A New Signature Bridge for the City of Los Angeles: The Sixth Street Viaduct

2017 Western Bridge Engineers' Seminar

September 6-8, 2017

INTRODUCTION

- Replacement Required – ASR Concrete
- 2012 International Design Competition
- Design Commenced in March 2013
- CMGC Project Delivery
- Viaduct Foundation Commenced August, 2016
- Construction Completion - Late 2020

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Sixth Street Viaduct Replacement

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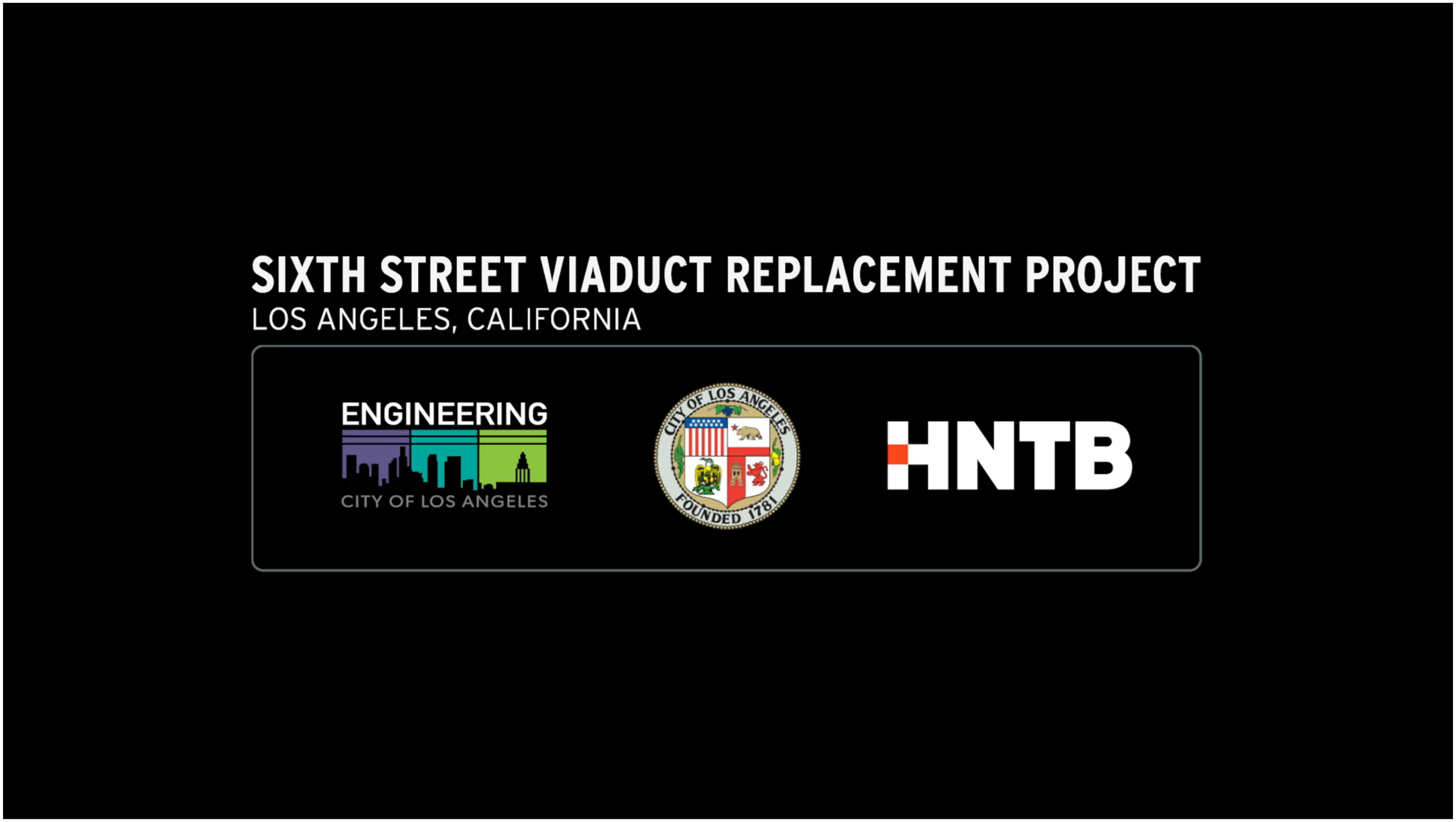
Sixth Street Viaduct Replacement



