Design and Construction Solutions on the Benicia-Martinez Bridge

2007 Western Bridge Engineers' Seminar

Presented by: Richard P. Foley, P.E.

September 26, 2007

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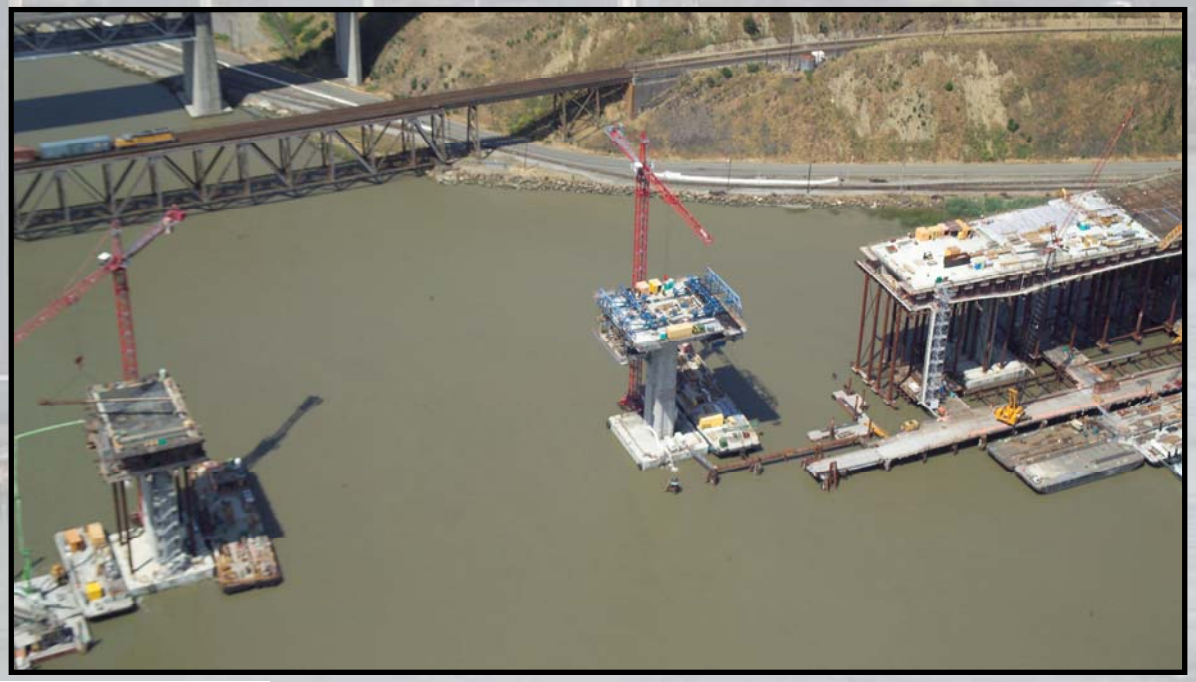
Project Team

Design: TyLin/CH2M Hill J.V.

Construction:Kiewit Pacific Co.

Owner:

State of California - Caltrans



Project Status

Bridge Opening:

August 26, 2007

Conversion of Existing:

Bid Opening October 2007

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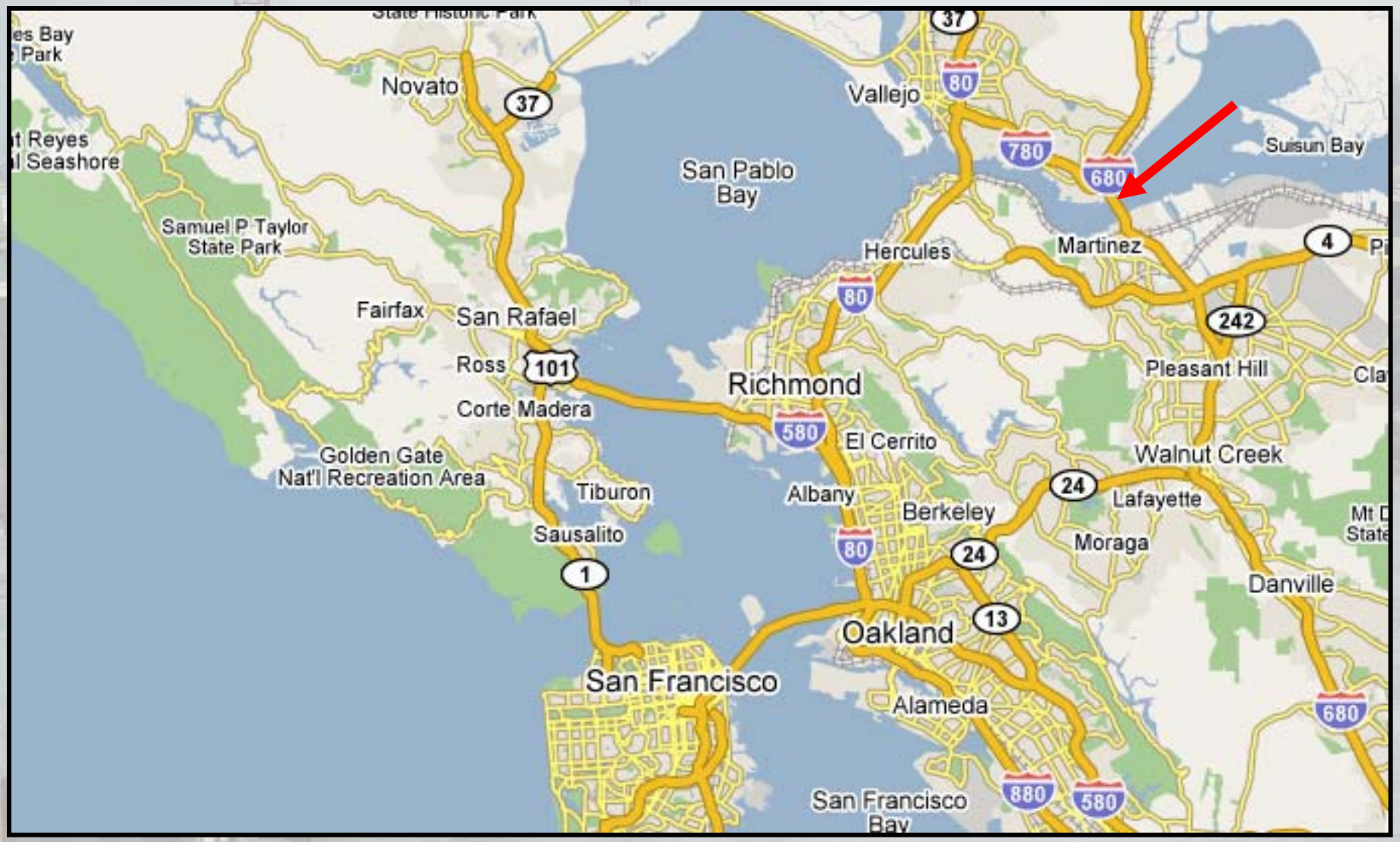
Eastern Portion of San Francisco Bay Area



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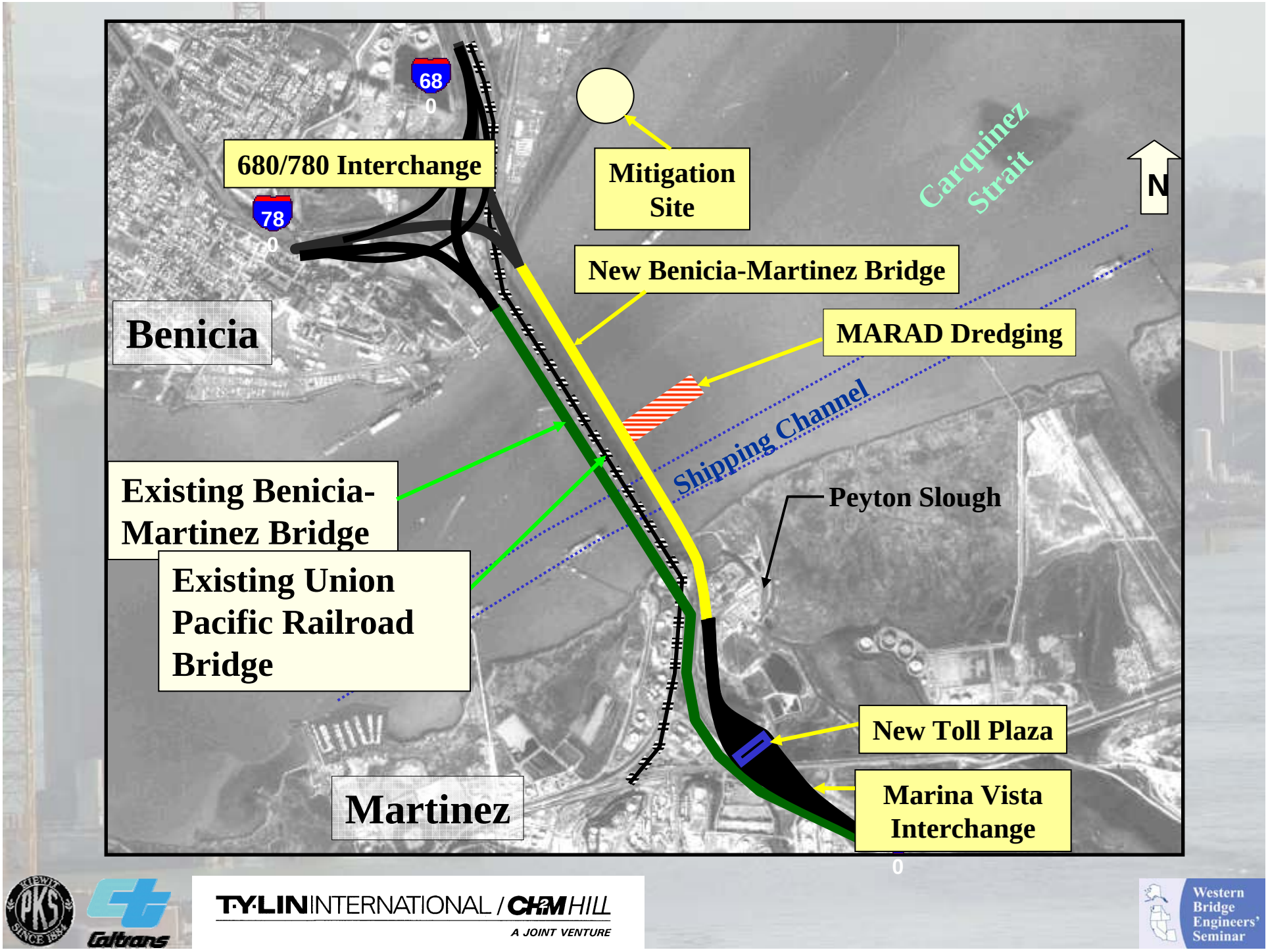
Regional Measure 1 – Congestion Relief Project



