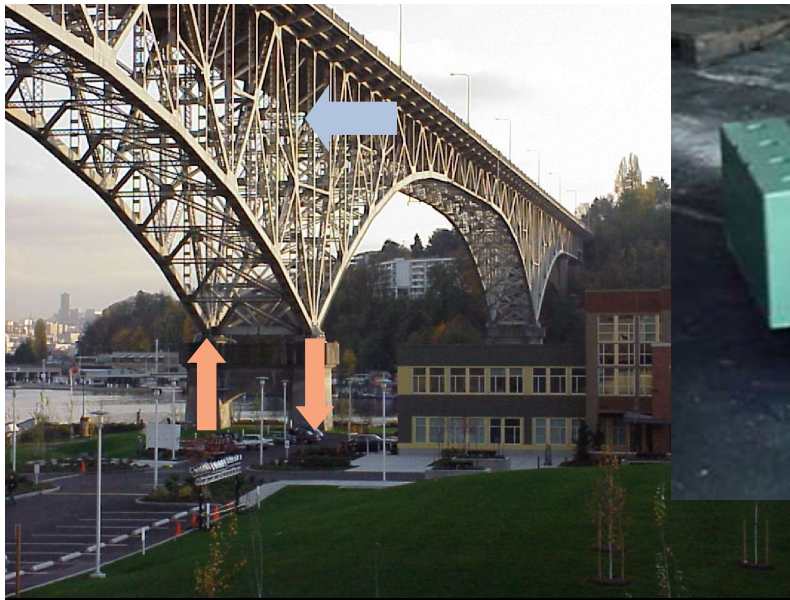




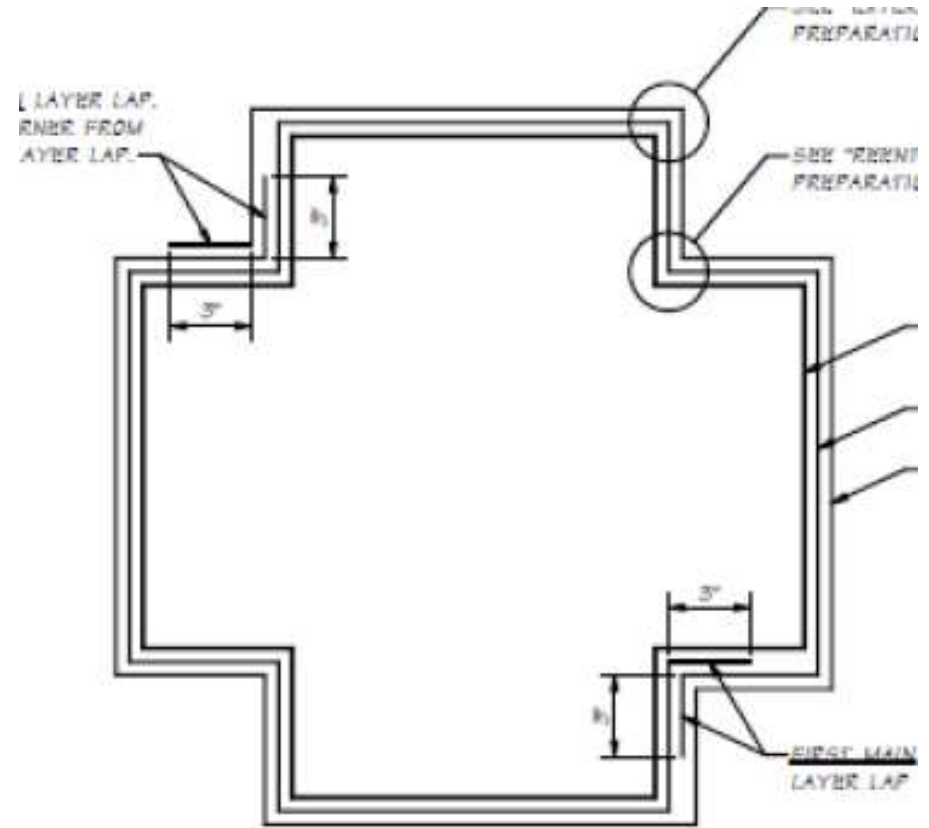
Aurora Avenue Bridge

Friction Pendulum Bearing Retrofit

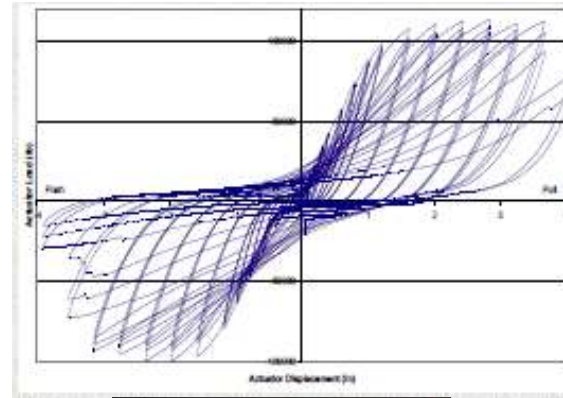
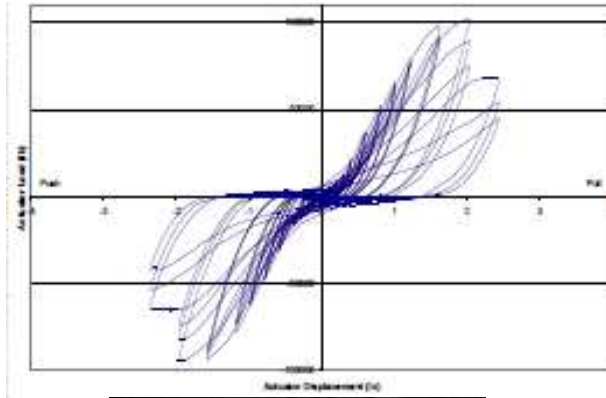
