In Span Hinge Replacement and Seismic Retrofit of the Flamingo Viaduct

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NEVADA DOT

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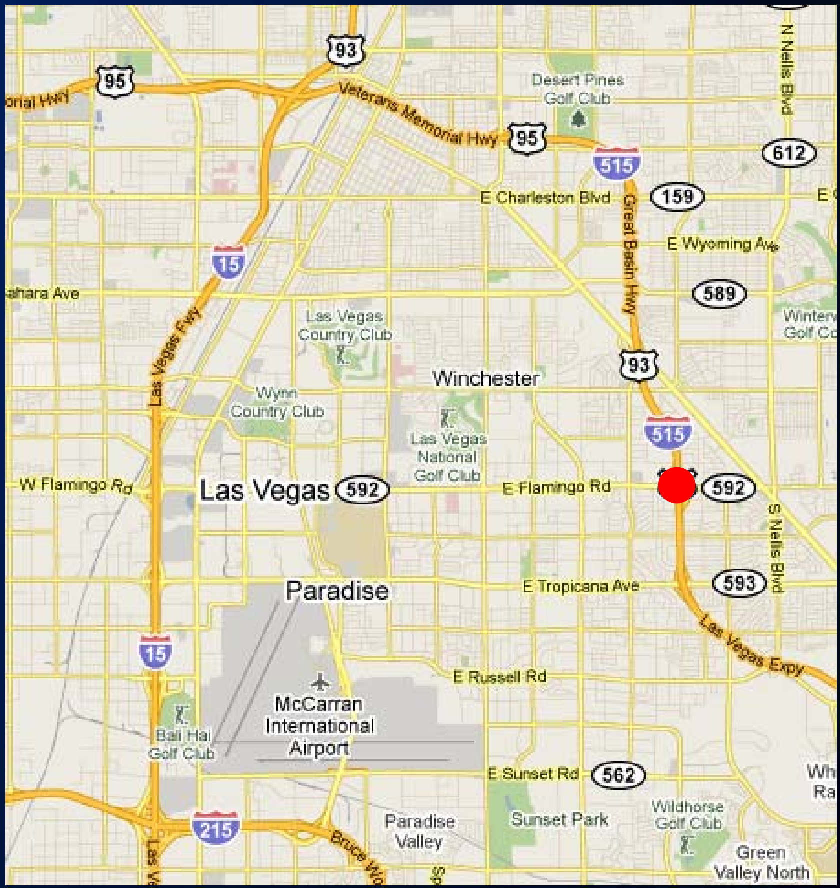
Presentation Outline

- Nevada Background
- Flamingo Viaduct
  - Project History
  - Structural Assessment
  - Seismic Strategy
  - Design Challenges
  - Construction



Nevada Seismicity??

	Mag >= 7.0	Mag >= 6.0	Mag >= 5.0	Mag >= 3.5
1st	Alaska	Alaska	Alaska	Alaska
	59	370	2050	14914
2nd	California	California	California	California
	16	114	675	10965
3rd	Nevada	Hawaii	Nevada	Hawaii
	4	29	159	2247
4th	Hawaii	Nevada	Hawaii	Nevada
	4	21	80	1586
5th	Missouri	Montana	Washington	Washington
	2	6	41	898
6th	Arkansas	Washington	Montana	Idaho
	2	5	25	613
7th	Washington	Wyoming	Wyoming	Wyoming
	1	5	22	392
8th	Montana	Idaho	Idaho	Montana
	1	4	18	321
9th	South Carolina	Oregon	Utah	Utah
	1	3	15	193
10th		Arkansas	Oregon	Oregon
		3	14	148

UNR Seismology

USGS

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Retrofit

- State adopted seismic prioritization
  - Importance and vulnerability
  - Life Safety or better
- 1971 San Fernando→
  - 1986 Caltrans Phase 1 (completed in 2000)
- 1989 Loma Prieta→
  - Caltrans increased research
  - NDOT begins prioritization in early 1990's
- 1994 Northridge
  - Caltrans Phase 2, Caltrans toll, CA Local

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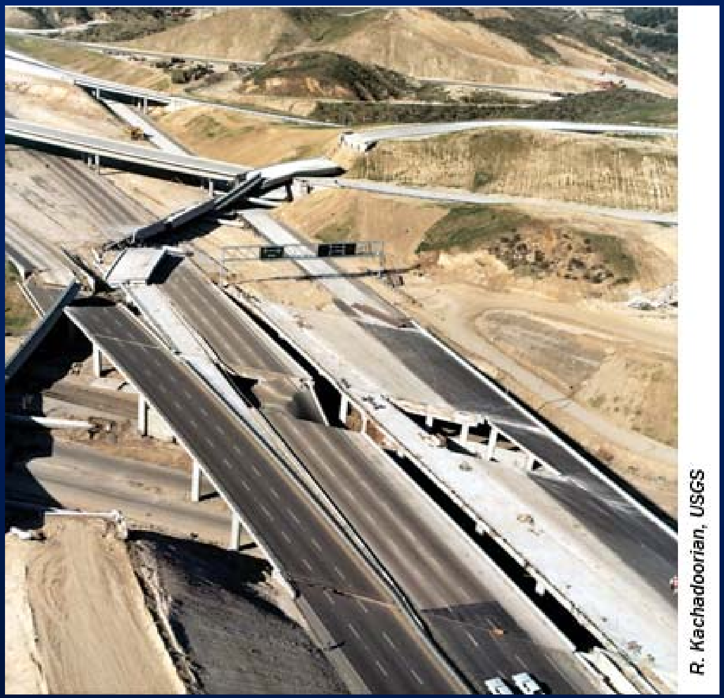
In-Span Hinge Failures

1971 San Fernando



1994 Northridge

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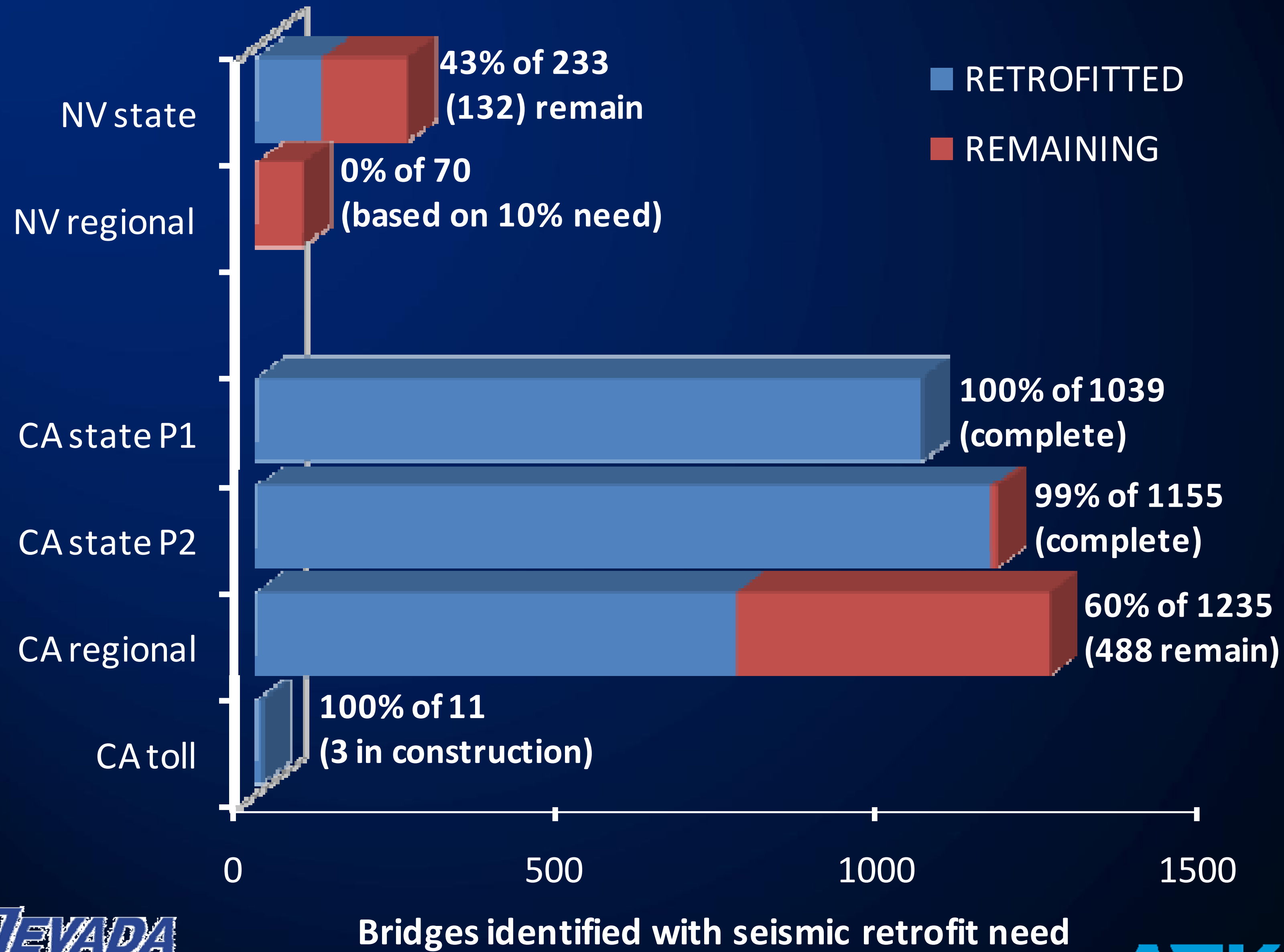
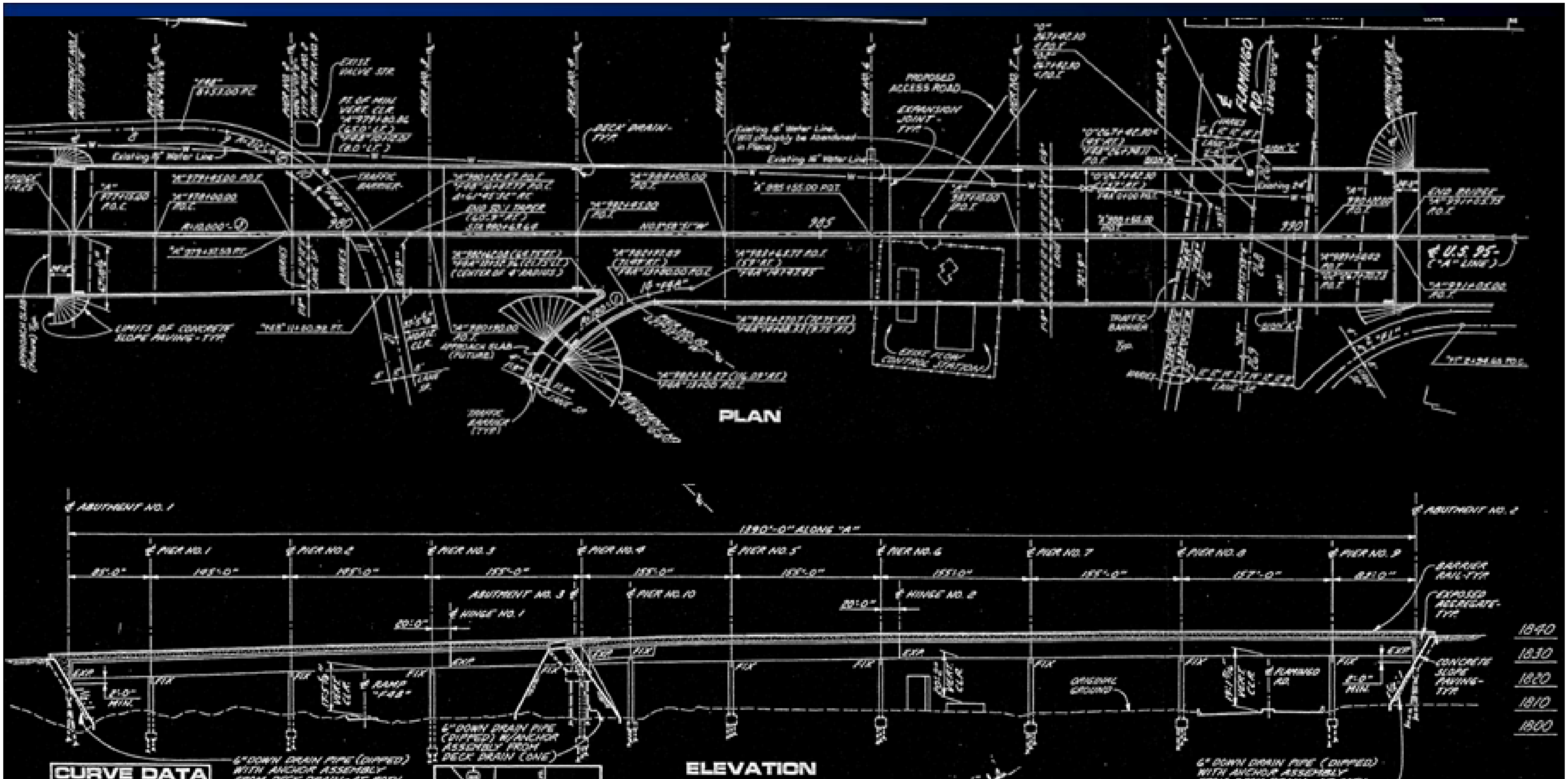


