Seismic Retrofit and Rehabilitation of the North Torrey Pines Road Bridge

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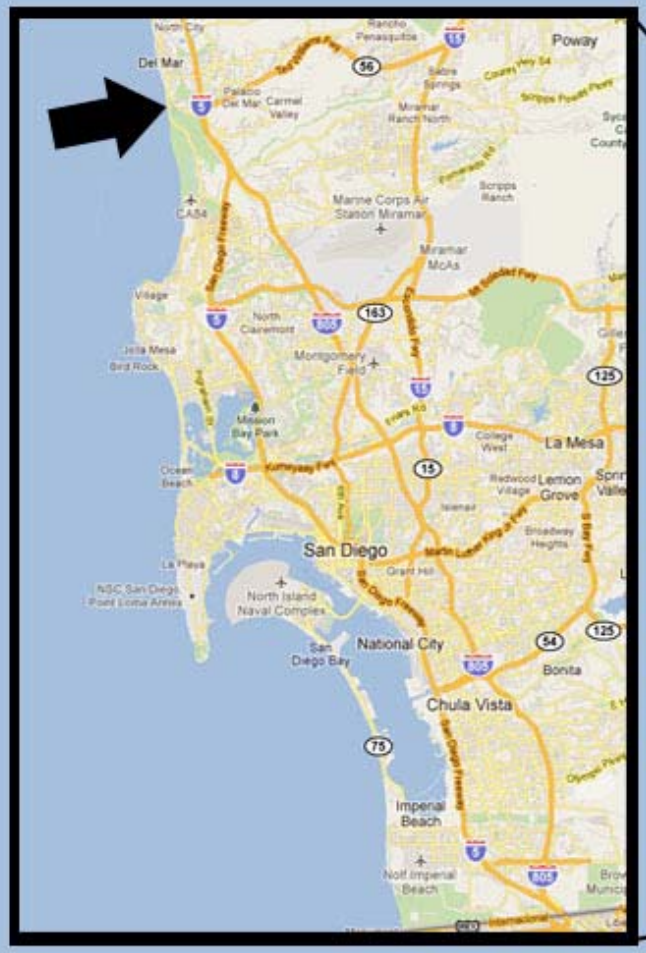
Presentation Outline

- Project Description / Background
- Bridge Corrosion & Seismic Issues (As-Built)
- Seismic Analysis & Design
- Bridge Retrofit/Rehab Construction

Bridge Location

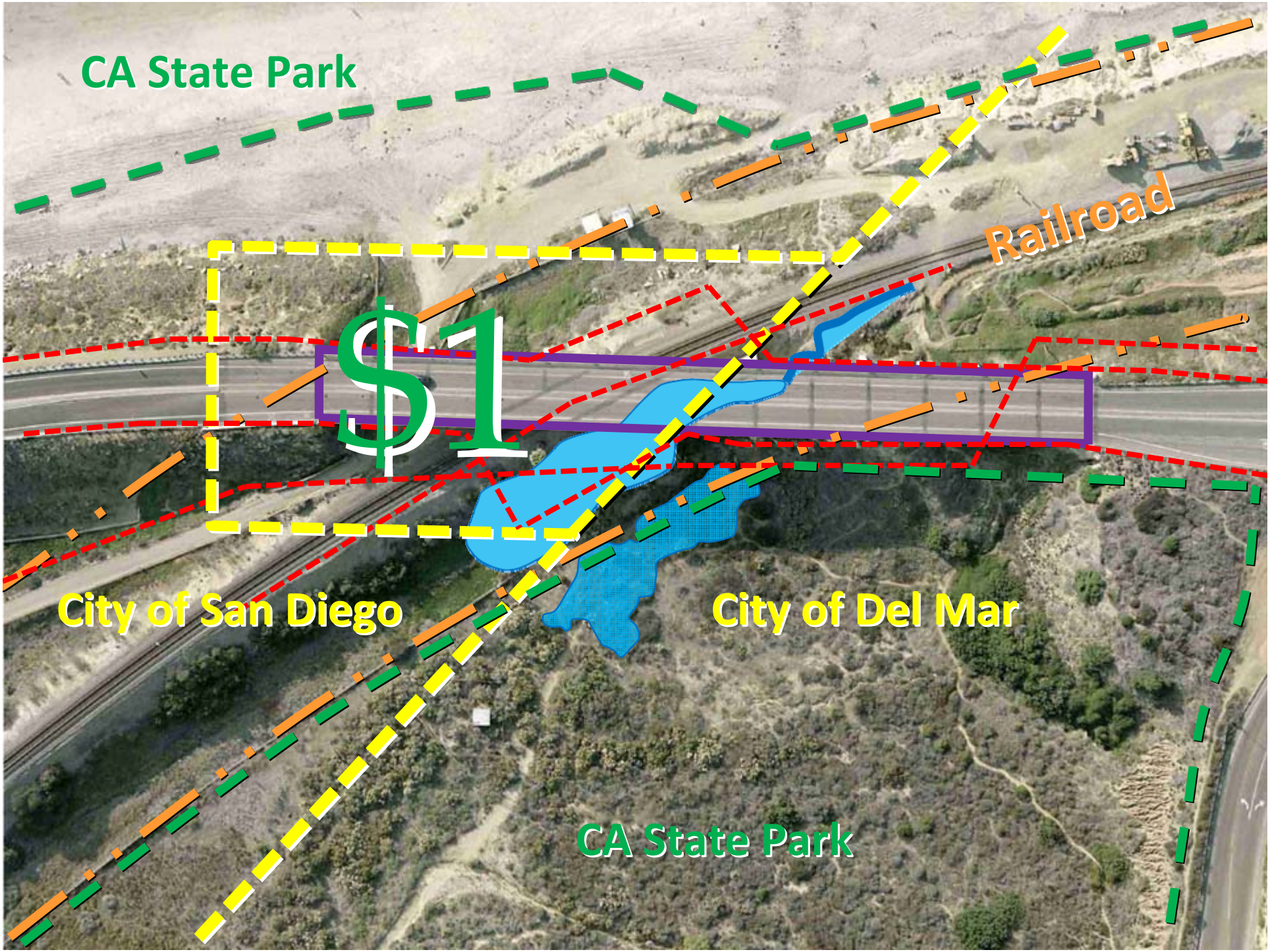


North Torrey Pines Road Bridge

- **Constructed in 1933 w/ 50-yr Design Life**
- **Owner: City of Del Mar**
- **Historic Resource**
  - City of Del Mar Local Historic Landmark
  - California Register of Historical Resources
  - Eligible for National Register of Historic Places
- **FHWA High Profile Project**
- **$40M Funded by HBRRP & CA Prop 1B**

Structure Description

- 550-ft-long tee-beam superstructure
- Bents 2-12 normal; Bents A-C skewed 63 deg
- Bents 2-7 on piles; Bents 8-12 spread footings

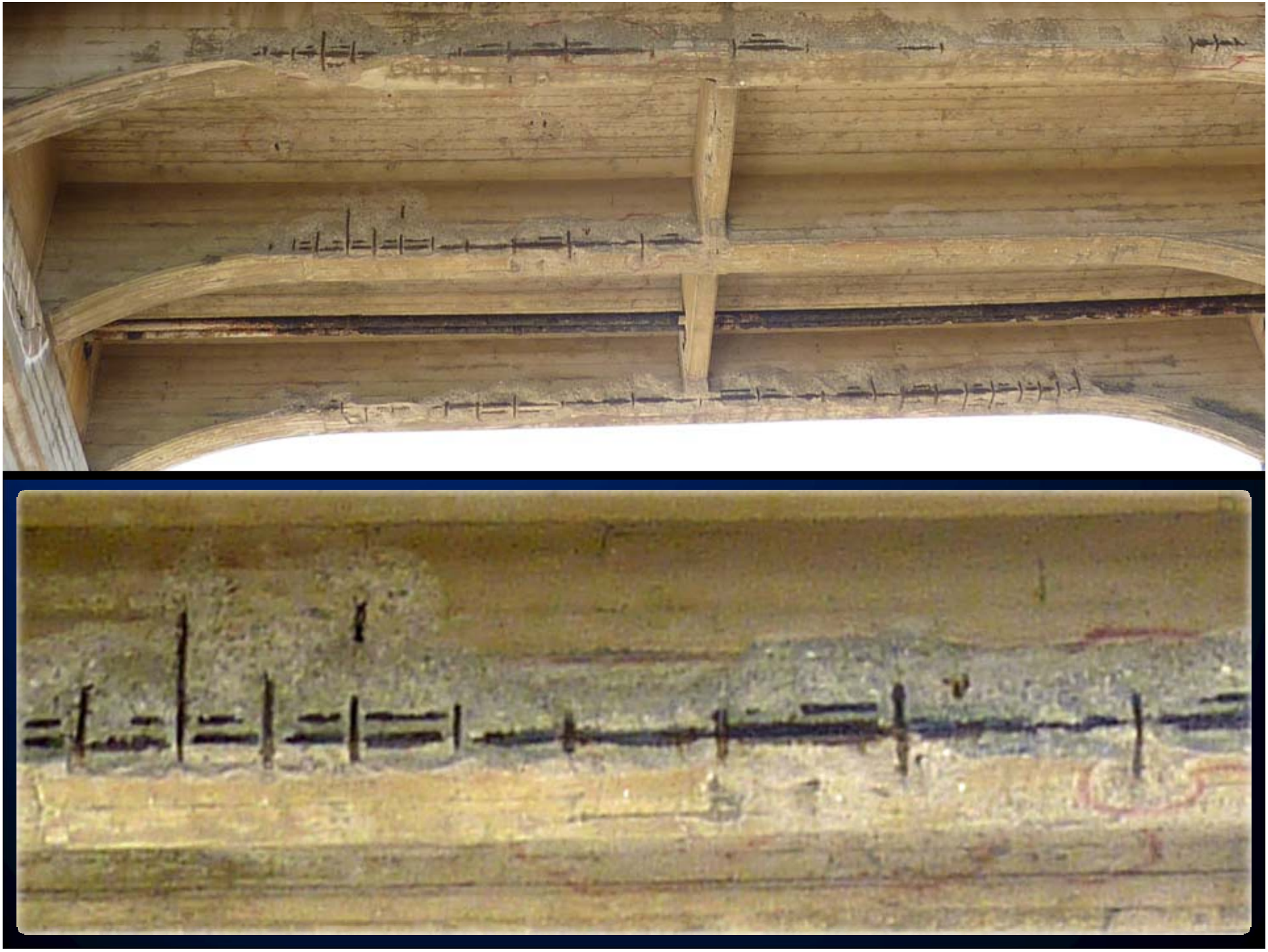

CA State Park
Railroad
$1
City of San Diego
City of Del Mar
CA State Park

Issues

- Corrosion and deteriorated concrete
  (especially superstructure)
- Extensive seismic issues