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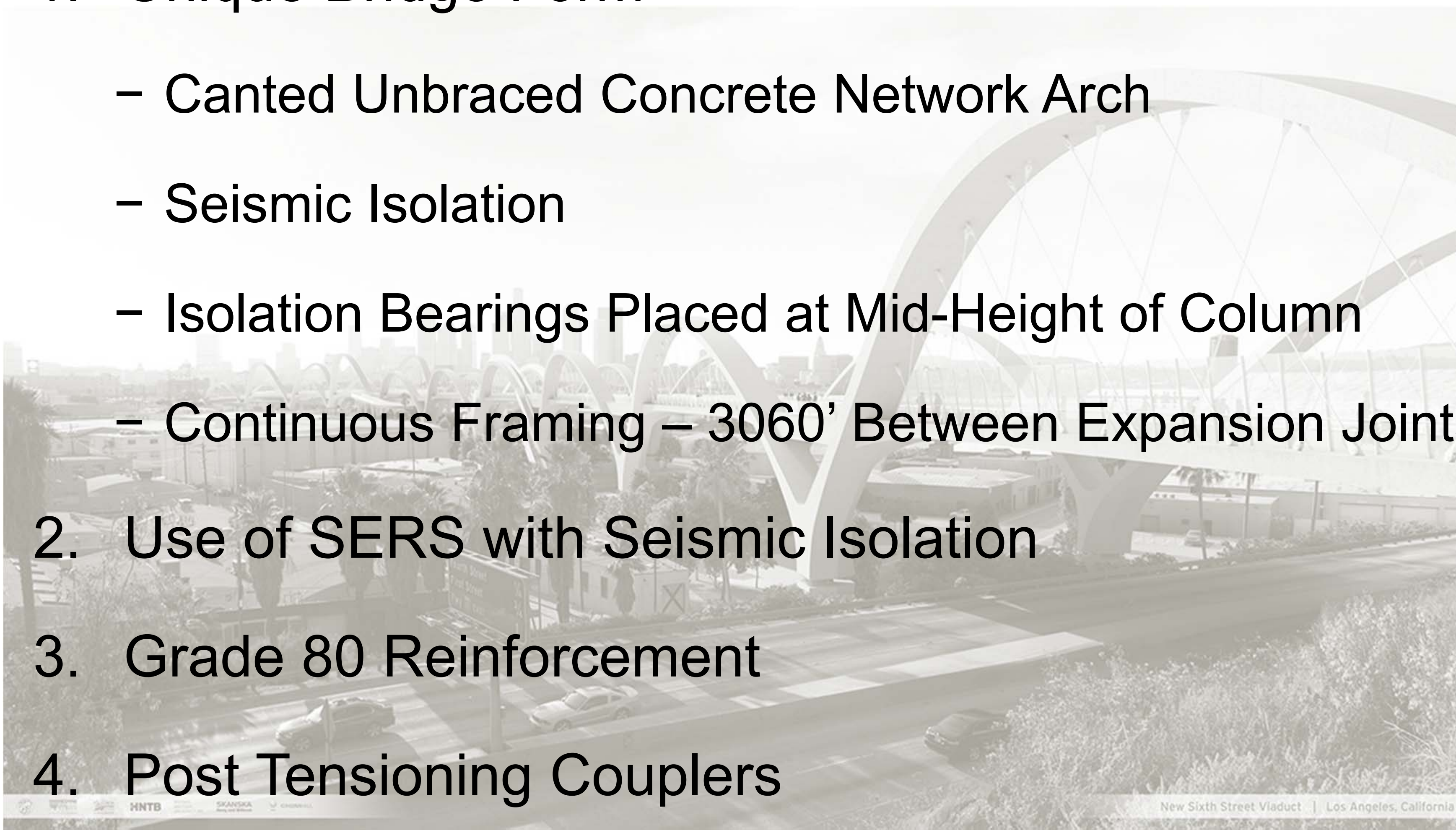
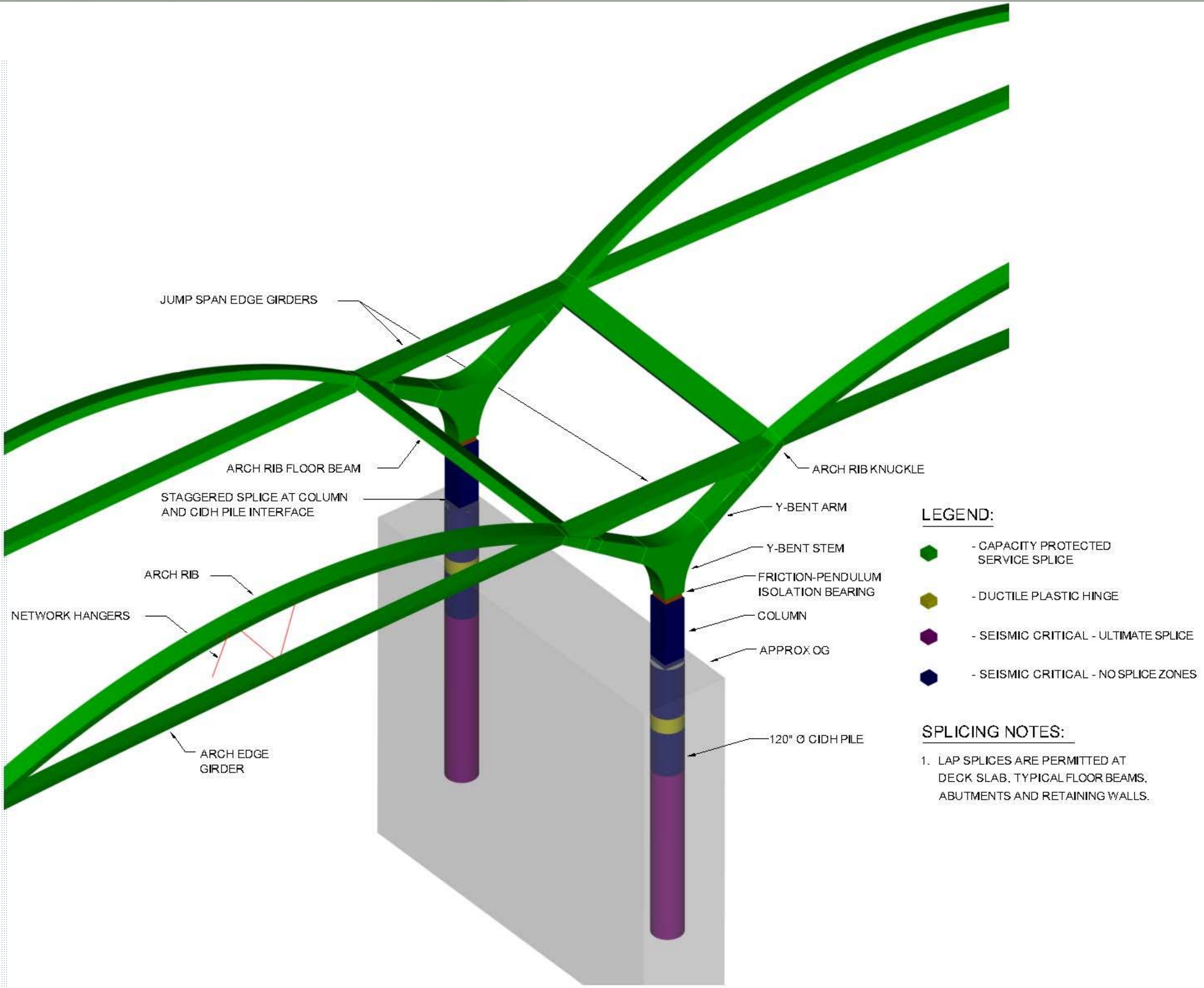
Agenda – Project Innovations