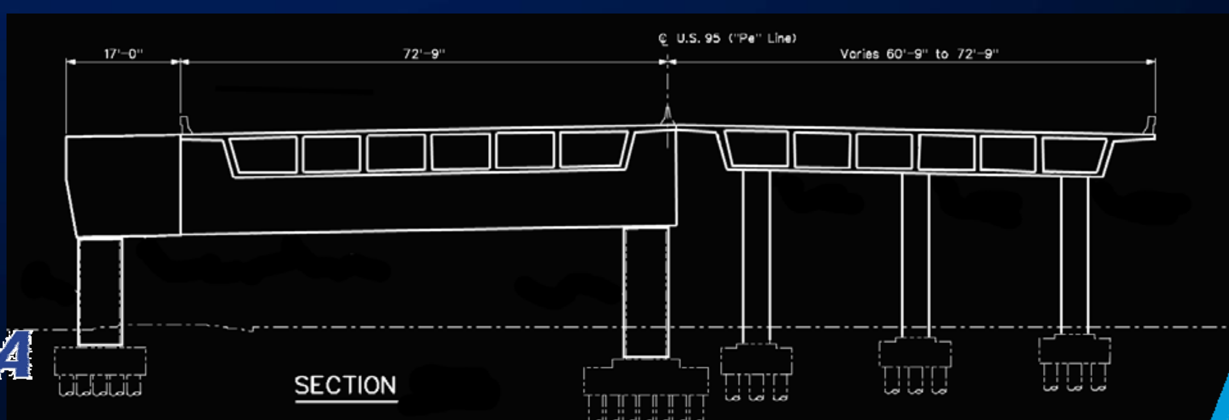
NV state
NV regional
CA state P1
CA state P2
CA regional
CA toll
43% of 233
(132) remain
0% of 70
(based on 10% need)
100% of 1039
(complete)
99% of 1155
(complete)
60% of 1235
(488 remain)
100% of 11
(3 in construction)
RETROFITTED
REMAINING
0
500
1000
1500
Bridges identified with seismic retrofit need

Flamingo Viaduct

- Las Vegas, NV, I-515 over Flamingo
- Owner: Nevada DOT
- Constructed in 1982
- 10-span continuous PT box girder
- Twin 72ft wide 1400ft structures with 2 ISH

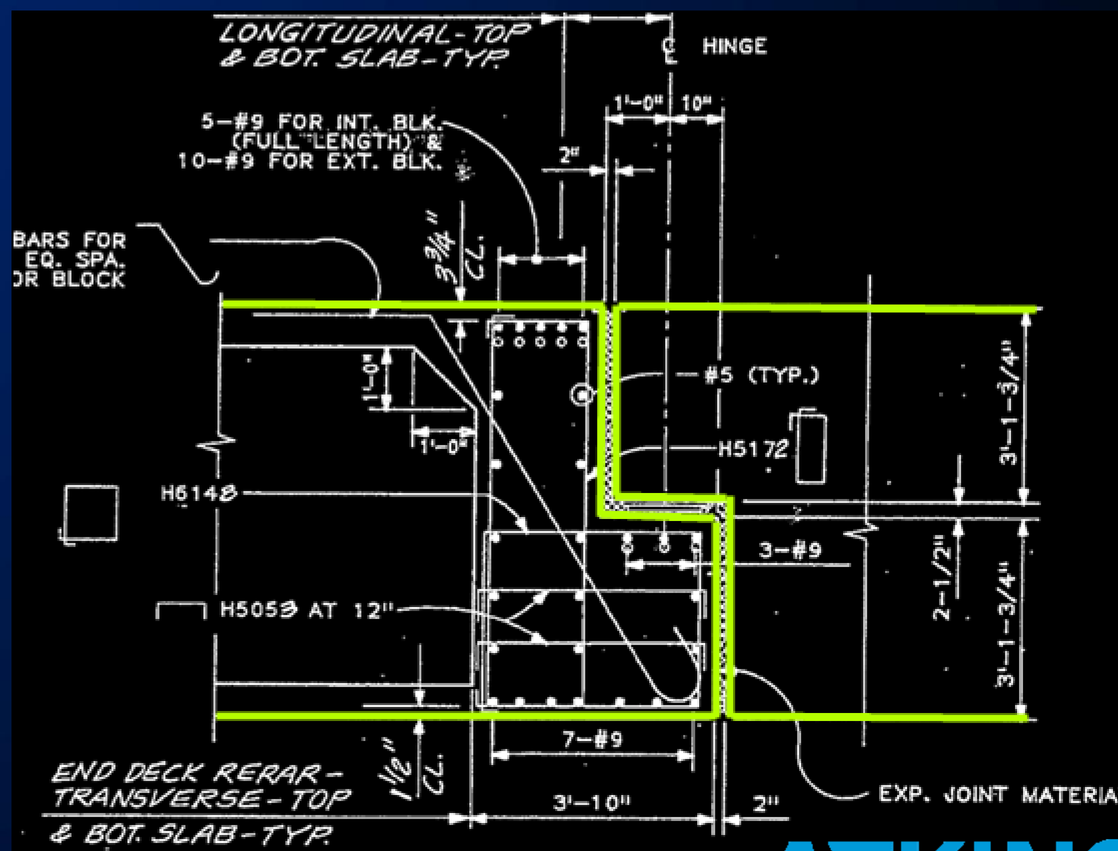
- Scope: Repair hinges, seismic retrofit/rehab
- $3.5M Retrofit/Rehab (small cost difficult task)


PLAN
ABUTMENT NO. 1
PIER NO. 1
PIER NO. 2
PIER NO. 3
PIER NO. 4
PIER NO. 5
PIER NO. 6
PIER NO. 7
PIER NO. 8
PIER NO. 9
ABUTMENT NO. 2
1840
1830
1820
1810
1800
ELEVATION
CURVE DATA


℄ U.S. 95 ("Pe" Line)
17'-0"
72'-9"
Varies 60'-9" to 72'-9"
SECTION

Observed Issues

- Excessive hinge movement (18” seat)
  - Designed for 2in, measured 8-10 in
  - Restrainers failed
  - Hinge seats
  - Columns hinged
  - Cap beam T & V



In-Span Hinge

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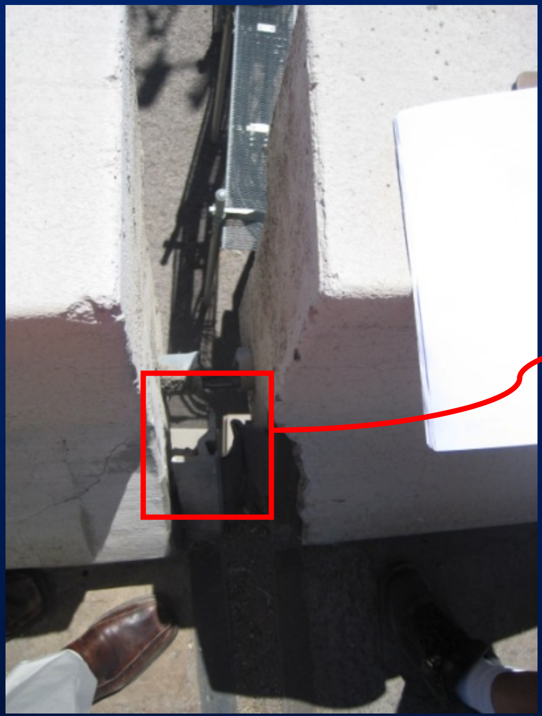
Bridge Rail Separation



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Column Plastic Hinging

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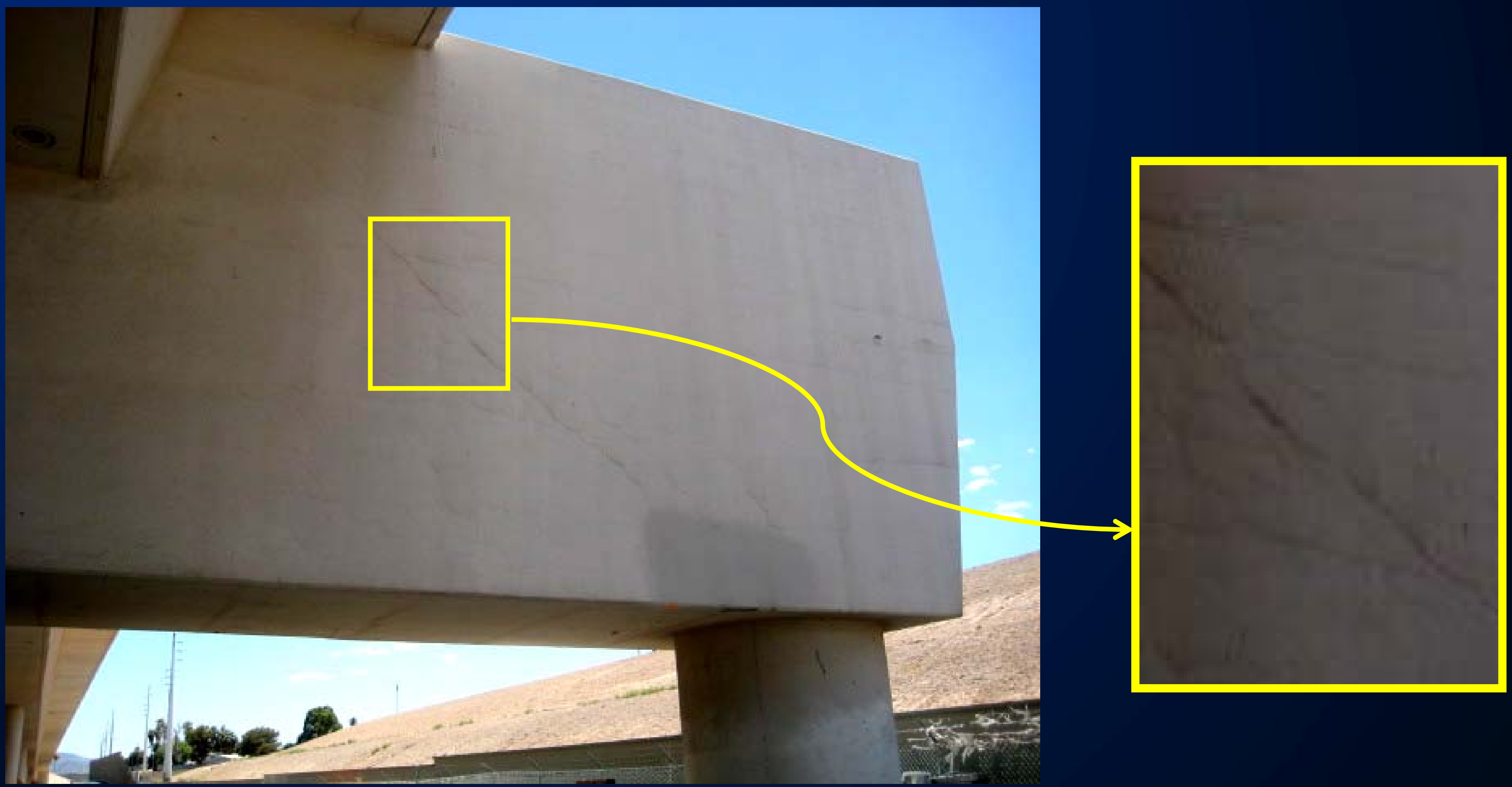
Outrigger T/V Cracking



