Structural Health Monitoring (SHM) of Floor-Beam/Stiffener Connections Benicia Martinez Bridge

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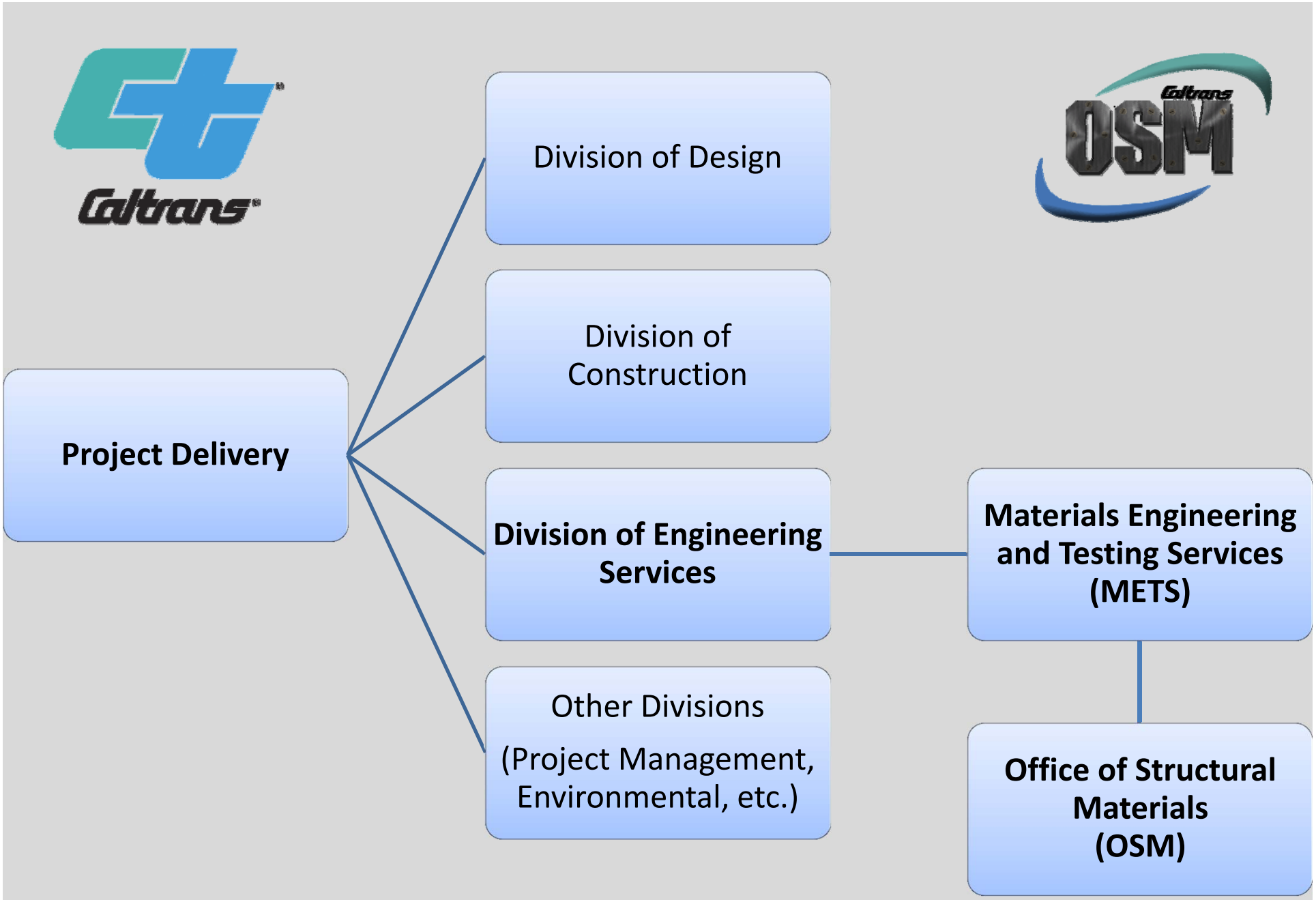
OFFICE OF STRUCTURAL MATERIALS, CALTRANS



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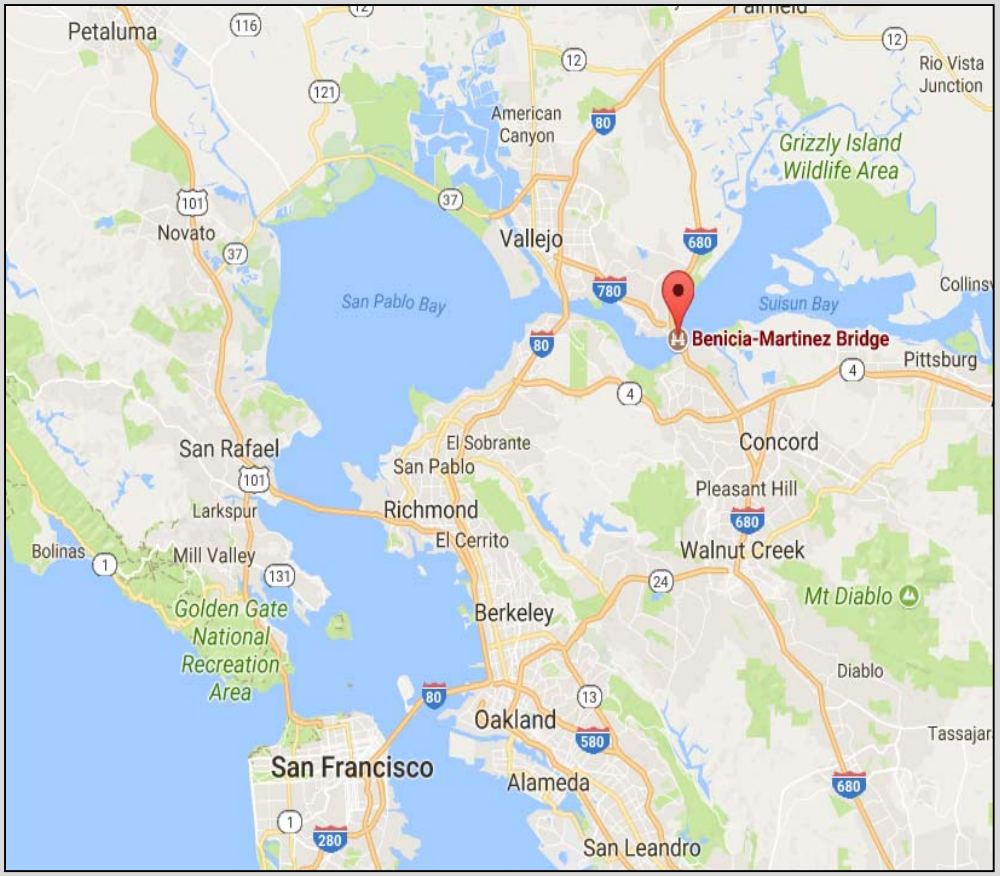
Agenda

- Introduction and Background
- Scope of Work and Purpose
- Monitoring Equipment
- Field Installation
- Baseline Measurements
- Future Steps

Benicia-Martinez Bridge

- Located in San Francisco Bay Area on I-680



Benicia-Martinez Bridge

Benicia-Martinez Southbound Bridge

- 1962: Opened with four lanes of two-way traffic
- 1991: Widened to six lanes of two-way traffic
- 1998: Seismic retrofit completed
- 2009: Bridge is reconfigured
  - 4 lanes with left and right shoulders
  - Bike path added to west side of bridge

Bridge Retrofit

- Why The Project Is Necessary?
  - Maintenance detected fatigue distress
  - Bridge retrofit strategy
- Alternative Solutions
  - Full repair without trial phase
  - Monitor bridge and validate outcomes of trial phase repairs
- Details of the Proposed Work

Big Picture Activities to Date

- ✓ Maintenance identified need for retrofit
- ✓ Design developed model and retrofit plans for select elements of the bridge
- ✓ OSM conducted pilot project to install and monitor structure to validate model and to establish baselines
- ➢ Project awarded to retrofit select elements of the bridge (Pier 8 / floor beam connection & Pier 2 / isolation bearing)

Structural Health Monitoring

- First Caltrans' bridge application where frictional strain gauges were deployed
- Periodic measurement of strain and acceleration