1. Unique Bridge Form
   - Canted Unbraced Concrete Network Arch
   - Seismic Isolation
   - Isolation Bearings Placed at Mid-Height of Column
   - Continuous Framing – 3060' Between Expansion Joints
2. Use of SERS with Seismic Isolation
3. Grade 80 Reinforcement
4. Post Tensioning Couplers



Unique Bridge Framing

- No Arch Rib Bracing
- 9^0 Canted Arch Ribs
- Network Arch
- 10 Continuous Arch Spans
- Expansion Joints at Abutments only
- Arch Continuity with Substructure
- Extensive Tuning to Balance Y-Arm Thrust
- Seismic Isolation with Bearings at Column Mid-Height



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Network Arches - Resources

- Professor Per Tveit – Father of Network Arch
  - Developed in Late 1950's
  - http://home.uia.no/pert/index.php/Home
- Presentation by Gregor Wollmann of HNTB
  - https://www.youtube.com/watch?v=Q5oQDyJaLcs

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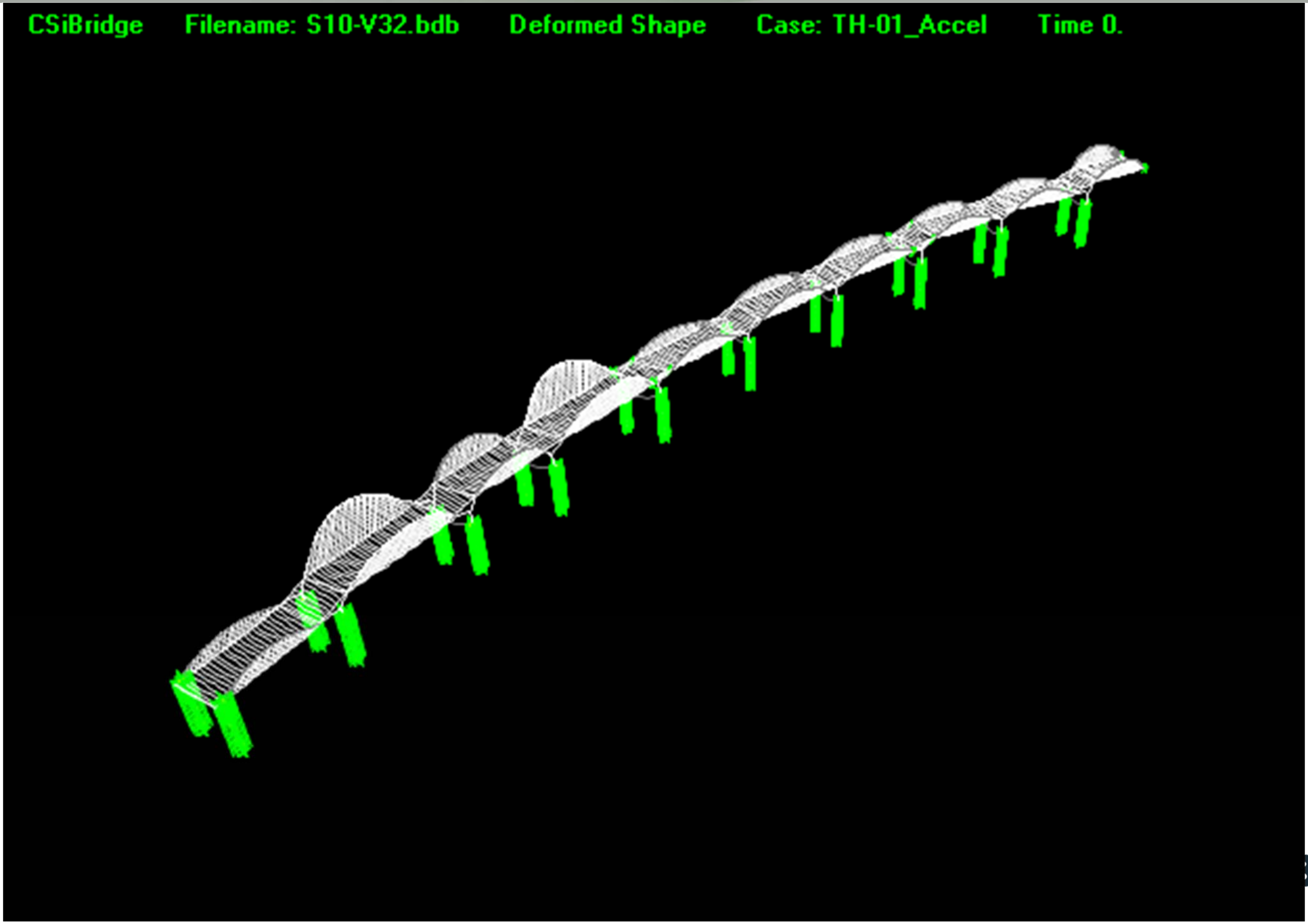
Network Arch Definition and Benefits