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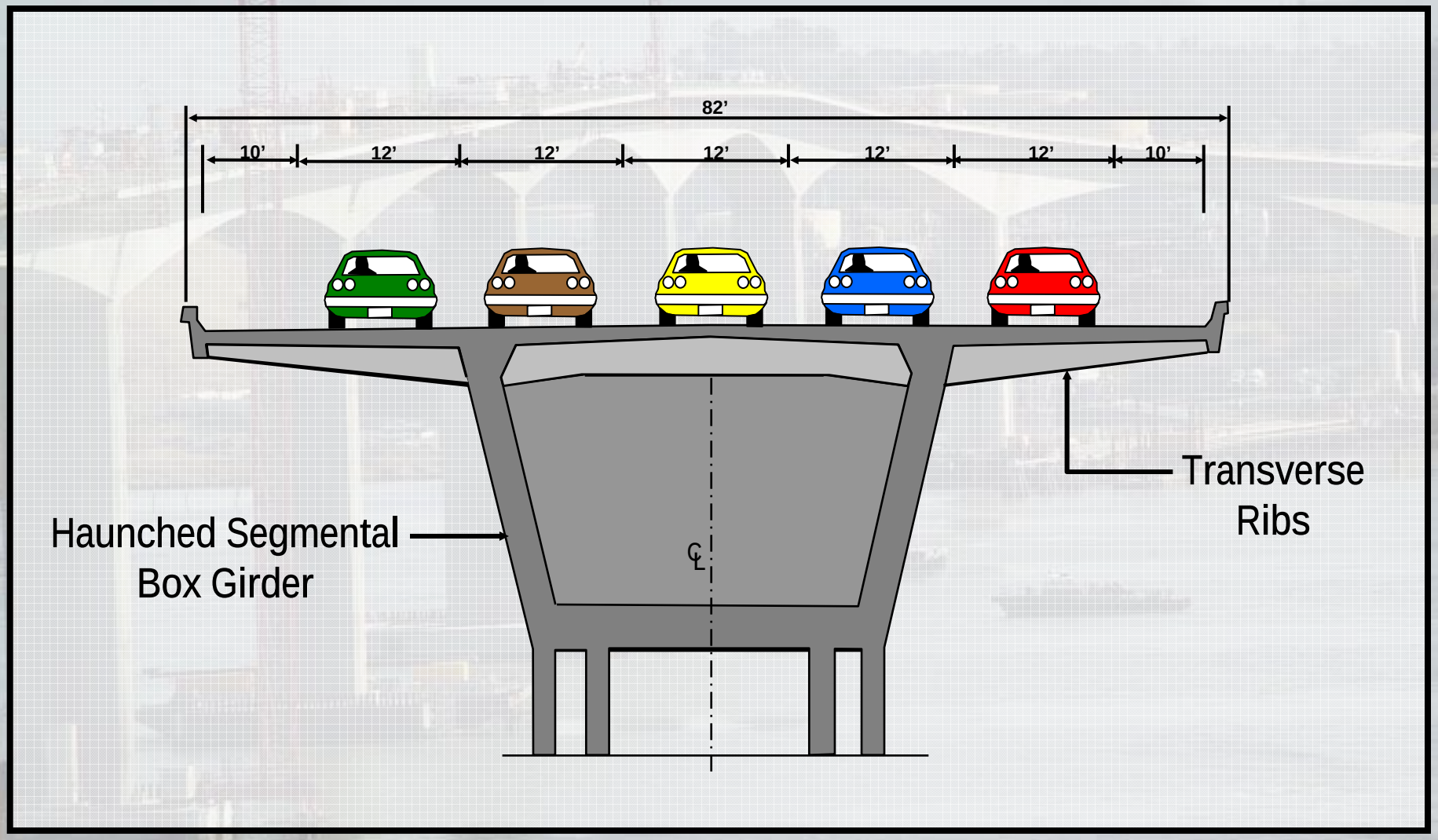
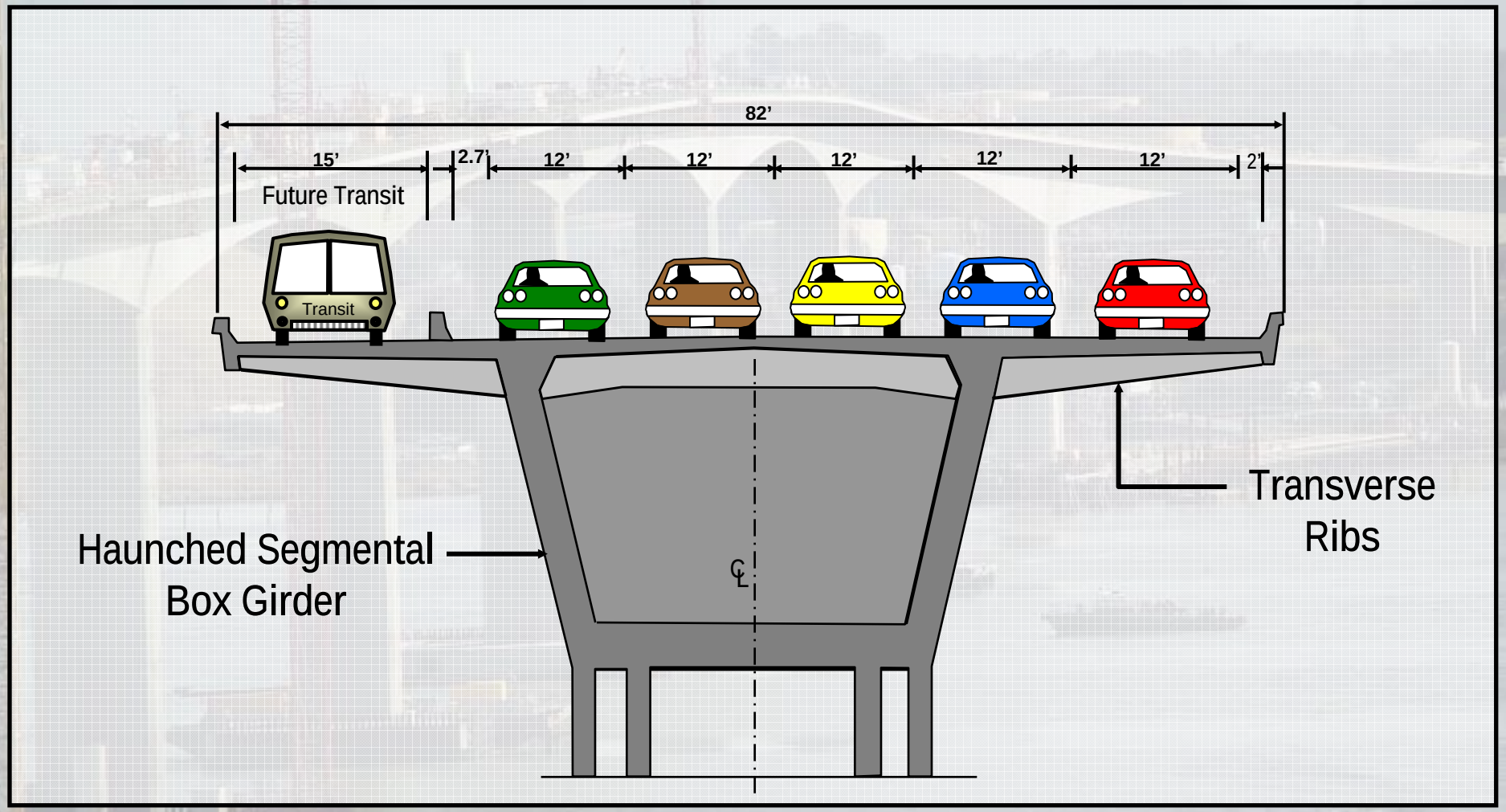
Typical Cross Section Northbound I-680



Typical Cross Section – Future Configuration



Cast-in-Place Balanced Cantilever Segmental Bridge

Form Traveler

1.4 Miles Long

344 Segments

High Performance Lightweight Concrete

660 Foot Main Spans

Challenging Foundations

Looking North - January 2006

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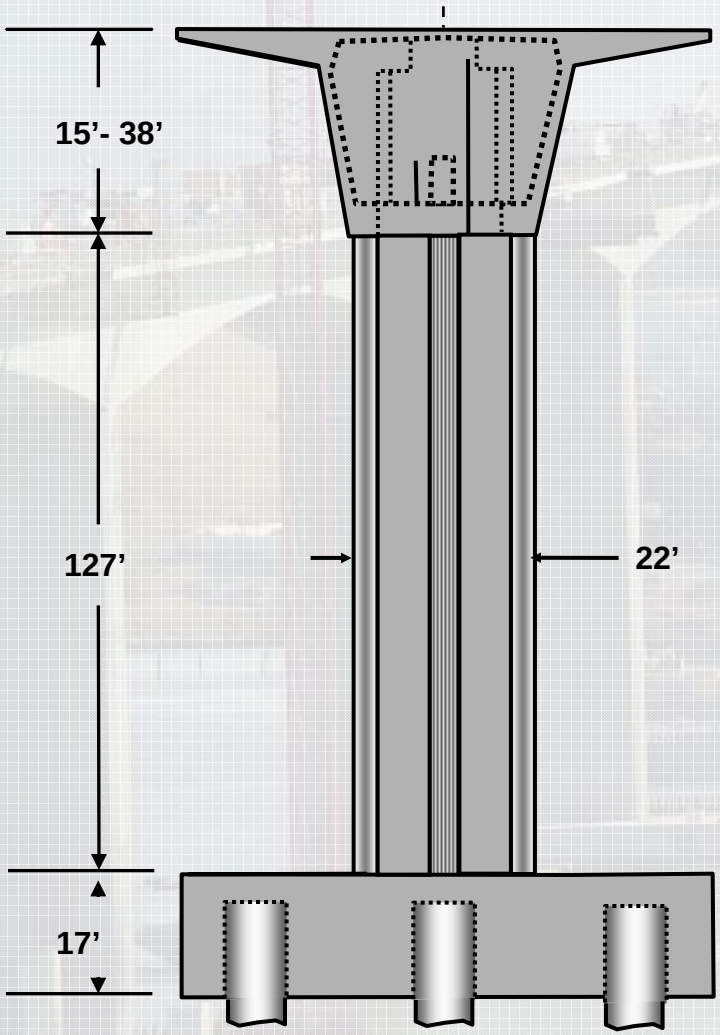
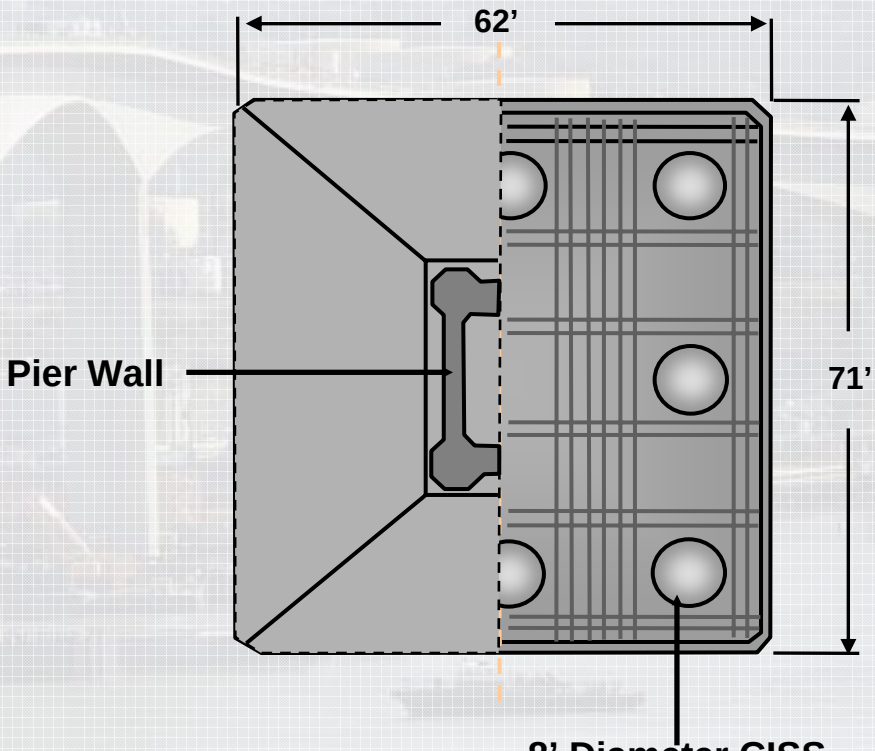
New Structure - Typical Pier Details