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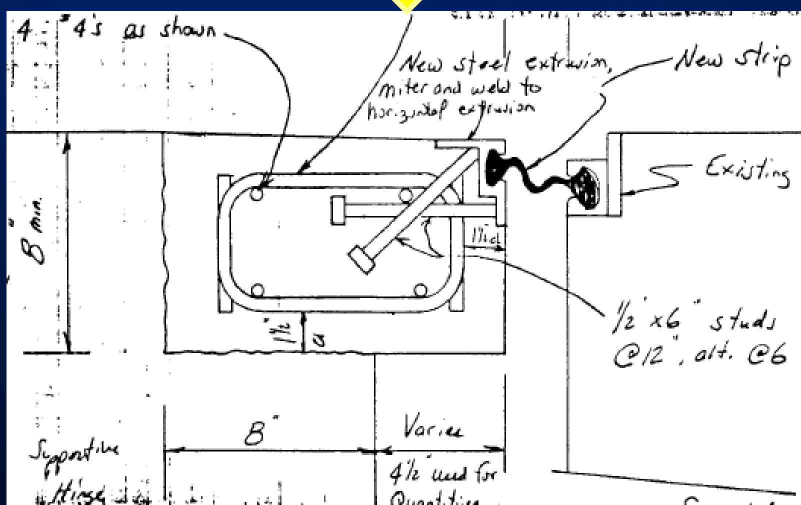
Timeline

- 1985 inspection reports noted excessive ISH movement
- 1992 expansion joints reconstructed
- 2003 Initial rehabilitation study (PB)
- 2007 Second Rehabilitation study (PBSJ)
- 2010 Retrofit/Rehabilitation Type Selection and Final Design
- (9 year project)

1992 Expansion Joint Reconstruction



2007 Study

Location	Case I Calculated Opening (in)	Case 2 Calculated Opening (in)	Case 3 Calculated Opening (in)	Average Field Measured Opening (in)
NB Hinge 1	7.63	8.08	8.32	8.19
NB Hinge 2	7.17	7.58	7.8	8.44
SB Hinge 1	7.86	8.33	8.59	8.19
SB Hinge 2	6.99	7.38	7.58	8.13
Case 1 - 3in initial + long term placed 12 weeks after stressing + thermal				
Case 2 - 3in initial + long term placed 6 weeks after stressing + thermal				
Case 3 - 3in initial + long term placed 4 weeks after stressing + thermal				

- Original design did not account for creep/shrinkage
- Seismic = 7.5in, remaining effective seat = 8-10 in
- 30 columns were pushed beyond Δy
- Outrigger bent has torsional/shear D/C issues
- Three concepts were developed

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Seismic Analysis to Finalize Strategy

- Criteria is Life Safety
- Columns already experienced displacement
- NDOT standard is FHWA manual
  - Method B, <u>C</u>, D
- Caltrans standard (FHWA D) makes sense
  - "Linear" RSA displacement demands (ATC6)
  - NL pushover disp. capacities & force demands
- Add shortening deformations to 100/30 seismic demand, $\Delta c > \Delta d$

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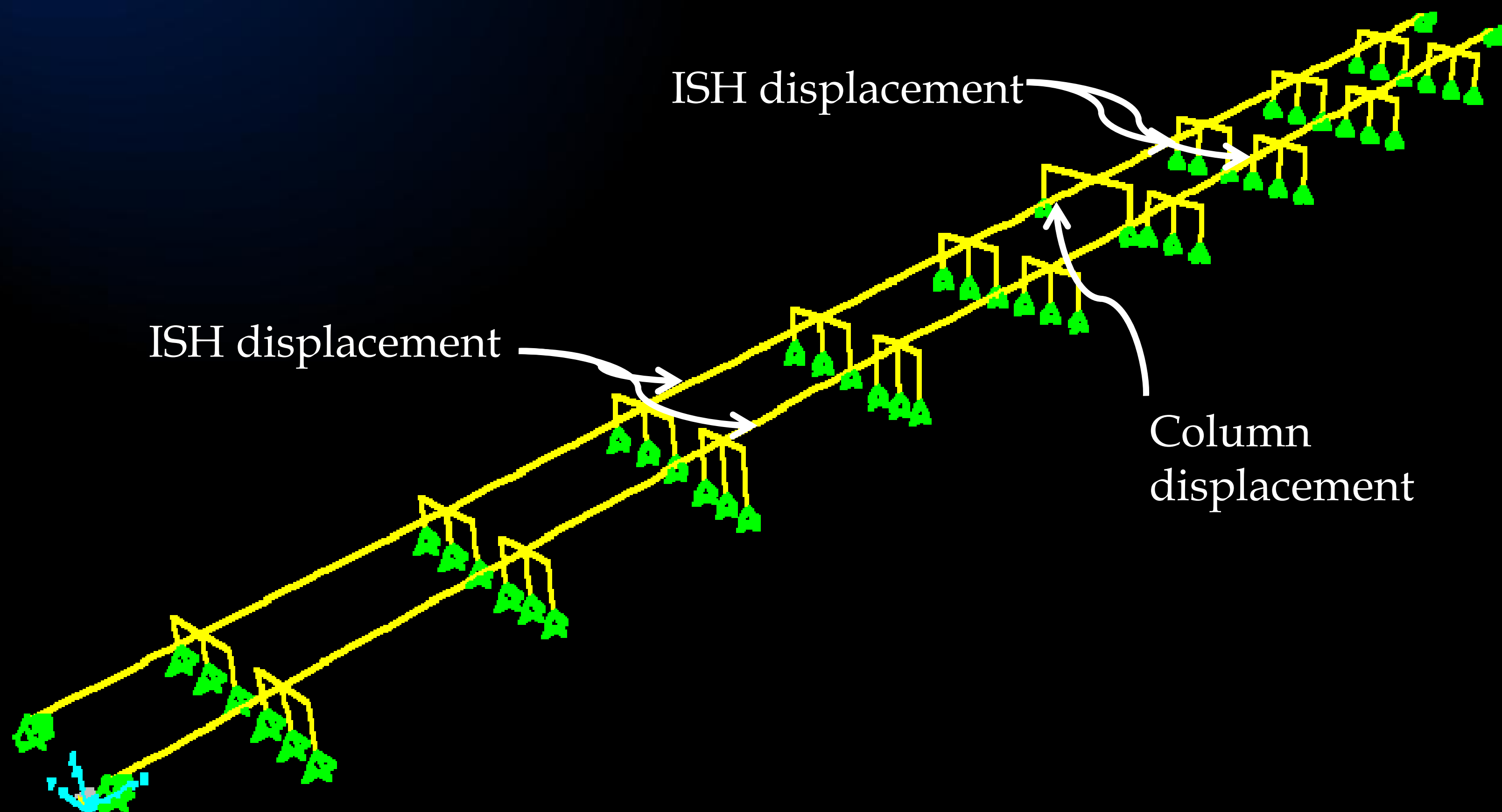
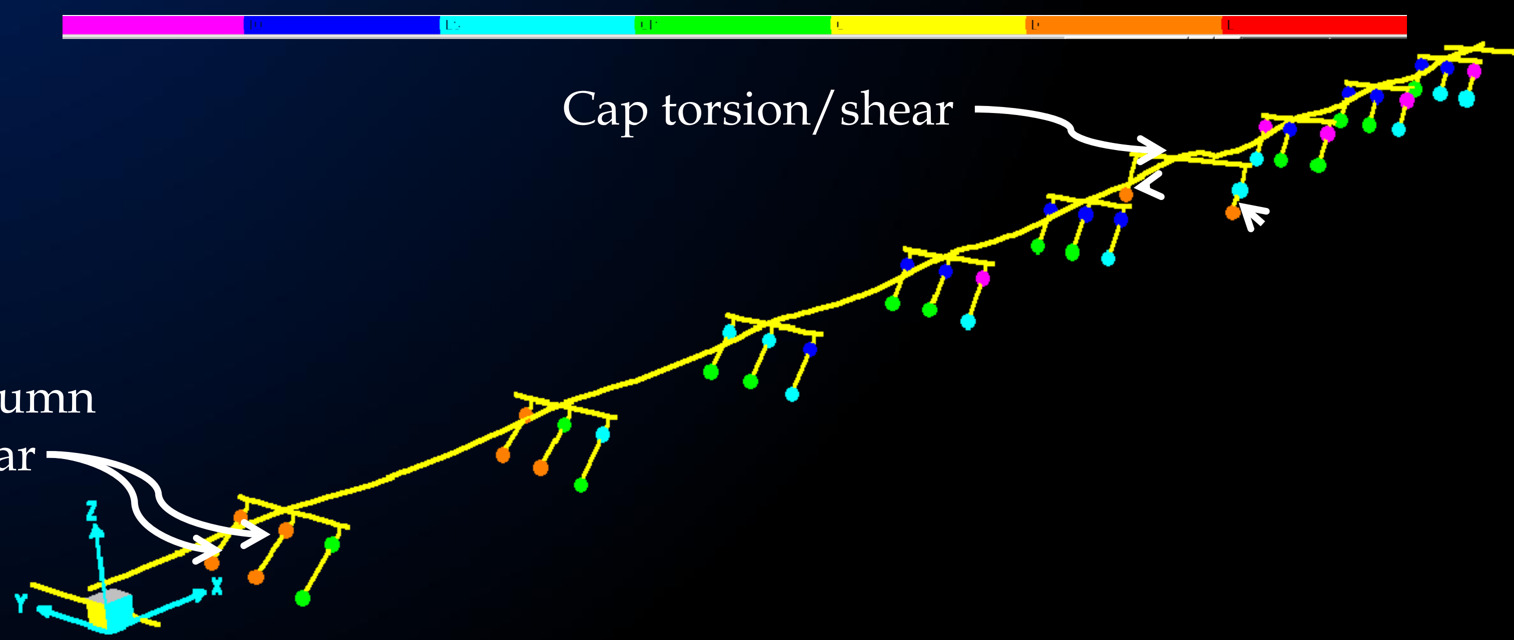
Linear RSA System



Nonlinear System Pushover



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Hinge Rehab Options

- Existing bearings failed
- Insufficient seat width

- 3 Options investigated
  - Internal Strong Back (similar to CT seat extender)
  - External Strong Back
  - Complete Reconstruction
- Appearance, MOT, invasiveness, reliability