Scope of Instrumentation Work

- Install structural monitoring system on the bridge
- Monitor four floor-beam/stringer connections at Pier 8
- Monitor one isolator bearing at Pier 2
- Collect vibration and strain measurements
- Provide summary report to bridge designers for retrofit strategy

Architecture of the Structural Monitoring System

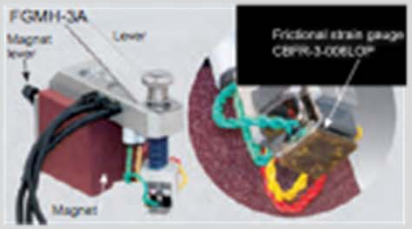
Accelerometers

FTP Server

Data Acquisition System

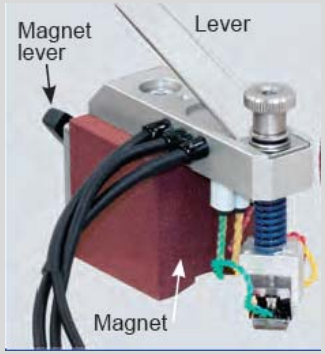
Server (Data processing)

Clients



Strain Gauges

Bridge Monitoring System



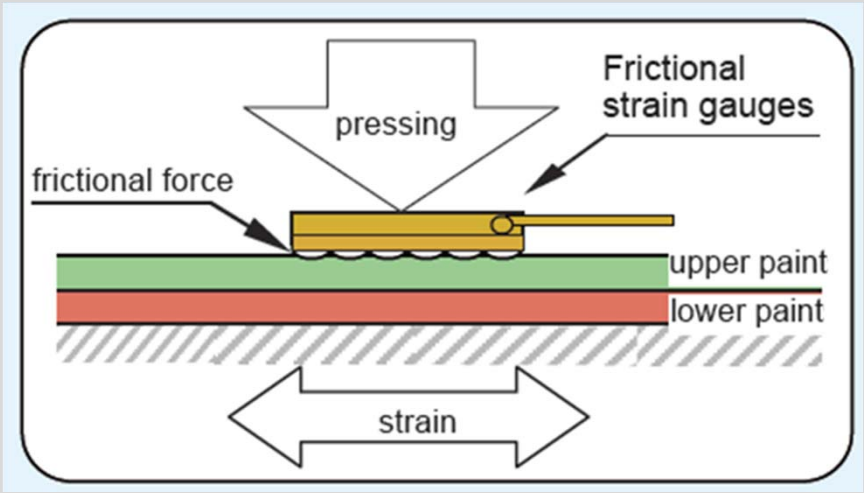
Number of Sensing Channels:

- 32 biaxial strain gauges, 8 per connection at Pier 8
- 12 triaxial accelerometers , 3 per connection at Pier 8
- 3 linear variable displacement transducers (LVDTs) at Pier 2 Bearing

Instrumentation Basics

Biaxial Strain Gauge

- It measures strain using friction generated on the contact surface of sensing element and the structure
- Easy mounting and detaching
- Paint removal, grinding, bonding and curing are not necessary
- Can be used repeatedly



Instrumentation Basics

Accelerometer:

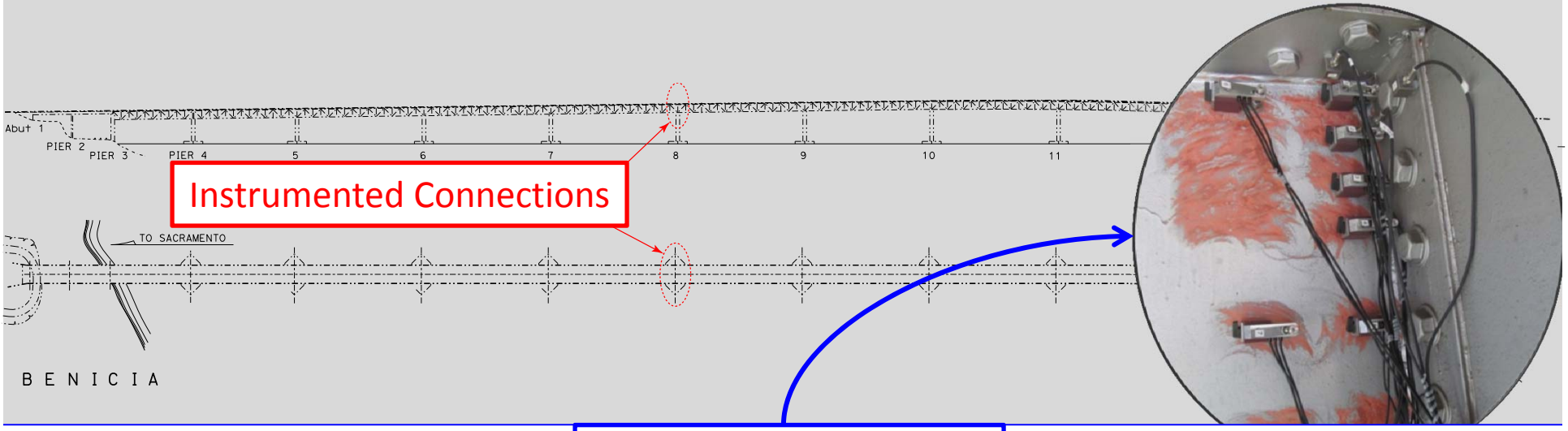
- Most common sensor for measuring vibration
- Estimation of velocity and displacement from acceleration measurements
- Measure low frequency motion