- Reduces shear demand on columns – avoids excavation of contaminated soils
- Reduces truss demands



FTP Retrofit of Approach Span Columns



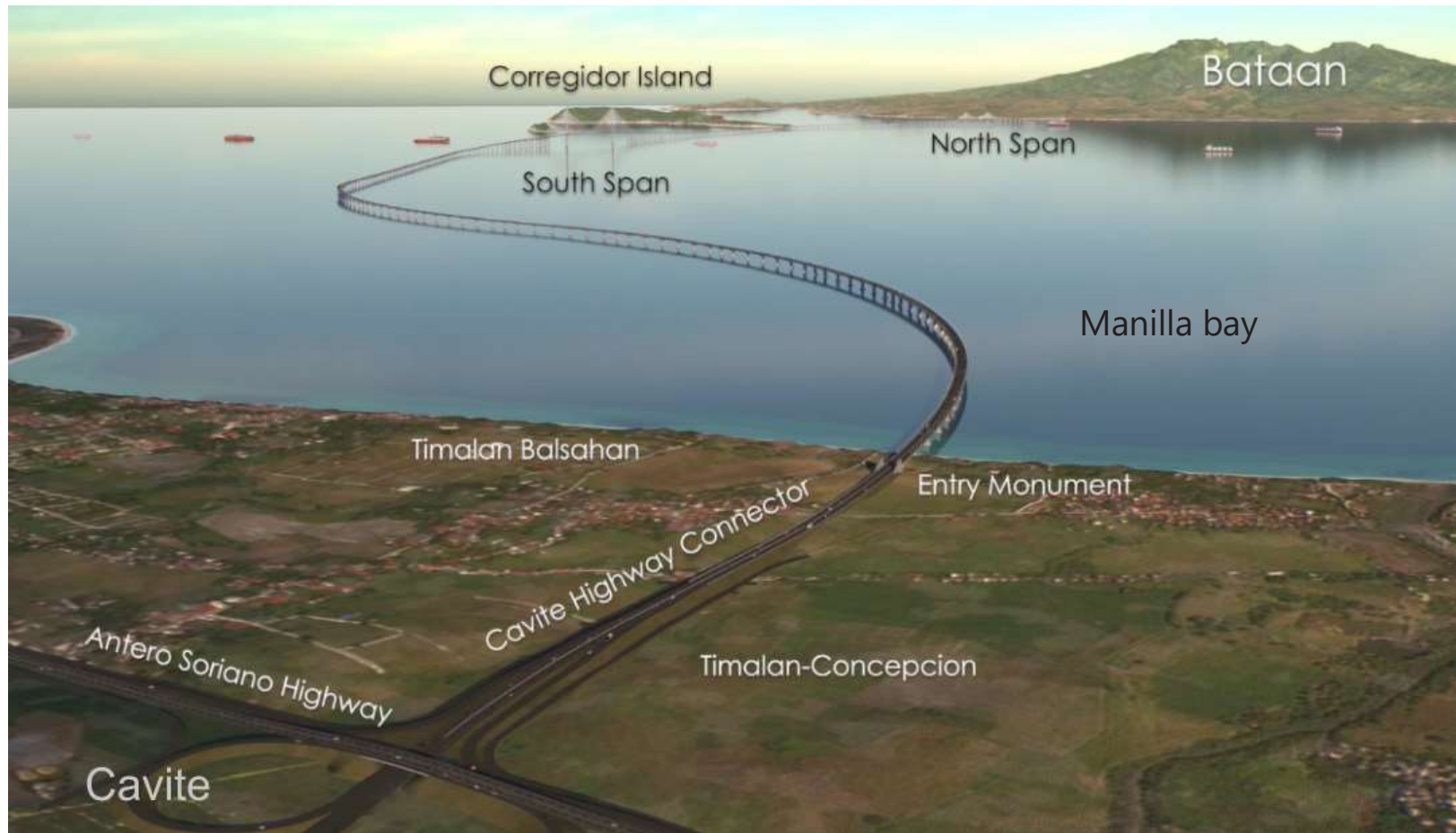
Test Program at Washington State Univ.