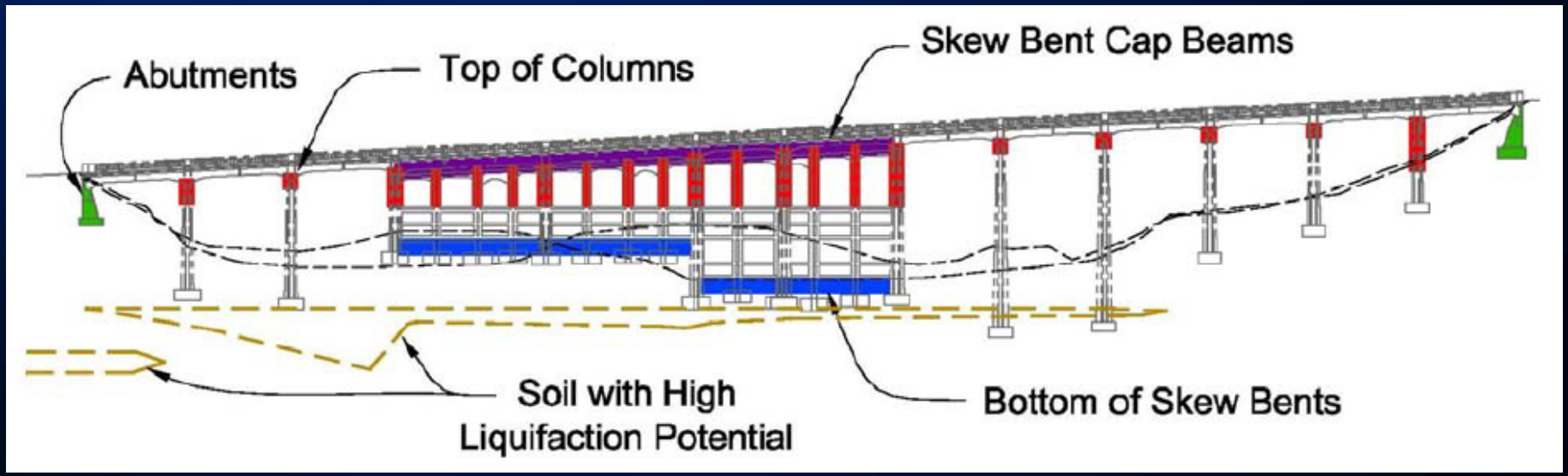

NO ENTRY
LOOSE CONCRETE
ABOVE


WARNING
RESTRICTED AREA
DUE TO THE POTENTIAL DANGERS AROUND
AND BENEATH THIS BRIDGE, ALL PERSONS
ARE RESTRICTED FROM PROCEEDING
BEYOND THIS POINT
PELIGRO
AREA RESTRINGIDA
POR LOS PELIGROS POTENCIALES
ALREDEDOR Y ABAJO DE ESTE PUENTE
TODAS LAS PERSONAS ESTAN RESTRINGIDAS
DE NO PASAR DE ESTE PUNTO



As-built Analysis

- Liquefaction/slope stability
- All columns & abutments are shear deficient
- Large substructure displacements
- Short top of bent seats
- Skew bent stiffness is large and demands require extensive retrofit (caps, columns, joints)



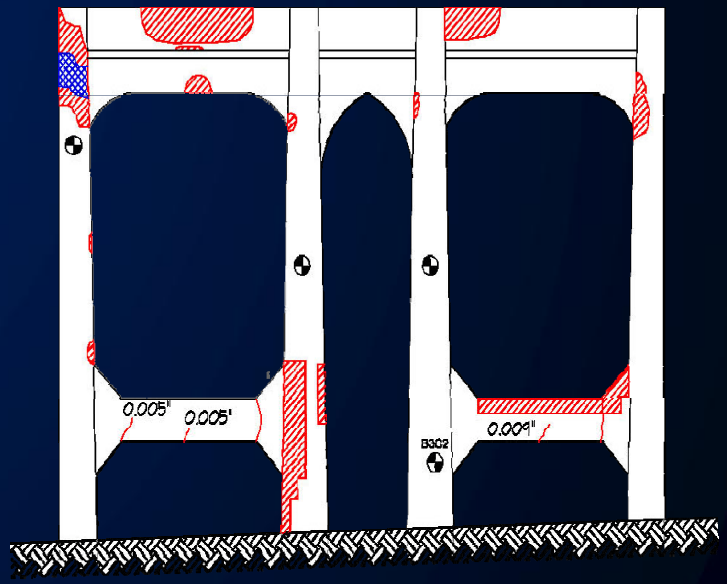
Scope

Keep the bridge!!!

1) Ensure structural integrity
   - Seismic; Corrosion
2) Preserve historic resource
   - Maintain historic eligibility
3) Maintain railroad clearances

Corrosion Management

- Substructure Rehabilitation Options
  - Total Replacement → *Loss of historic status*
  - Ongoing patch and repair
  - Chloride Extraction (ECE)
  - Cathodic Protection
- Approved Corrosion Plan
  - Replace corroded materials
  - Cathodic Protection System
    - Mesh anodes + discrete anodes + deep anode well
  - Replace everything above the bearing seats!
  - Regular inspections and maintenance



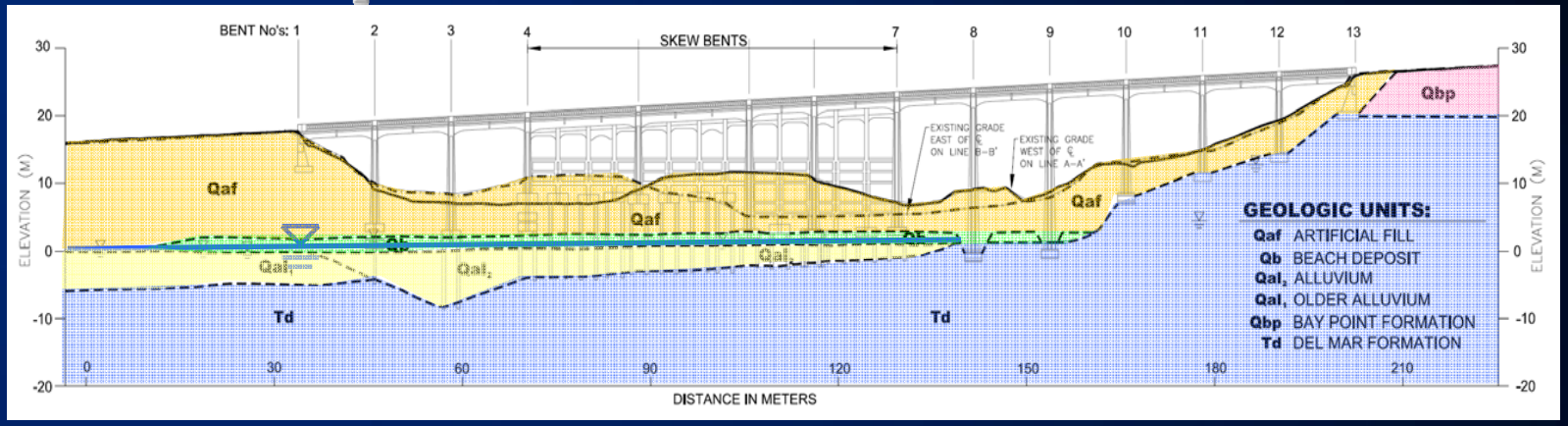
Seismic Analysis & Design

As-Built Analysis→

Criteria → Value Analysis → Retrofit Analysis → Final Design

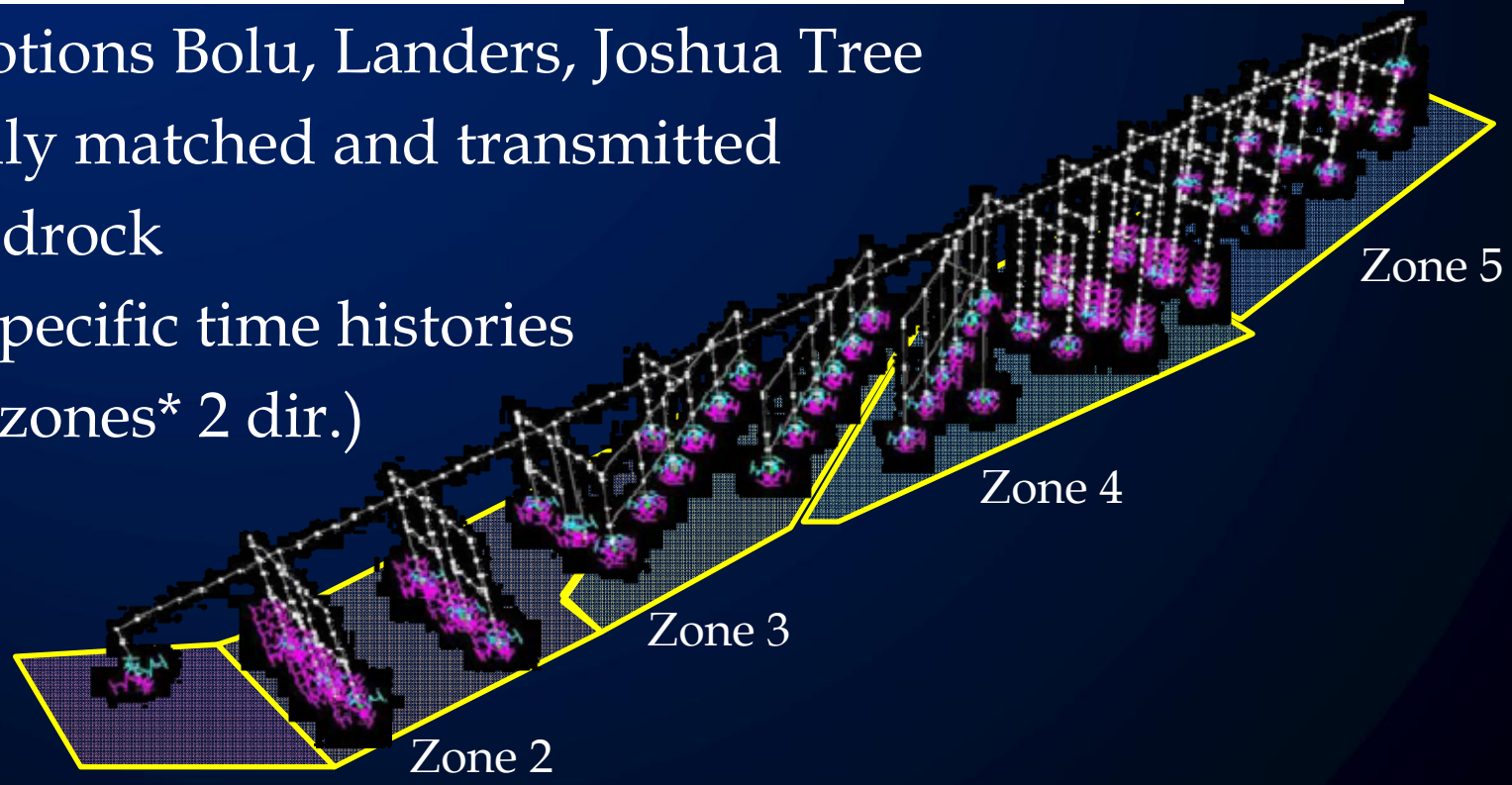
- Criteria = Life Safety
- CA Standard is RSA/Pushover
- Non-Standard Bridge
  - Nonlinear time history analysis
- Assume Mitigated Deterioration/Corrosion