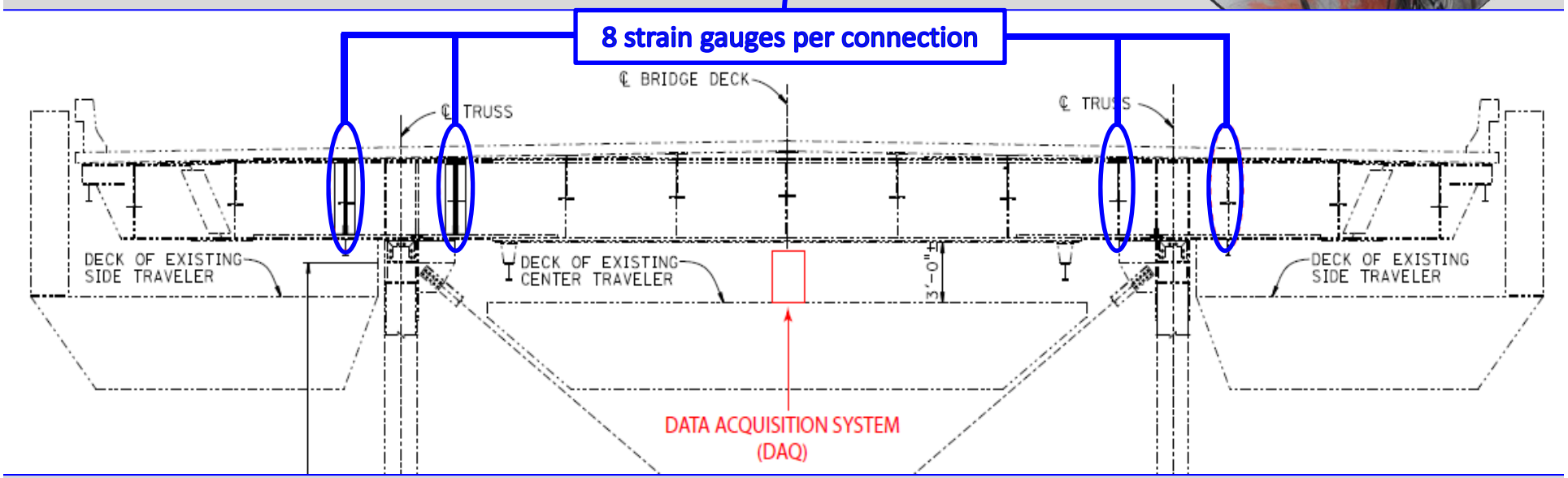
Instrumentation Basics

Linear Variable Displacement Transducer

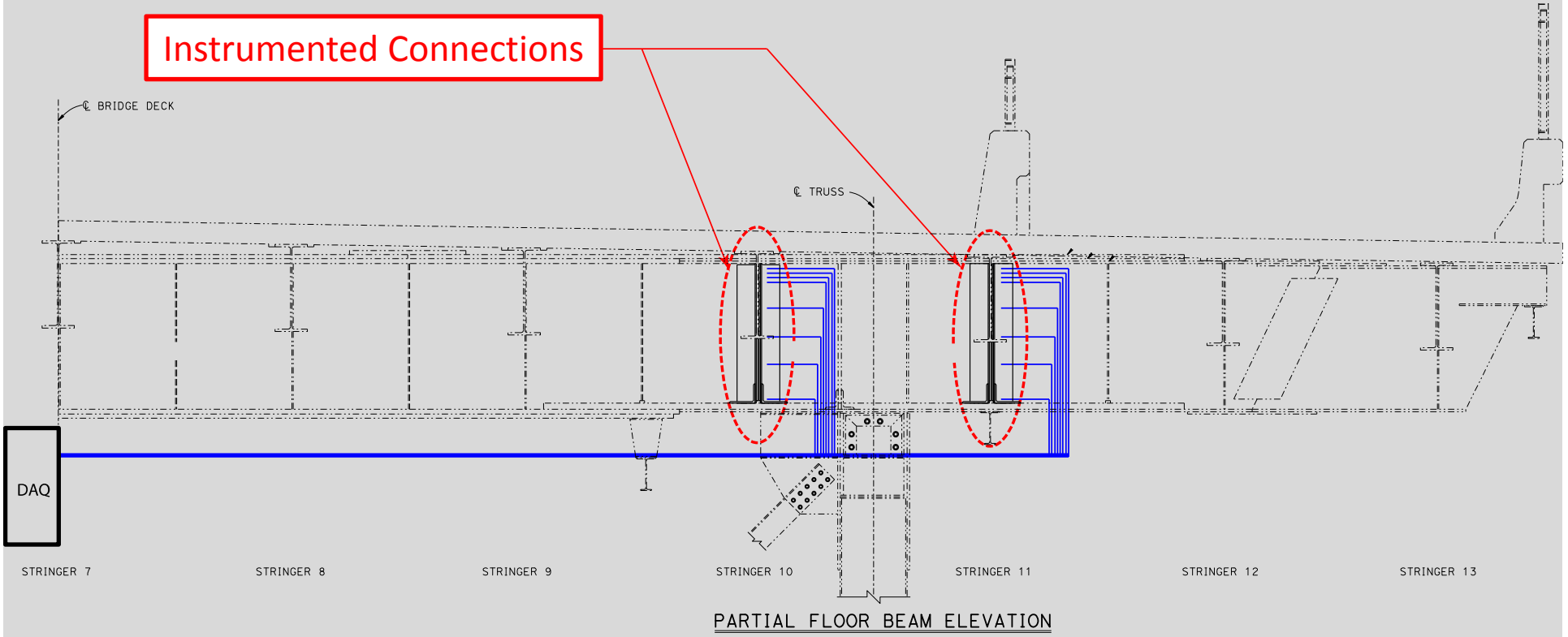
- LVDT attached with a tip adapter measures relative displacement along an axis
- Rigid stainless steel carriers with easy installation
- Accurate and reliable, even in wet conditions