Bataan-Cavite Interlink Bridge, Philippines

Bataan-Cavite Interlink (BCIB) Project - 32.15 km



BCIB Marine Viaduct

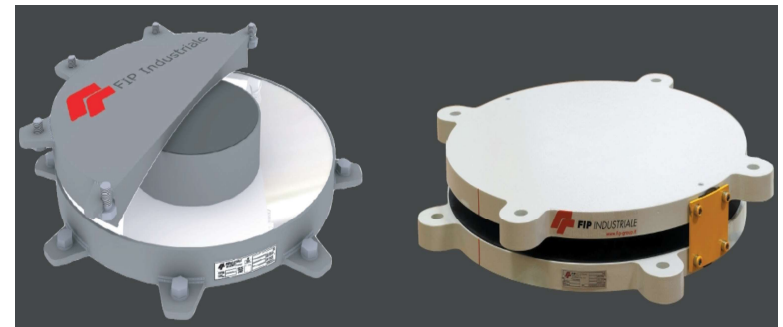


BCIB North & South Channel Bridges

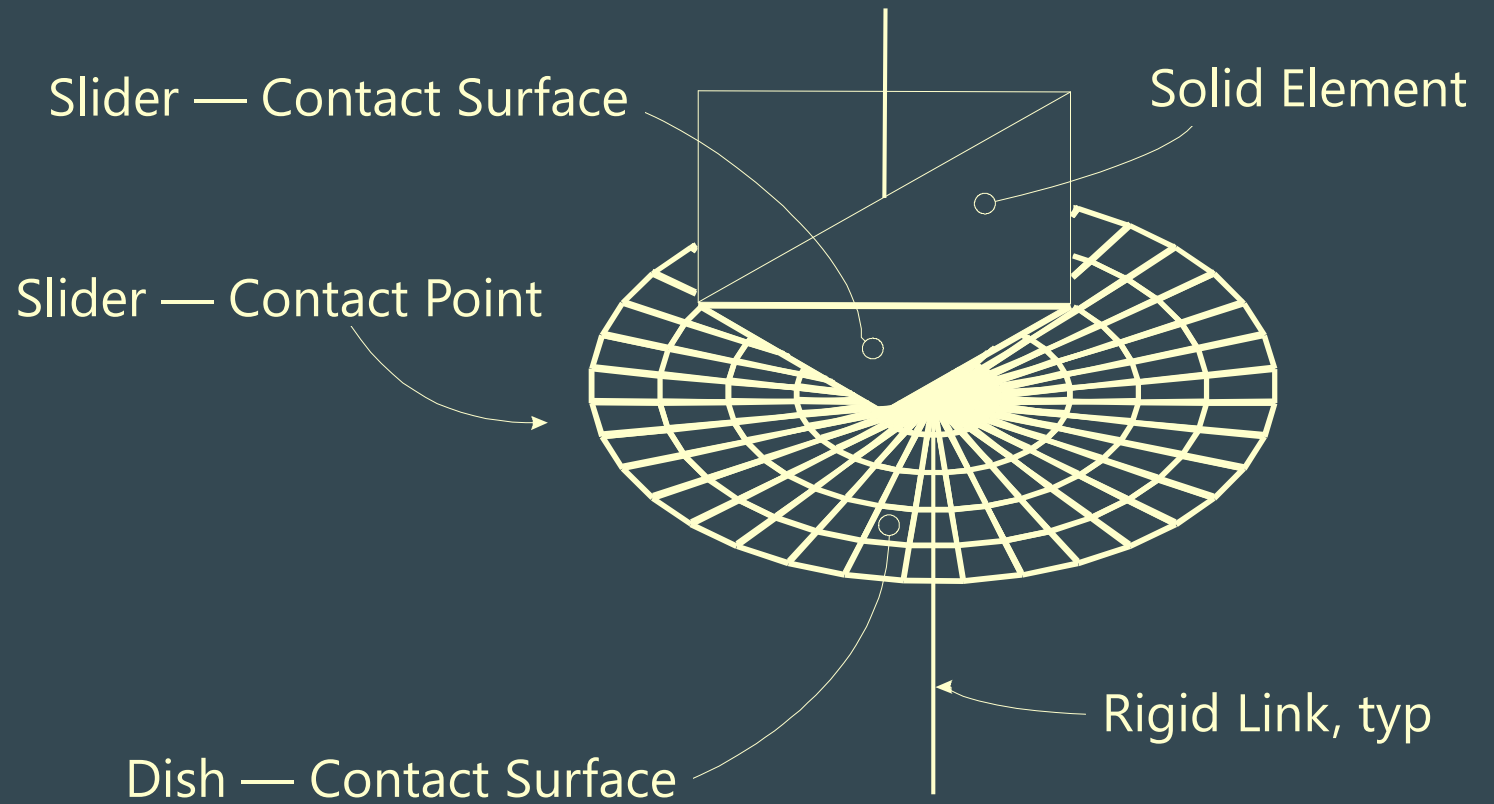
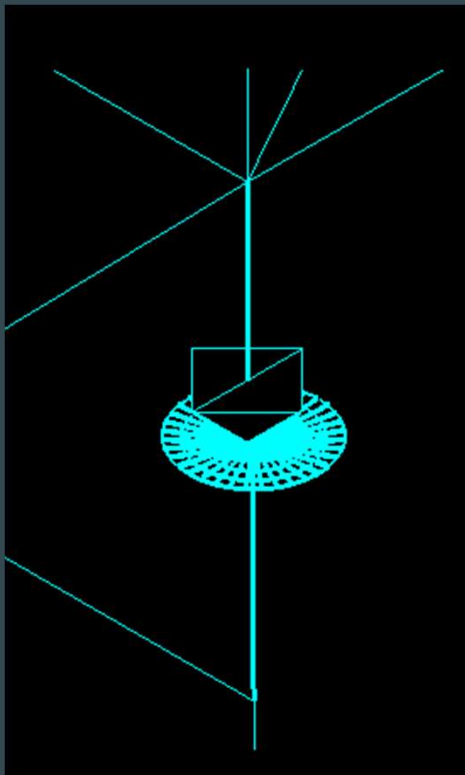