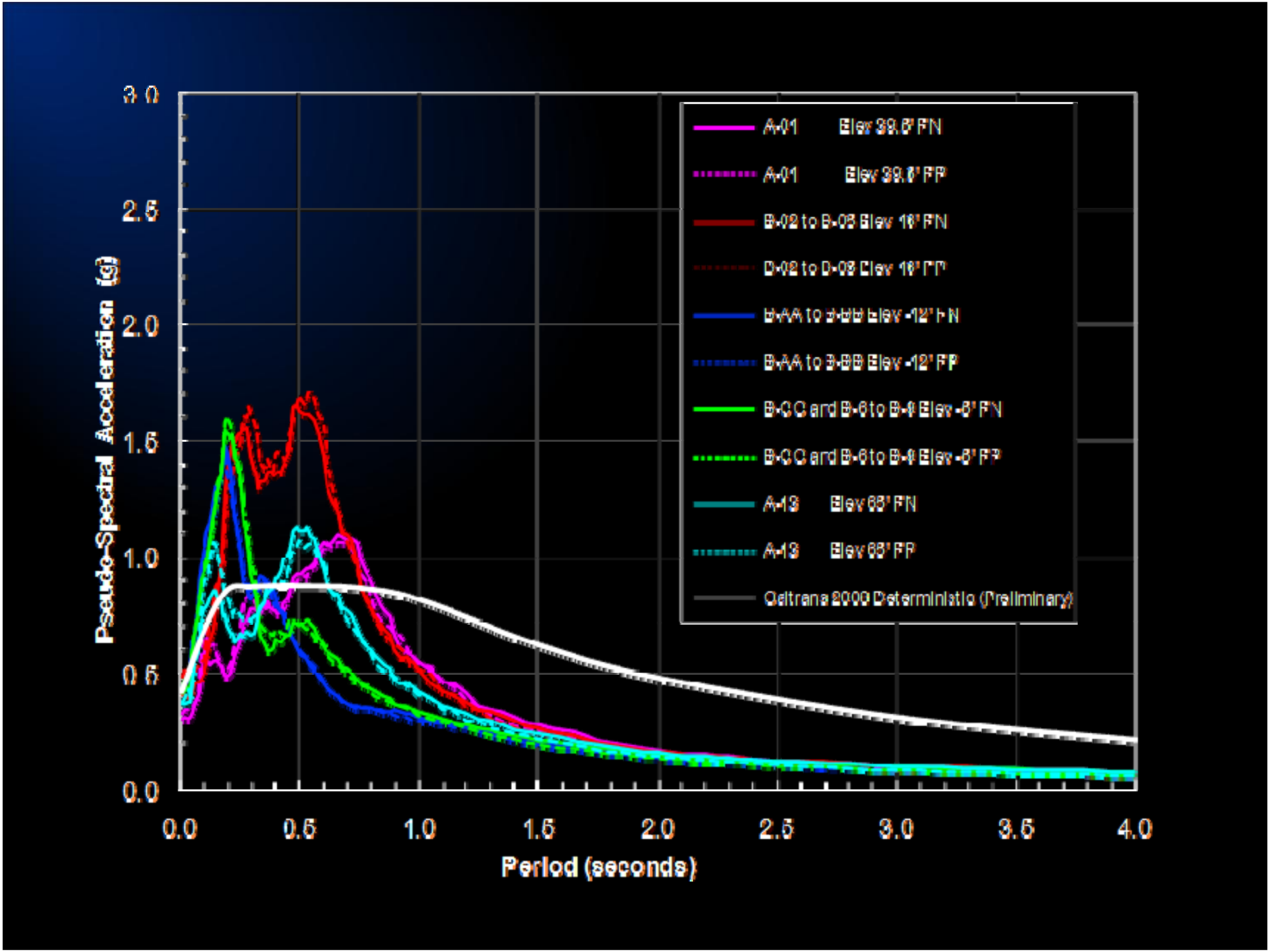
Earthquake Ground Motions



- Seed motions Bolu, Landers, Joshua Tree
- Spectrally matched and transmitted from bedrock
- 30 site specific time histories

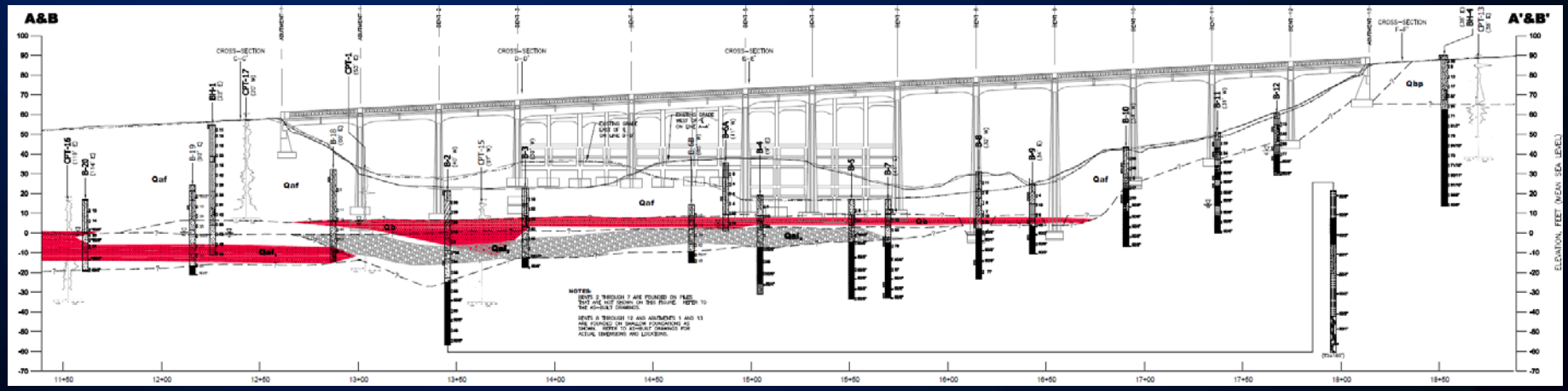
(3 EQ * 5 zones* 2 dir.)