Pier 8 Instrumented Connections

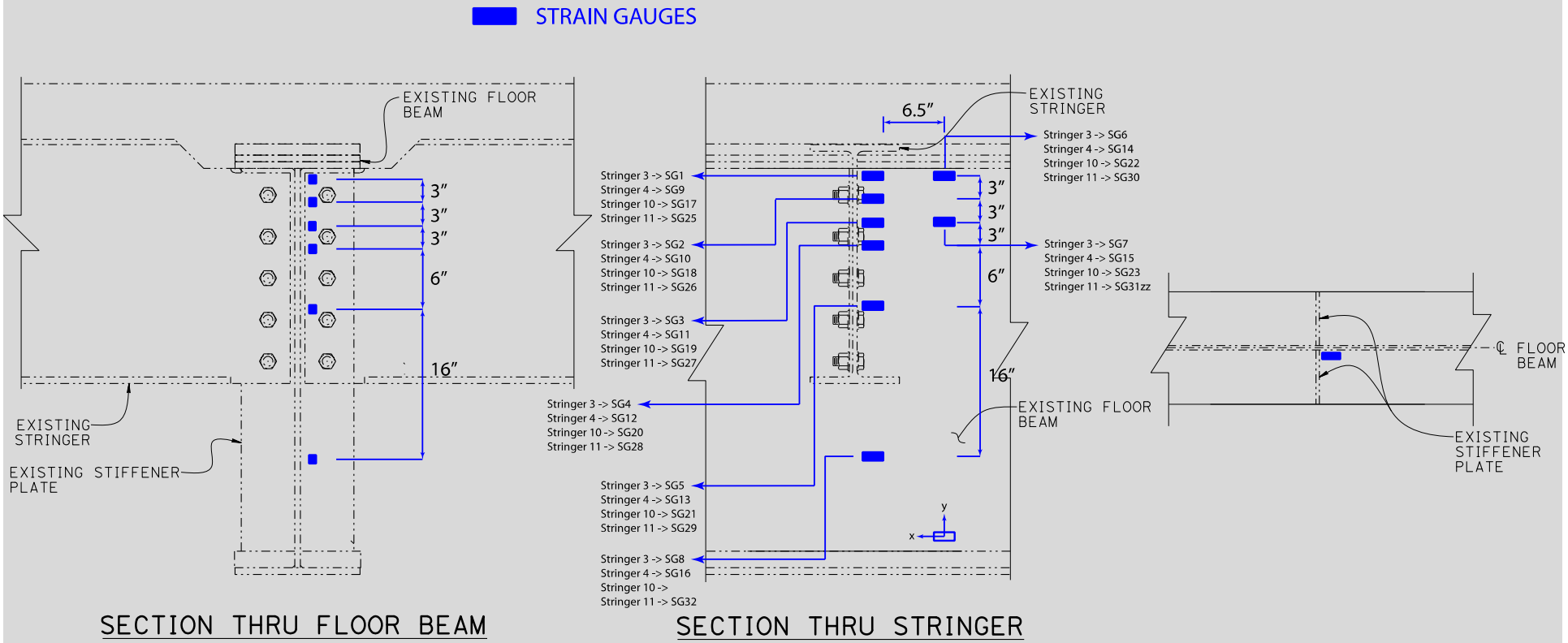




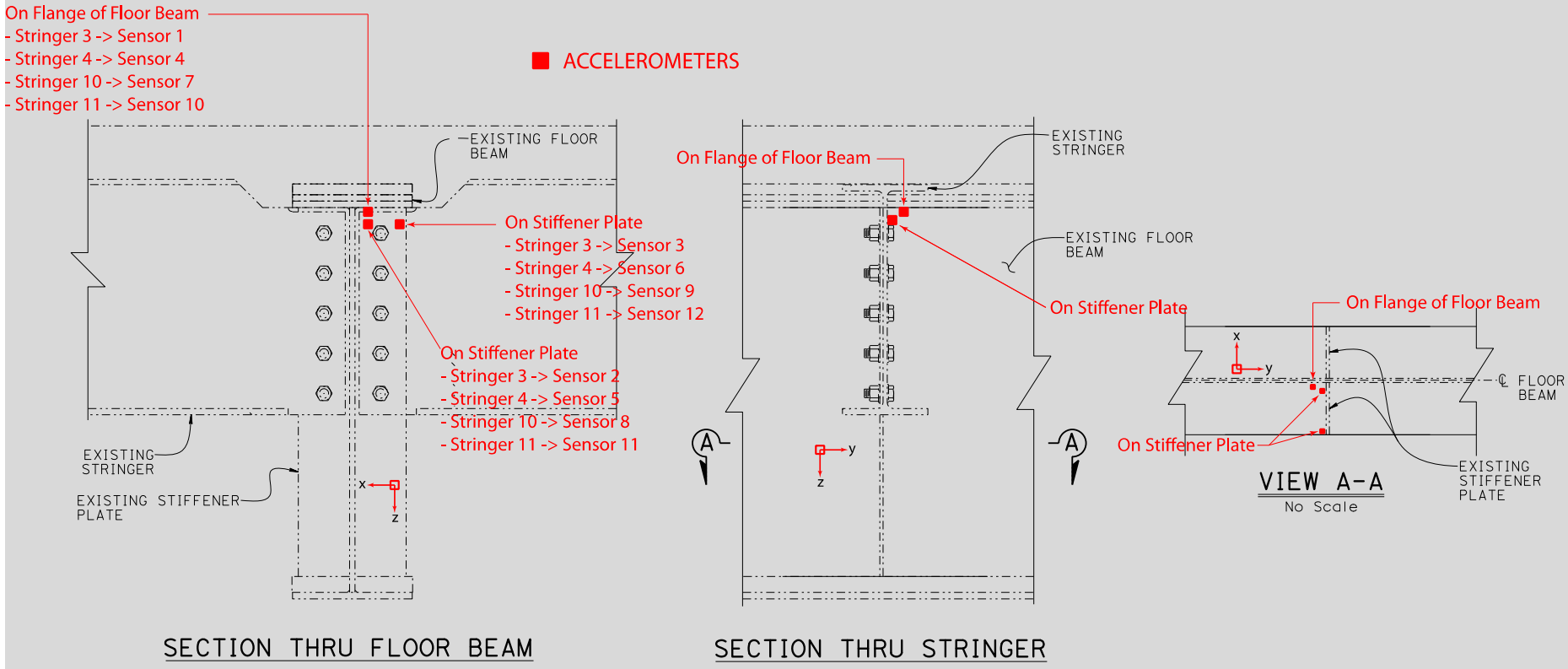
Pier 8 Floor-Beam/Stringer Connections



Pier 8 Strain Gauges on Floor-Beam/Stringer Connections

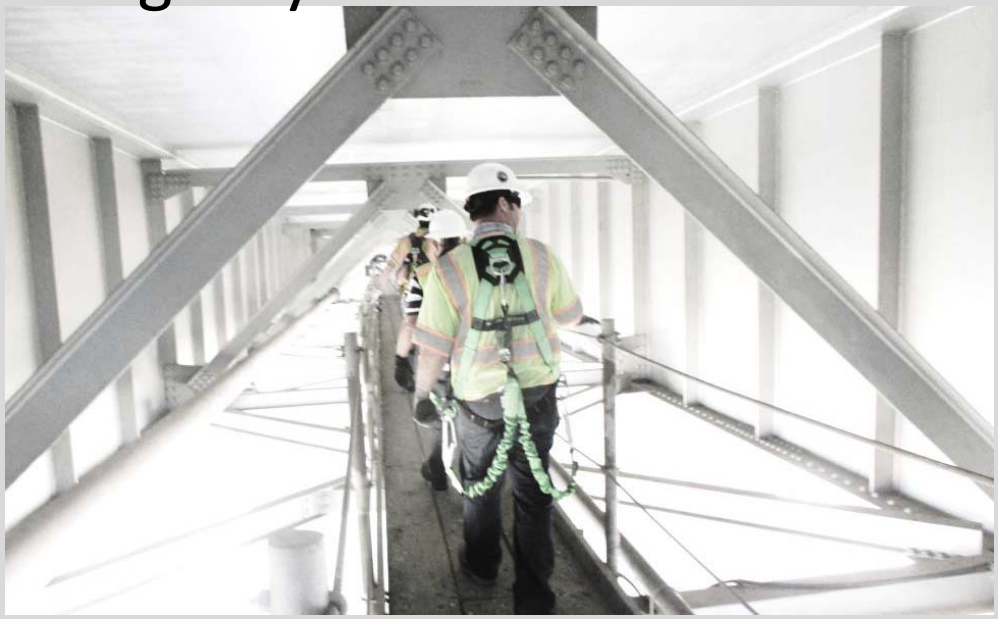


Pier 8 Accelerometers on Floor-Beam/Stringer Connections



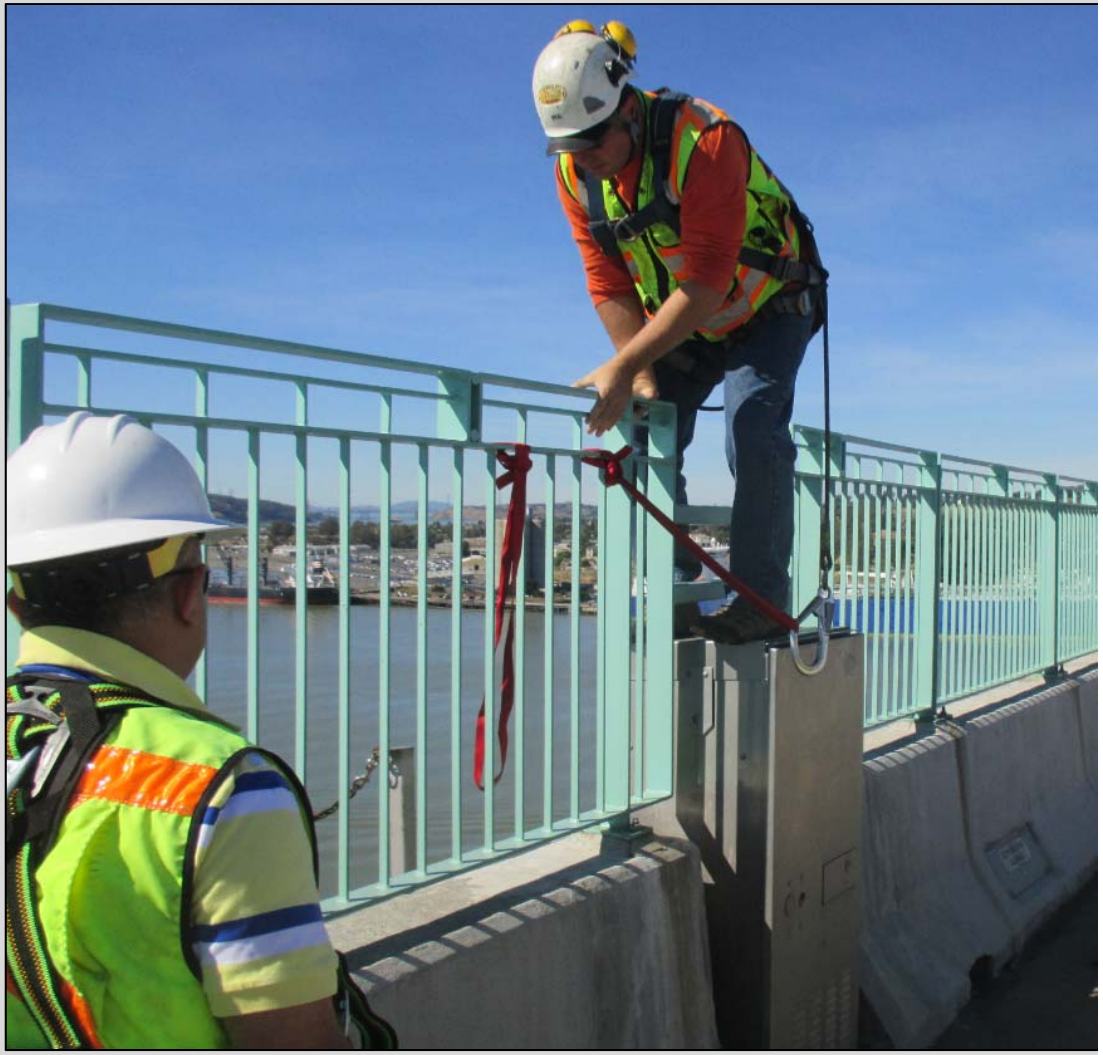
Installation Challenges

- Access limitations
- Sensor location/sensor installation
- Timeline/equipment lead time
- Main traveler during emergency
- Windy weather
- Secure equipment