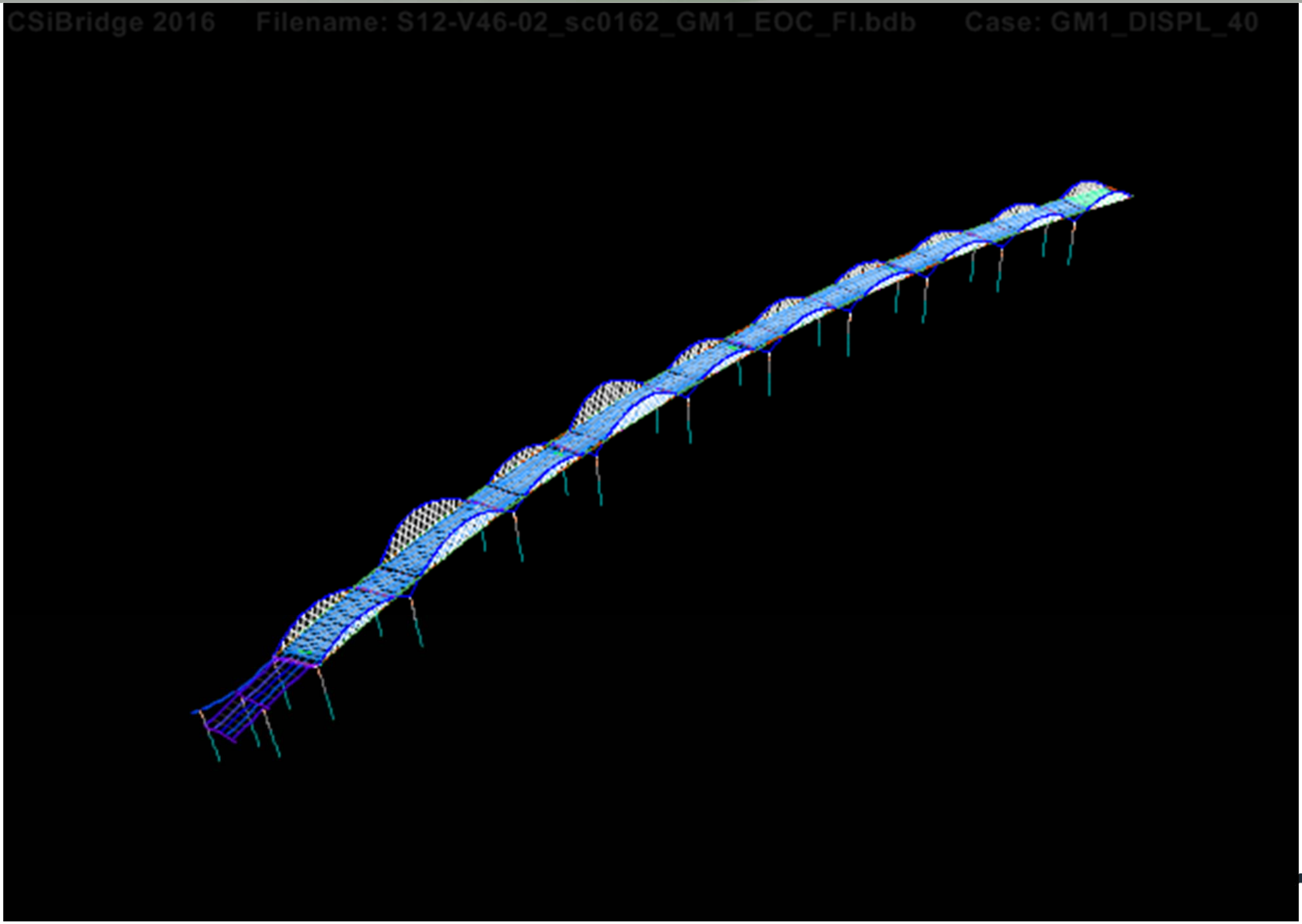
- Hangers must be Installed at an Angles
- Some Hangers must Cross at Least Twice
- Minimizes Moments in Arch Ribs and Edge Girder Ties from Unbalanced Loading
- Reduces Size of Arch Ribs and Edge Girder Ties

Seismic Response Before Isolation

Displacements x20



Seismic Response After Isolation
Displacements x20



Reasons for Selecting Pendulum Bearings

- Triple Pendulum Bearings Provide Small 6.5’ x 6.5’ Size
- Single Pendulum Bearings Will Increase Size to Over 10’ x 10’
- Single Pendulum Bearings Cost More and Provide Inferior Performance
- Lead Rubber Bearings Will Increase Force to Foundation System
- Lead Rubber Bearings Lack Rapid Strength and Stiffness Increase Characteristics to Activate SERS