Major Factors to Consider

Environmental

Funding

Safety

Politics

Right-of-way

Function

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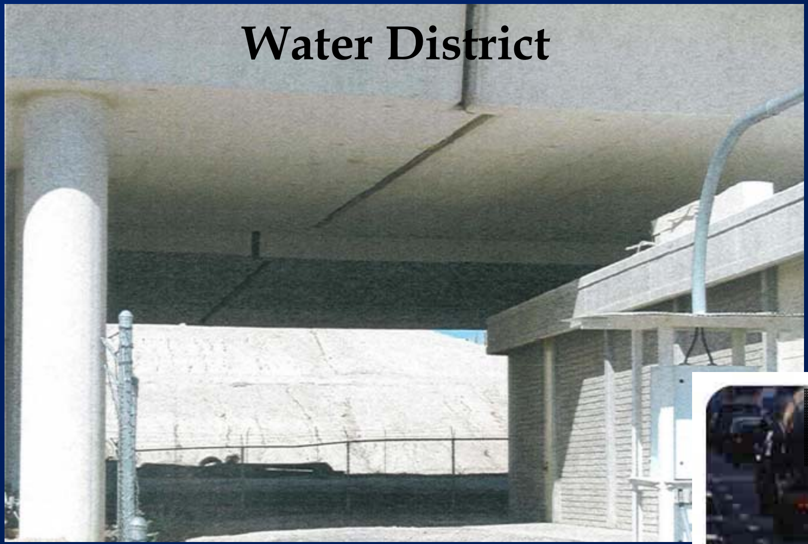
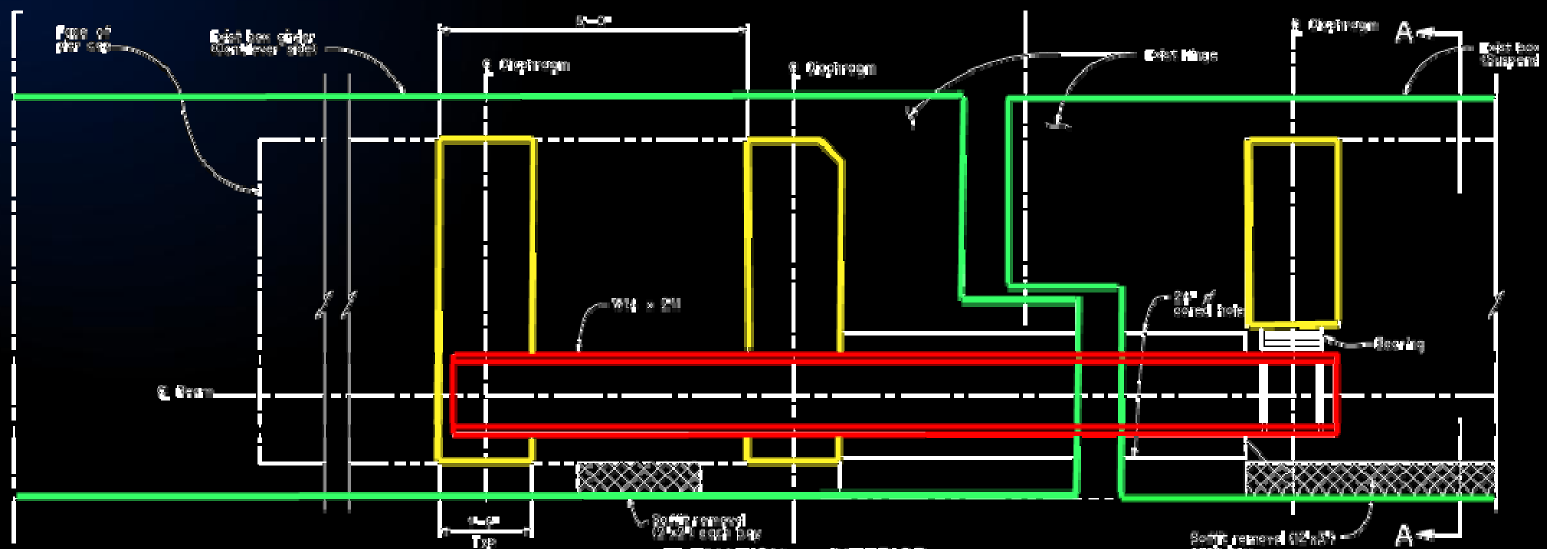
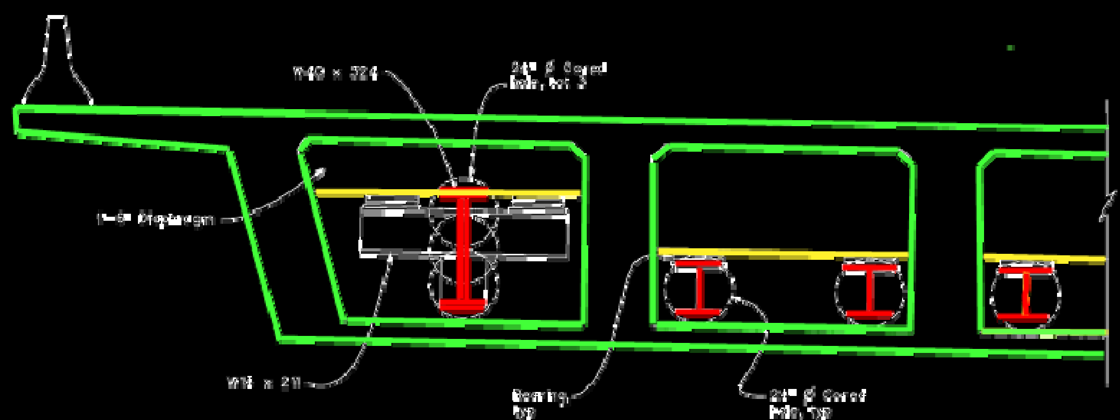
Project Constraints



Internal Strong Back



ELEVATION – INTERIOR



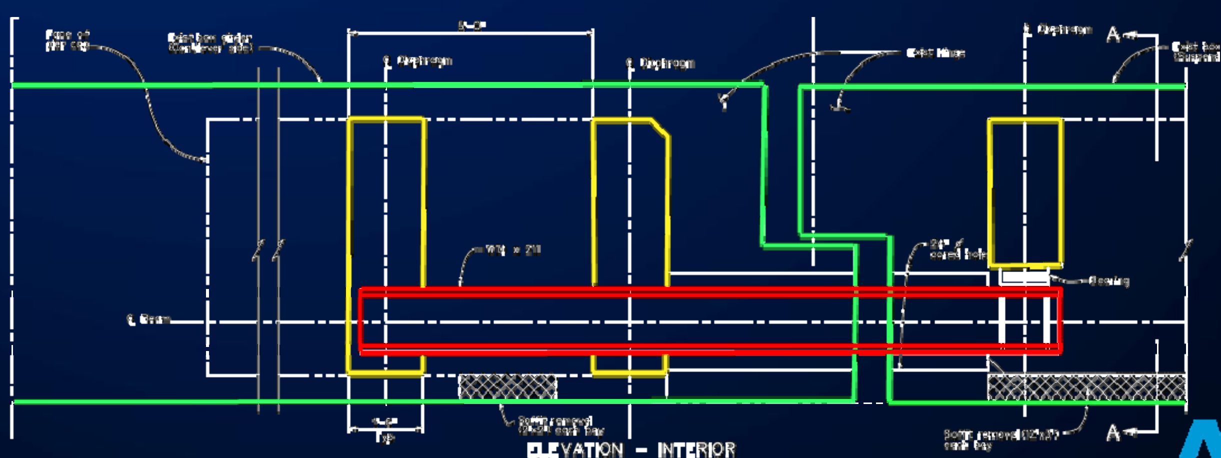
SECTION A–A

ADVANTAGES

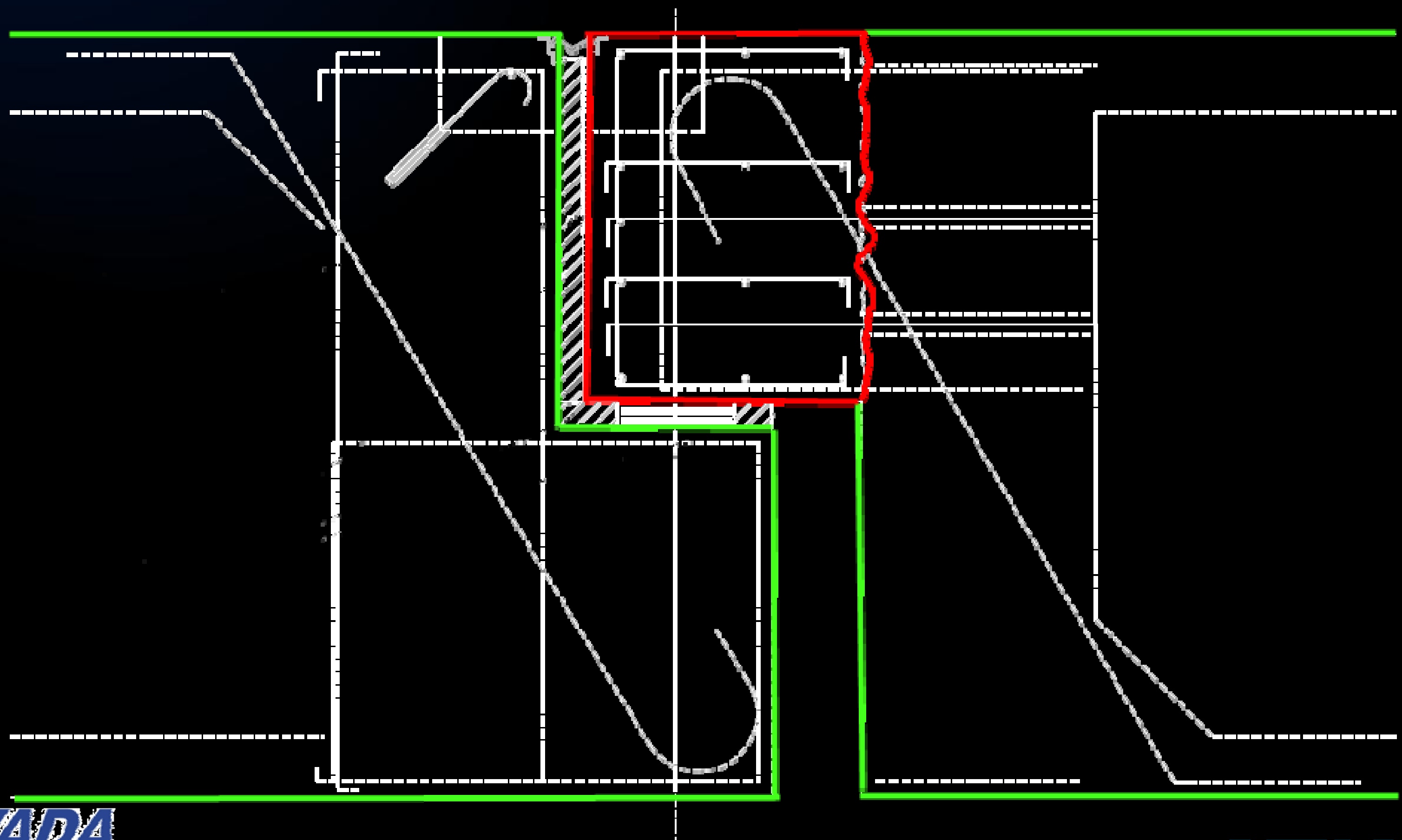
- ✓Minor Traffic Impact
- ✓No Future Maintenance
- ✓No Impact on Bridge Aesthetics
- ✓Bearing Pads Accessible for Inspection