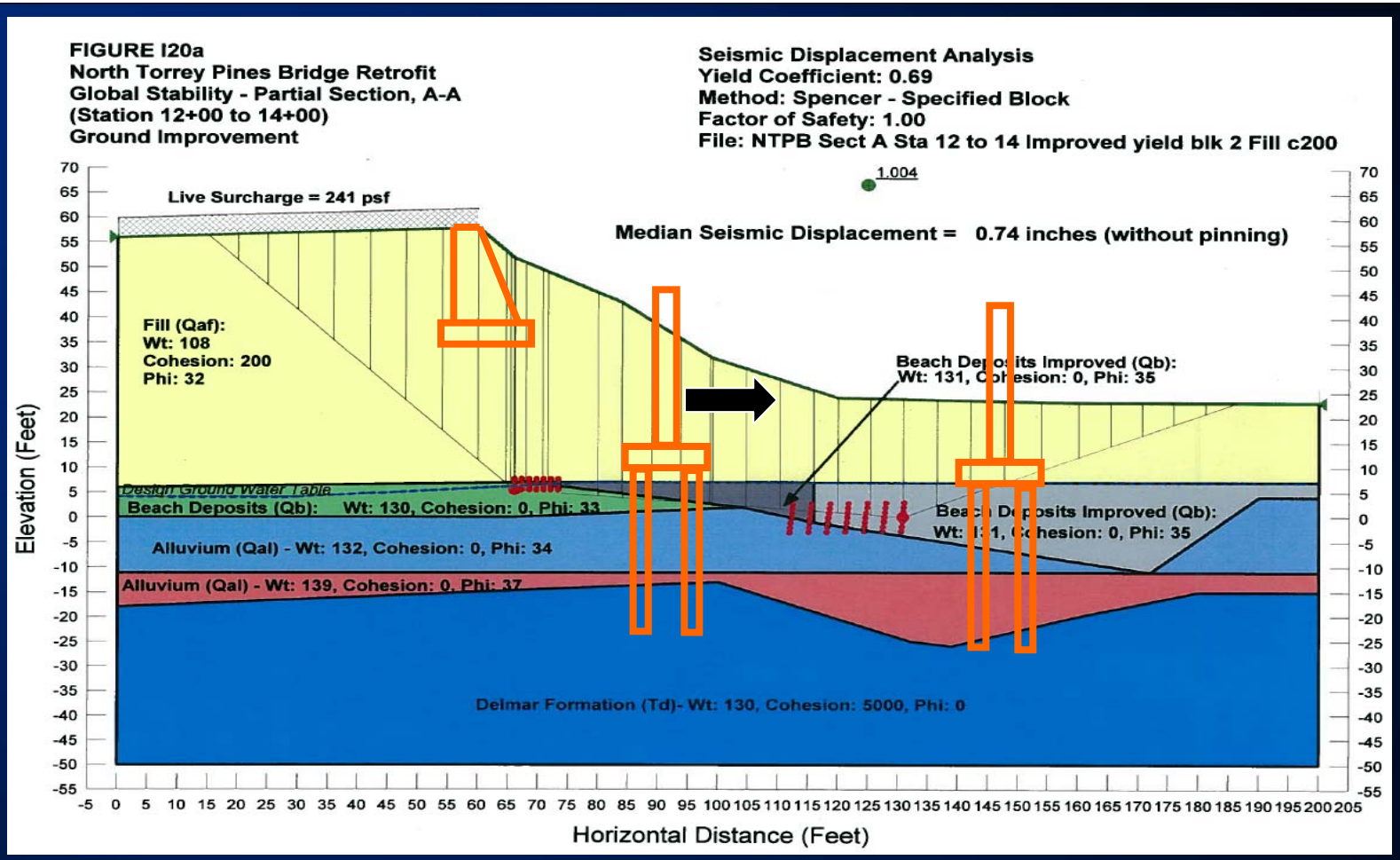



Pseudo-Spectral Acceleration (g)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Period (seconds)
A-01 Elev 39.6' FN
A-01 Elev 39.6' FP
B-02 to B-03 Elev 18' FN
B-02 to B-03 Elev 18' FP
B-AA to B-BB Elev -12' FN
B-AA to B-BB Elev -12' FP
B-CC and B-6 to B-9 Elev -6' FN
B-CC and B-6 to B-9 Elev -6' FP
A-13 Elev 63' FN
A-13 Elev 63' FP
Caltrans 2009 Deterministic (Preliminary)

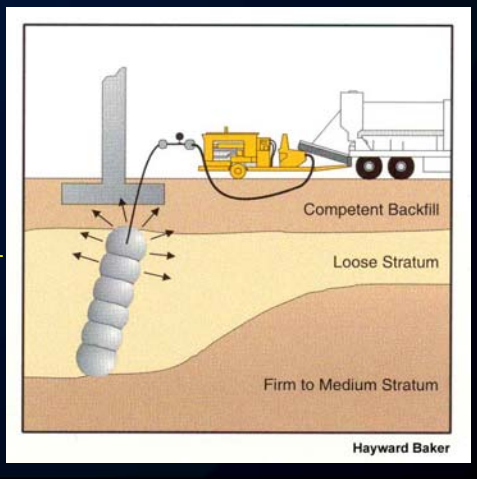
Slope Stability & Liquefaction

- Slope disp. before ground improvement up to 40in
- Liquefied layer depth up to 12ft thick
  - $(N1)_{60}$ of liquefiable layers 12±





During design process VA →
soil improvement most economical solution
(compaction grouting)



Retrofit Development

Value Analysis→

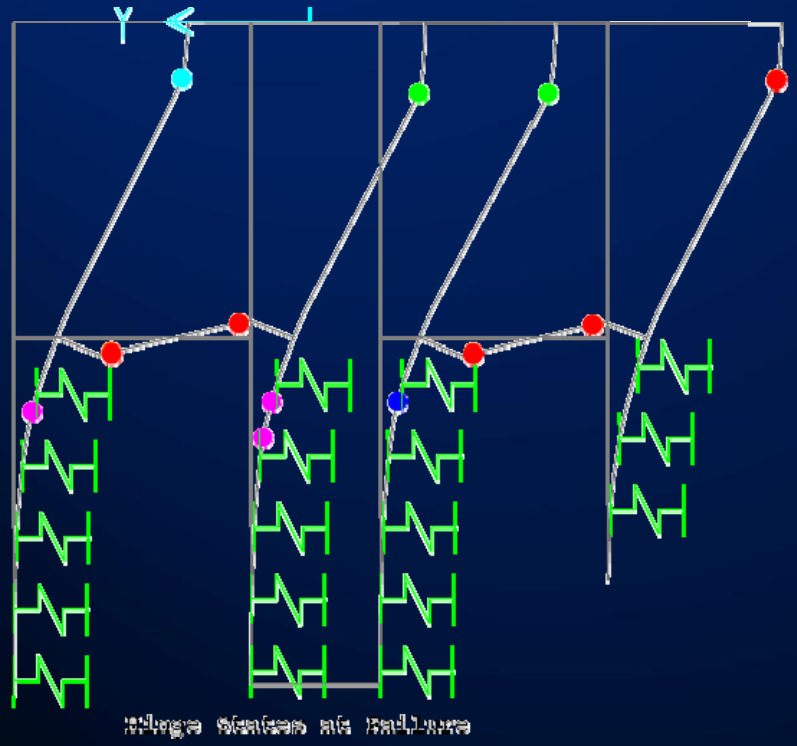
- **Compaction grouting ground improvement**
- **Corrosion repairs and mitigation**
- **New Post-tensioned superstructure**

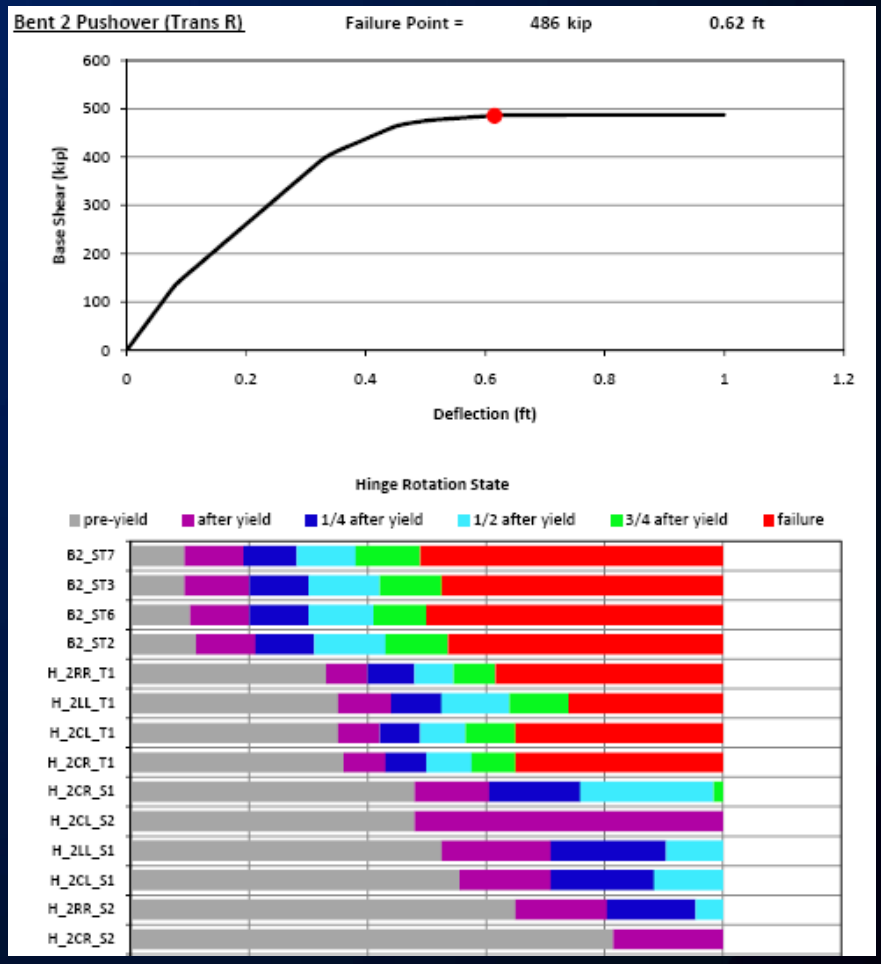
Retrofit Analysis→

- Local Bent Pushover
  - Displacement capacities
  - Capacity protection
- Global System NTHA/RSA
  - Displacement demands
  - Secondary effects

Pushover Analyses

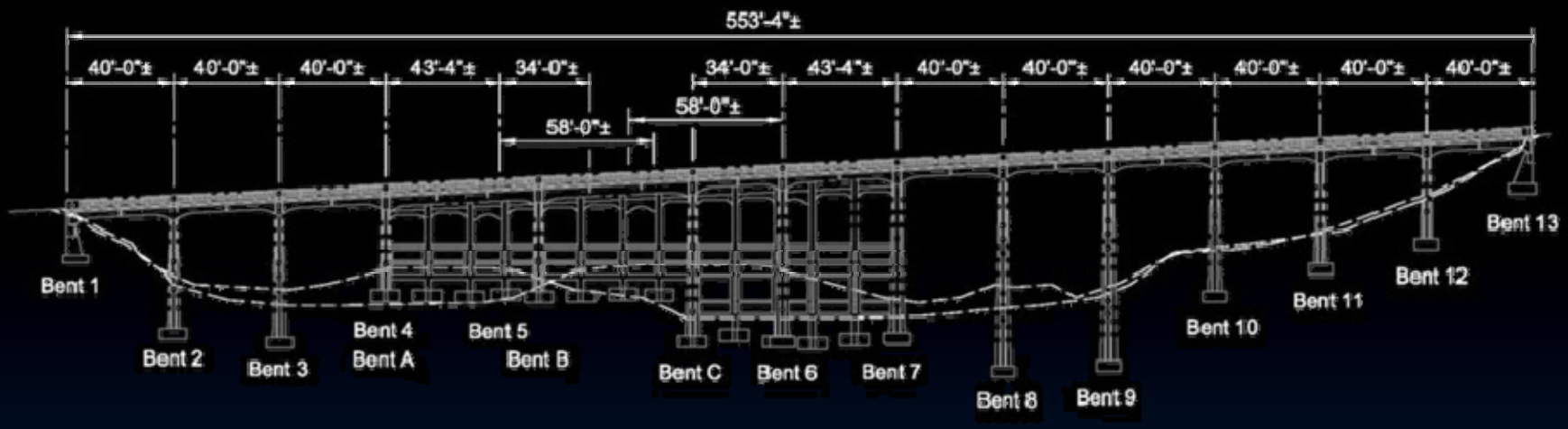
- 3 Each Bent
- Displacement Capacities
- Force Demands (Capacity Protection)