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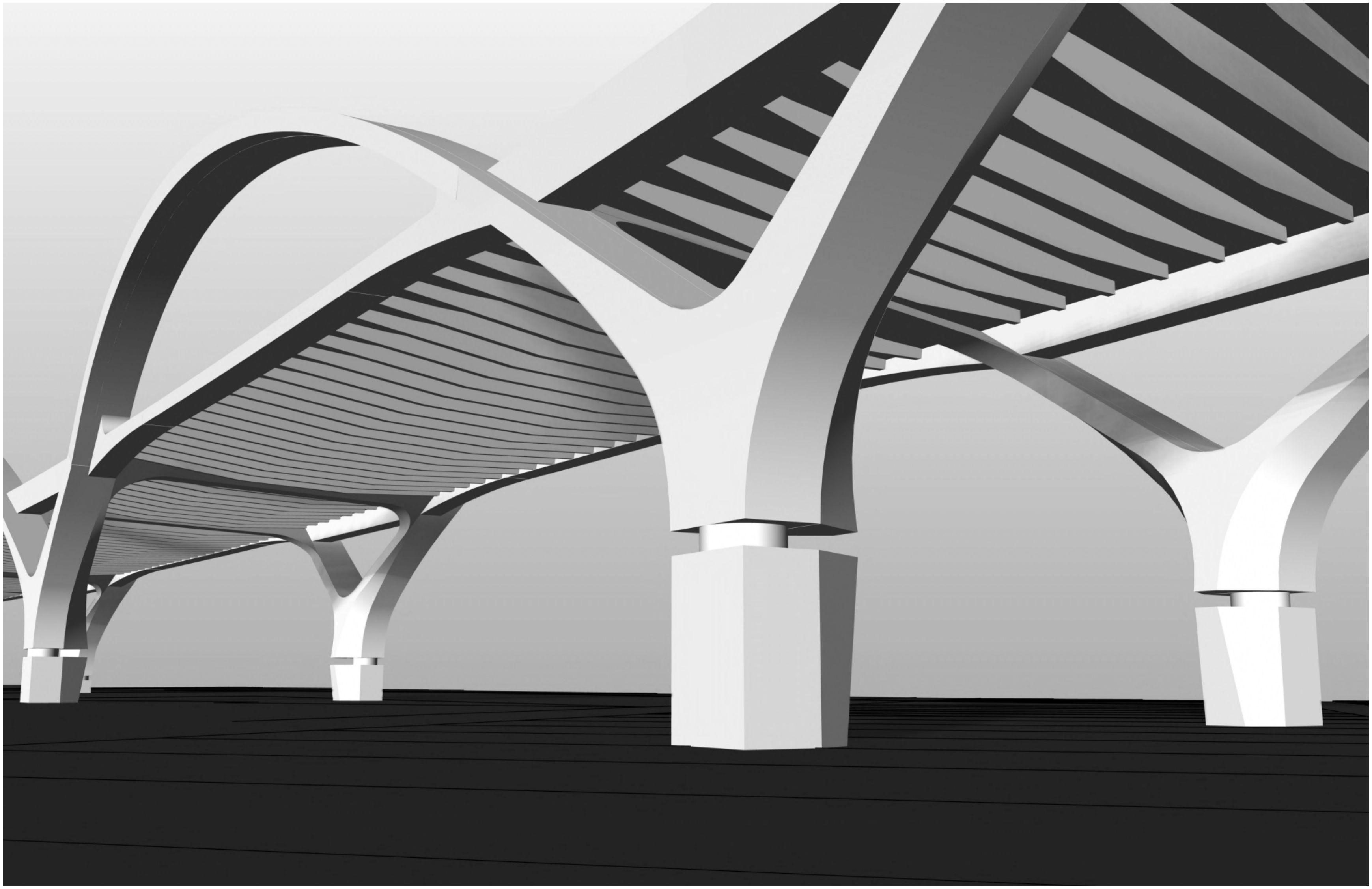
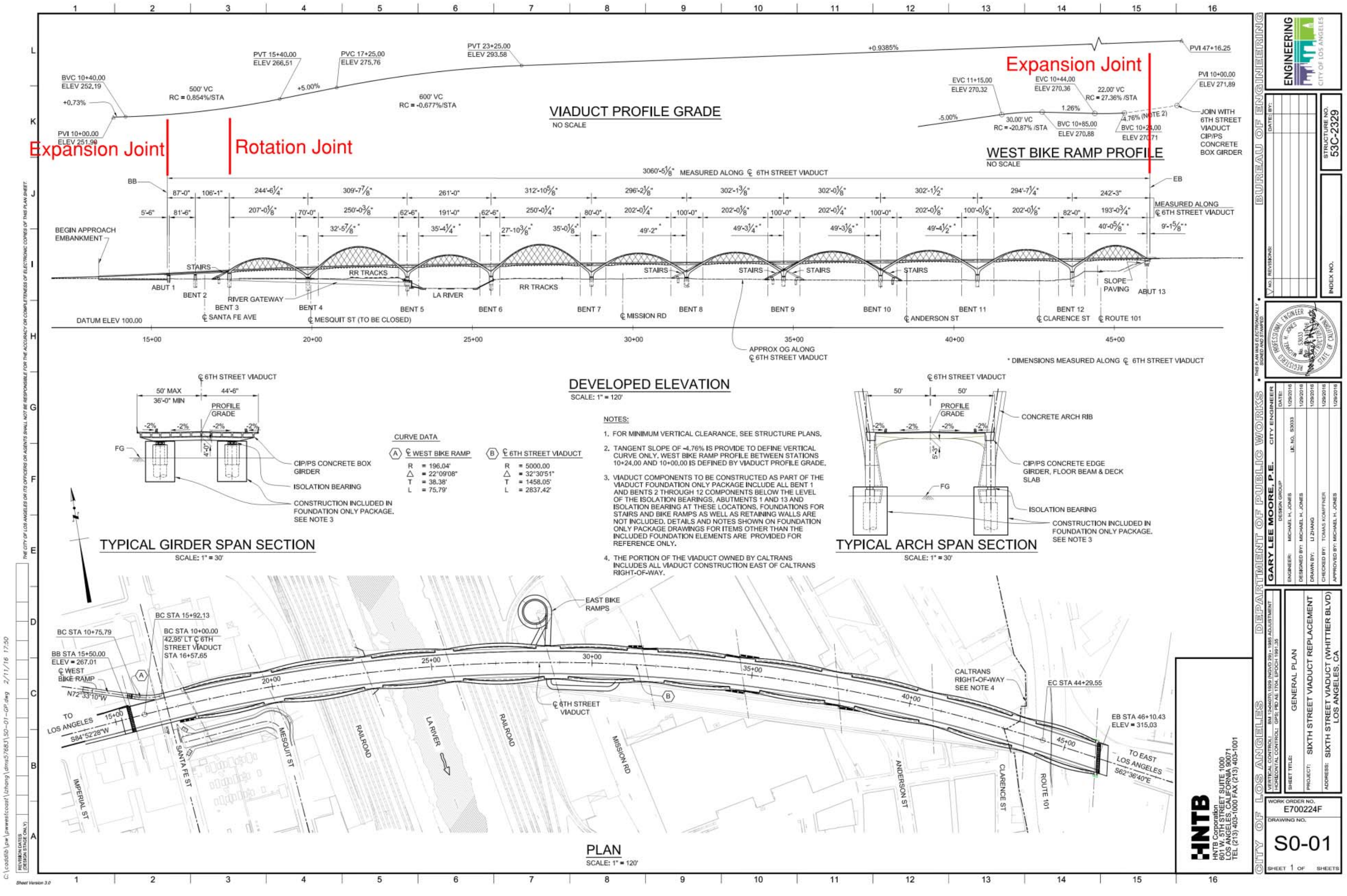
Isolation Bearings Placed at Mid-Height of Column