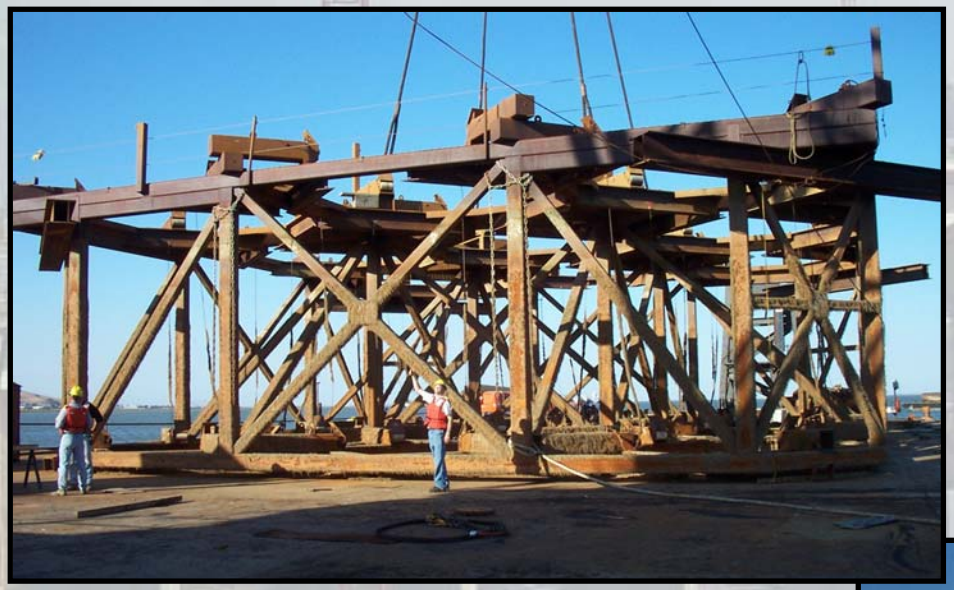


Pier Elevation



Footing Plan

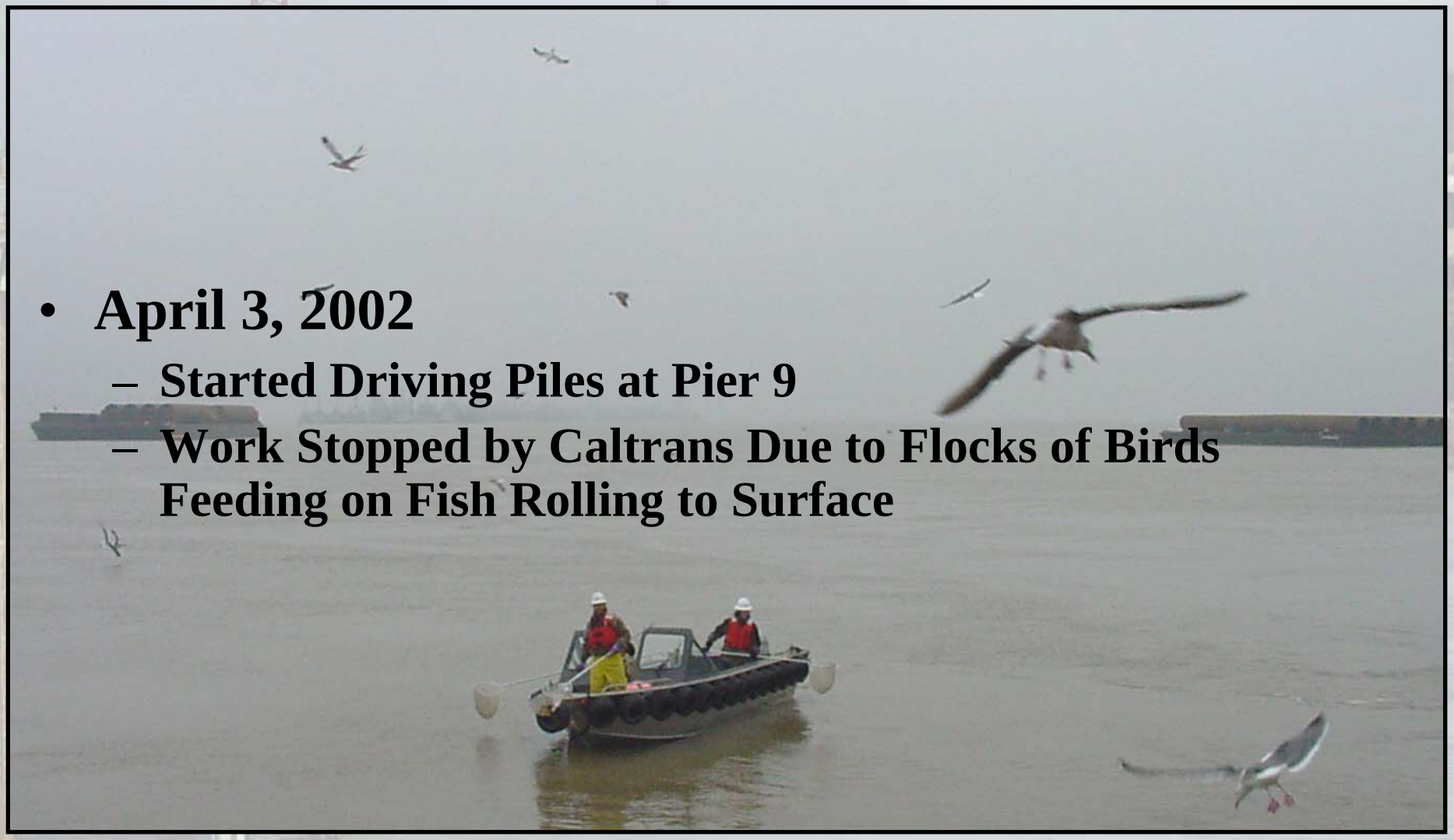
Pile Driving Operations



Preparation

- Design/Construct Template
- Place Template
- Procure Derricks
- Mobilize Hammer
- Begin Driving Operations

Pile Driving - Noise Attenuation Systems



- **April 3, 2002**
  - **Started Driving Piles at Pier 9**
  - **Work Stopped by Caltrans Due to Flocks of Birds Feeding on Fish Rolling to Surface**

Pile Driving - Noise Attenuation Systems

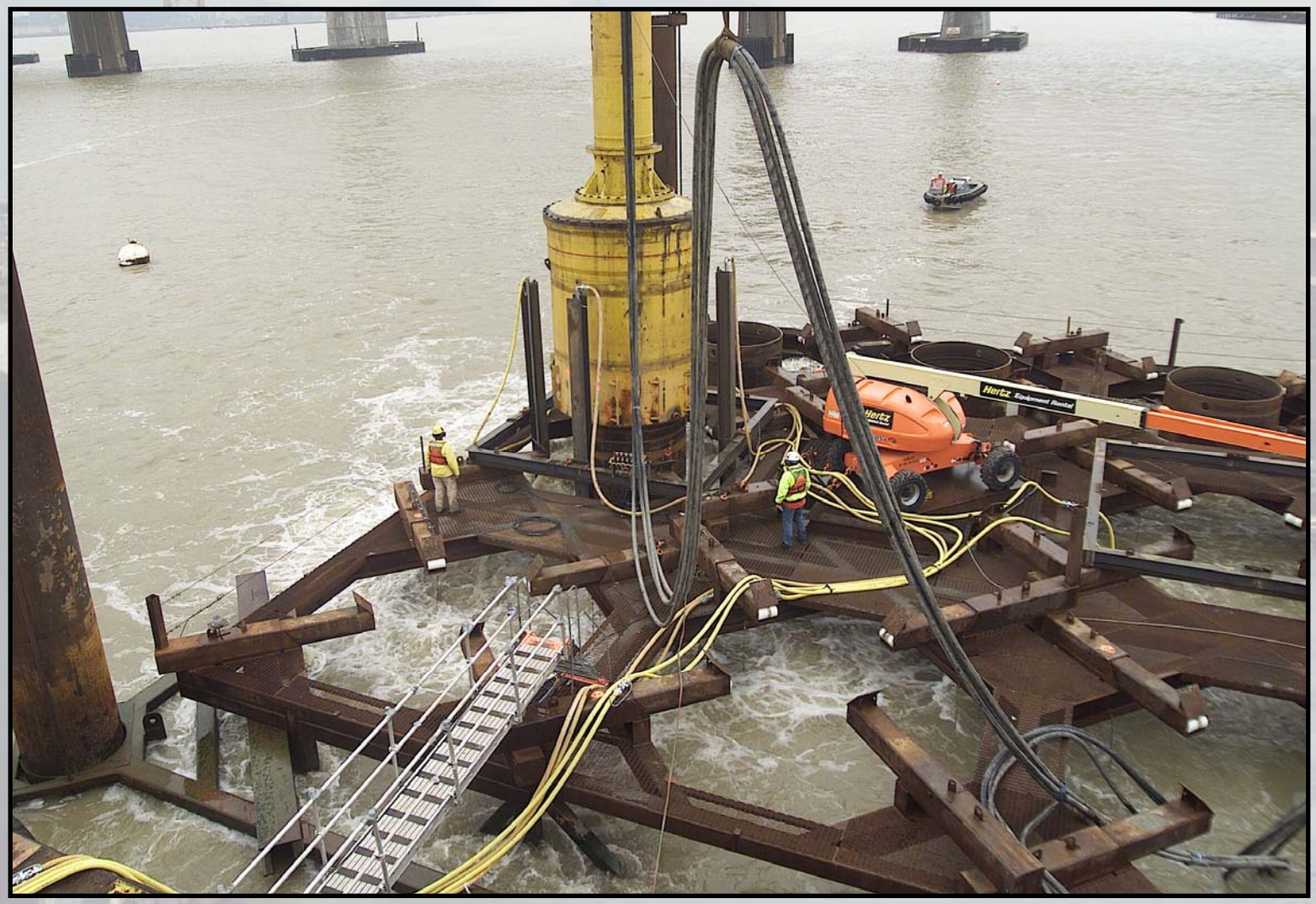
- **August 16, 2002 to October 31, 2002**
  - **Allowed to Perform Driving During Slack Current Windows**
  - **Fabricating IP/ABC Systems for Production Use**

- **November 1, 2002 to June 14, 2003**
  - **No Pile Driving Allowed Without Noise Attenuation**
  - **Switched Production to the ABC Due to Concerns Over Implementation of the IP/ABC System**

- **January 20, 2003**
  - **ABC Underwater Acoustic Testing**
  - **Similar Results to IP/ABC**
  - **30 dB Reduction in Noise Levels**

Portion of Bubble Tree

Air Bubble Curtain Noise Attenuation System



Menck Hammer Driving Piles While Bubble Trees Are In Use

Bubble Tree in Operation

Pile Driving - Noise Attenuation Systems

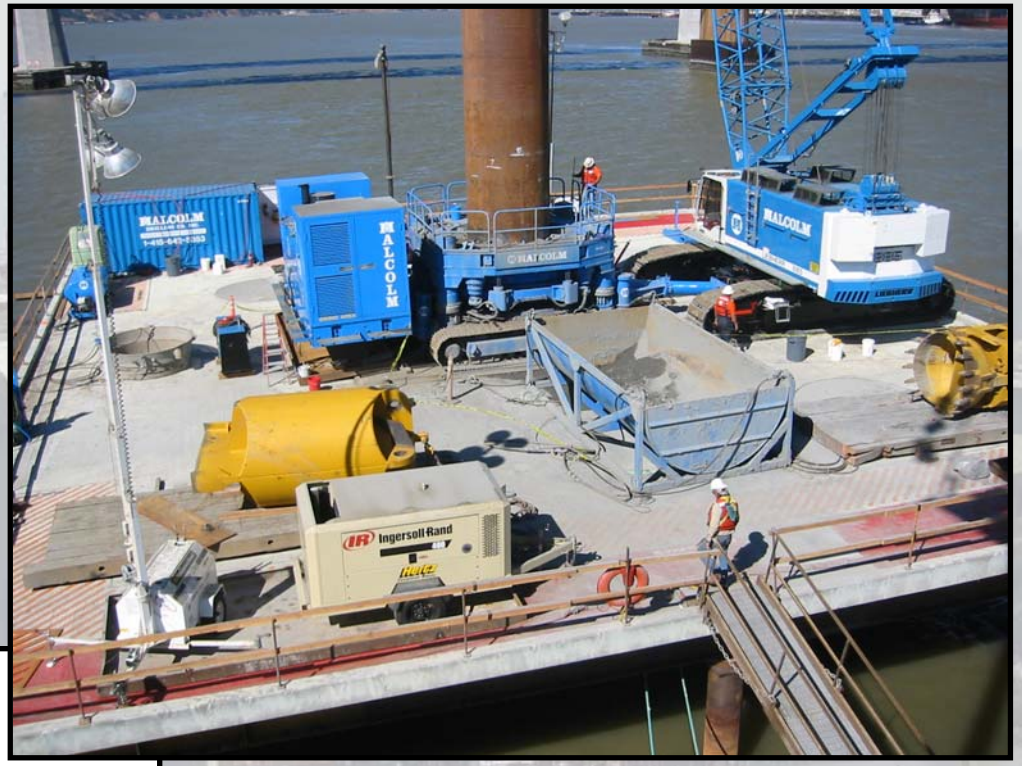
- Why was this issue not anticipated?
  - No known history of fish take on the Benicia-Martinez Retrofit or on the New Carquinez Bridge Projects
  - SFOBB Pile Demonstration Project was being sent out for bid at roughly the same time as the New B/M Bridge was bidding – B/M hammer was 25% of SFOBB hammer
  - Increasing awareness of the issue by regulatory agencies with tighter restrictions on allowable noise levels (highest "safe" dB readings allowed by NMFS/NOAA were actually lower than the best results the ABC achieved)
  - Potentially affecting a commercially viable species (i.e. salmon) and several endangered species (Sacramento Split-tail, Delta Smelt)

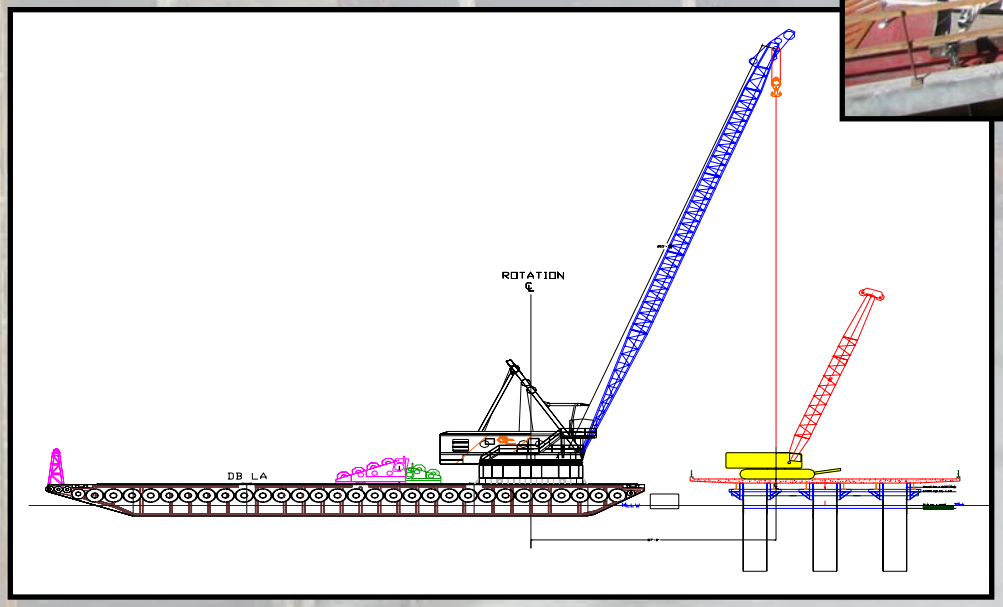
Pile Driving - Noise Attenuation Systems

- Lessons Learned
  - Pile driving in ANY body of water will require a noise attenuation investigation on future projects
    - Already implemented on Caltrans jobs in Eureka and the Bay Area
    - Implemented on private jobs (Valero Pier in Benicia)
    - Implemented on local government jobs (4th Street Bridge in SF)
  - Caltrans has patented the bubble curtain
    - State has protected its right to use the best available technology in the future
    - Protects the State from having to pay to use technology that the State paid to develop