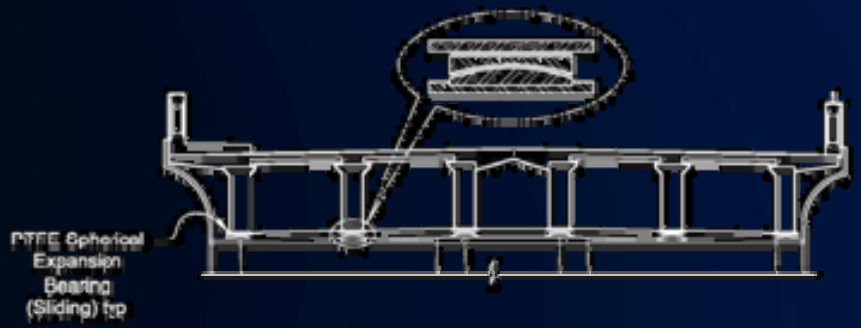


NTHA (RSA Check)

- NTHA: Fiber elements, mult. supp. excitation
- RSA: Cracked stiffness enveloped spectra



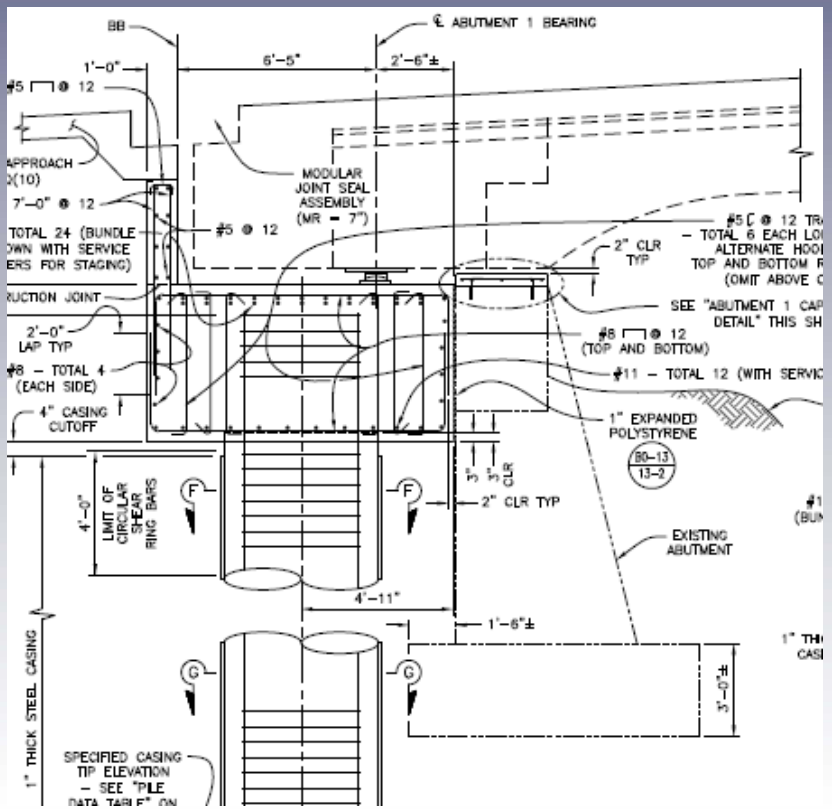
- Typical Bents (2-12)
  - All capacity protection sufficient except column shear
- Skew Bents (A-C)
  - Strong direction requires isolation
    - For strong direction design as elastic with friction from isolators →1.8g + 20% friction (conserv.)



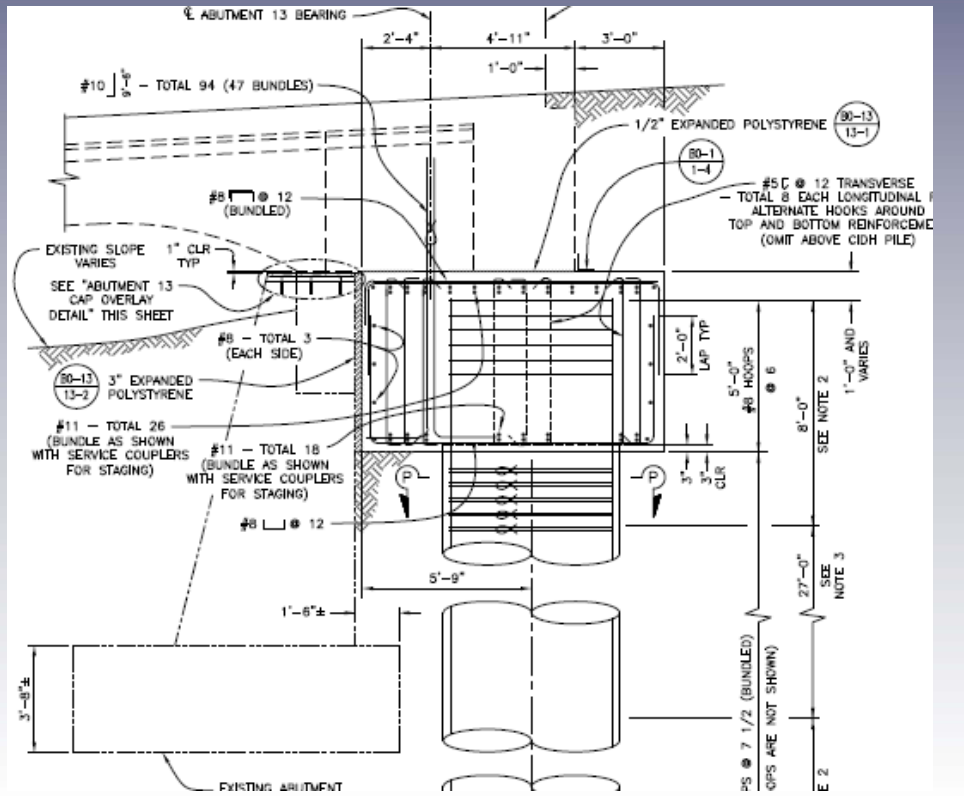
Support Location	Longitudinal Direction	Transverse Direction	Support Location	Longitudinal Direction	Transverse Direction
Abut 1	Free	Pinned	**Bent 6**	Free	Free
Bent 2	Free	Pinned	**Bent 7**	Free	Free
Bent 3	Free	Pinned	**Bent 8**	Pinned	Pinned
Bent 4	Free	Free	**Bent 9**	Pinned	Pinned
Bent 5	Free	Free	**Bent 10**	Pinned	Pinned
Bent A	Free	Free	**Bent 11**	Pinned	Pinned
Bent B	Fixed	Free	**Bent 12**	Pinned	Pinned
Bent C	Free	Free	**Abut 13**	No Bearing (Integral)	

Abutments

- Tuned for seismic demands
  - FB-Multi-Pier pushovers
  - Multiple RSA analyses



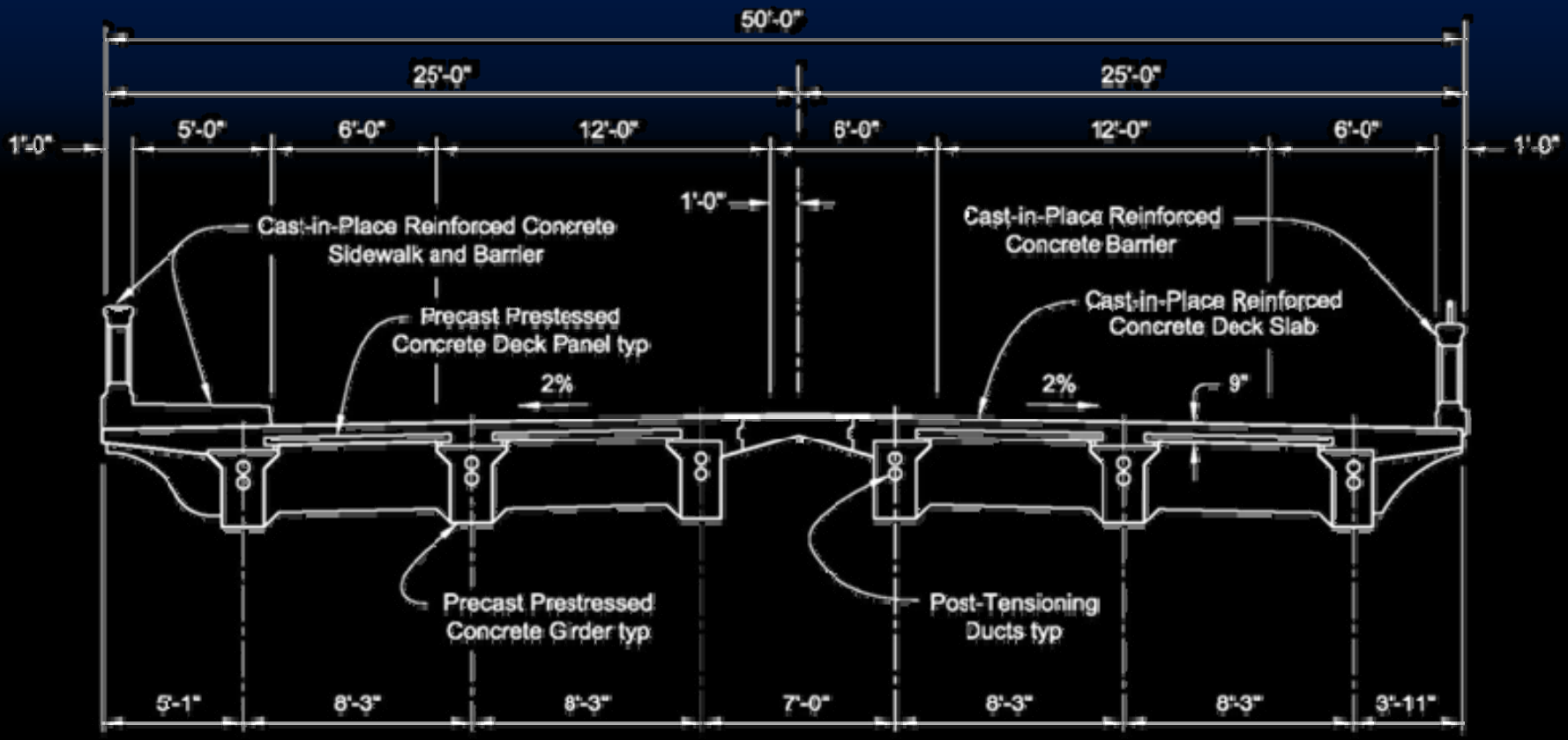
South (free/pin)



North (pin/pin)