BCIB Friction Pendulum System

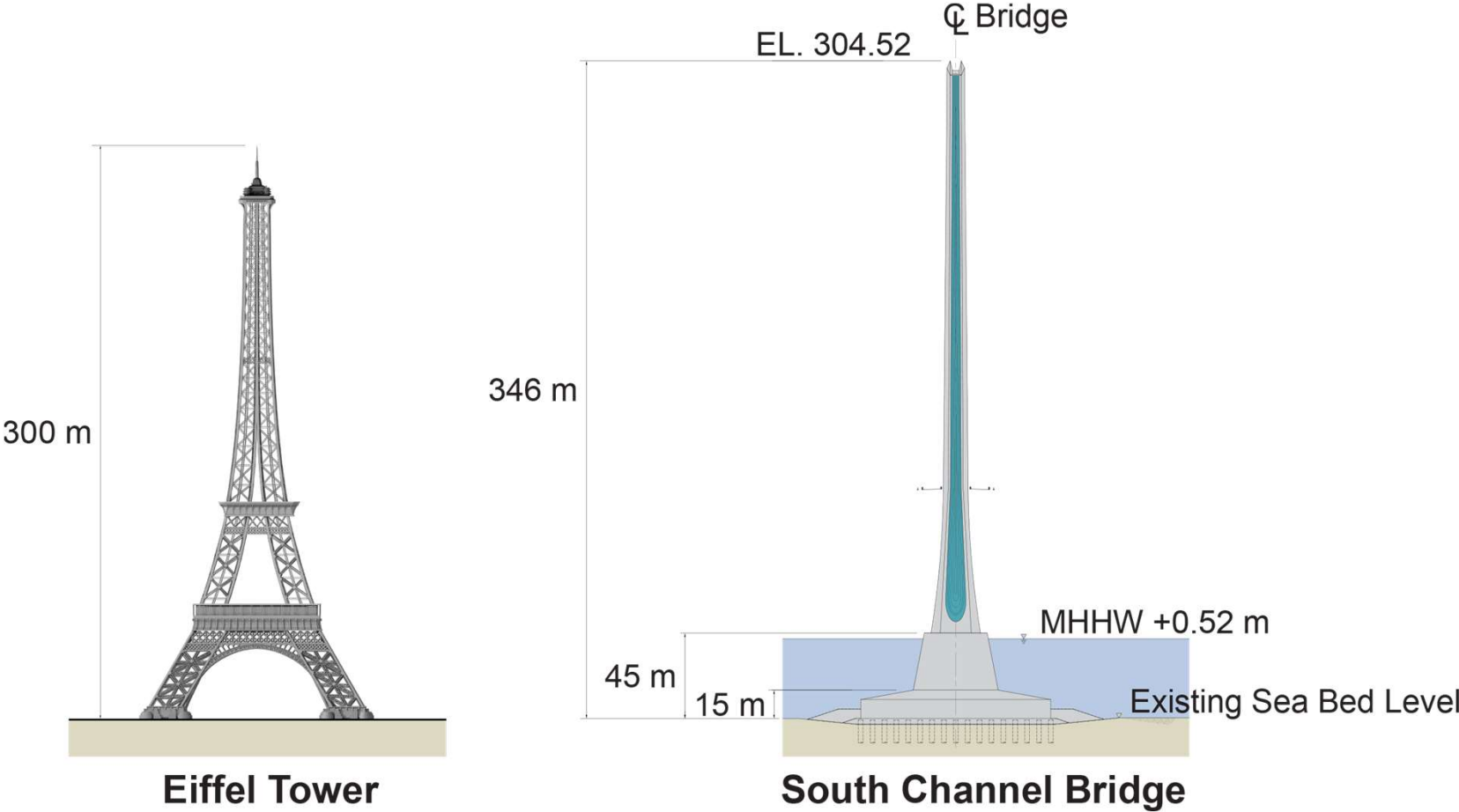
Seismic Isolation Using FPS Bearing on Marine Viaducts