DISADVANTAGES

- ×Complex Structural Modification



Hinge Replacement



ADVANTAGES

✓No Future Maintenance

✓No Aesthetic Impact

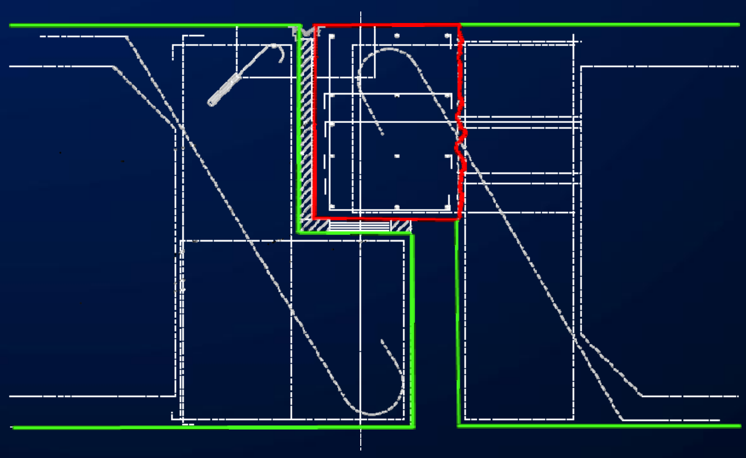
DISADVANTAGES

×Complex Structural Modification

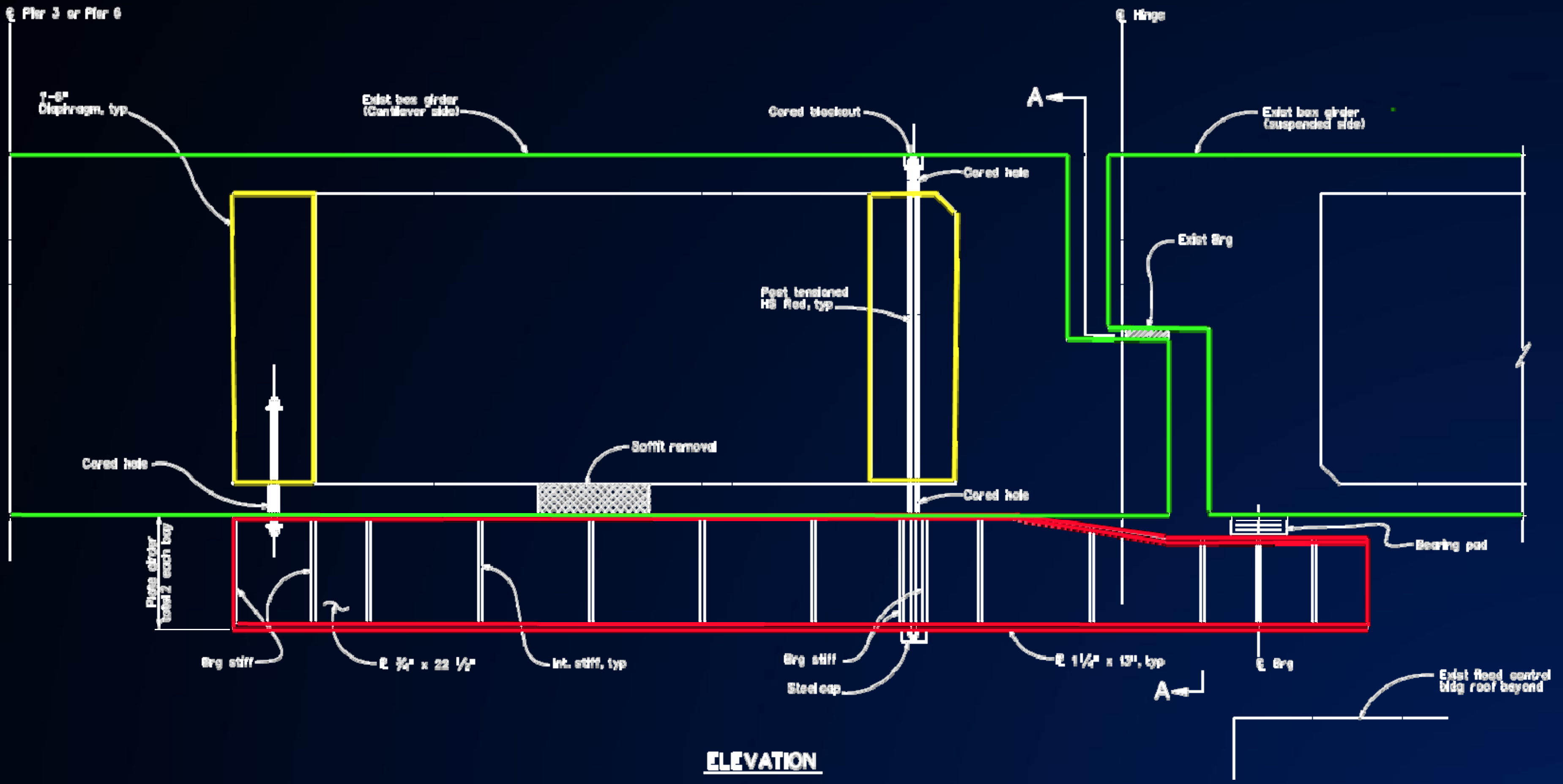
×Significant Impact to Traffic

×High Cost

×Bearing Pads Inaccessible



External Strong Back



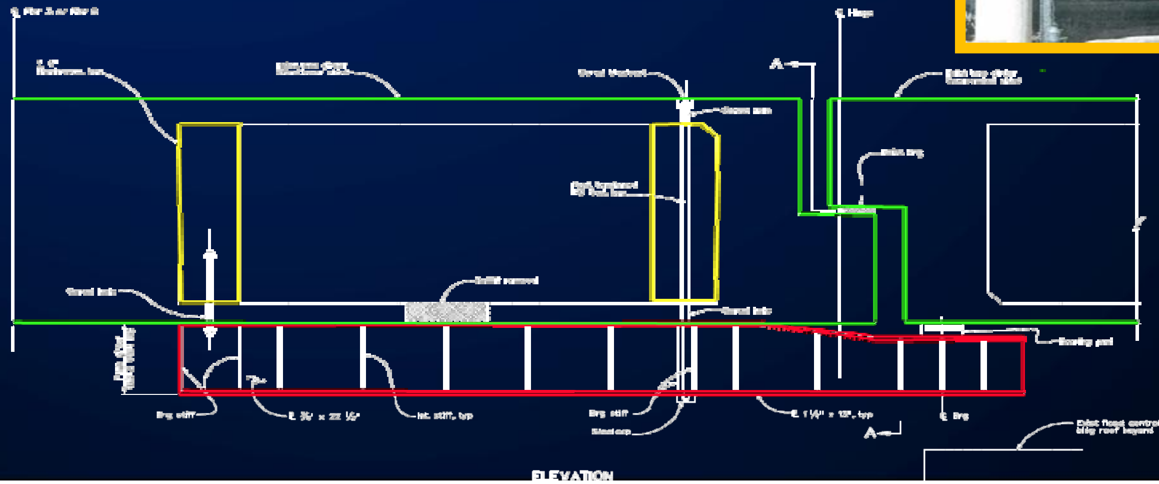
ELEVATION

ADVANTAGES

- ✓Ease of Construction
- ✓Low Cost
- ✓Minor Traffic Impact
- ✓Bearing Pads Accessible for Inspection

DISADVANTAGES

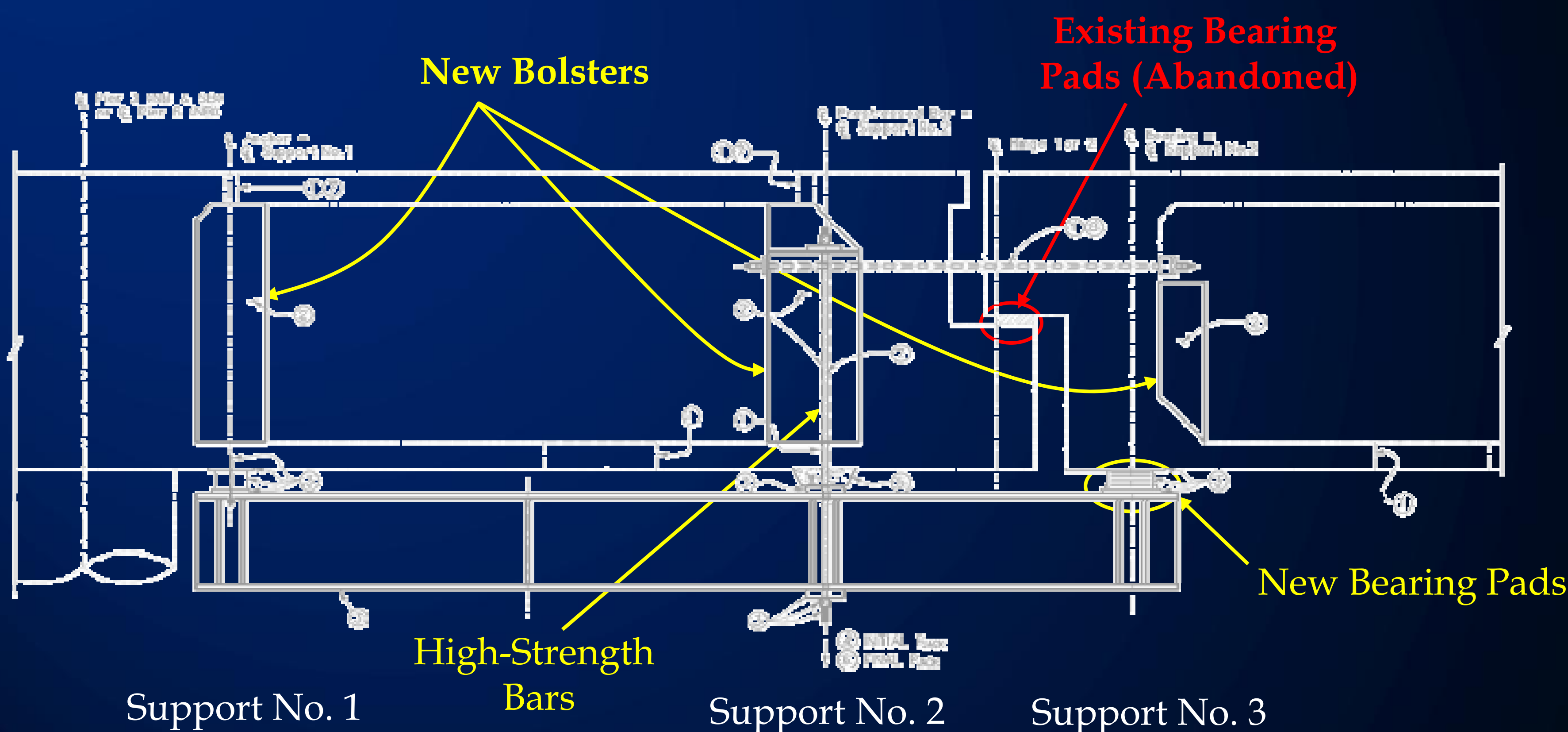
- ×Aesthetics
- ×Future Maintenance



Rehabilitation/Retrofit Design

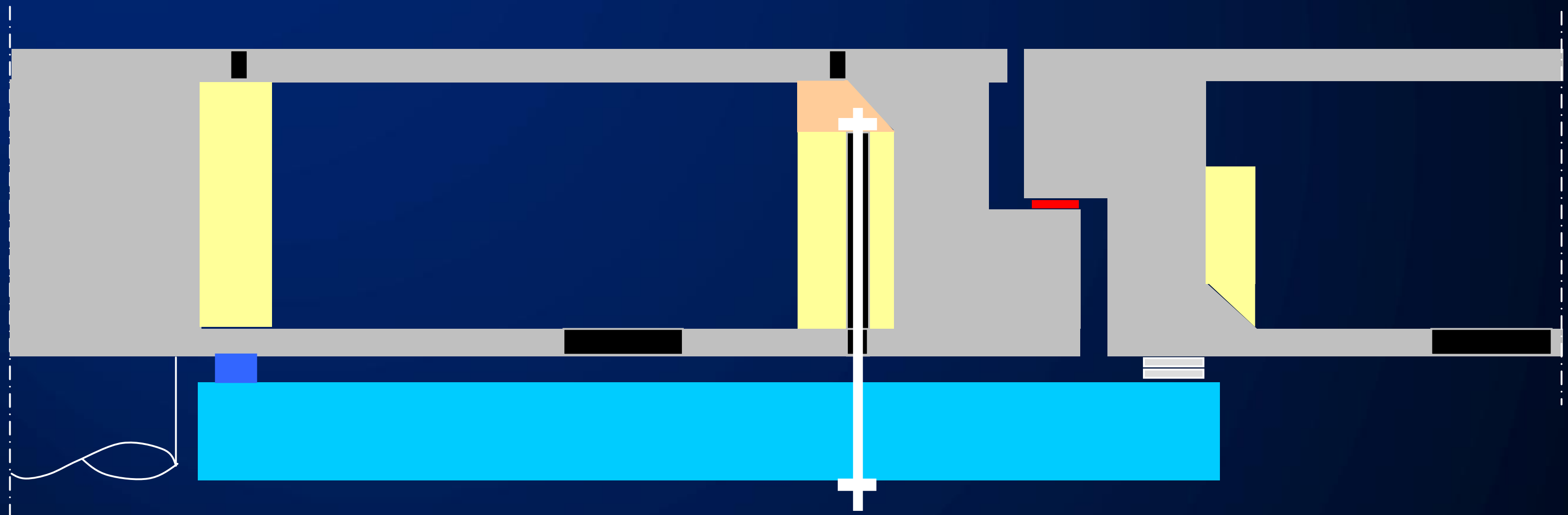
- Rehabilitation Overview
- Construction Sequence
- Rehabilitation Design Challenges
- Check of Existing Structure
- Seismic Assessment & Retrofit