Installation Photos

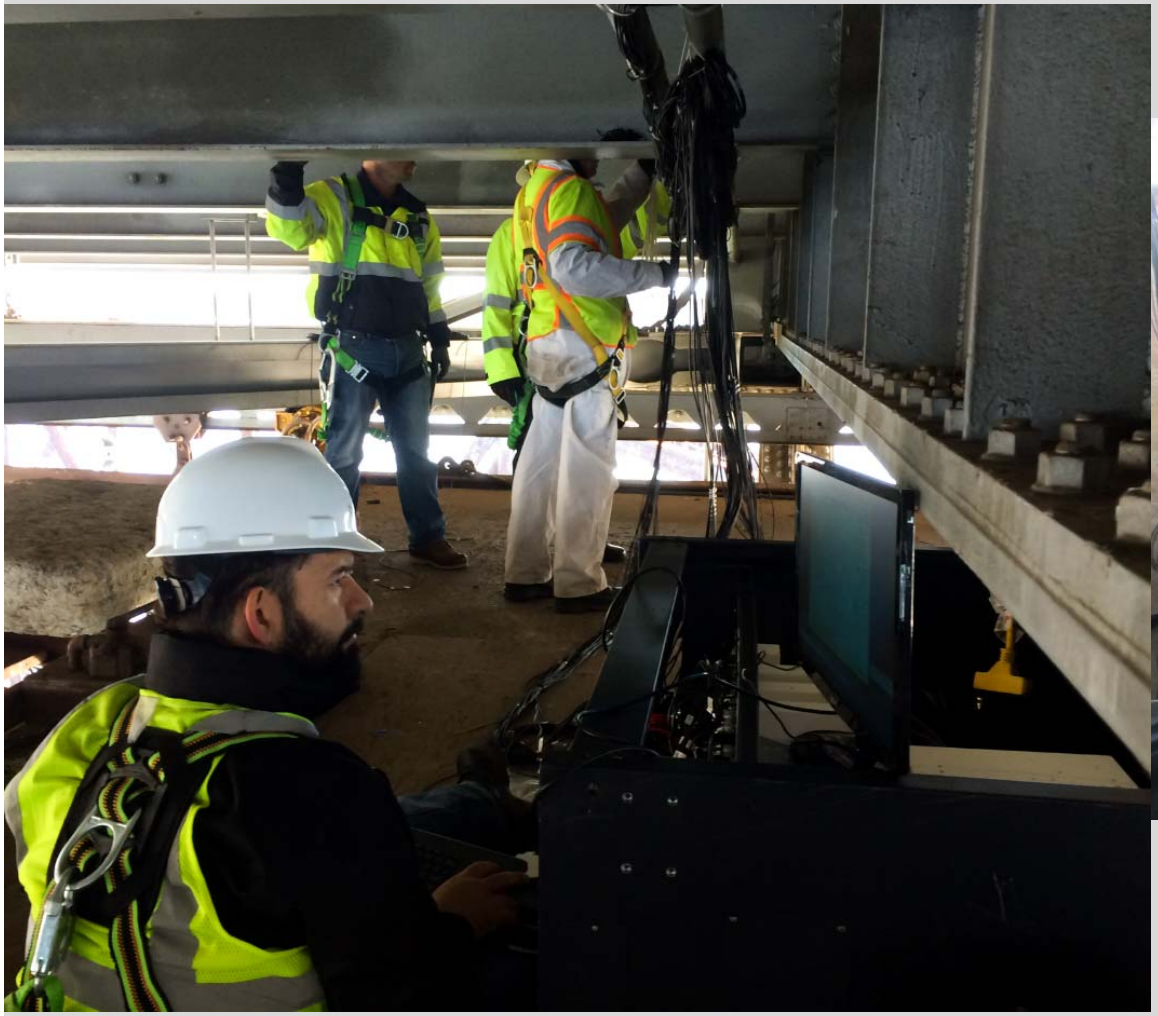
Access Limitation



Access from Side Traveler to Main Traveler

Main Traveler

Installation at Floor-Beam/Stringer Connection



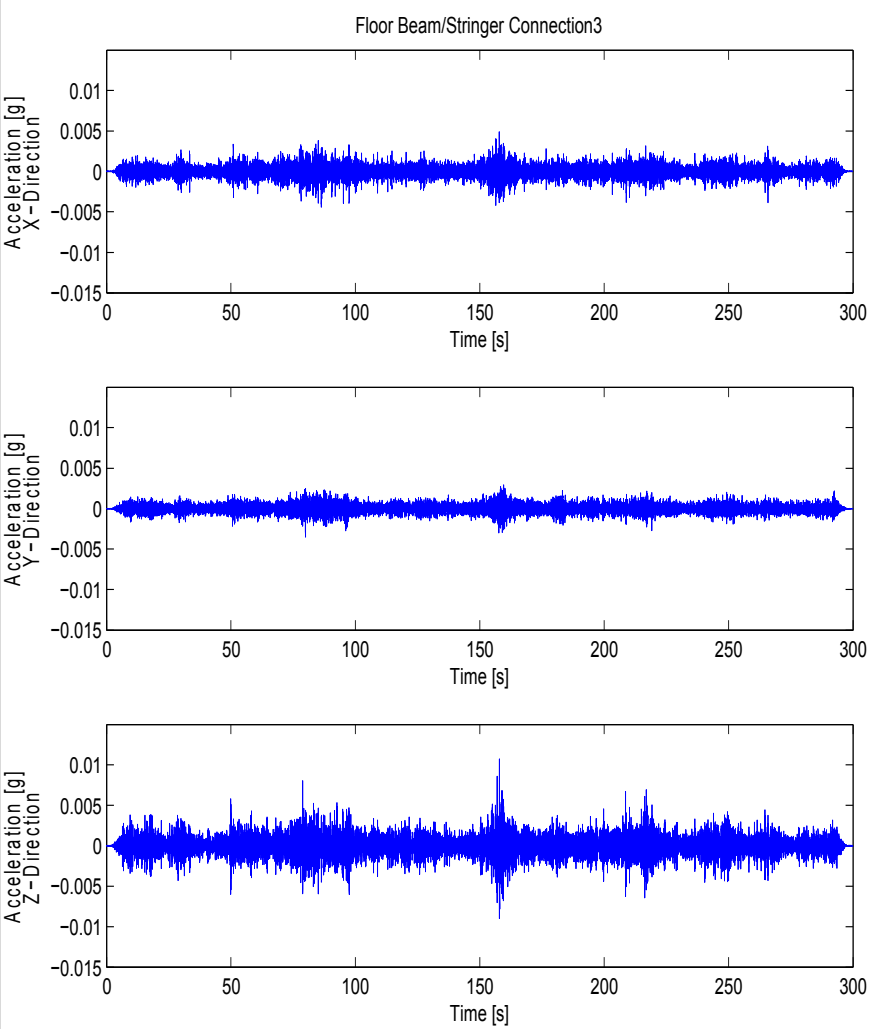
Strain Gauges