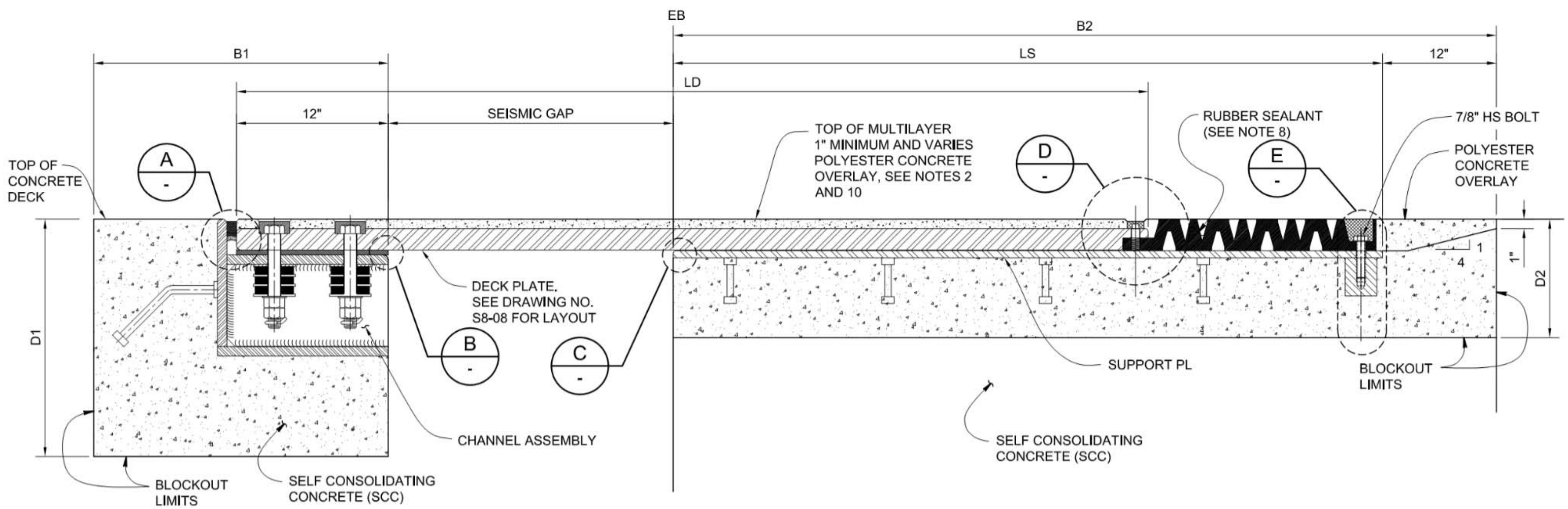


Continuous Framing – 3060’ Between Expansion Joints



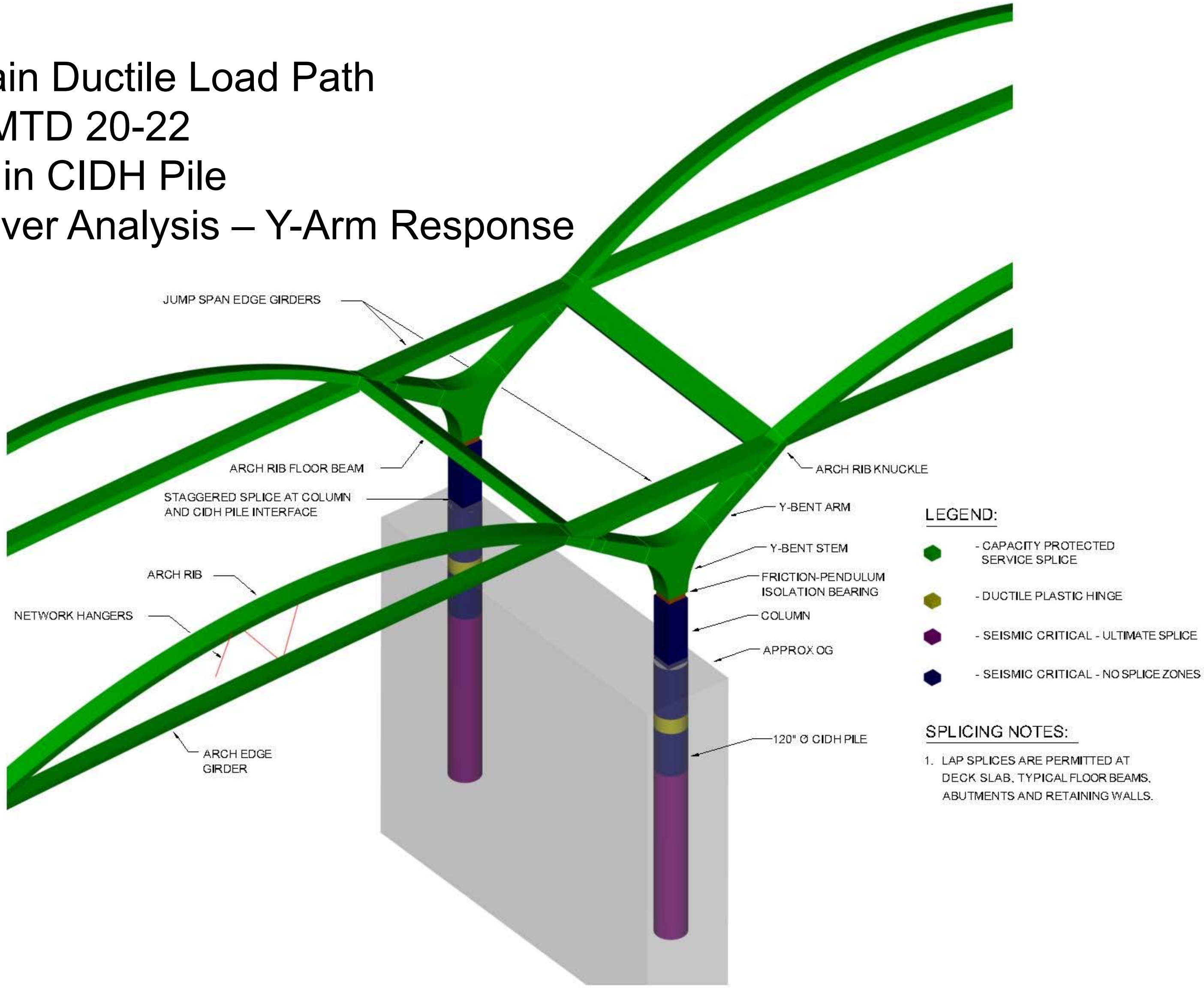
Caltrans Type II Seismic Expansion Joint

Seismic Gap = 30”
MR = 14”



Use of SERS with Seismic Isolation