Removal of Overburden for Rock Sockets

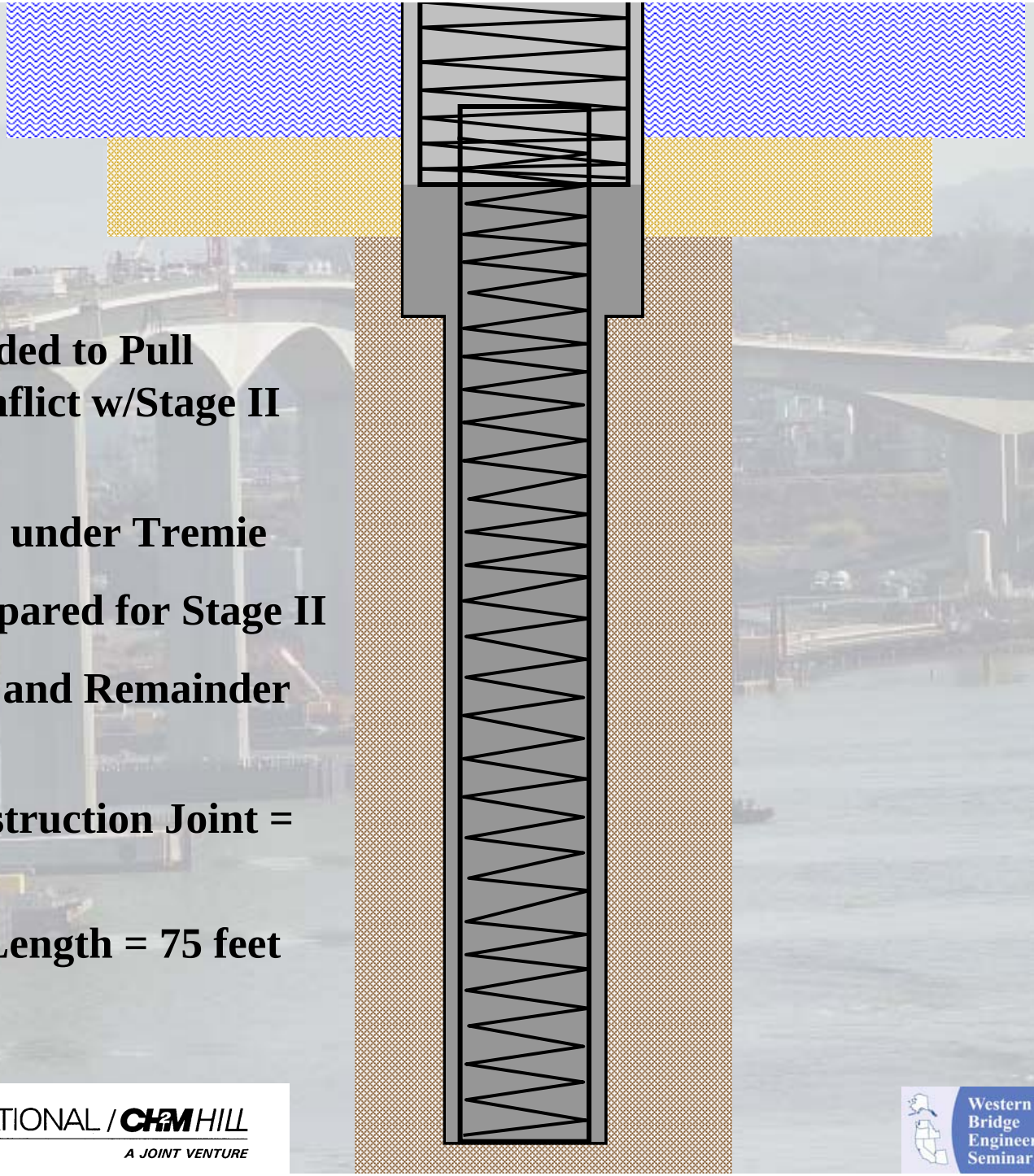
Rotator Equipment Spread





- **Work performed on Temporary Platforms**
- **Five (5) Temporary Platforms Constructed for the Project**

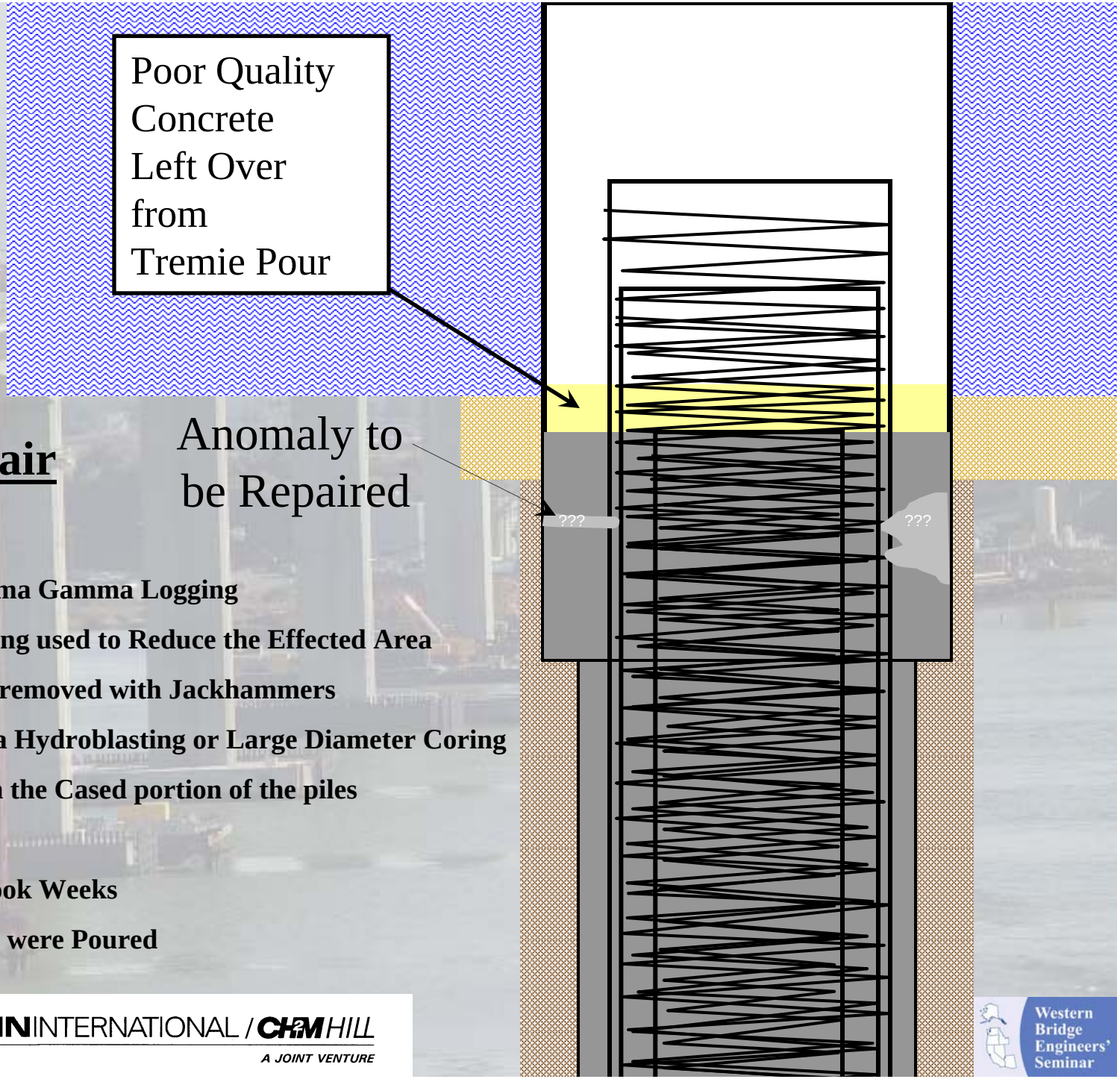
Rotator Installation



- Construction Joint Needed to Pull Temporary Casing – Conflict w/Stage II Cage
- Stage One cage poured under Tremie
- Construction Joint prepared for Stage II
- Stage II Cage installed and Remainder Poured
- Average Depth to Construction Joint = 90 feet
- Average Rock Socket Length = 75 feet
- Longest Pile = 285 feet

Anomaly Repair & CJ Prep Spread

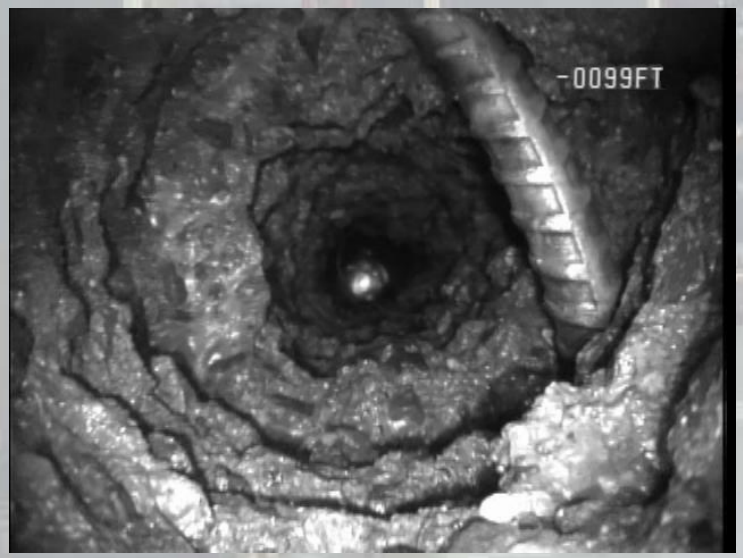
Anomaly Repair & CJ Prep

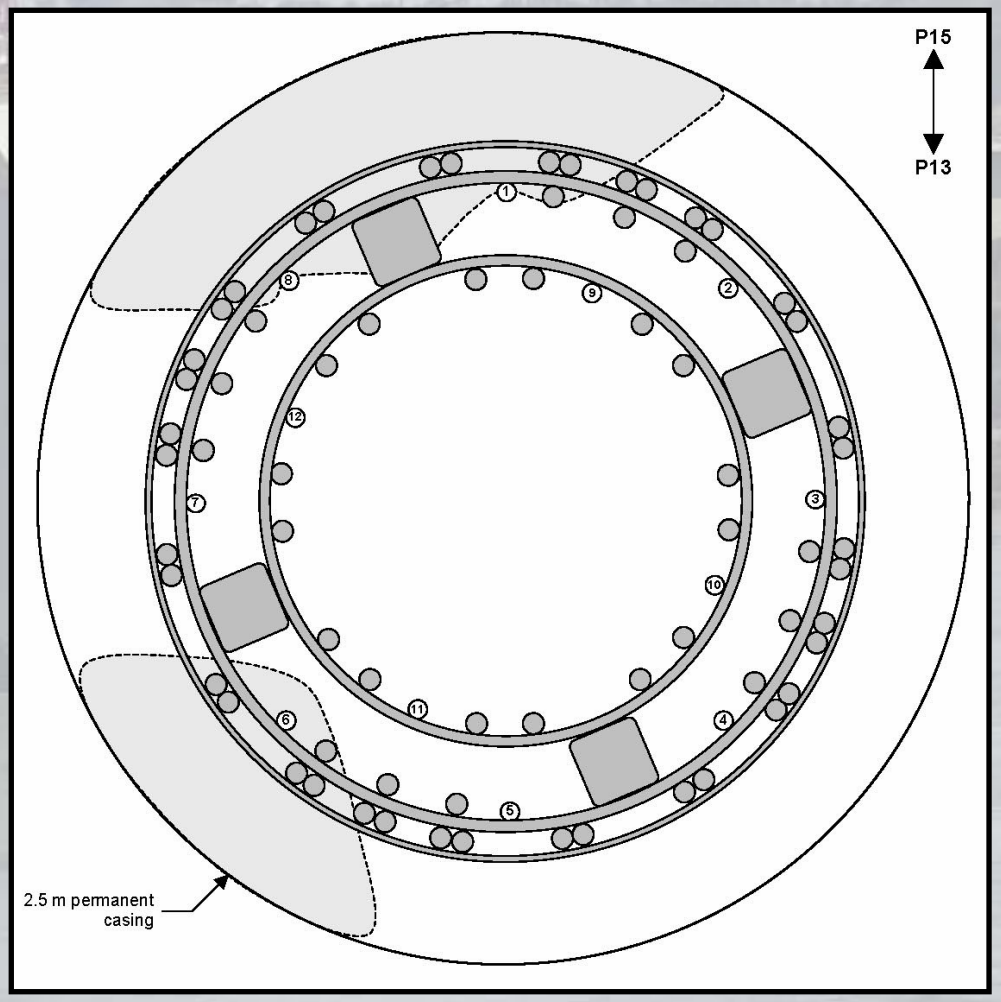


- **All Piles received Gamma Gamma Logging**
- **Cross Hole Sonic Logging used to Reduce the Effected Area**
- **Poor Quality Concrete removed with Jackhammers**
- **Anomalies Repaired via Hydroblasting or Large Diameter Coring**
- **Most anomalies were in the Cased portion of the piles**
- **Plastic Hinge Area**
- **CJ Prep and Repairs took Weeks**
- **Occurred after all Piles were Poured**

Cross-Section of Pile at Anomaly

- **Typical Anomaly in Casing Portion**
- **Core Intact - Verified by CSL**
- **Hydro-Blasting verified with a Camera Lowered into Gamma Tubes**