Superstructure

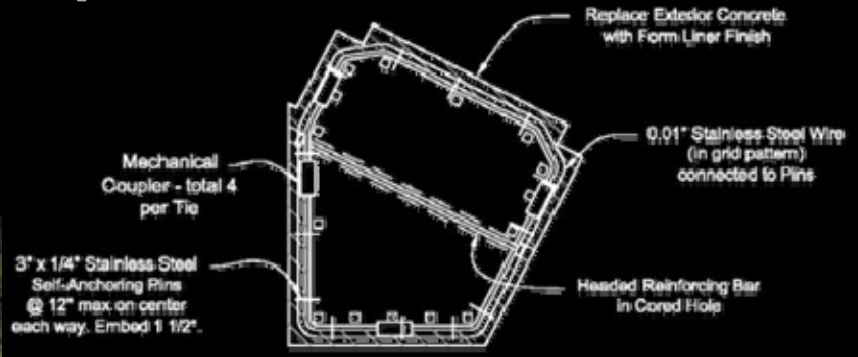
- New continuous precast P/S superstructure
- P/T for seismic stiffness/capacity



Column Repair/Retrofit/Protection

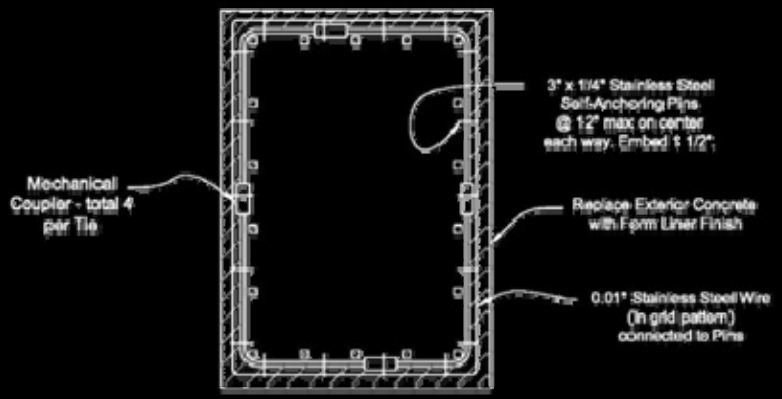
Skin and replace steel...

Really!?!



SKEW BENT
RETROFIT COLUMN SECTION

No Scale



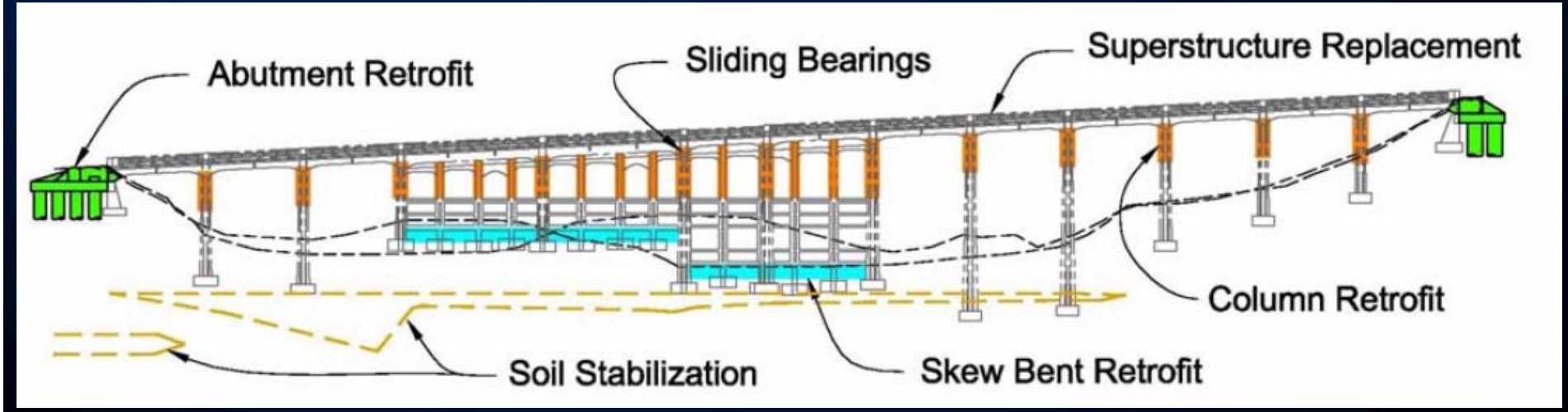
NON-SKEW BENT
RETROFIT COLUMN SECTION

No Scale

Solution

- Compaction grouting ground improvement
- Corrosion repairs and mitigation
- New Post-tensioned superstructure

- *Partial Isolation: Sliding, guided, and fixed spherical PTFE*
- *New deep foundation abutment systems*
- *Skew bent shear walls (below grade)*
- *Shear reinforcement retrofit of columns*

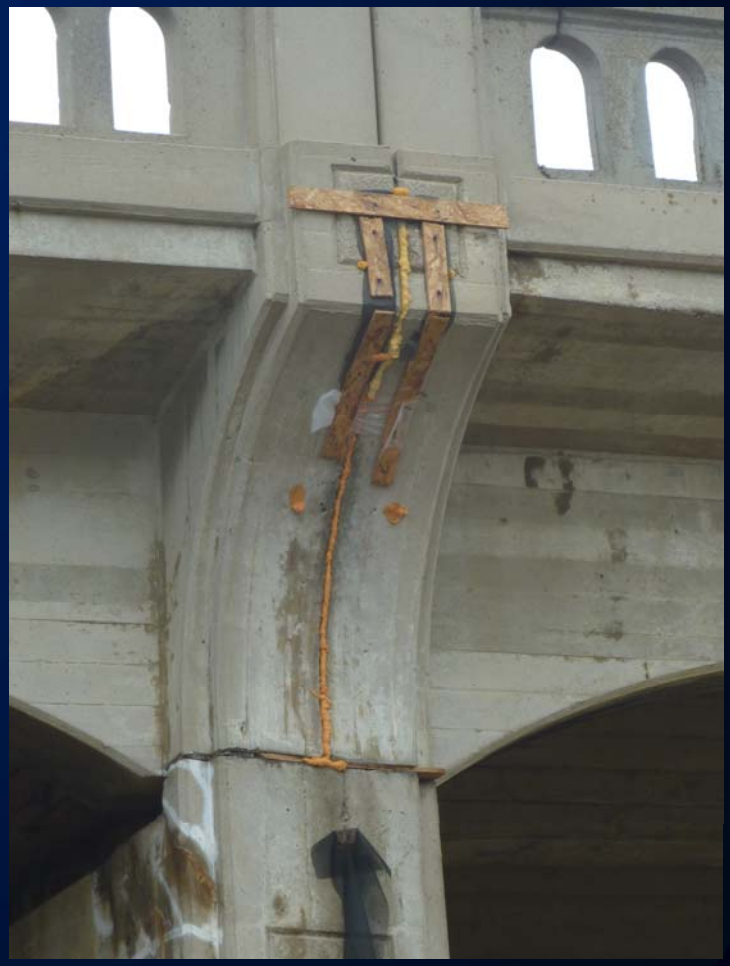


Construction Phase

- Oct 2010: Winning Bidder: Flatiron West, Inc.
- Dec 2010: Notice to Proceed

Ground-breaking!

Bat Relocations



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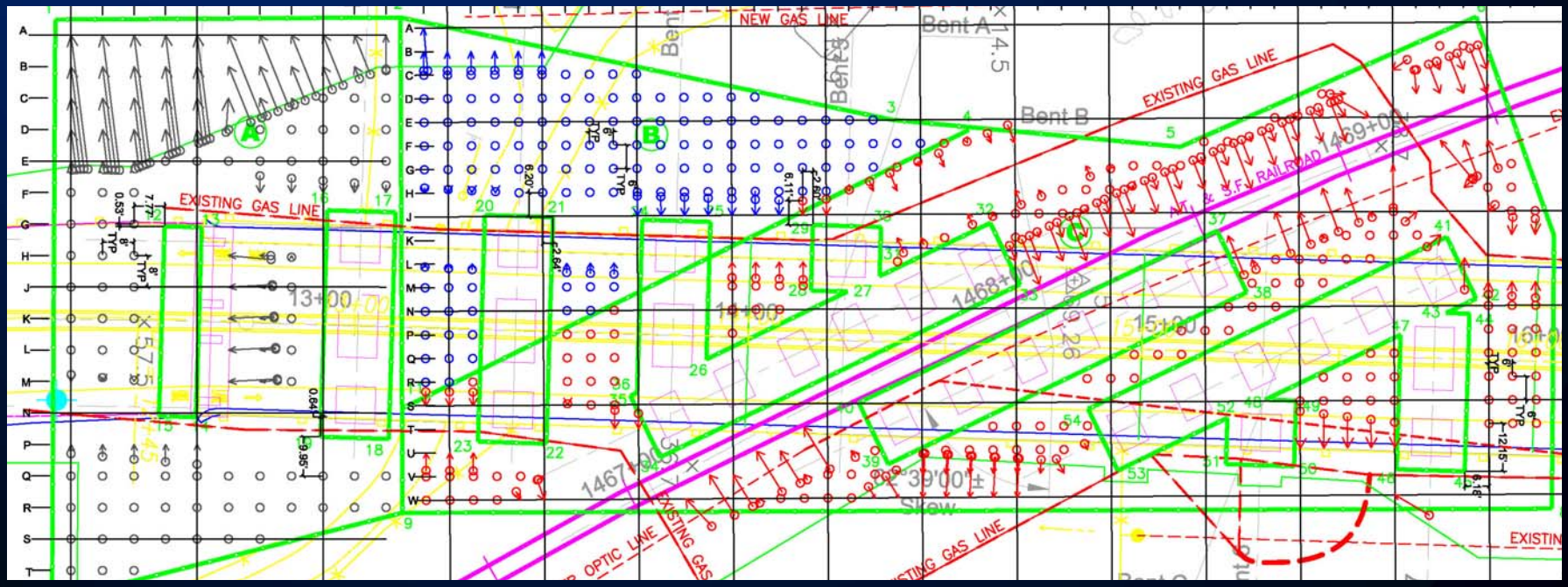
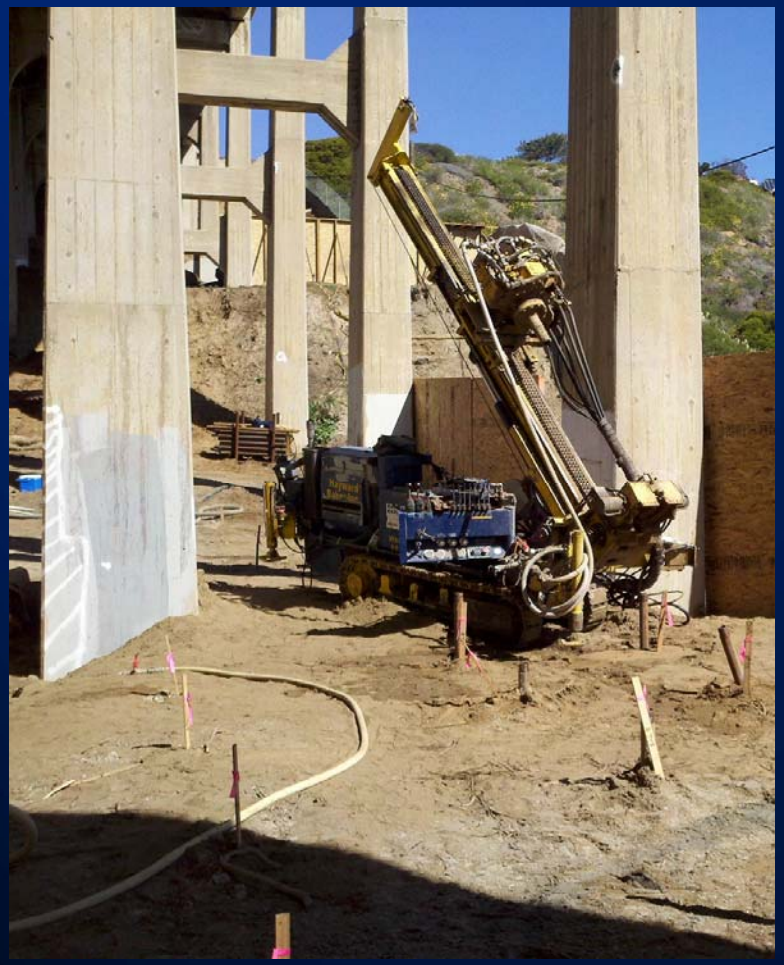