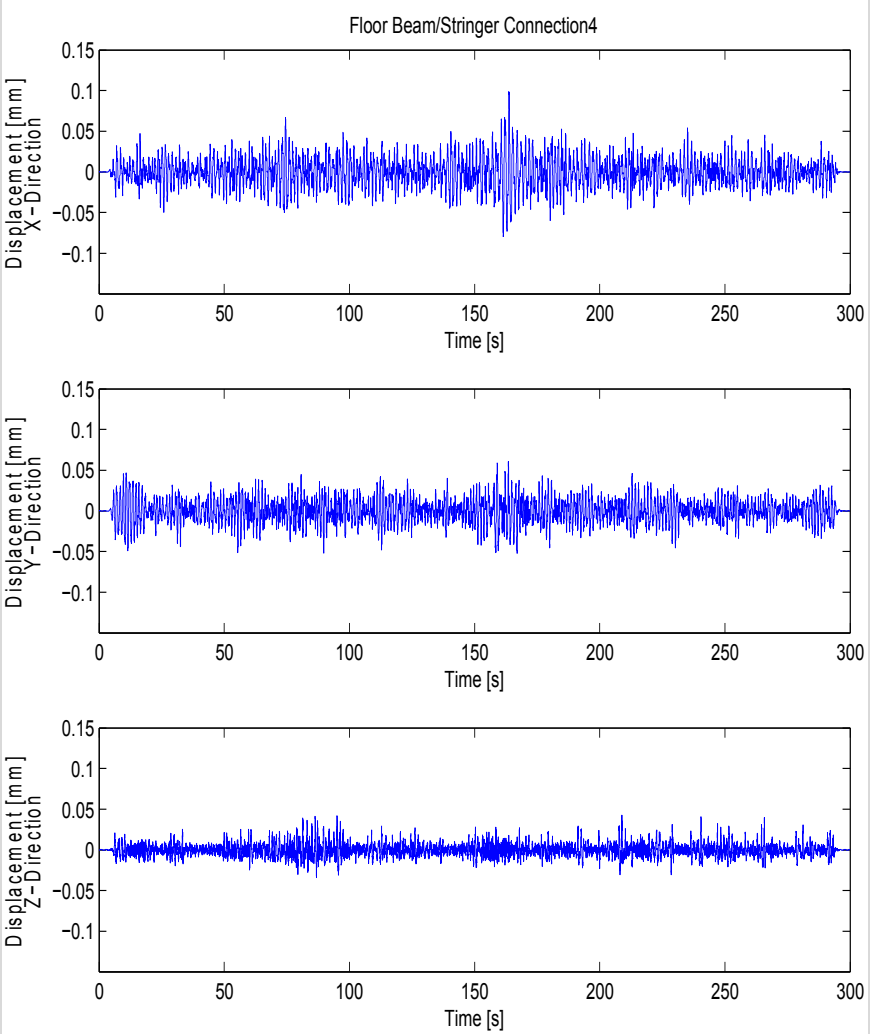
Accelerometers


11/01/2016

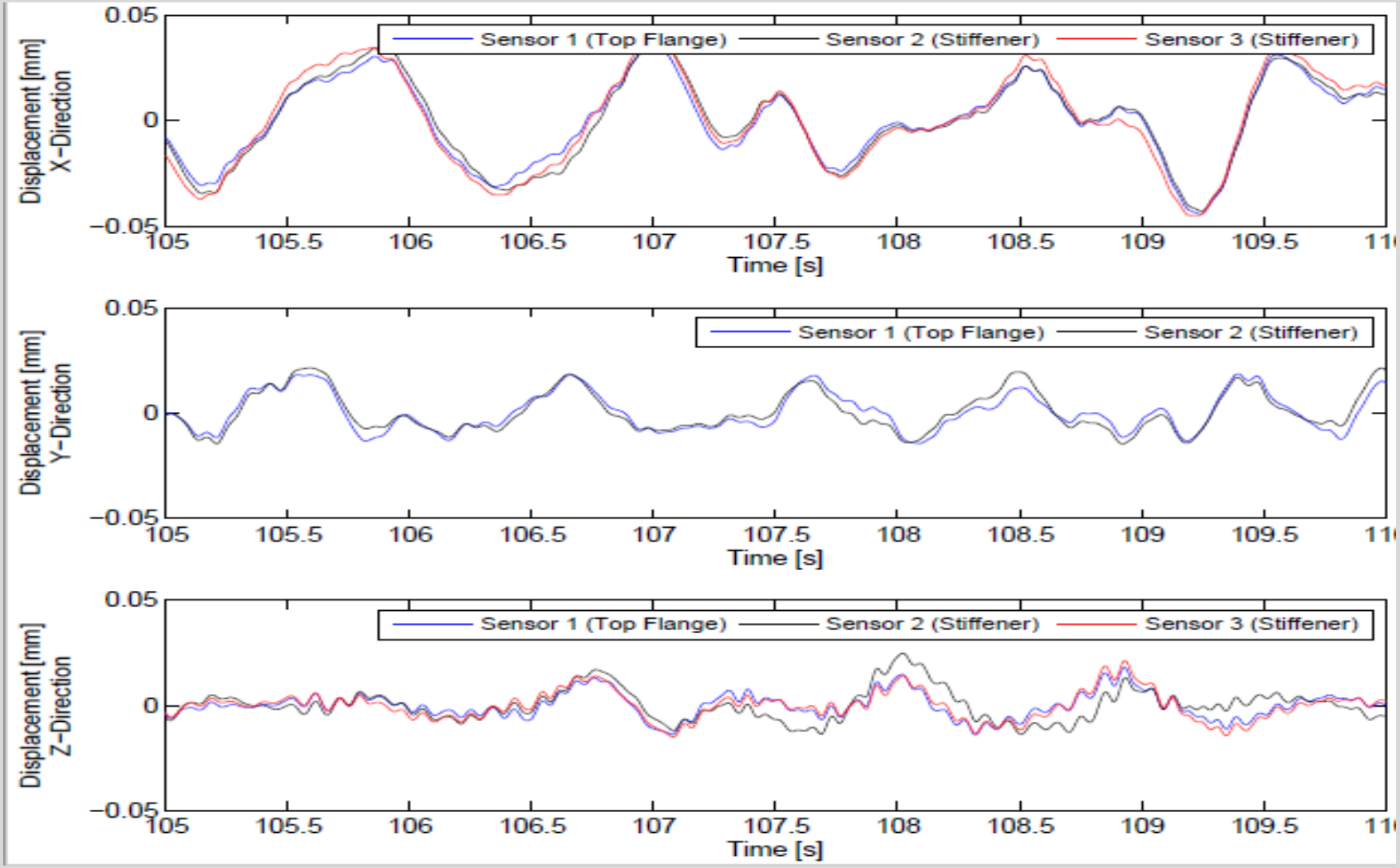
Phase 1 Results
Acceleration and Displacement

Typical Acceleration and Displacement Time-Histories on Floor-Beam/Stringer Connections