High Performance Sand-Lightweight Concrete

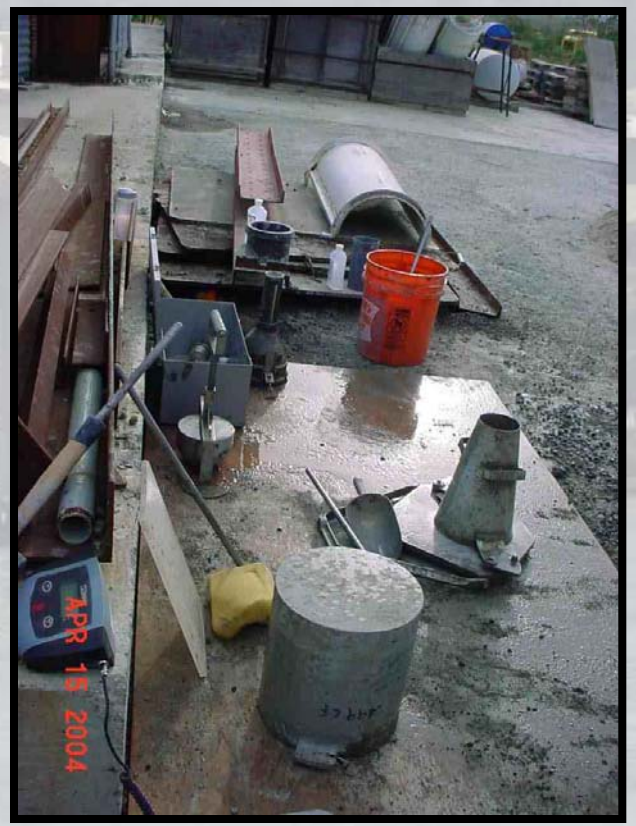
Equilibrium Unit Weight - 120 pcf +0/-5

Modulus of Elasticity-At least 3.4×10^6 psi @ 28 days

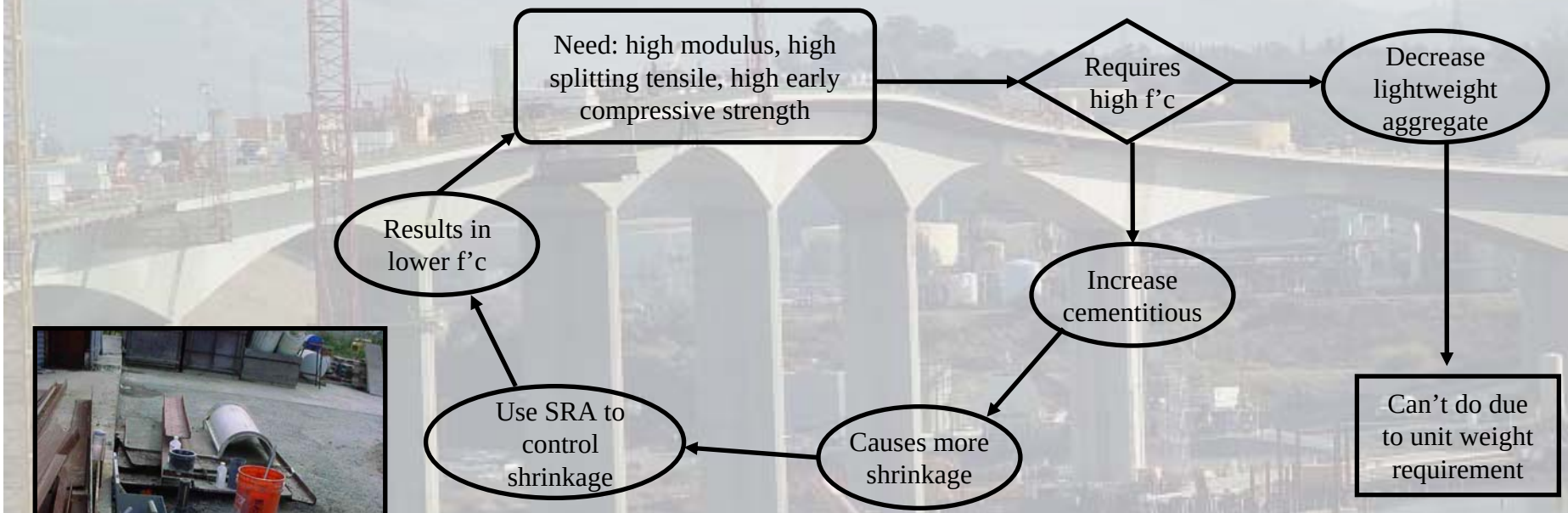
Creep- The specific creep coefficient, as determined in accordance with ASTM C 512, after 365 days of loading, shall not exceed 0.48 millionths/psi.

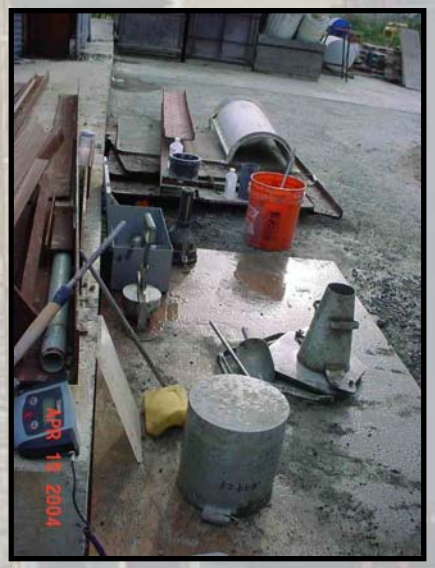
Shrinkage- The shrinkage strain shall not exceed 0.05% after 180 days of drying

Tensile Strength- The tensile strength shall be not less than 464 psi at 14 days, 493 psi at 28 days and 522 psi at 90 days

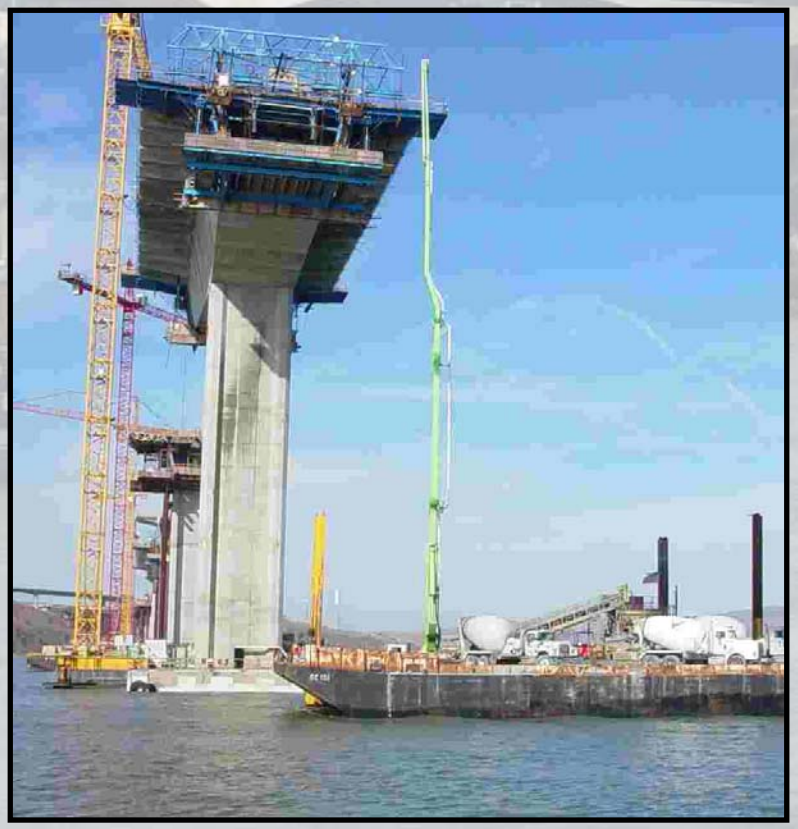


Interaction of Structural Concrete Properties

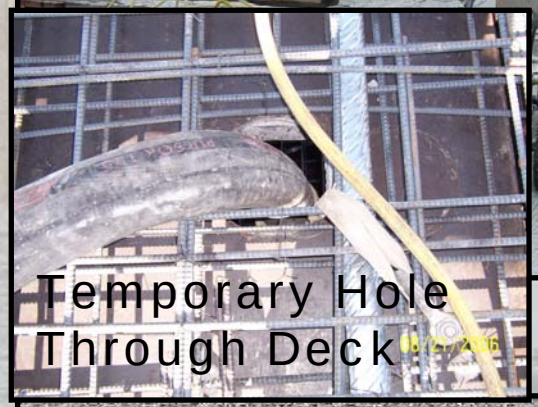


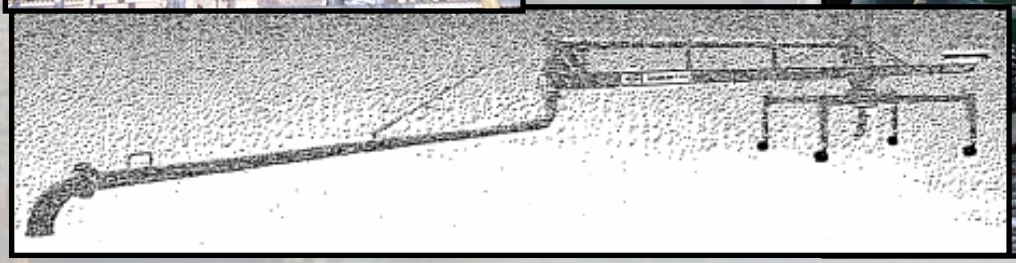


Lightweight Concrete Placed w/Both Pumps and Buckets



Krete-Placer Directs Concrete to Segment Portions





Articulated Arm to place to all areas of deck & pour holes / tremies to areas below deck

Lightweight Concrete Heat of Hydration Control

Concrete Batched with Chilled Water and 30% Ice

Dosed with Liquid Nitrogen

Post Cooling with Water
Running through PVC Tubing

Expansion Joint Functions

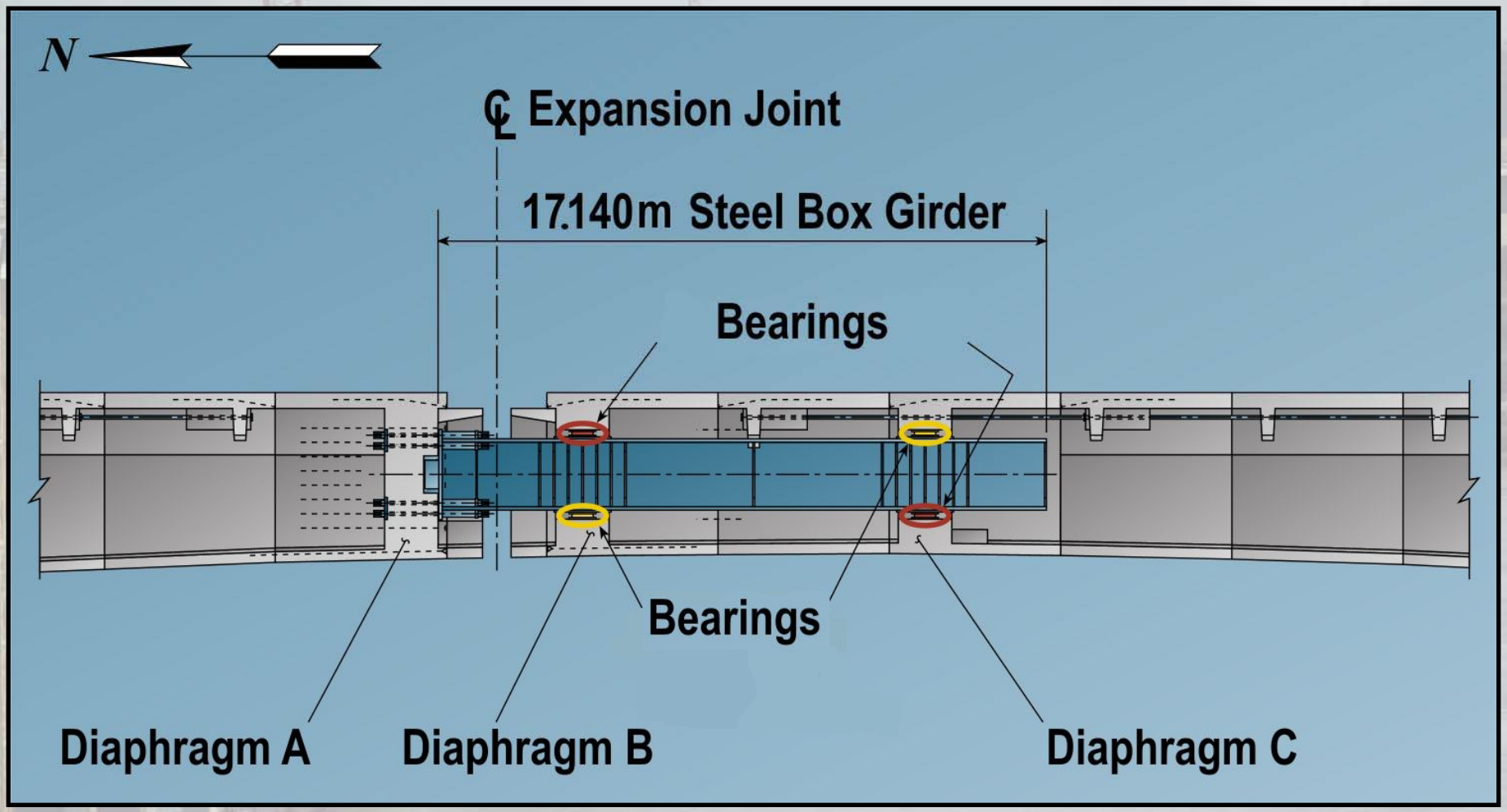
Structural level

- transfer vertical and lateral forces
-allow for longitudinal displacement
- minimize transverse and vertical displacements
- minimize rotations