Compaction Grouting



Construction Phase

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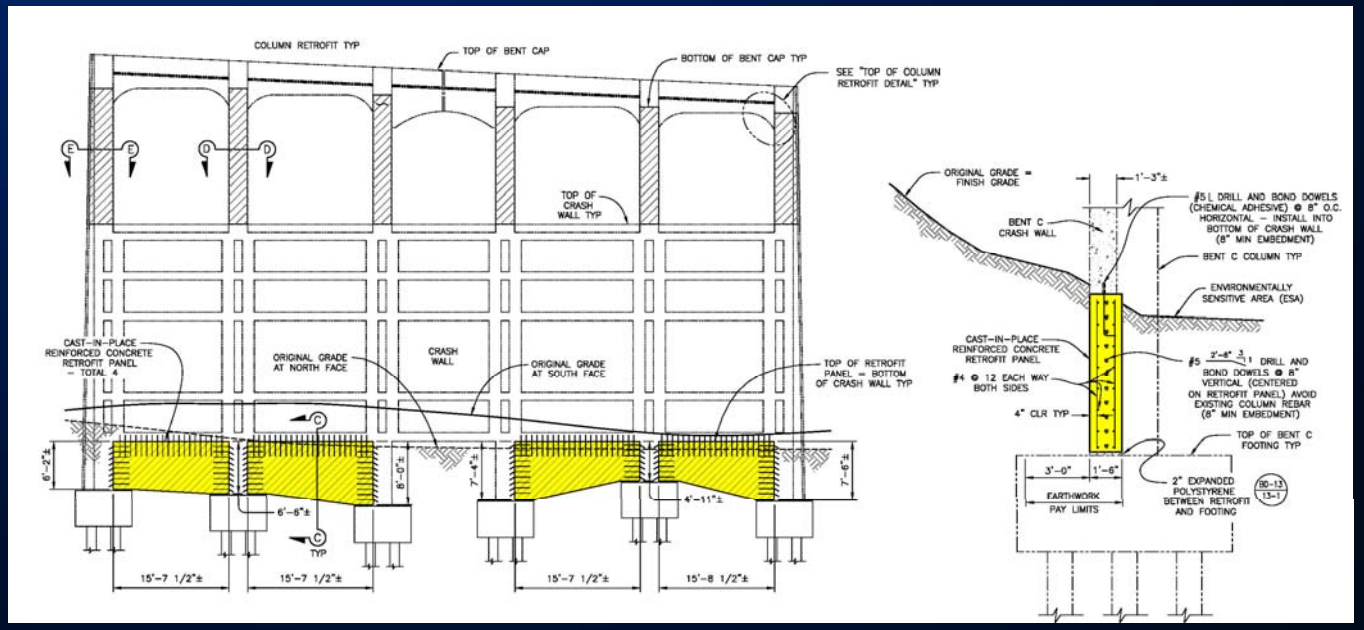
- Jun 2011: Shear Wall Retrofit



Shear Wall Infill Panels

Construction Phase

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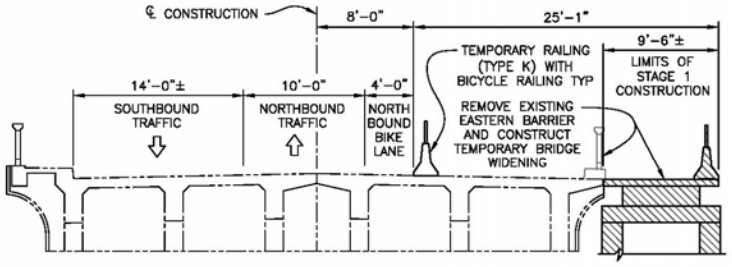
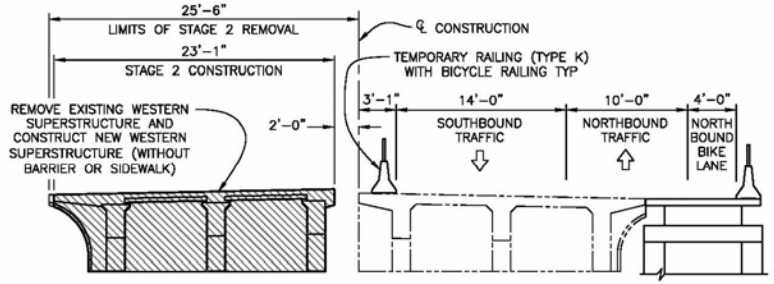
- Jun 2011: Shear Wall Retrofit
- Sept 2011: Temporary Bridge Widening

Construction Staging



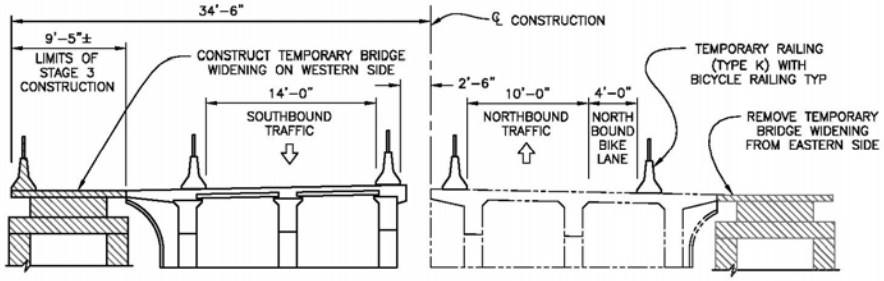
STAGE 1 – REMOVE EXISTING BARRIER AND CONSTRUCT TEMPORARY WIDENING

1" = 5'–0"



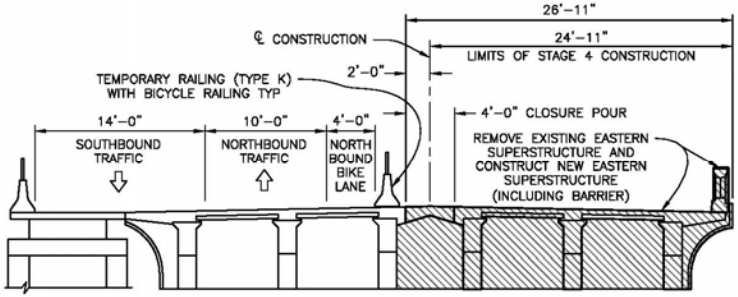
STAGE 2 – REMOVE AND REPLACE PORTION WESTERN SUPERSTRUCTURE

1" = 5'–0"



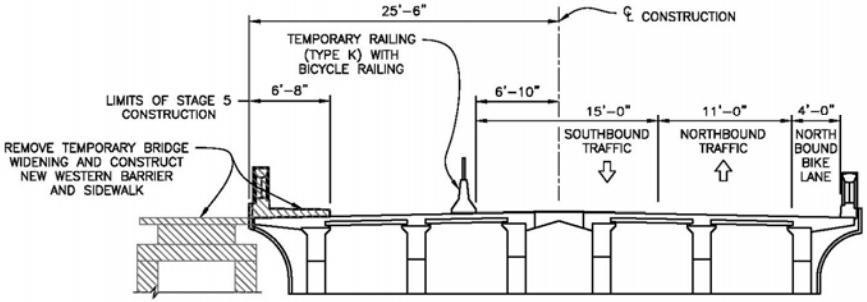
STAGE 3 – RELOCATE TEMPORARY WIDENING

1" = 5'–0"



STAGE 4 – REMOVE AND REPLACE EASTERN SUPERSTRUCTURE

1" = 5'–0"



STAGE 5 – REMOVE TEMPORARY WIDENING, POST-TENSION BRIDGE, AND REPLACE WESTERN BARRIER AND SIDEWALK

1" = 5'–0"

NOTES:

1. TEMPORARY RAILING (TYPE K) TO BE BOLTED TO DECK IF LESS THAN 2'–0" FROM EDGE OF DECK.
2. TEMPORARY BICYCLE RAILING SHALL HAVE A MINIMUM HEIGHT OF 4'–6" ABOVE RIDING SURFACE WITH A MAXIMUM OPENING SIZE OF 8" AND BE CAPABLE OF RESISTING 50 LB/FT ALONG TOP OF RAILING.