Hinge Rehabilitation

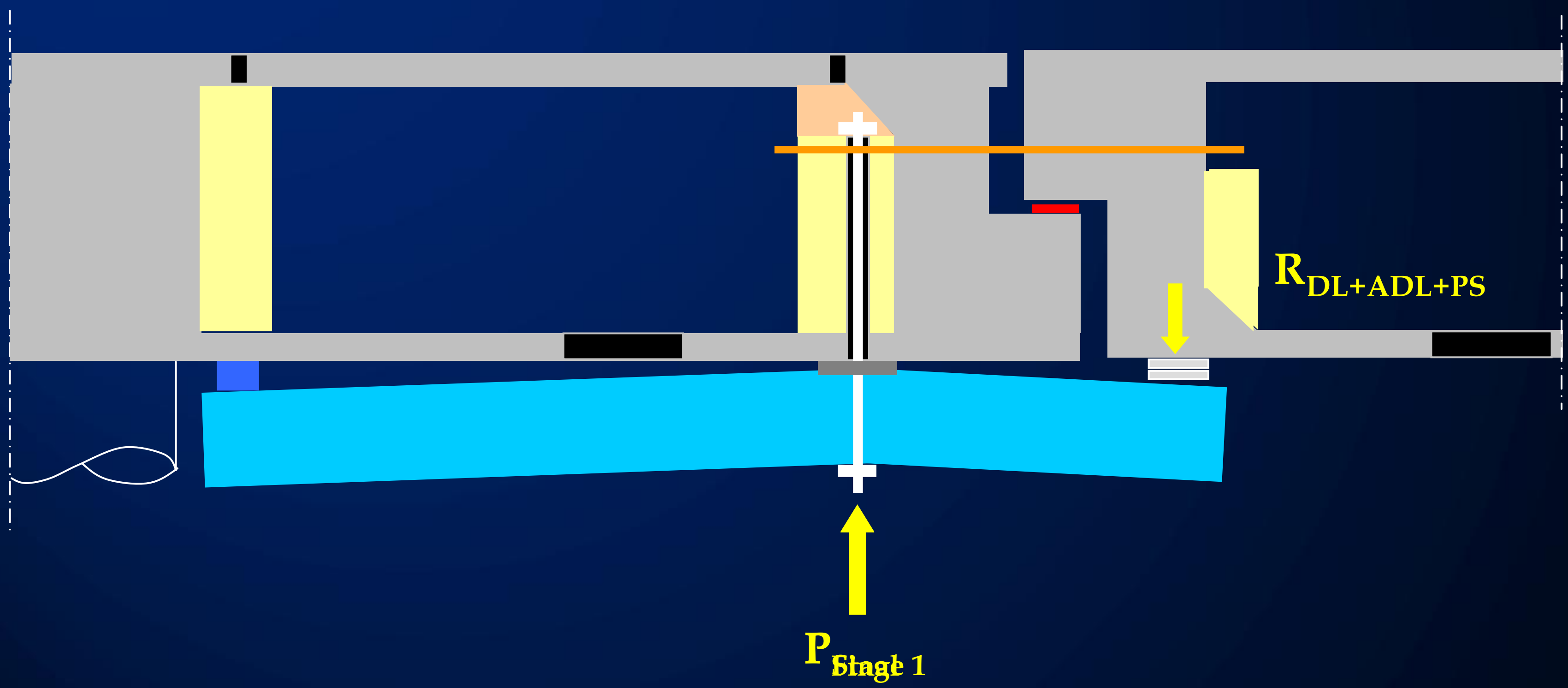


- New bearing pads are active for permanent loads reactions
- New bearing pads designed to take full live load reactions

Hinge Rehabilitation Construction Sequence

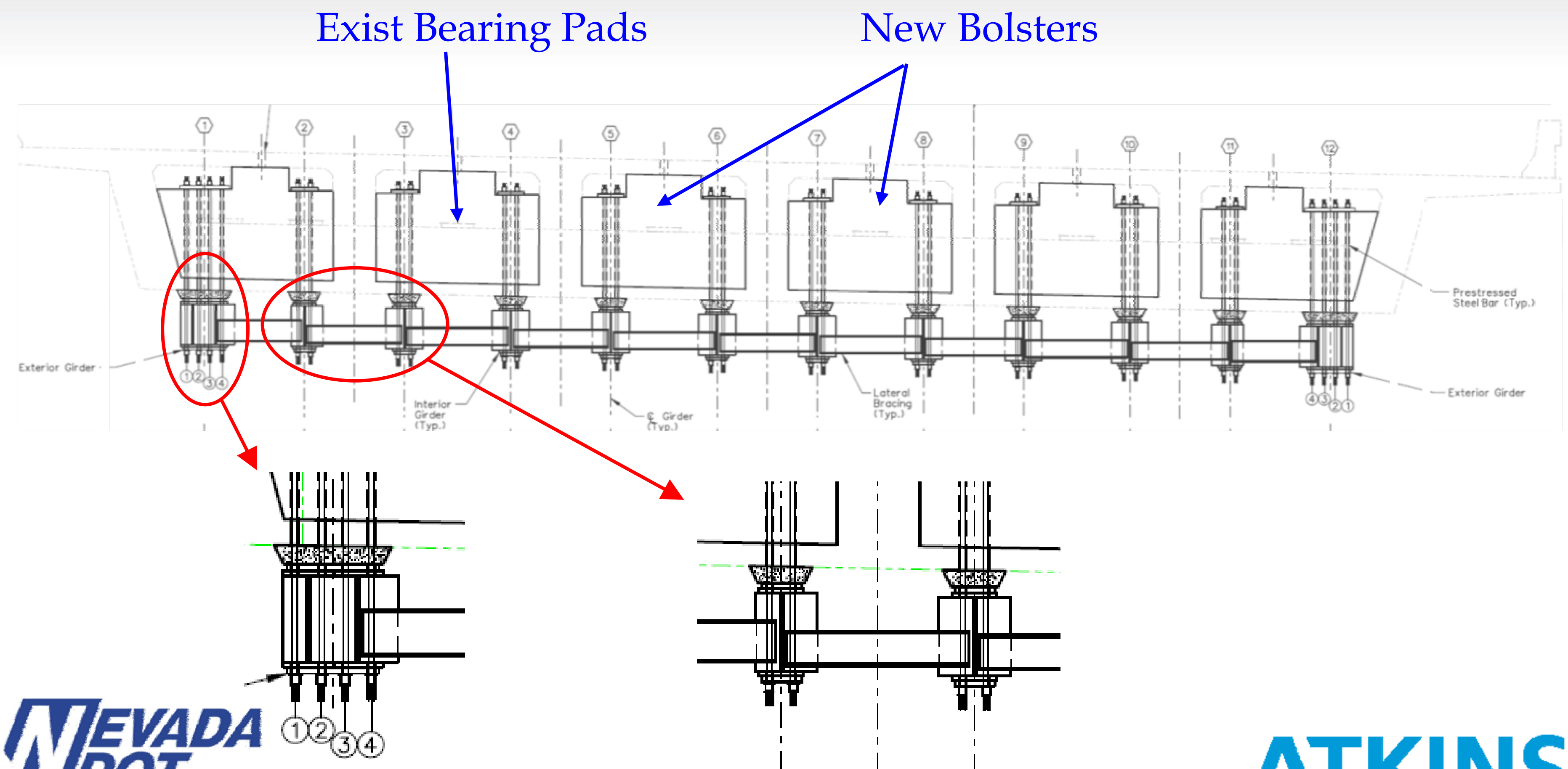


Hinge Rehabilitation Construction Sequence



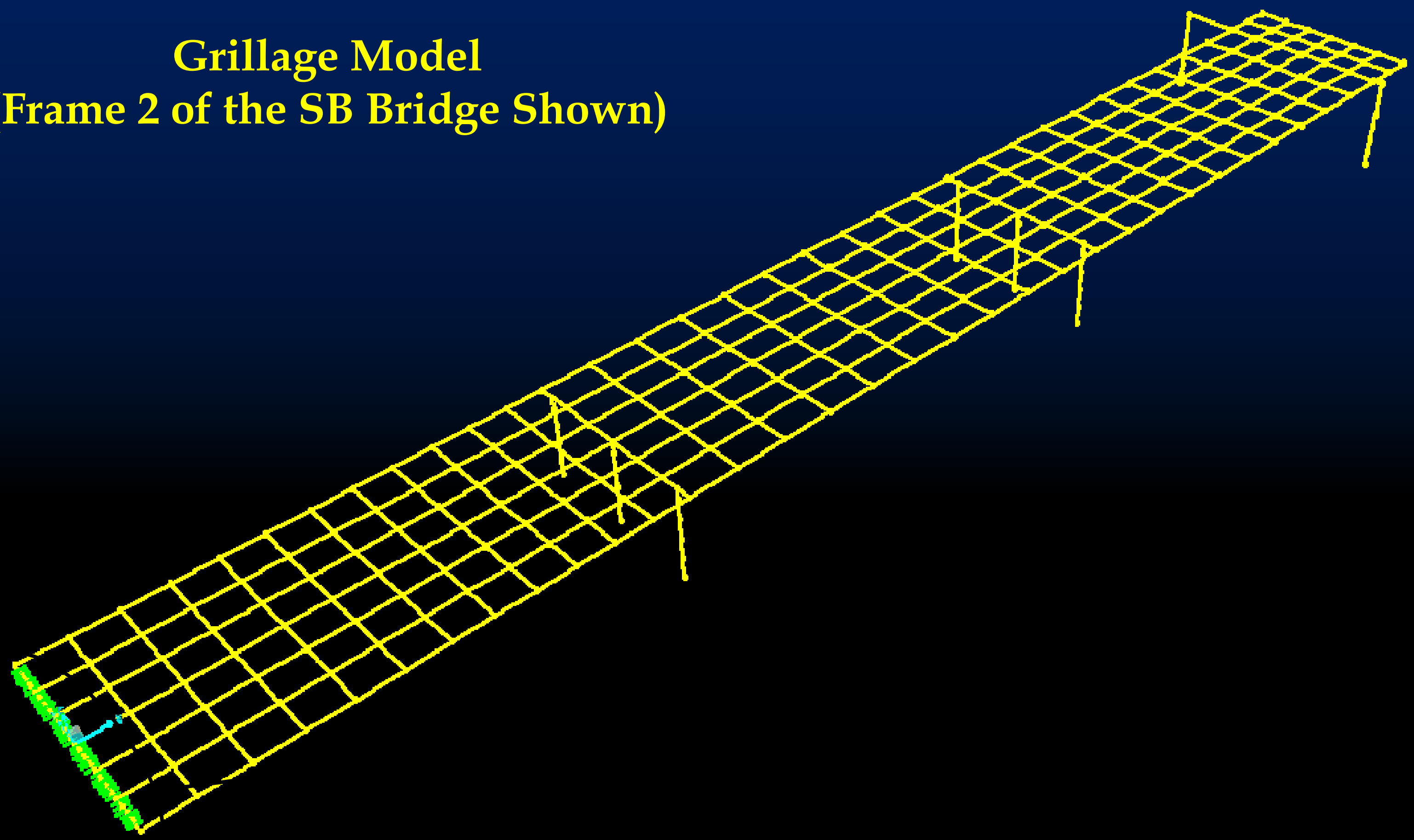
PT Bars Stressing Sequence

- PT bars are NOT stressed simultaneously at all new steel beam locations
- Effect of stressing sequence of PT Bars at different beam locations is investigated by nonlinear analysis (SAP2000)