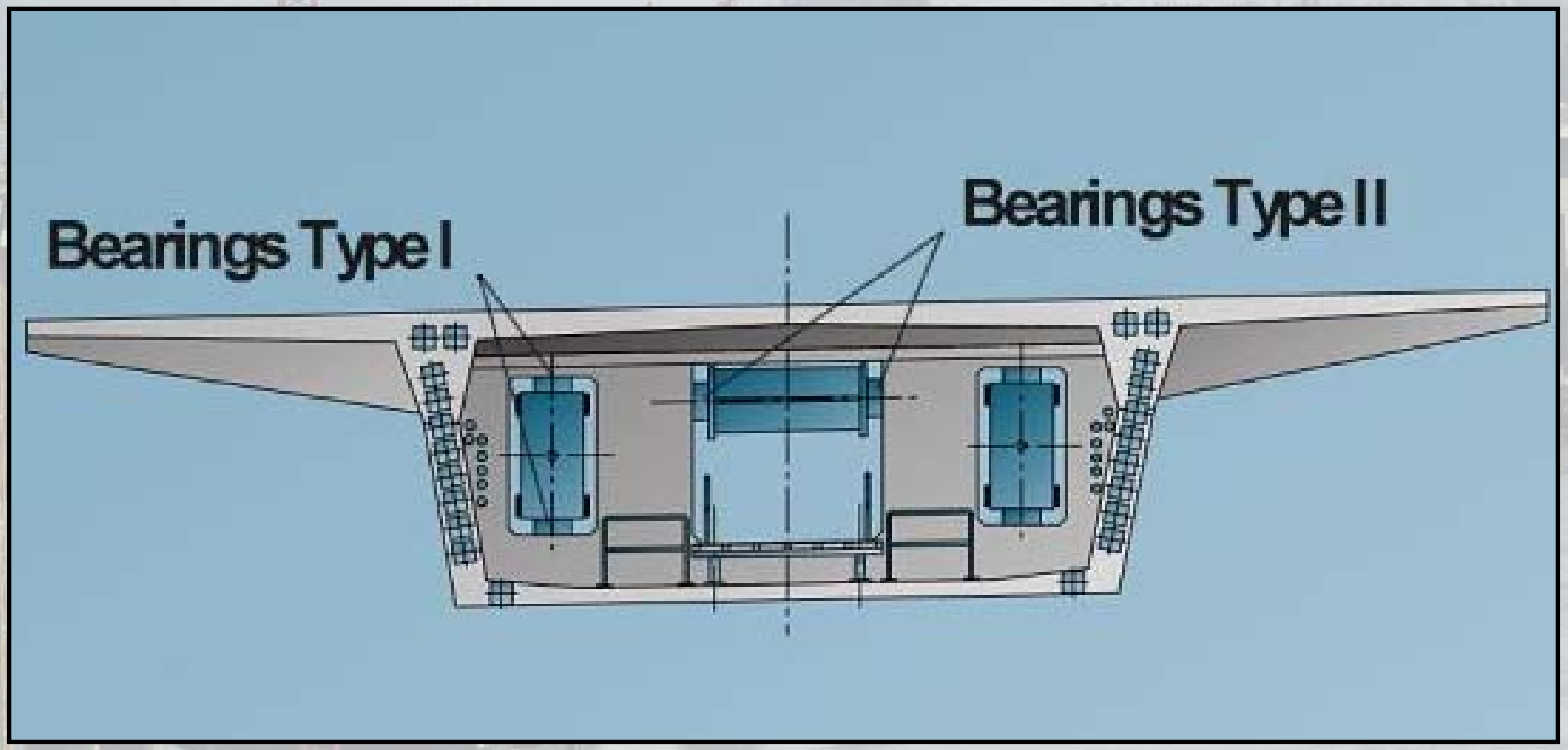
Roadway level

- bridge the gap between structures
- allow for movements
- prevent ingress of water

Expansion Joint Structural Solution



Expansion Joint Structural Solution



Box Girder Bearings
Type I

Functions:
- Transfer Vertical Loads in Both Directions
- Allows Sliding
- Allows Rotation
- Measure Reactions - Monitoring
- Compensate for Height Variations

Constraints:
- Replacement
- Limited Space

Plate Girder Bearings - Type II

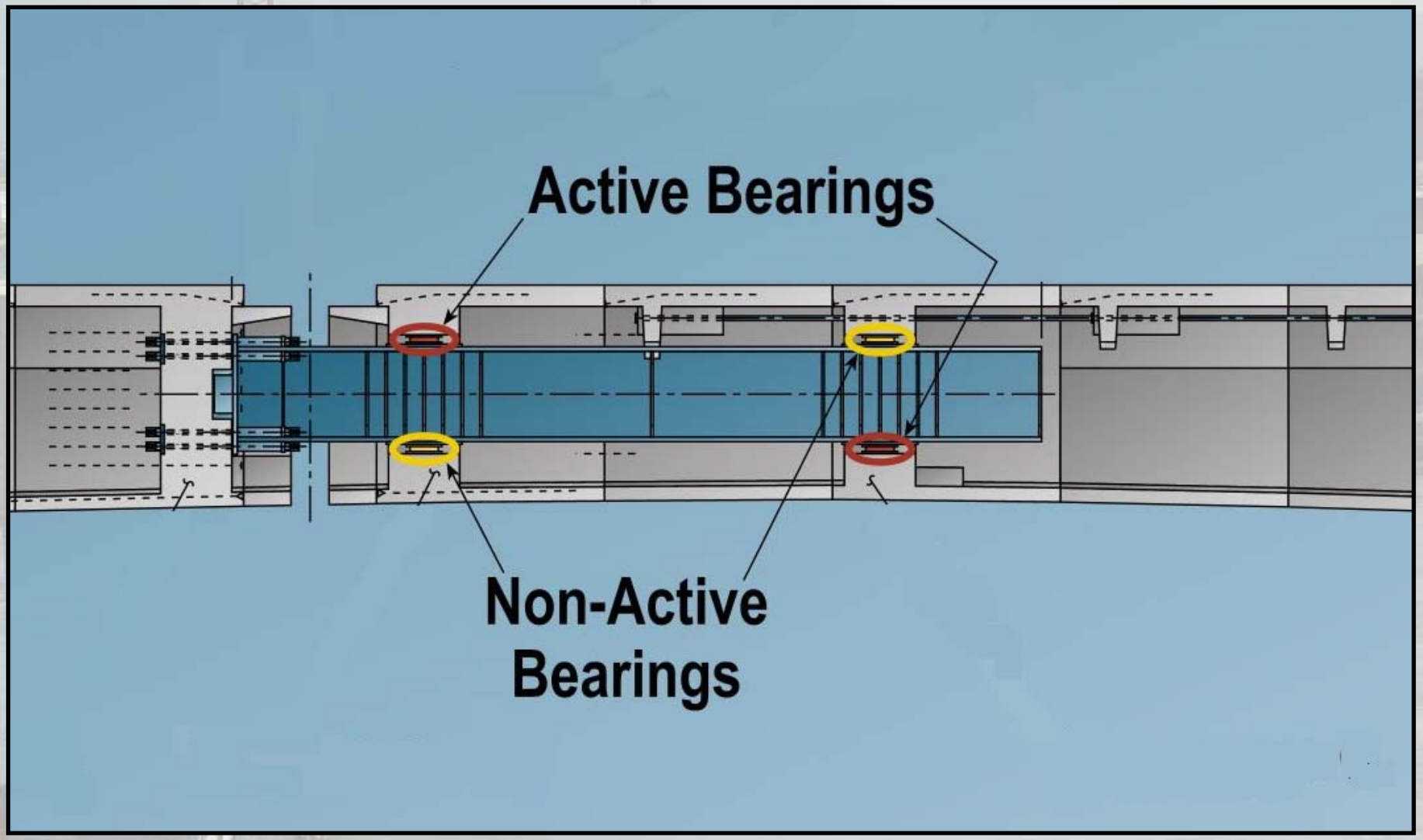
Functions:

- Transfers Horizontal Loads in Both Directions
- Allows Sliding
- Allows Rotation
- Compensate for Height Variations

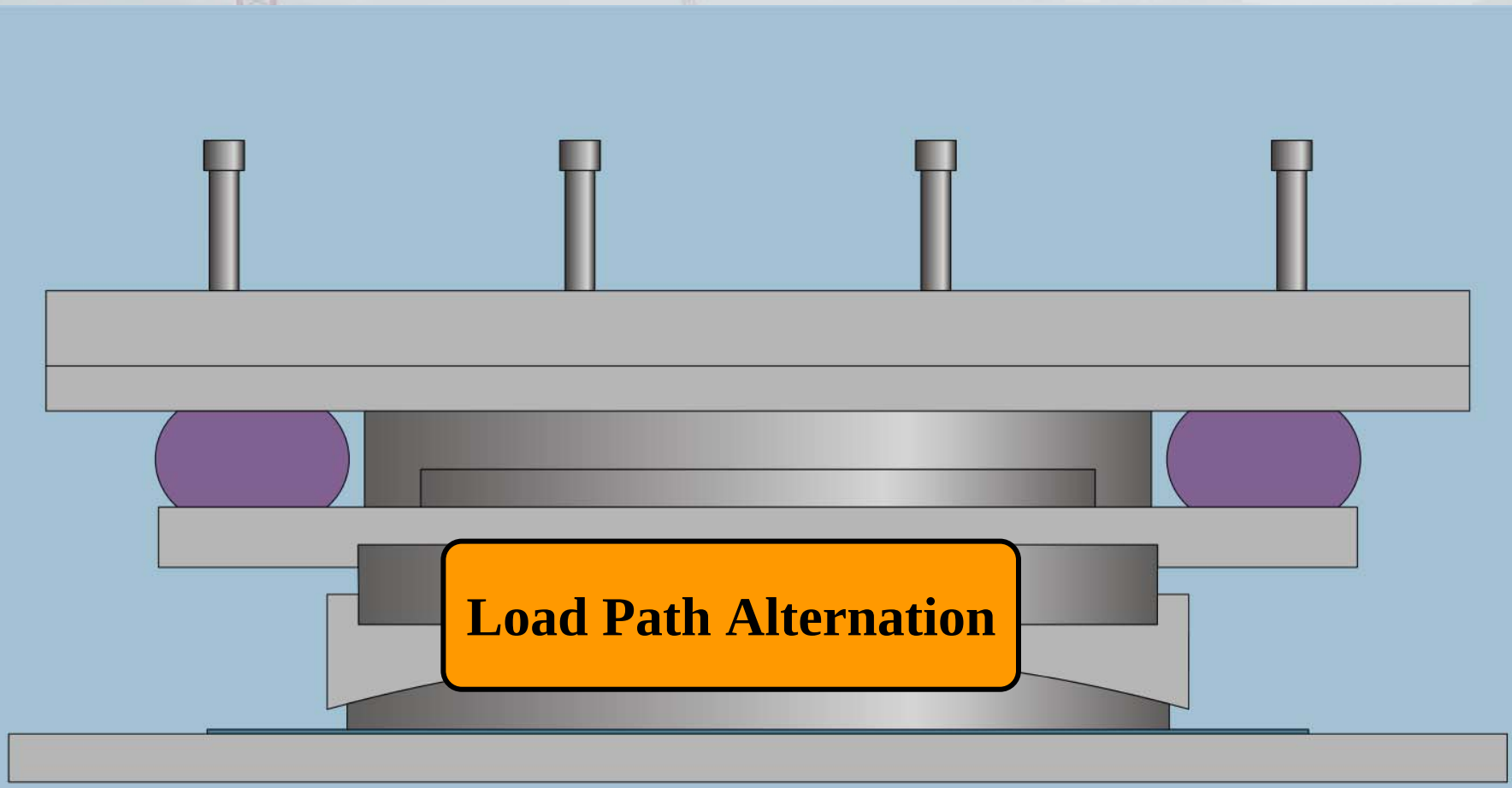
Constraints:

- Installed Vertically
- Replacement
- Limited Space

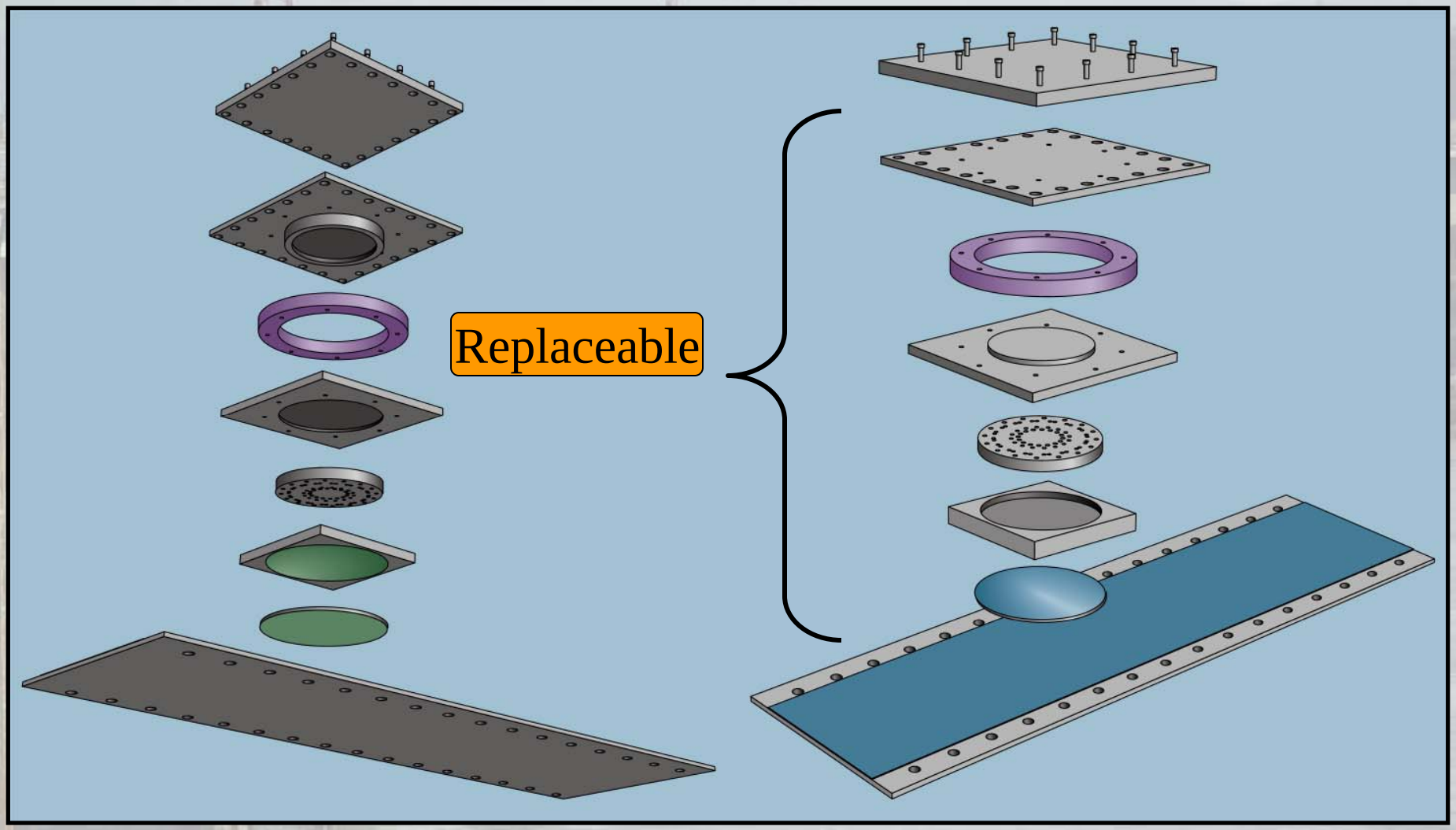
System Behavior - Active and Non-Active Bearings