- Maintain Ductile Load Path
- Draft MTD 20-22
- Hinge in CIDH Pile
- Pushover Analysis – Y-Arm Response



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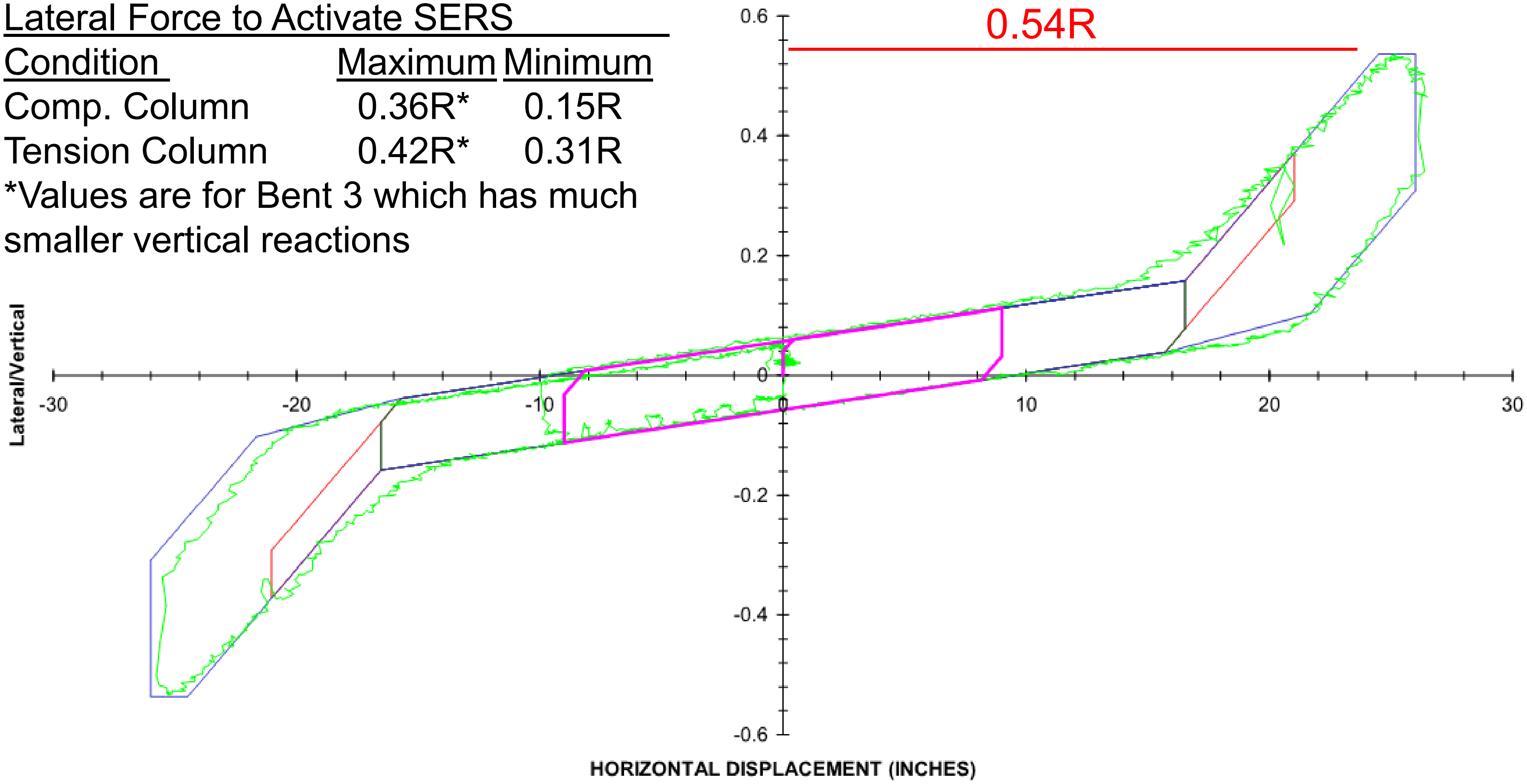
Lateral Capacity of Bearing at 50" Displacement