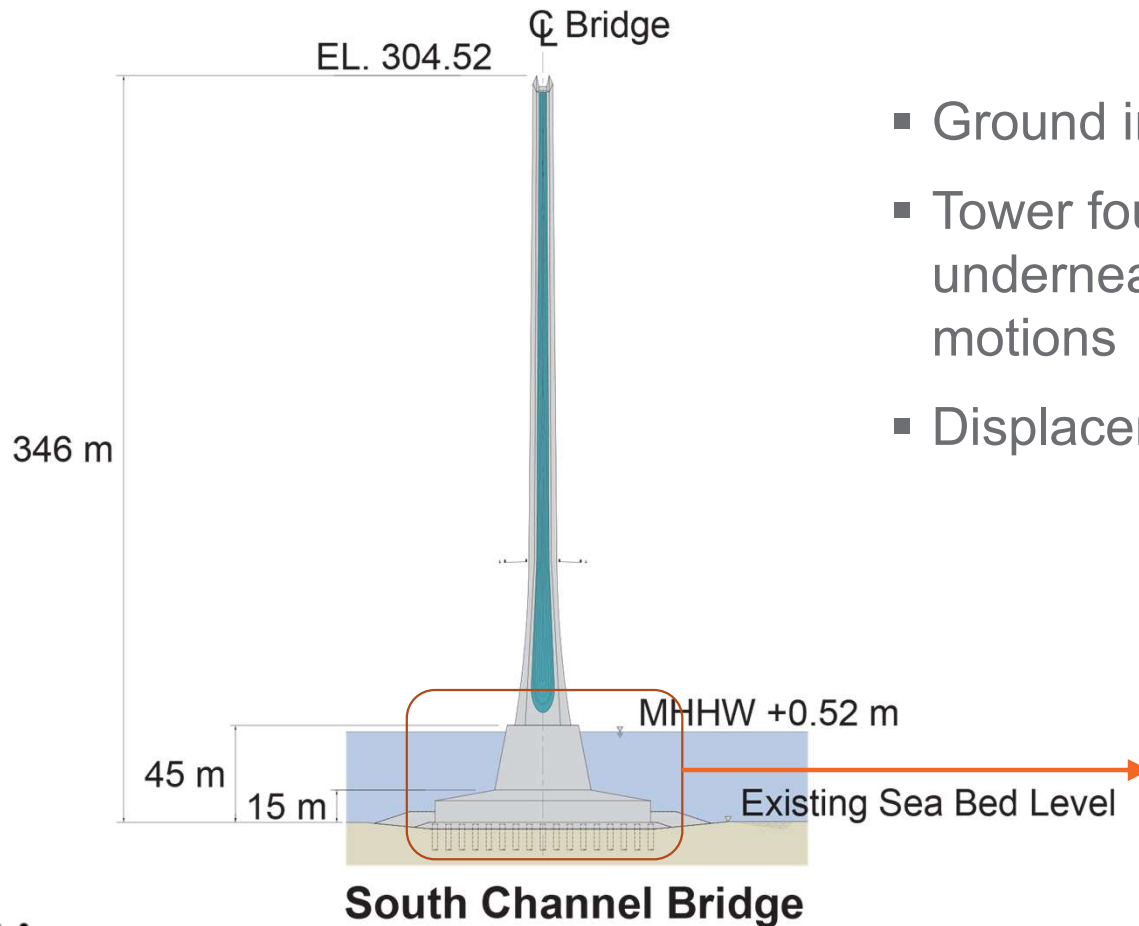
Contact Surface Analysis - Animation



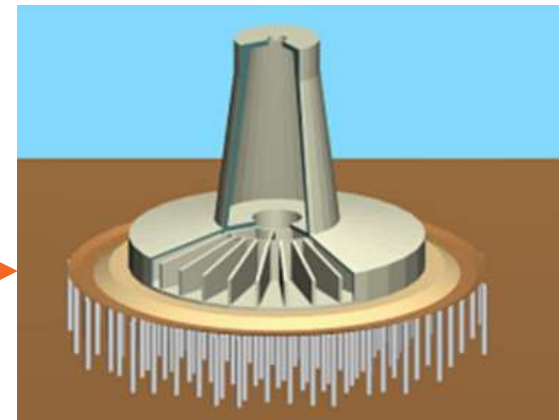