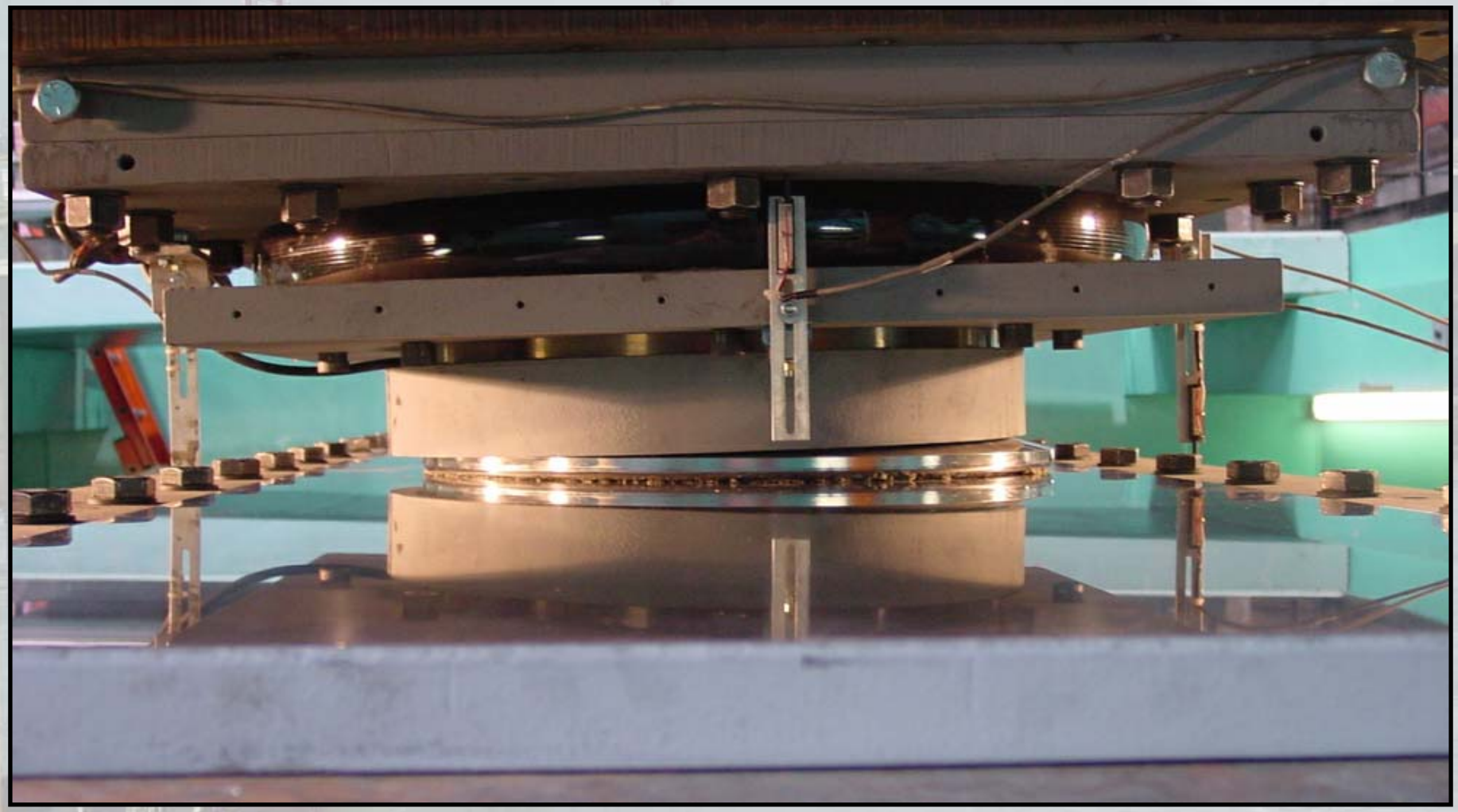
Height Compensation – Pre-Compression



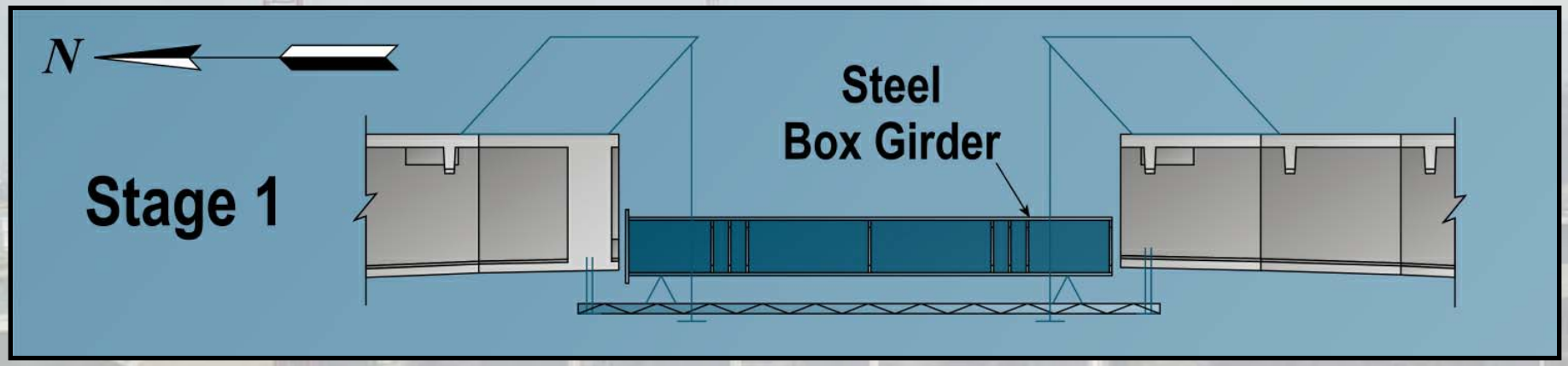
Replaceable Seismic Bearing



Full Scale Proof Testing @ UC San Diego

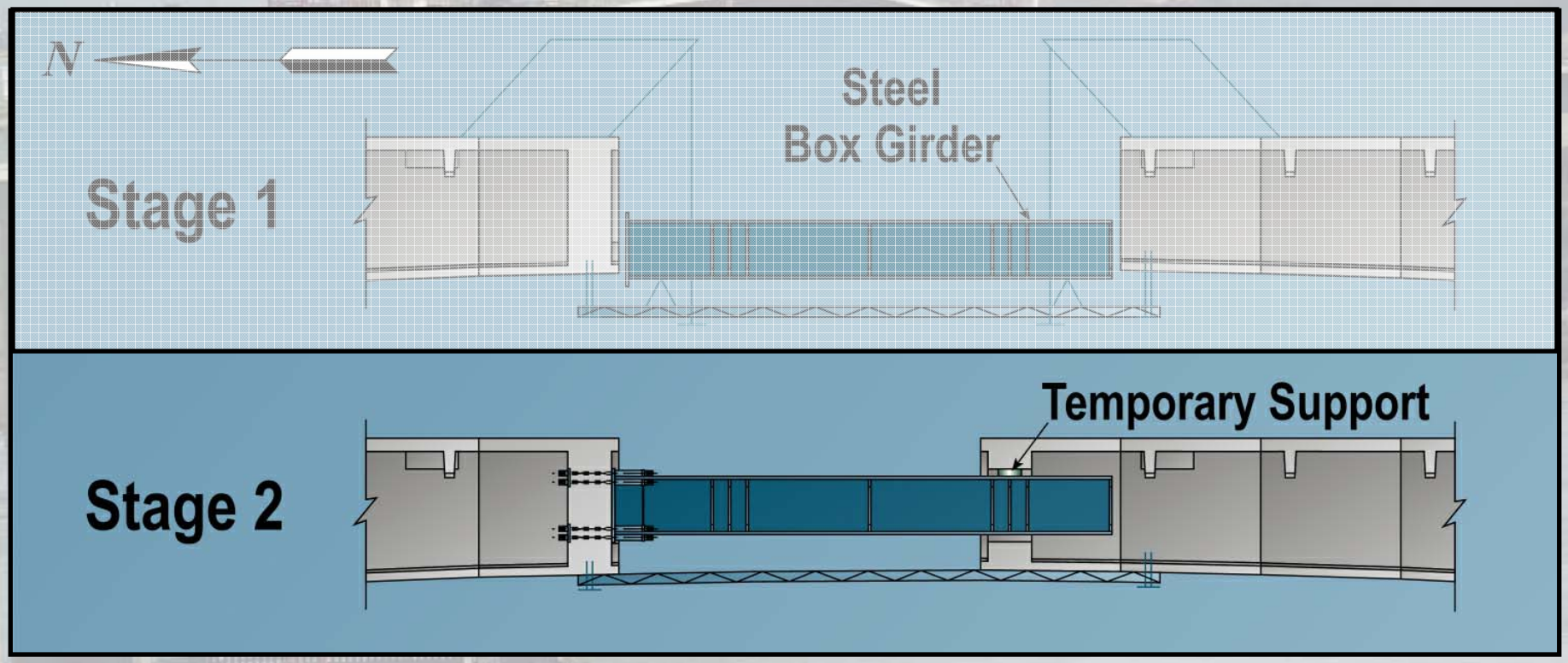


Installation – Build Diaphragms Around Girders



From Land To Sea To Structure

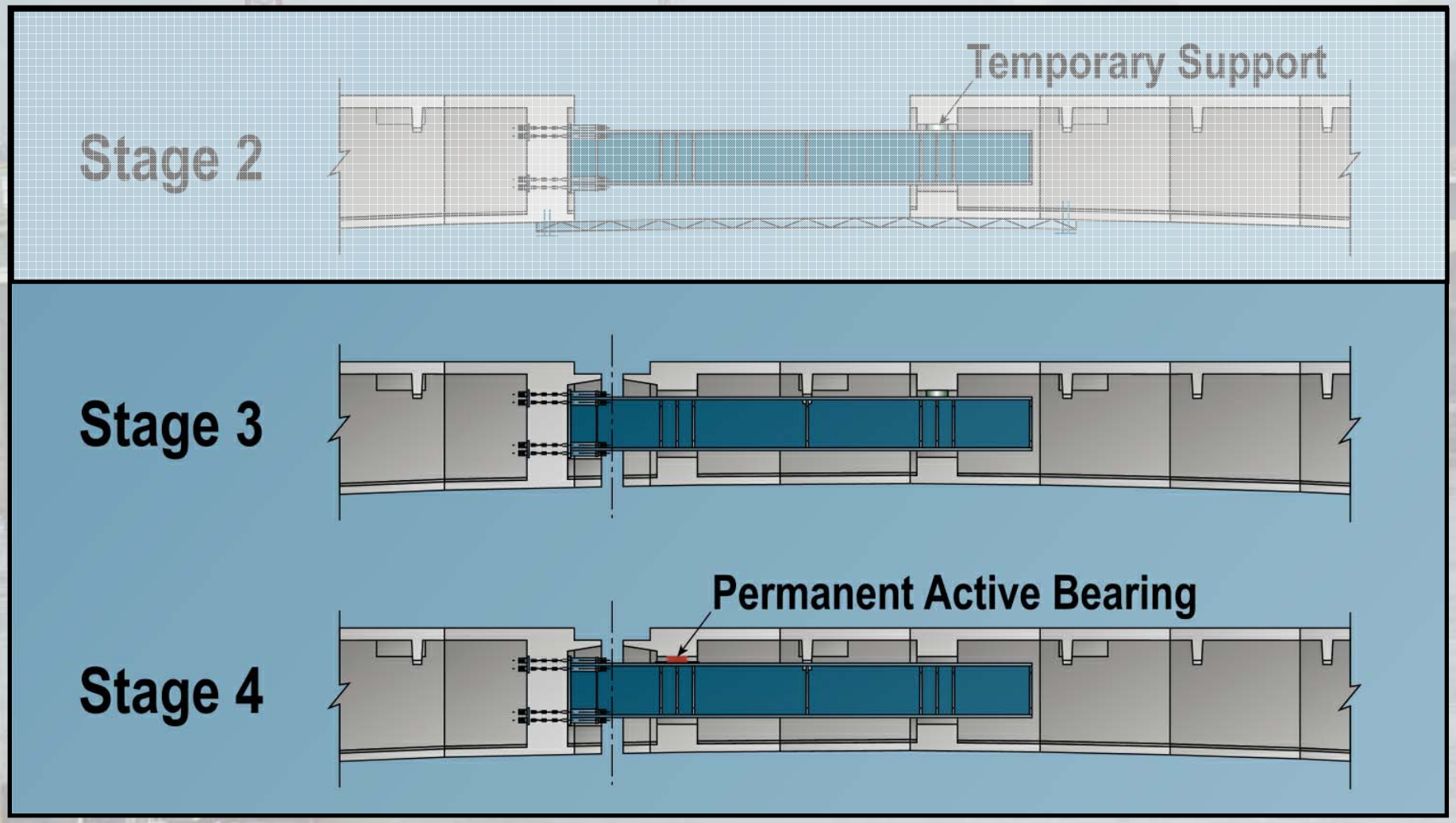
Installation – Place Girders-Build Diaphragms