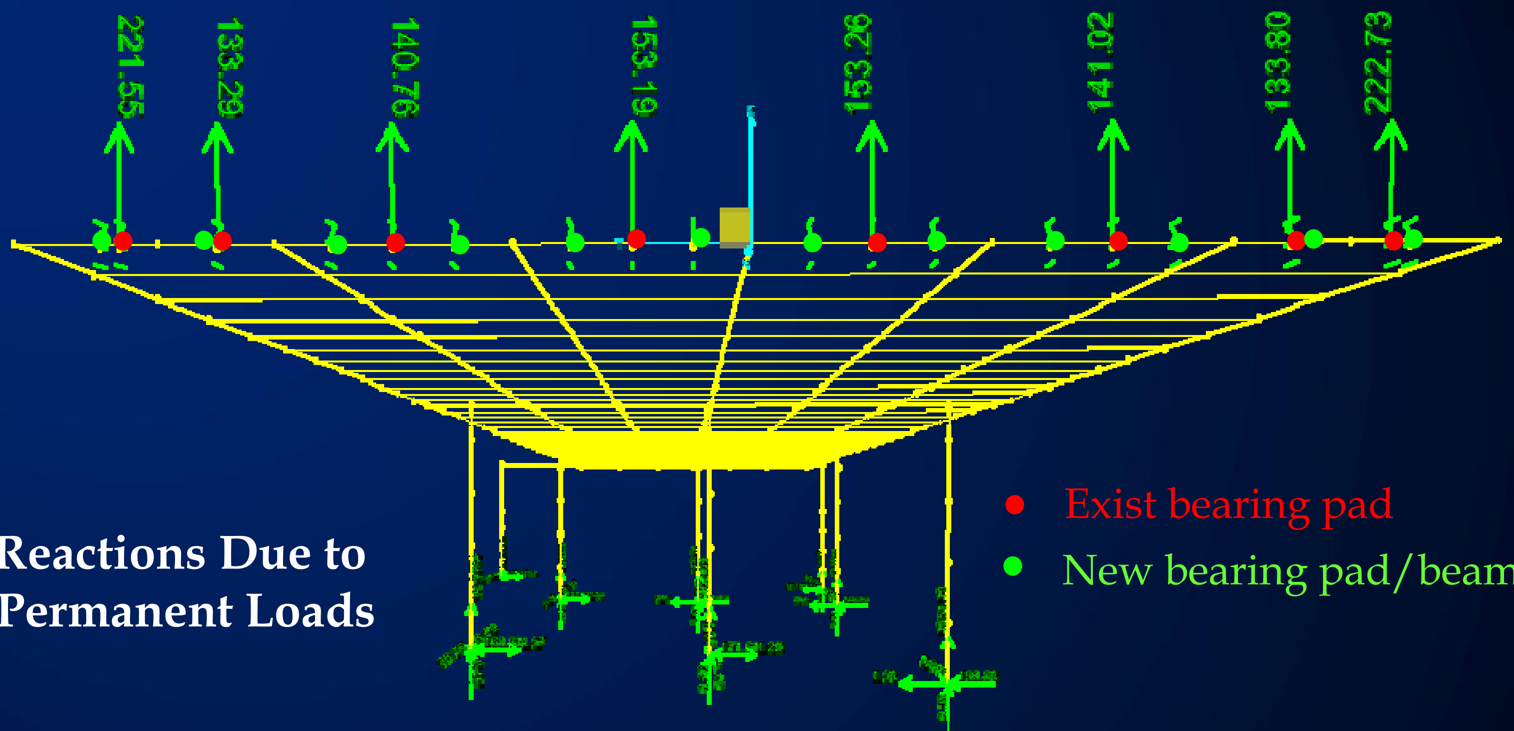


PT Bars Stressing Sequence

Grillage Model
(Frame 2 of the SB Bridge Shown)



PT Bars Stressing Sequence

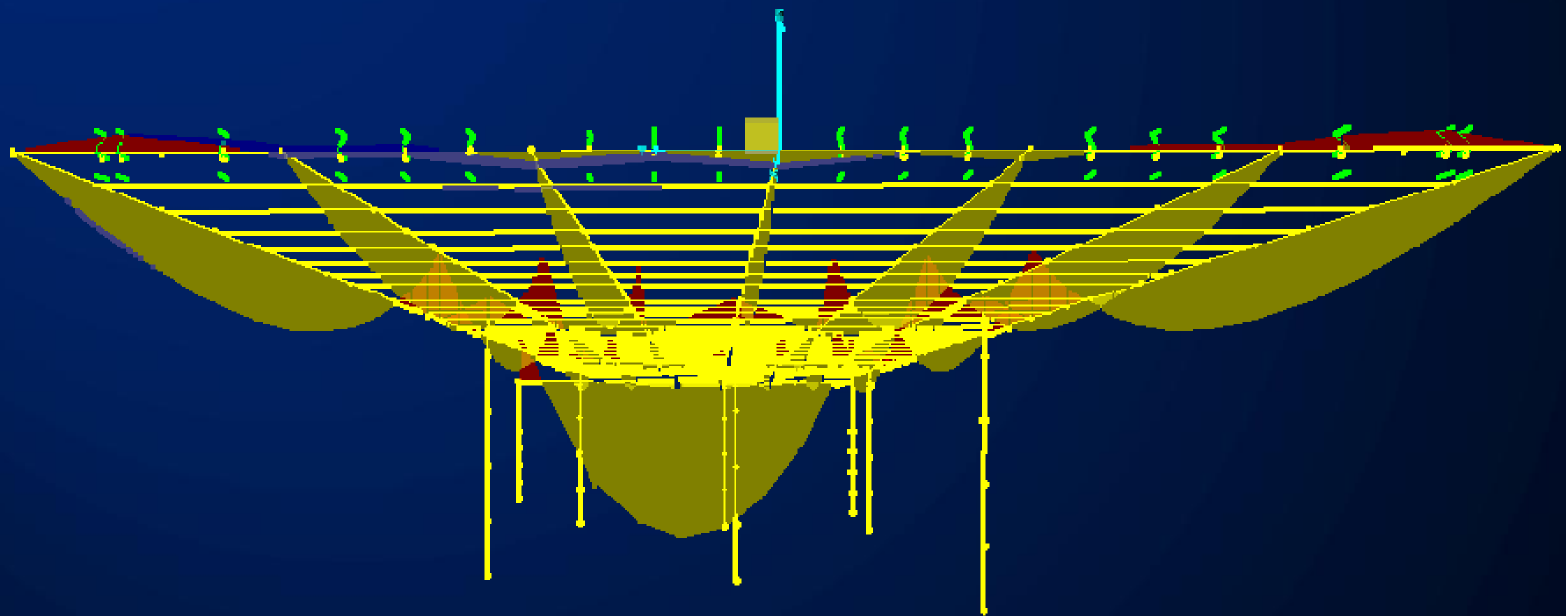


Reactions Due to Permanent Loads

- Nonlinear spring (compression-only) elements used to model existing bearing pads and new steel beams/bearing pads
- Initial load case is permanent loads (reactions on existing pads only)
- Model loaded in the same sequence specified for stressing of PT bars

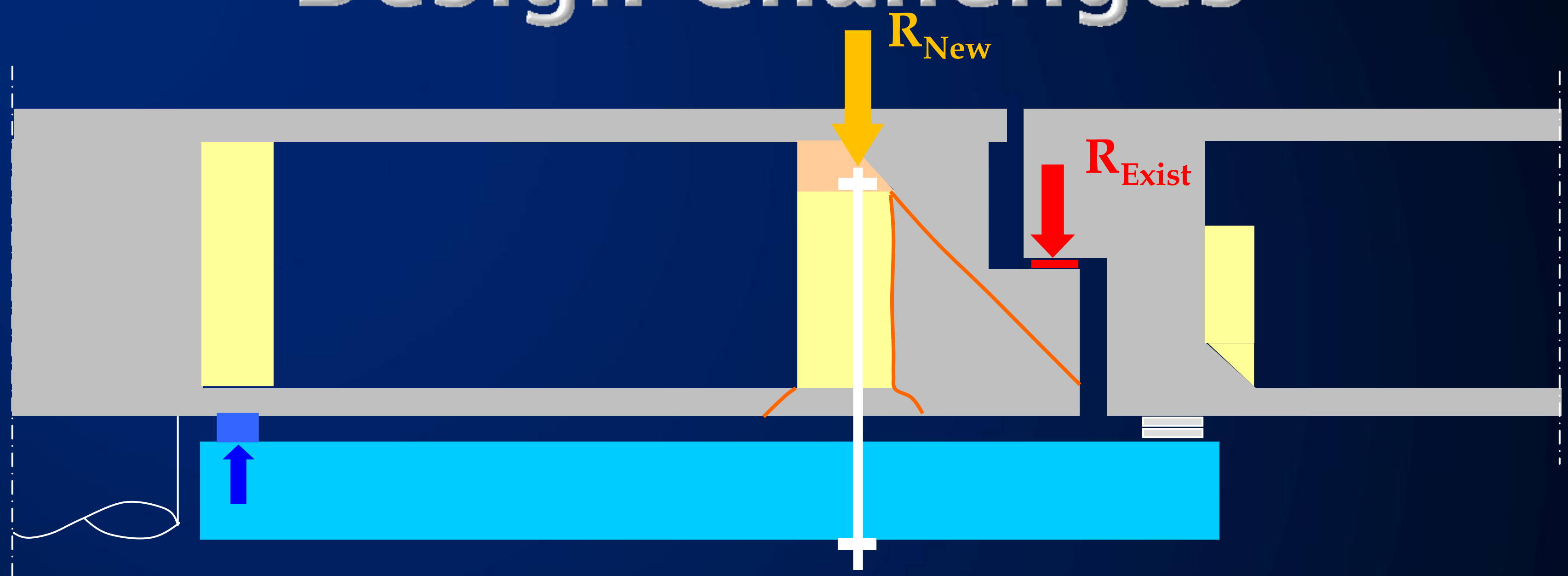
PT Bars Stressing Sequence

Bending Moment Due to Jacking of PT Bars at the Exterior Steel Beams (Left Side)



- Hinge diaphragms checked for forces due to PT bars stressing
- Bending moment is less than cracking moment and flexural capacity

Design Challenges



- New reactions on hinge diaphragm are about 50% higher than reactions in the existing condition
- Transverse analysis and check of hinge diaphragms and bolster
- Diaphragm is modelled as a beam supported on springs
- Possible failure modes of the bolster have been checked
- Special attention to design of PT Bars