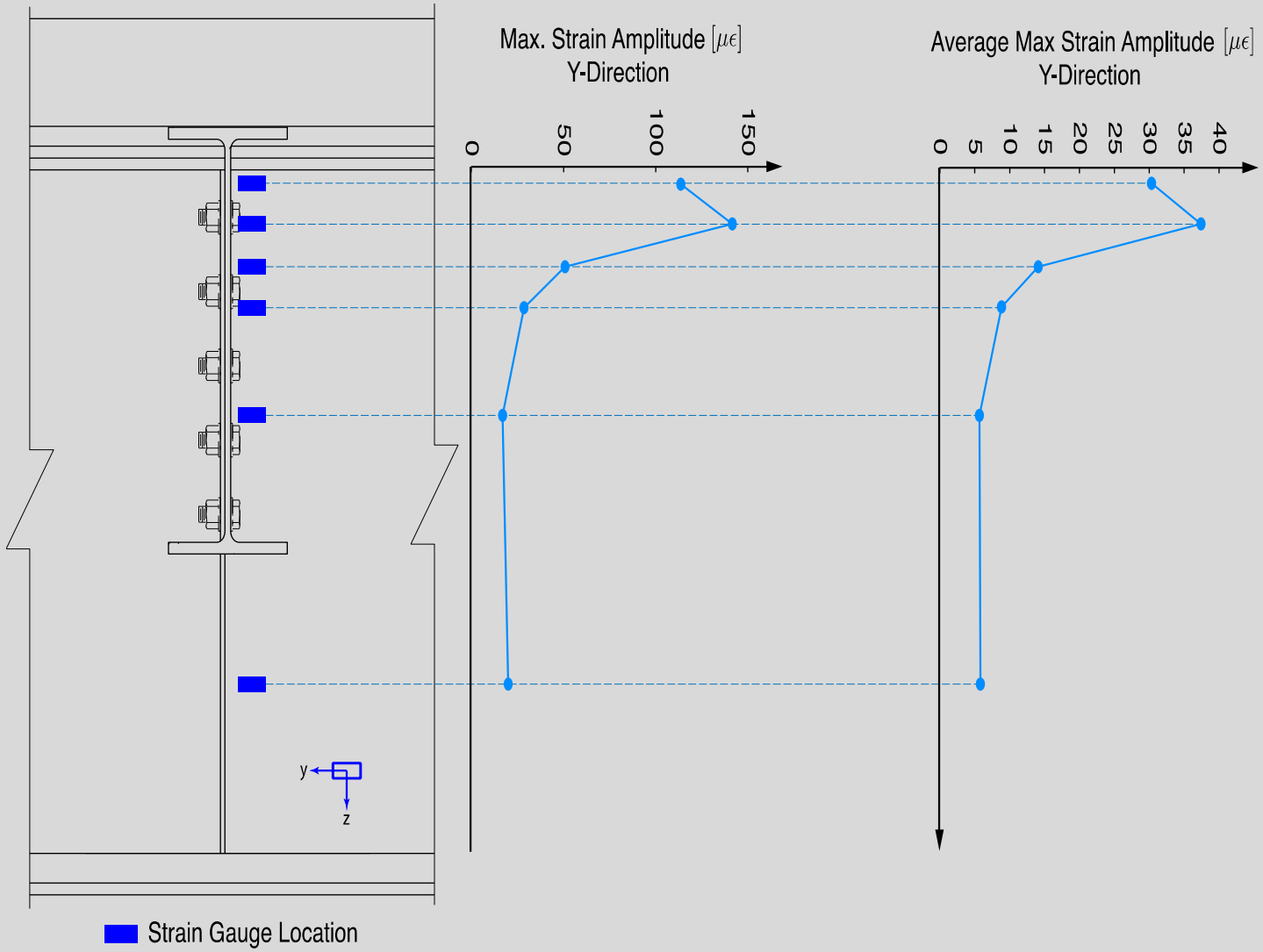




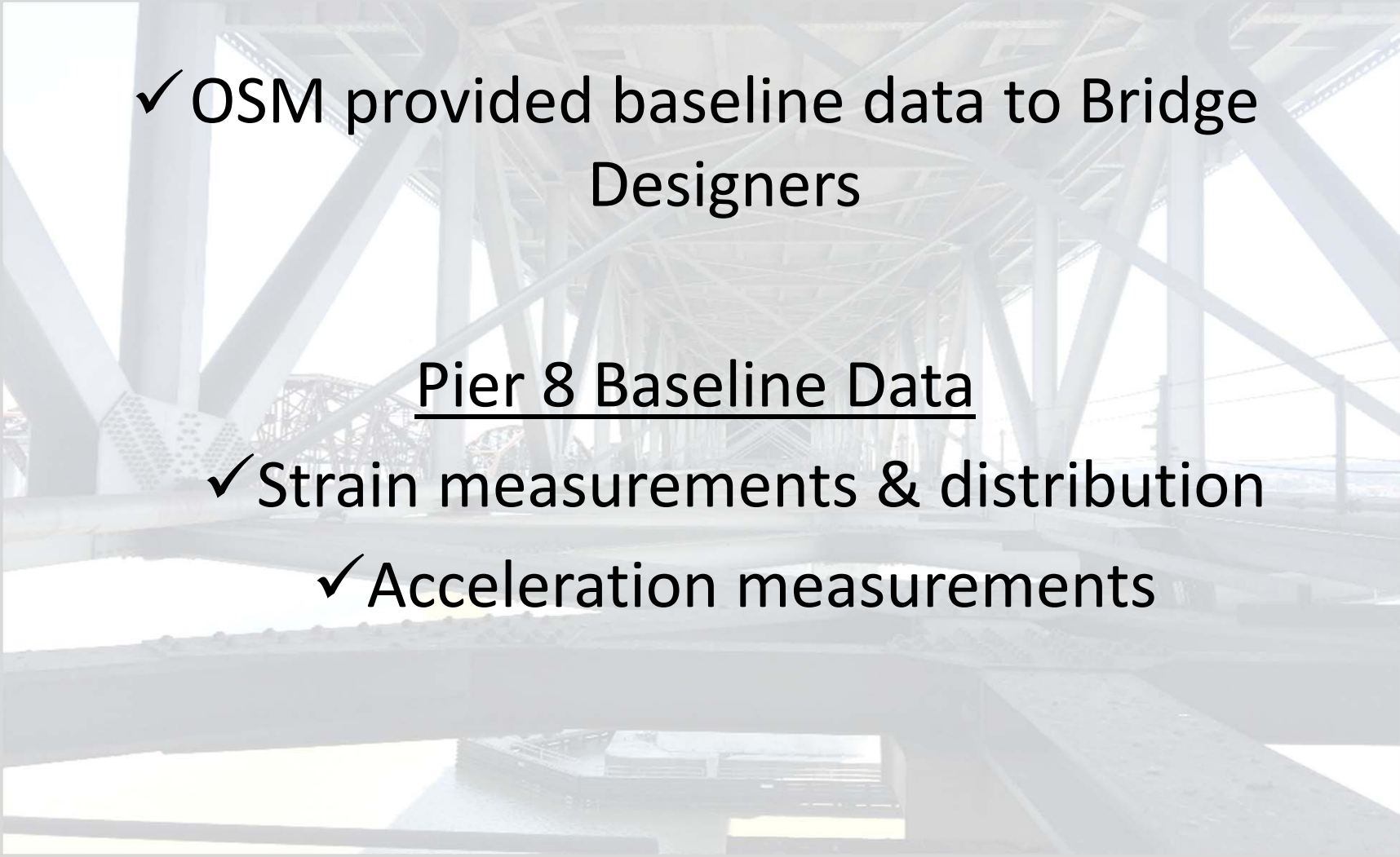
Relative Motion of the Stiffener with respect to Floor Beam Top Flange