Place Box Girders – Build Diaphragm “C”

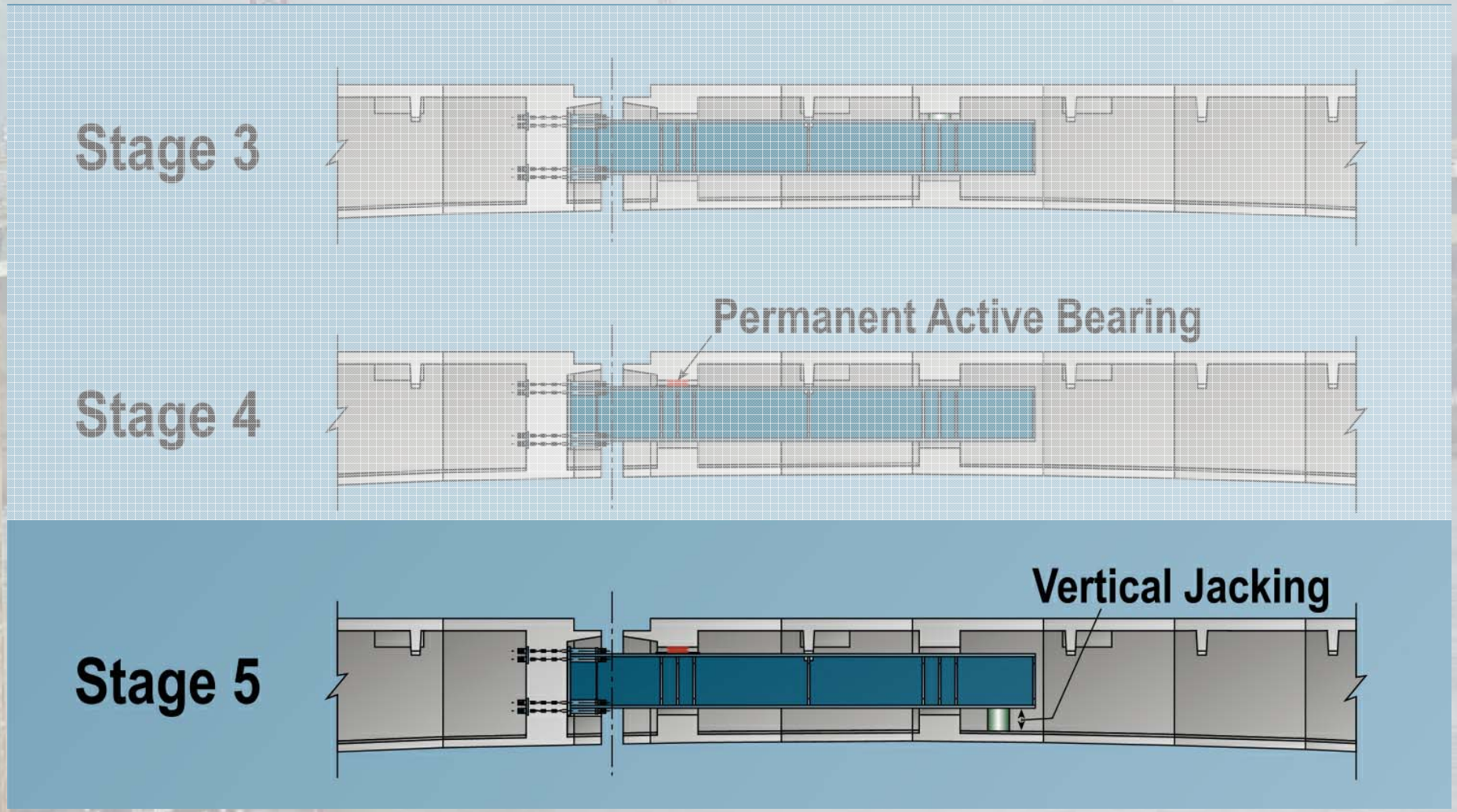
Installation – Temporary Bearing after Construction of Diaphragm C

Construct Diaphragm “B” Install Bearing

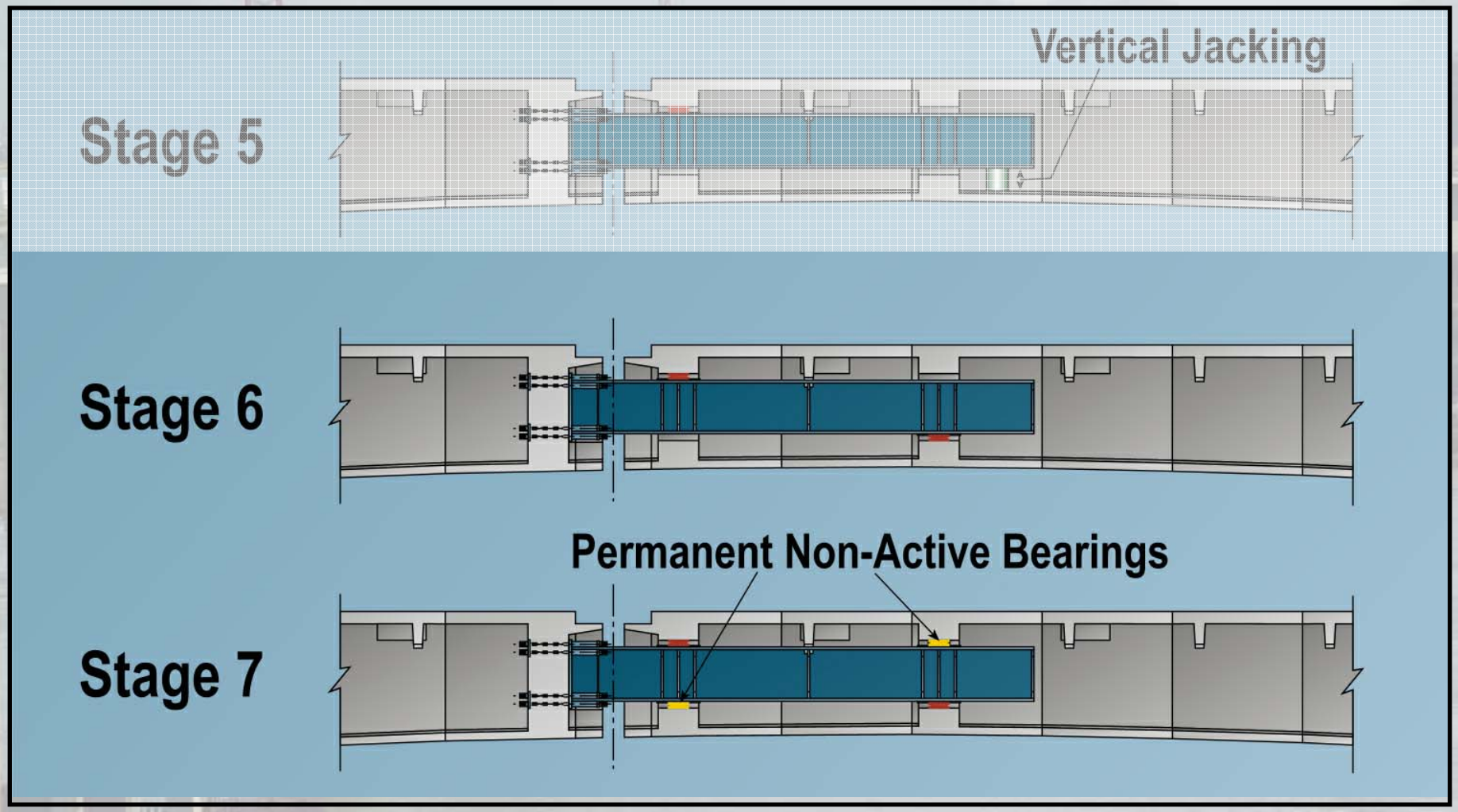


Permanent Bearing Installed – Diaphragm “B”

Installation – Vertical Jacking to Pre-Flex Beam



Install 2nd Active Bearing & Non-Active Bearings



Bearing Installation

Summary

Expansion Joint

- Complex Mechanism - Functionality is Key to Successful Operation of the Bridge. Especially in Seismic Regions.

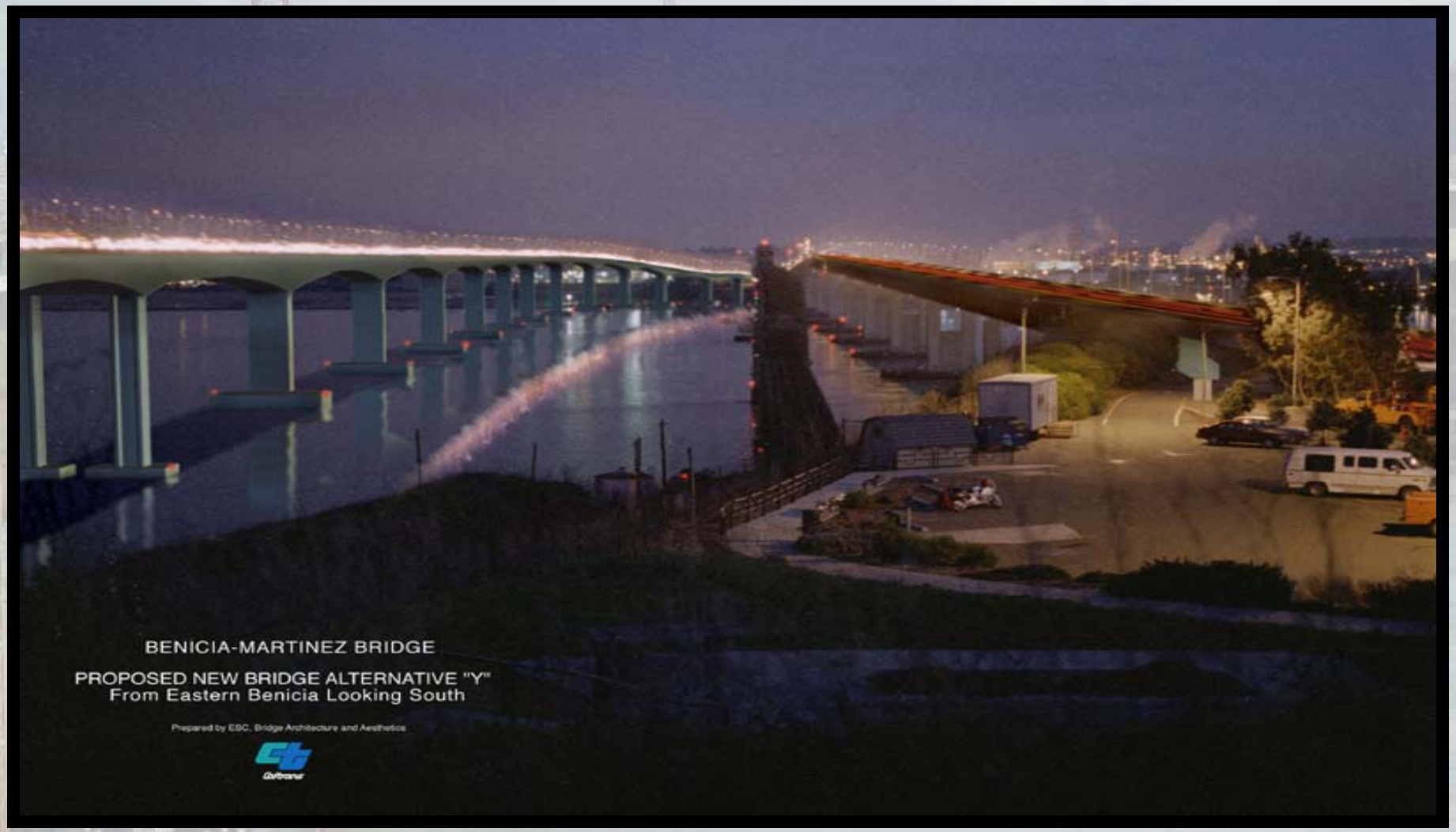
- Overall Performance Depends on Individual Components

- Robust, Simple, Replaceable & Maintenance Free Mechanism

- Utilizes Conventional Structural Materials

- Proof Testing of Custom Design Items

Nighttime Simulation - Looking South



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Questions?

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