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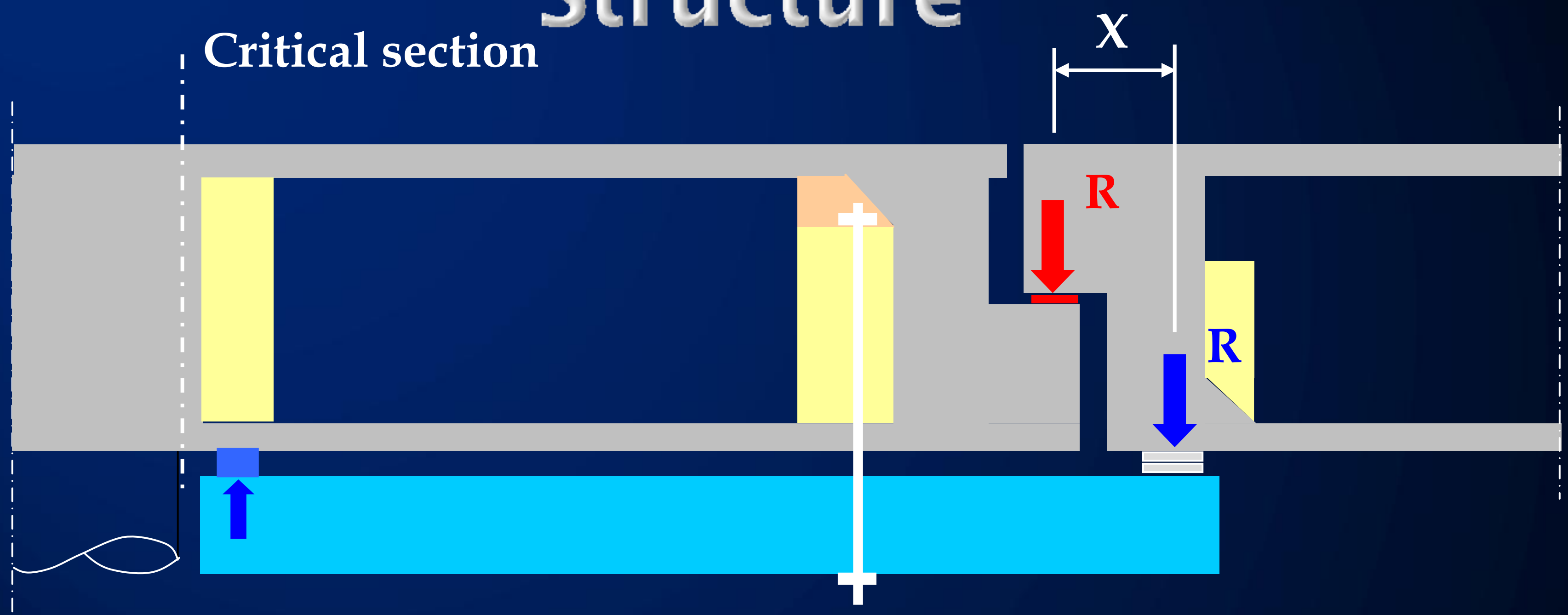
Check of the Existing Structure



- Additional eccentricity of load on the short side of the hinge results in higher moments and tensile stresses at top of the superstructure
- Additional moment = R*X (X is approximately 3 ft)
- Additional moments and shears due to weight of bolsters and steel beams

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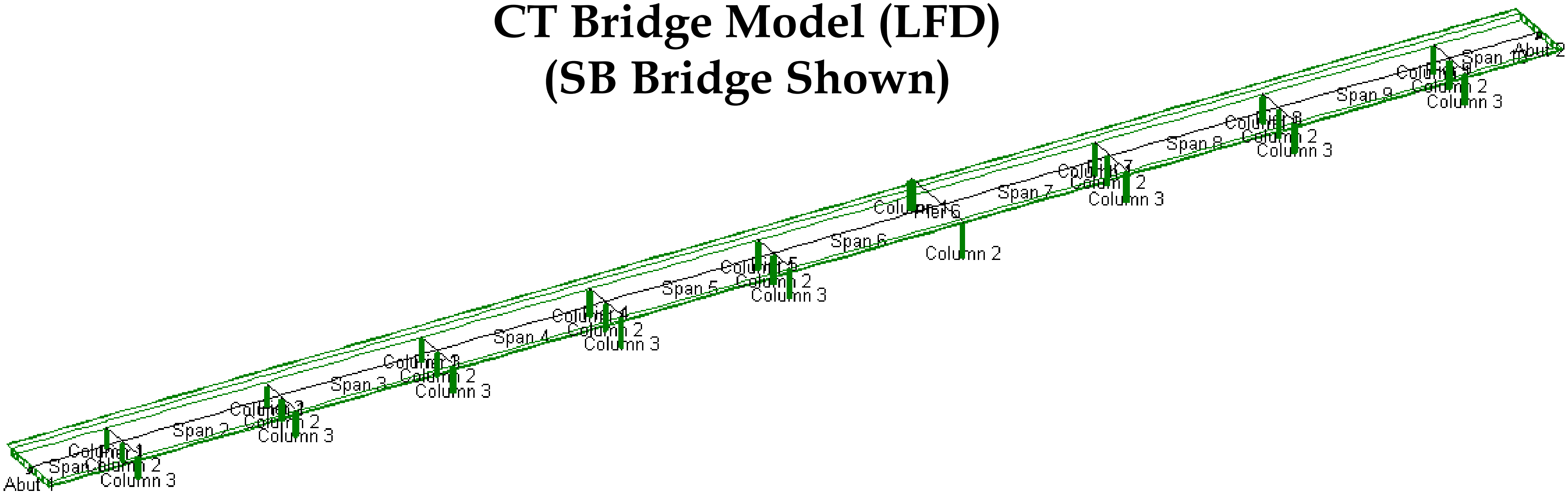
Check of the Existing Structure

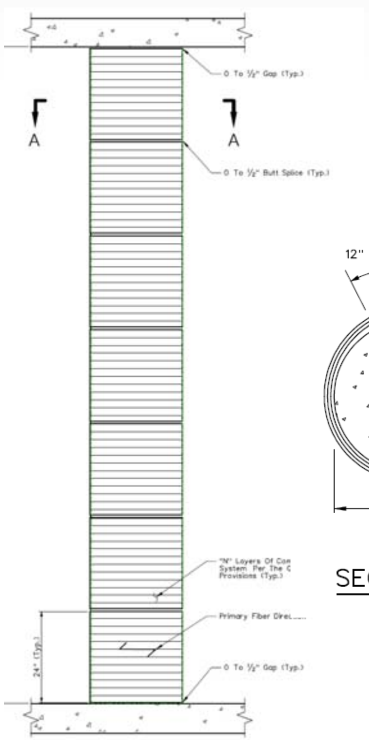
- Concrete stresses under service loads are within the acceptable limits
- Flexural and shear capacities are adequate

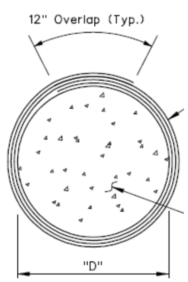
CT Bridge Model (LFD)
(SB Bridge Shown)



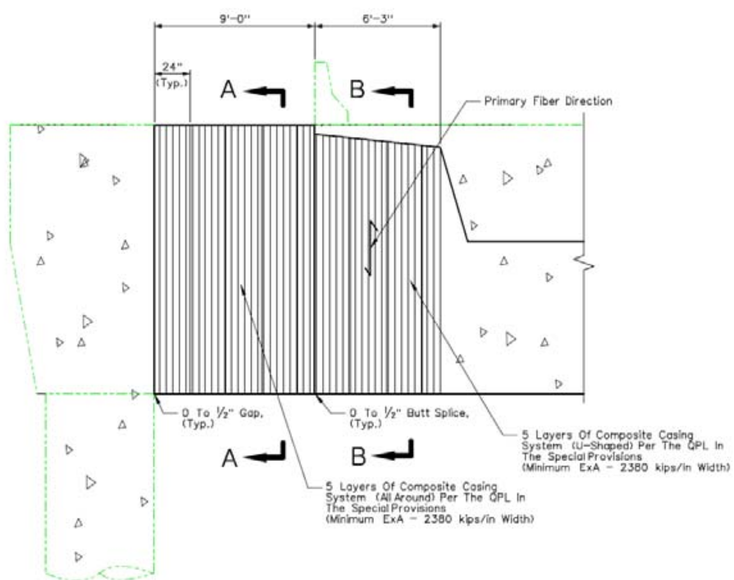
Seismic Retrofit

- Elastic dynamic & pushover analyses
- Displacement demand exceeds capacity for one column
- Shear demand exceeds capacity for 4 columns
- Column retrofit & outrigger bent cap retrofit by fiberwrap composite system

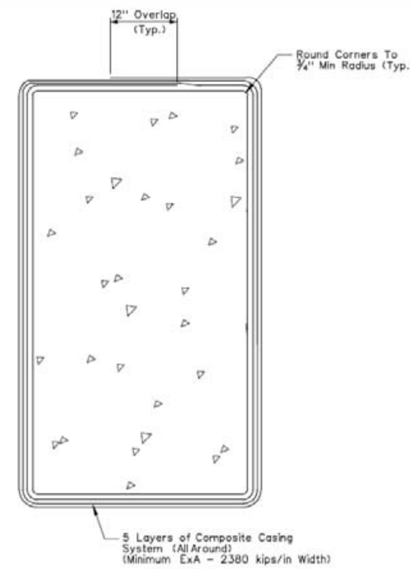




SECTION "A–



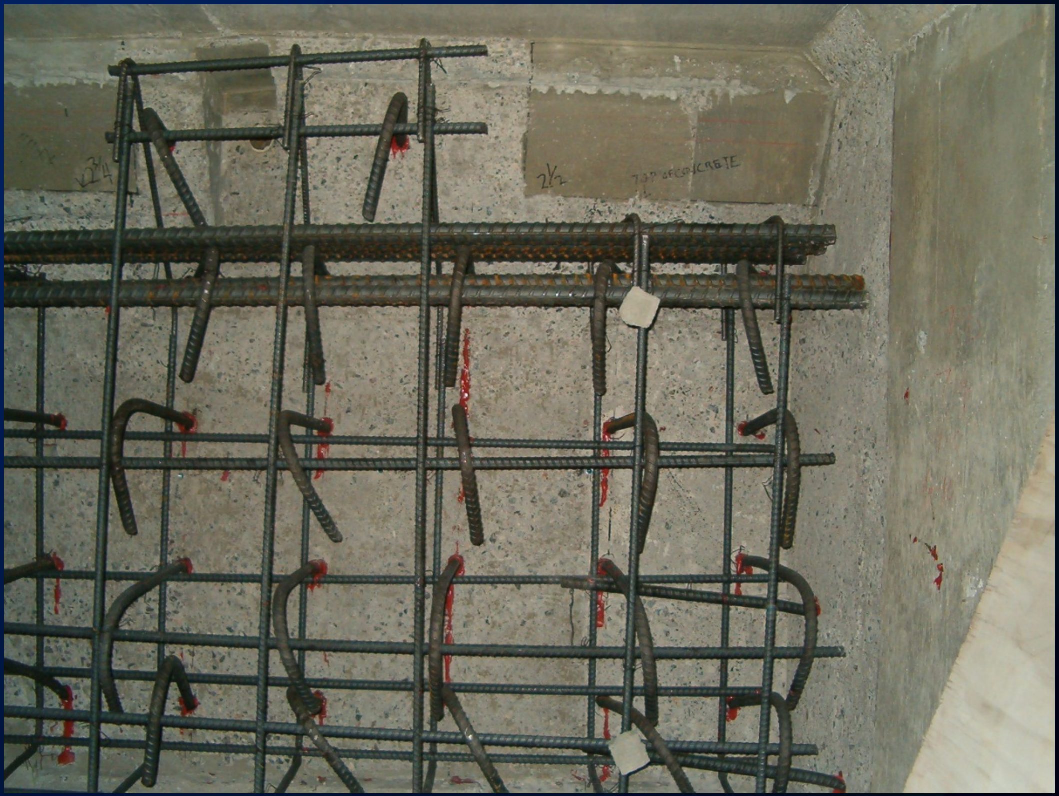
SB PIER 6 CAP ELEVATION



SECTION "A–A"

NOTE: NOT ALL LAYERS SHOWN FOR CLARITY

Construction



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Summary

- Multiple Alternatives Available for Replacement of ISH (staging, aesthetics)
- External Strong Back Proved Best Alternative for This Case
- In-Depth Analysis Necessary for Force Transfer
- Scheduled Completion end of 2011

Acknowledgements

- Nevada DOT (owner, project manager)
  - Todd Stefonowicz, NDOT Bridge
- Atkins (formerly PBSJ) (prime consultant)
  - Jaime Chang and Las Vegas Team

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