BCIB South Channel Bridge Tower



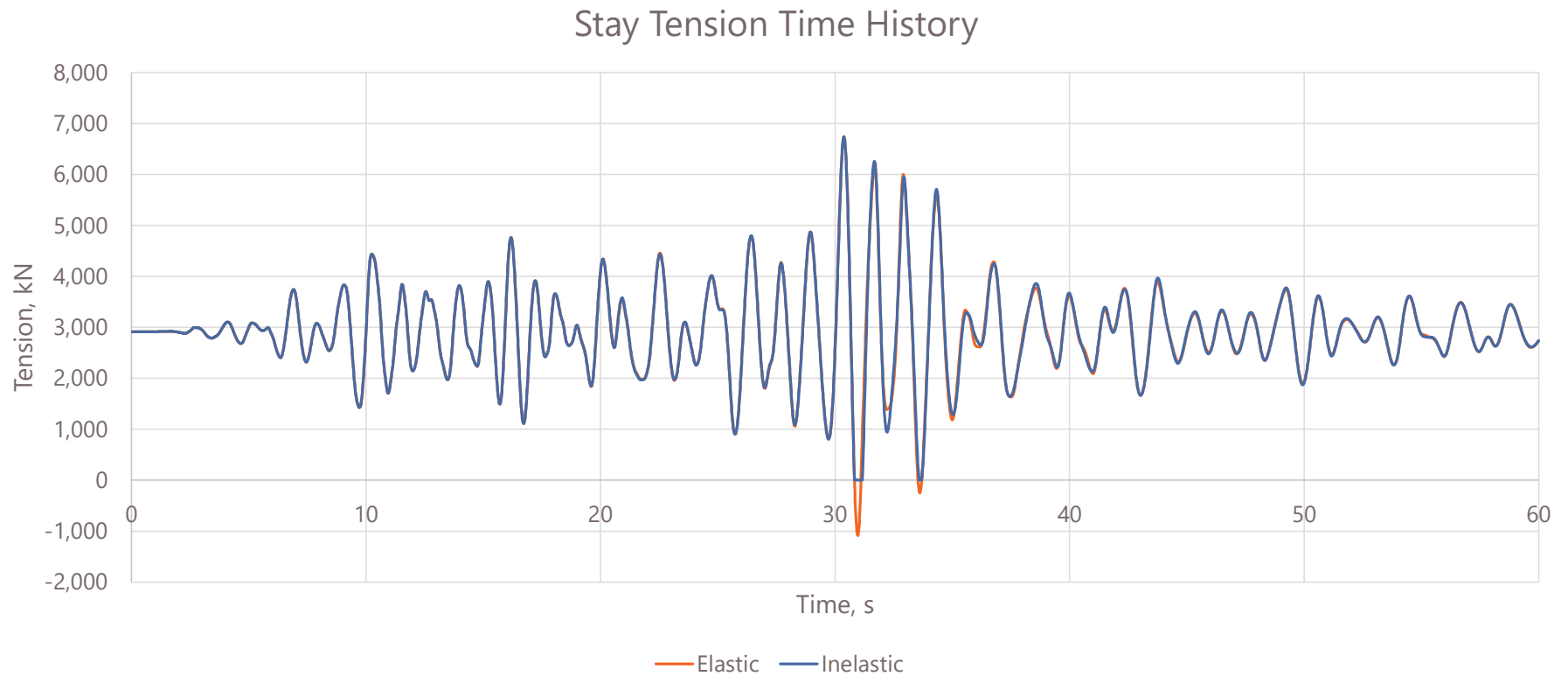
Issue: Base Isolation at Tower Foundations