Strain Distribution



Structural Monitoring Data



✓OSM provided baseline data to Bridge Designers

Pier 8 Baseline Data

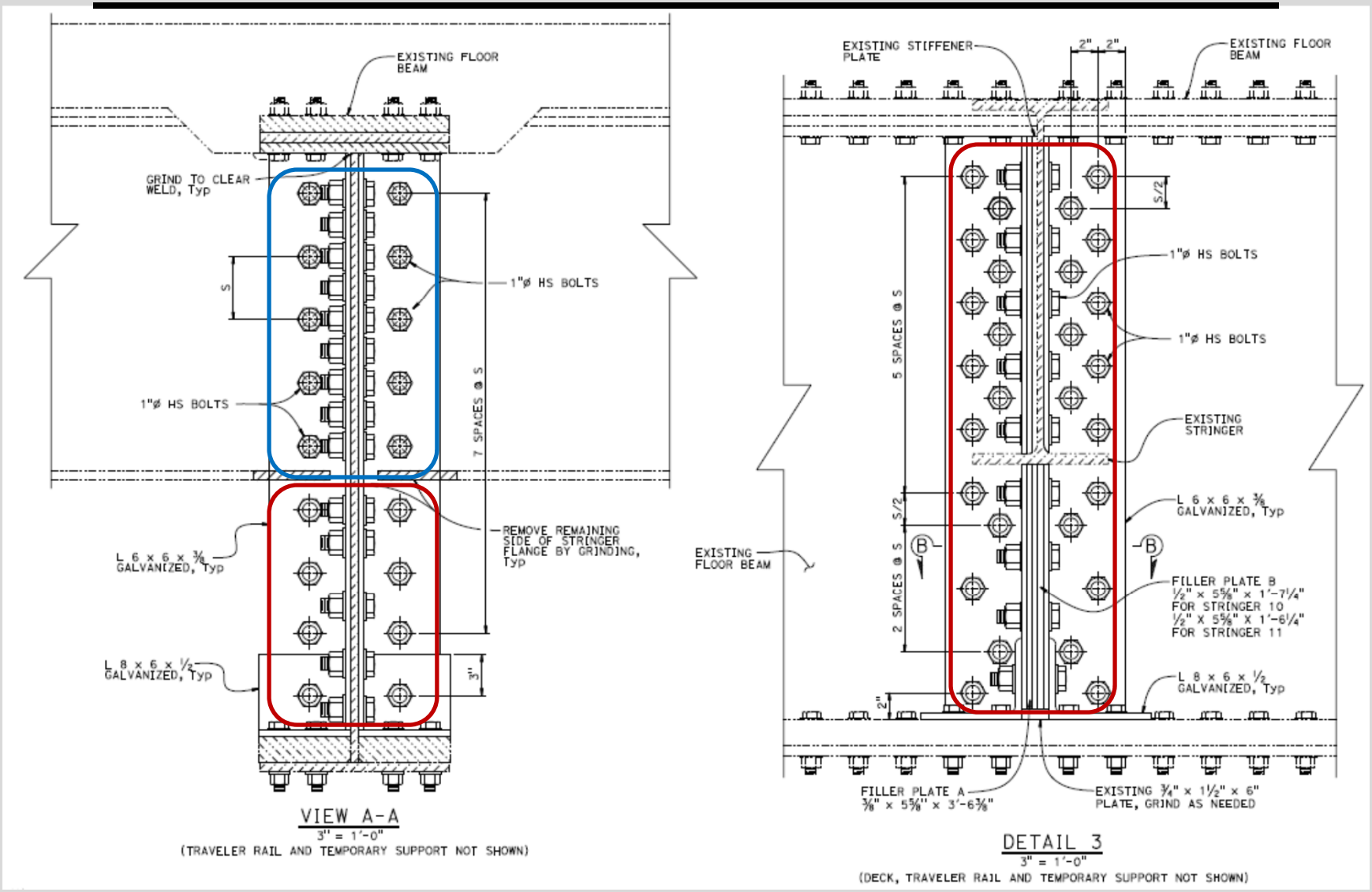
✓Strain measurements & distribution

✓Acceleration measurements

New Bolts in New bolt holes

New Bolts in Existing Bolt holes

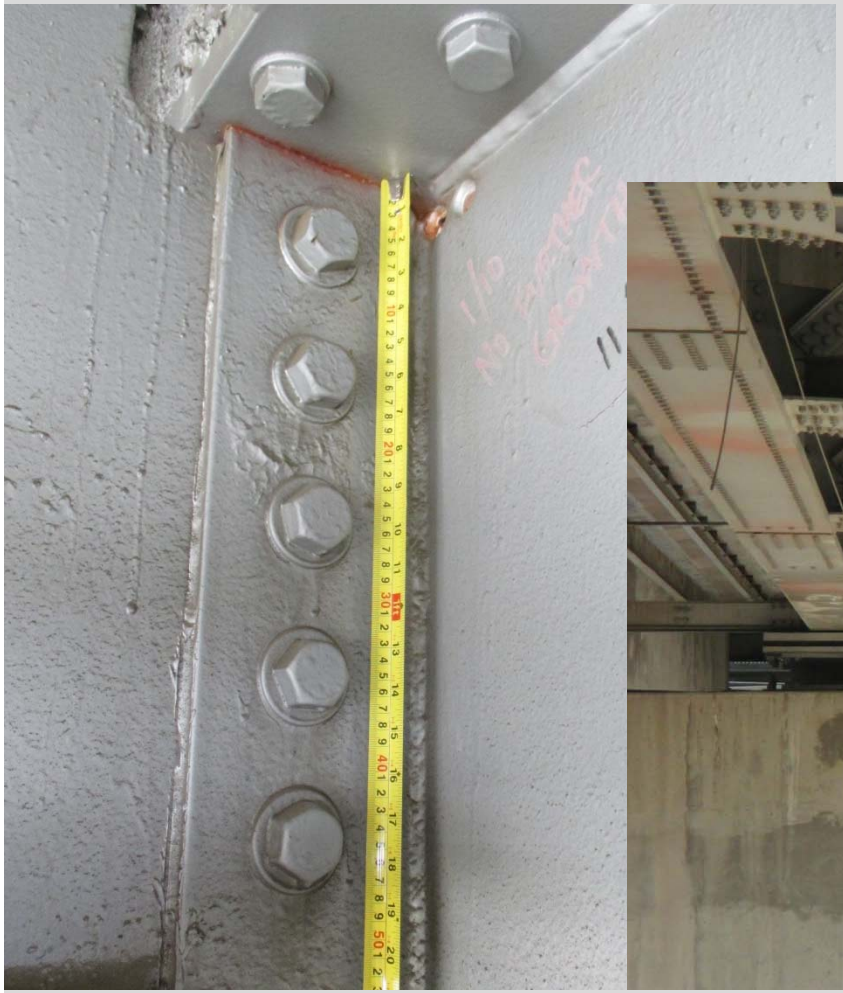
Pier 8 - New Connection Details



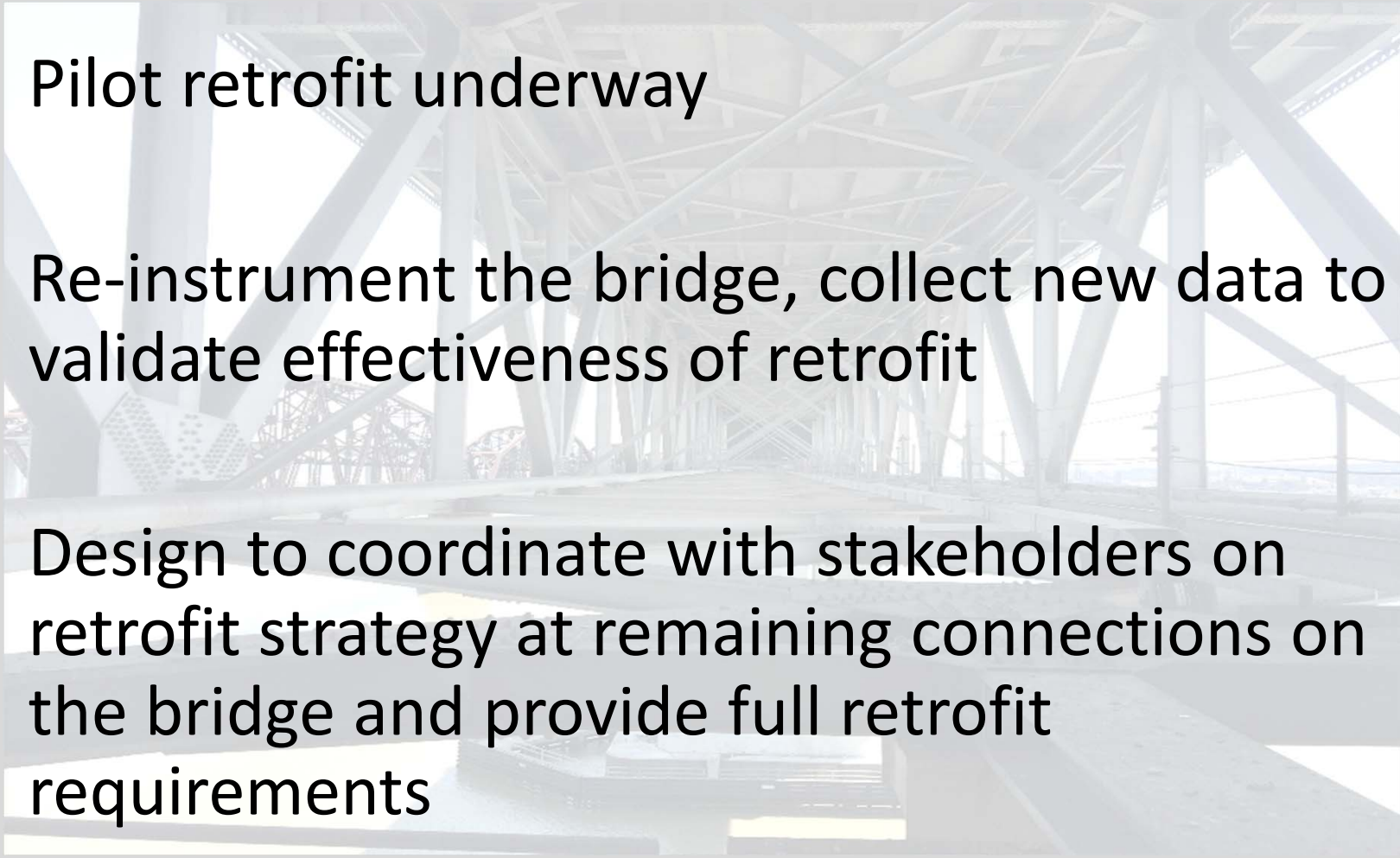
LVDTs at Pier 2

Displacement transducers to measure the longitudinal and vertical displacements on the isolator bearing.

Next Step: Retrofit Strategy



Big Picture Activities



- Pilot retrofit underway
- Re-instrument the bridge, collect new data to validate effectiveness of retrofit
- Design to coordinate with stakeholders on retrofit strategy at remaining connections on the bridge and provide full retrofit requirements

2011 AASHTO Manual for Bridge Evaluation (MBE) Chapter 8 states:

"The actual performance of most bridges is more favorable than conventional theory dictates. When a structure's computed theoretical safe load capacity or remaining fatigue life is less than desirable, it may be beneficial to the bridge owner to take advantage of some of the bridge's inherent extra capacity that may have been ignored in conventional calculations."

Thank you

Discussion/Questions