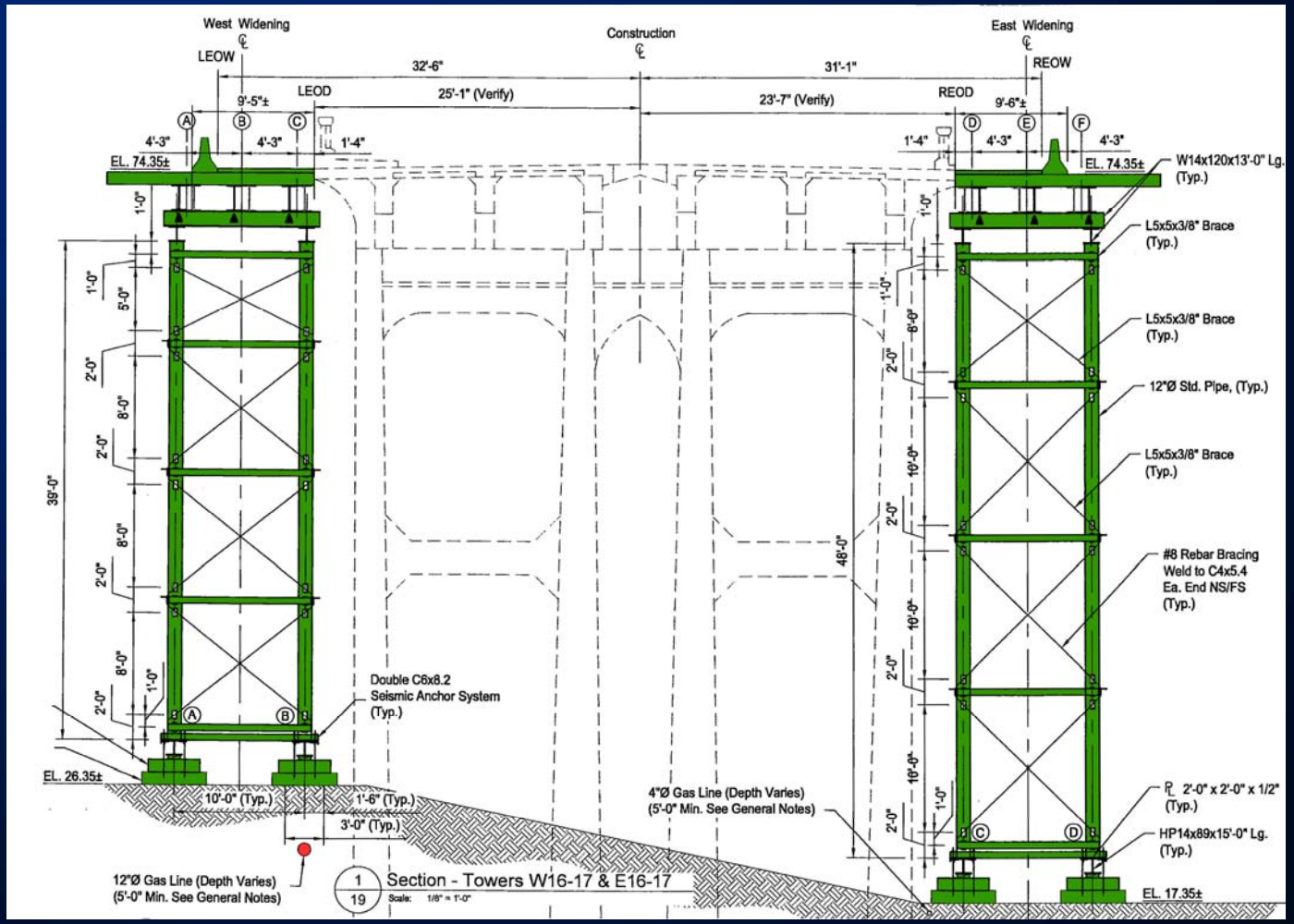
LEGEND:

– – – – – – – – – INDICATES EXISTING STRUCTURE

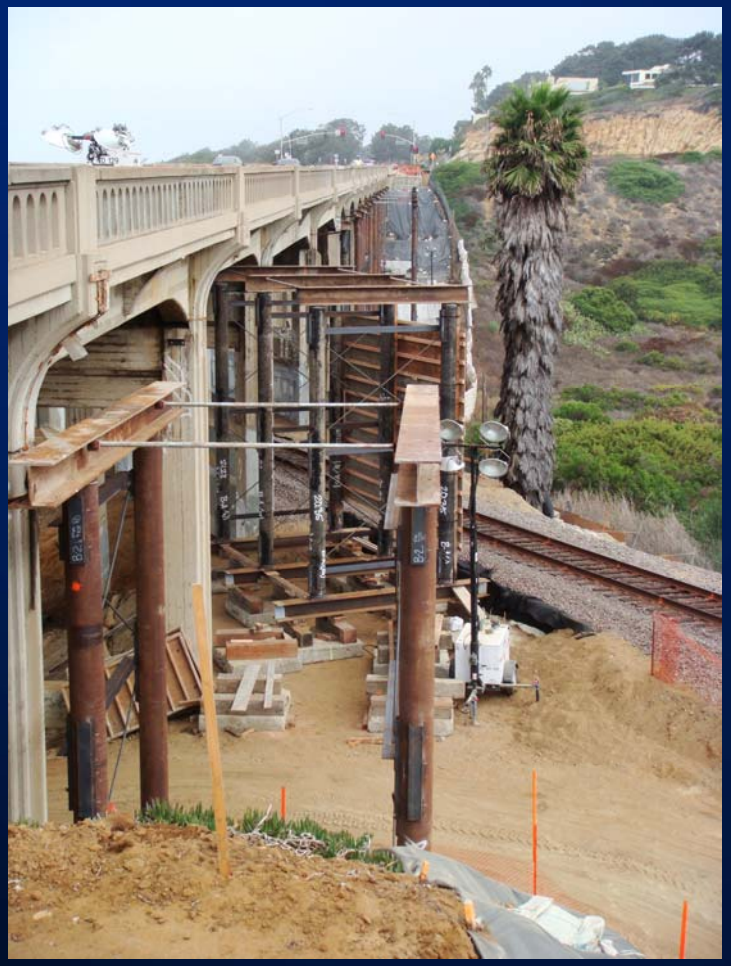
———————— INDICATES NEW STRUCTURE

▨ INDICATES AREA OF WORK DURING STAGE

Temp. Bridge Widening



Temporary Bridge Widening



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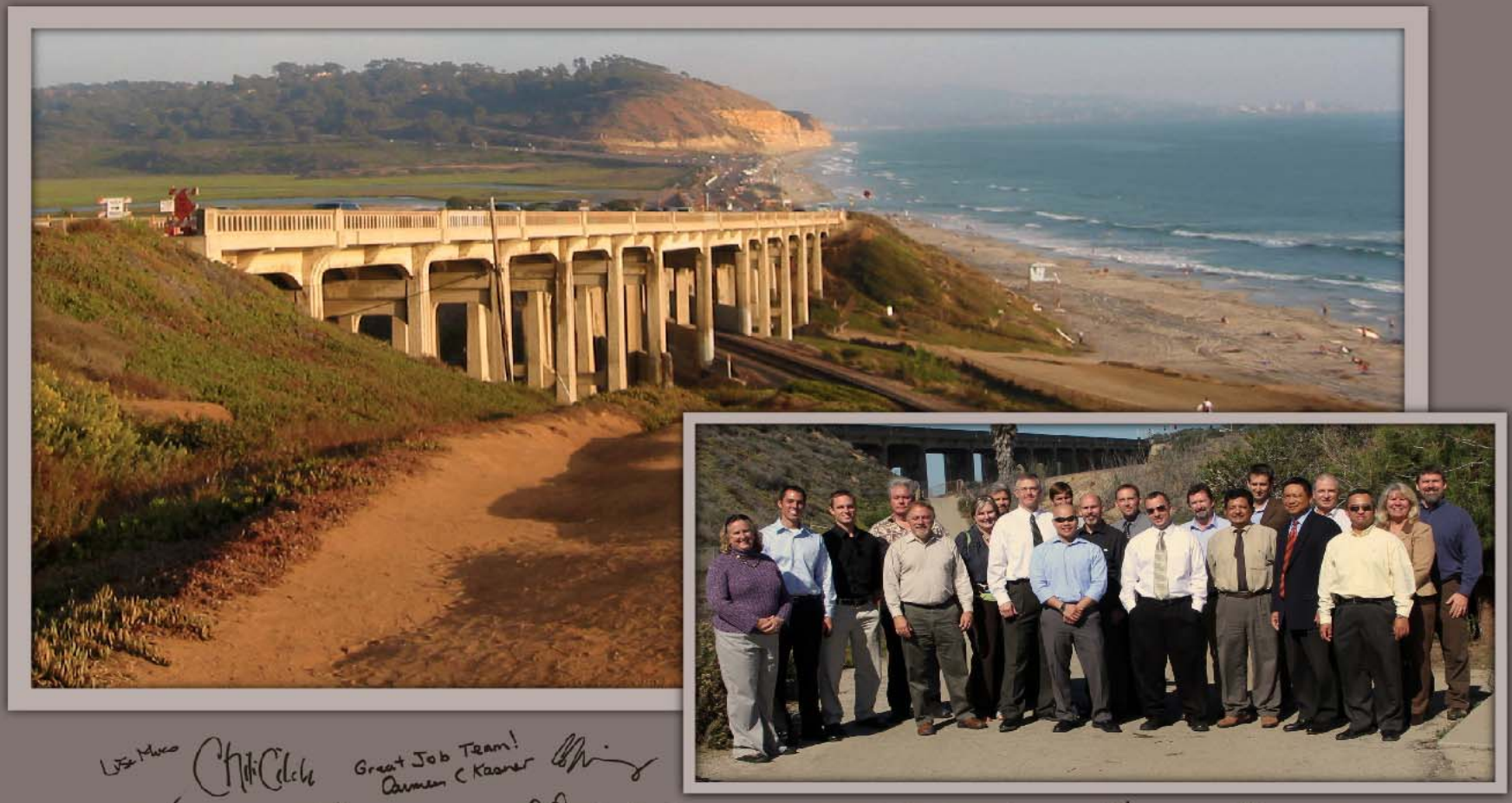
- Est. Completion Date: August 2013
- Incl. 1-year Planting: August 2014

Acknowledgements



Questions?