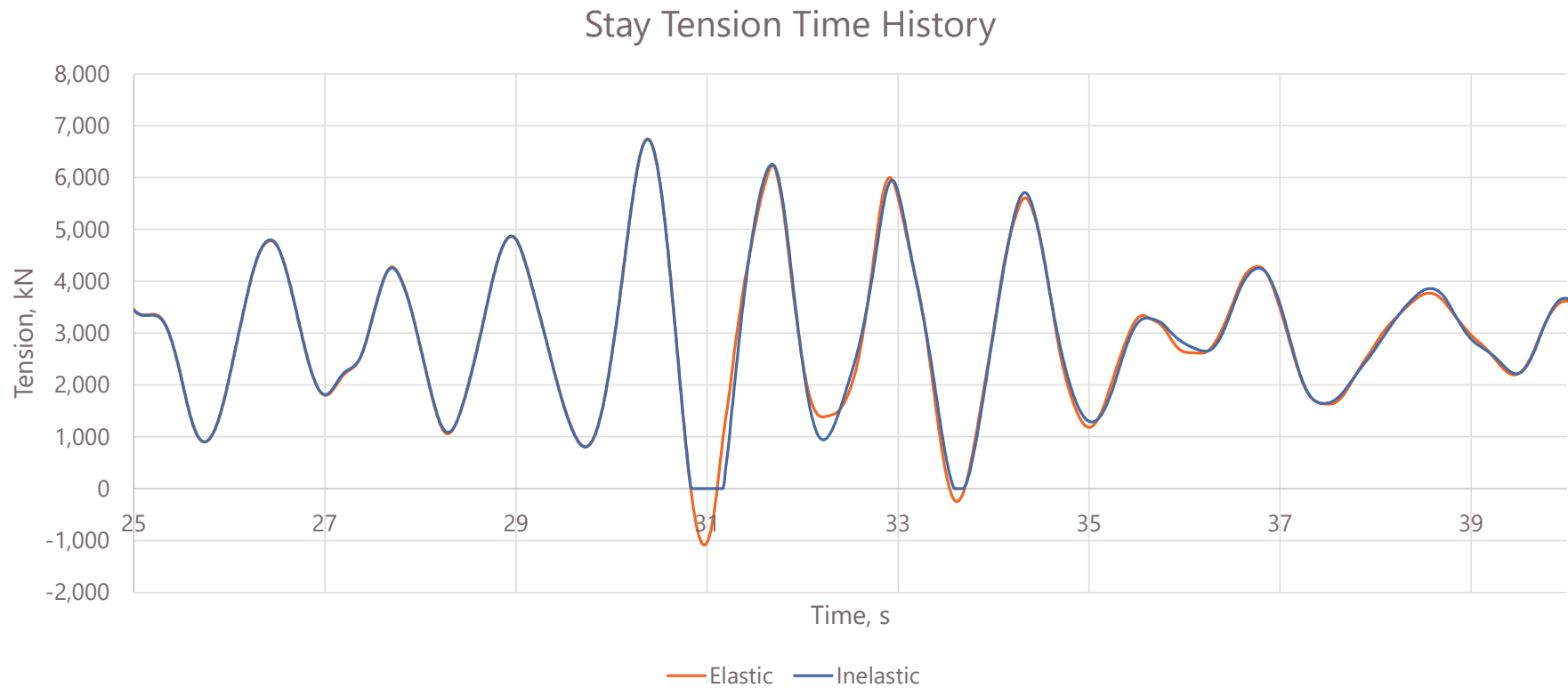
- Ground improvement by inclusion piles
- Tower foundation isolated from soil underneath to lessen effect of ground motions
- Displacements about 0.5 m



Issue: Slackening of Stays

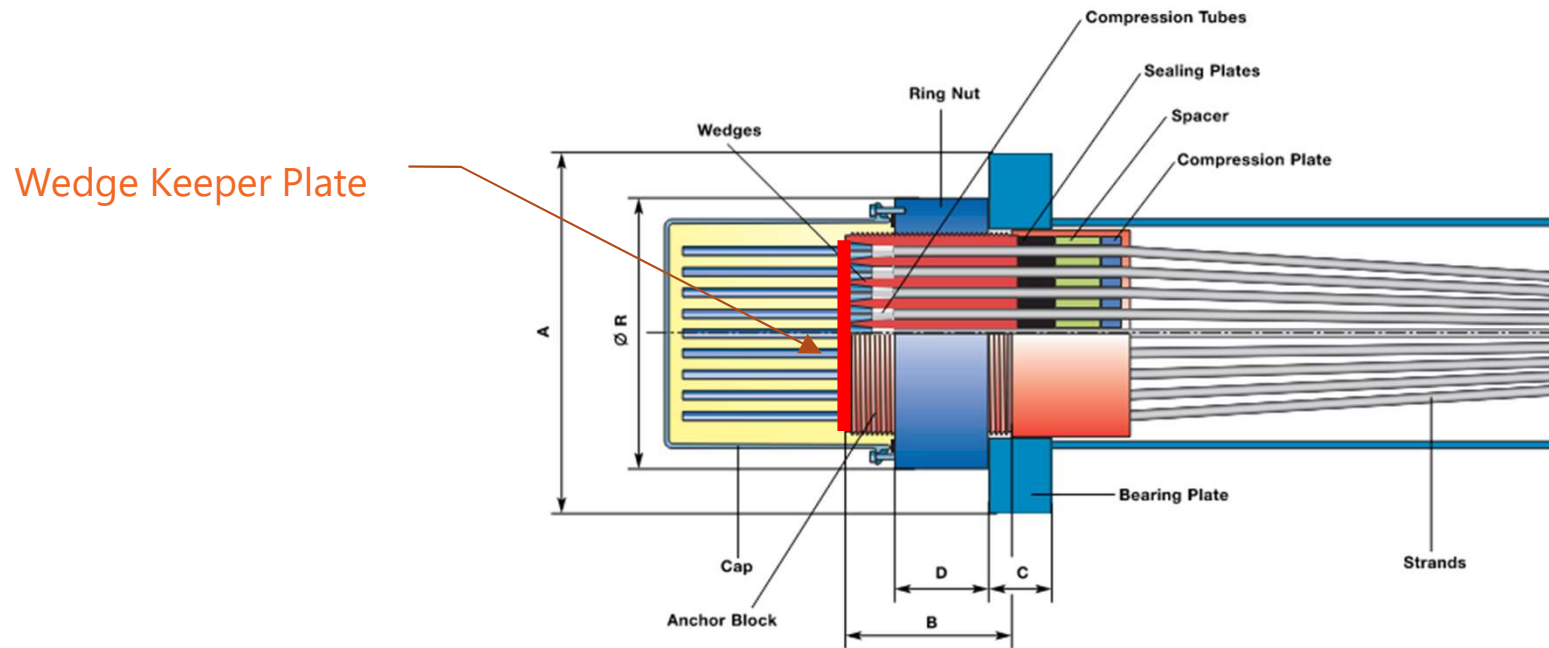


Issue: Slackening of Stays



Issue: Slackening of Stay Cables

– Use of wedge keeper plates

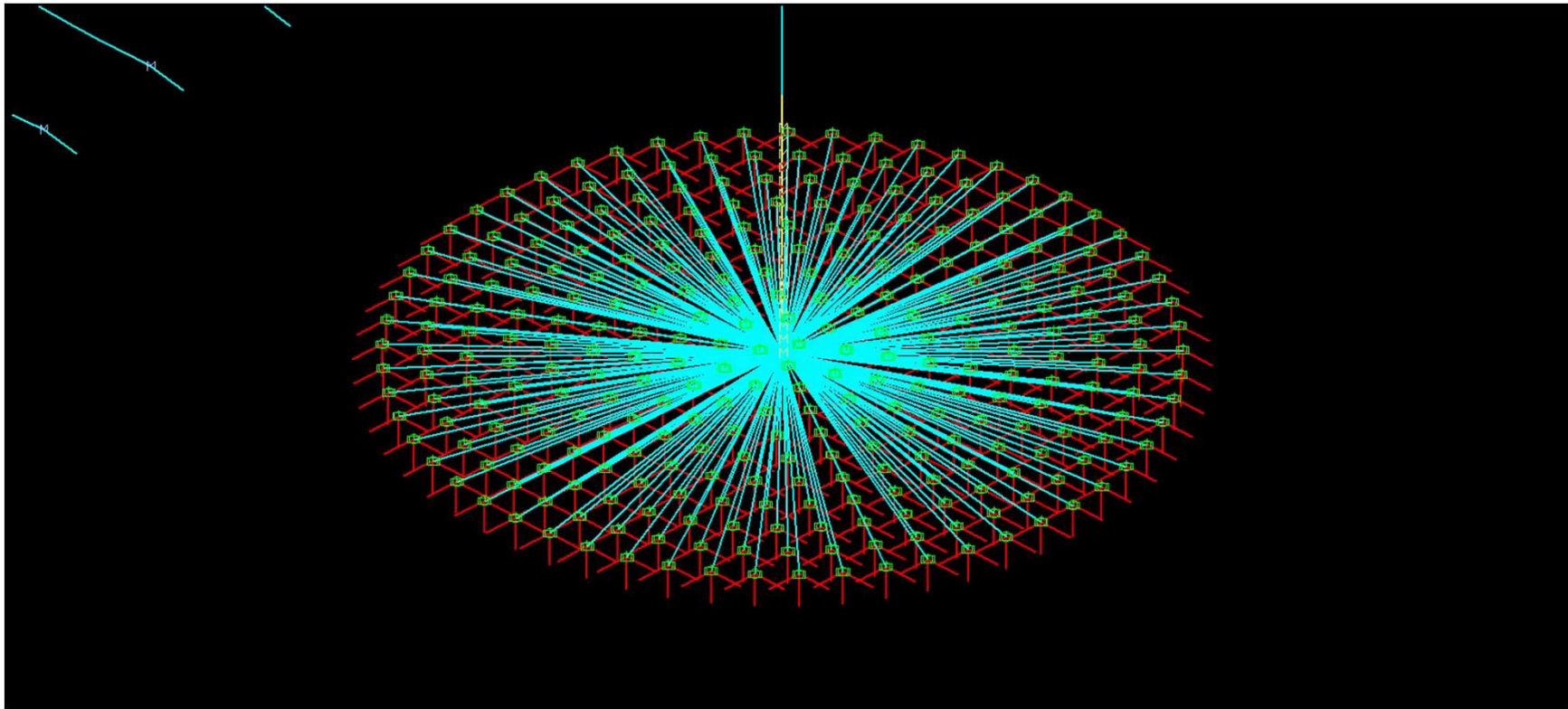




Issue: Allowable Strains for Performance Based Design

- Allowable strains for
 - Concrete, reinforcing steel, structural steel
 - FEE, SEE events
 - Minimal, repairable, significant damage
- Variation in values from project to project
- NCHRP 949 Proposed AASHTO Guidelines for Performance-Based Seismic Bridge Design
- NCHRP 532; Seismic Design of Non-Conventional Bridges
- Difficult to choose values with confidence

Tower Isolated Caisson Movement - Animation



Closing Remarks

- Testing invaluable for validation of concepts for seismic retrofit and design – even for single projects
- There are still unanswered questions for seismic design of bridges
- (Precast girder bridges – slamming at abutments)