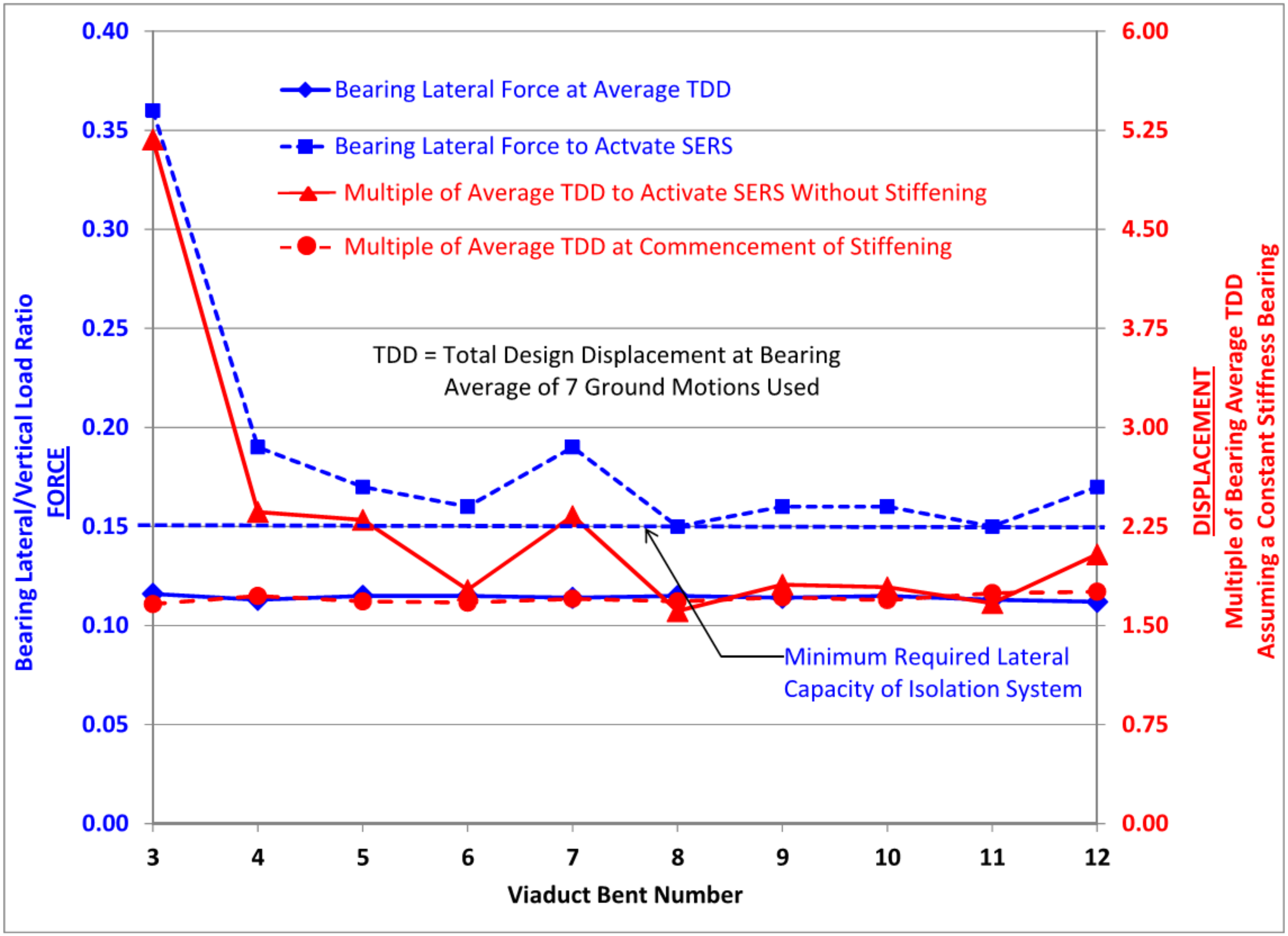
Lateral Force to Activate SERS

Condition	Maximum	Minimum
Comp. Column	0.36R*	0.15R
Tension Column	0.42R*	0.31R

*Values are for Bent 3 which has much smaller vertical reactions



Isolation Performance to Activate SERS



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EPS Developed New Bearing Concept

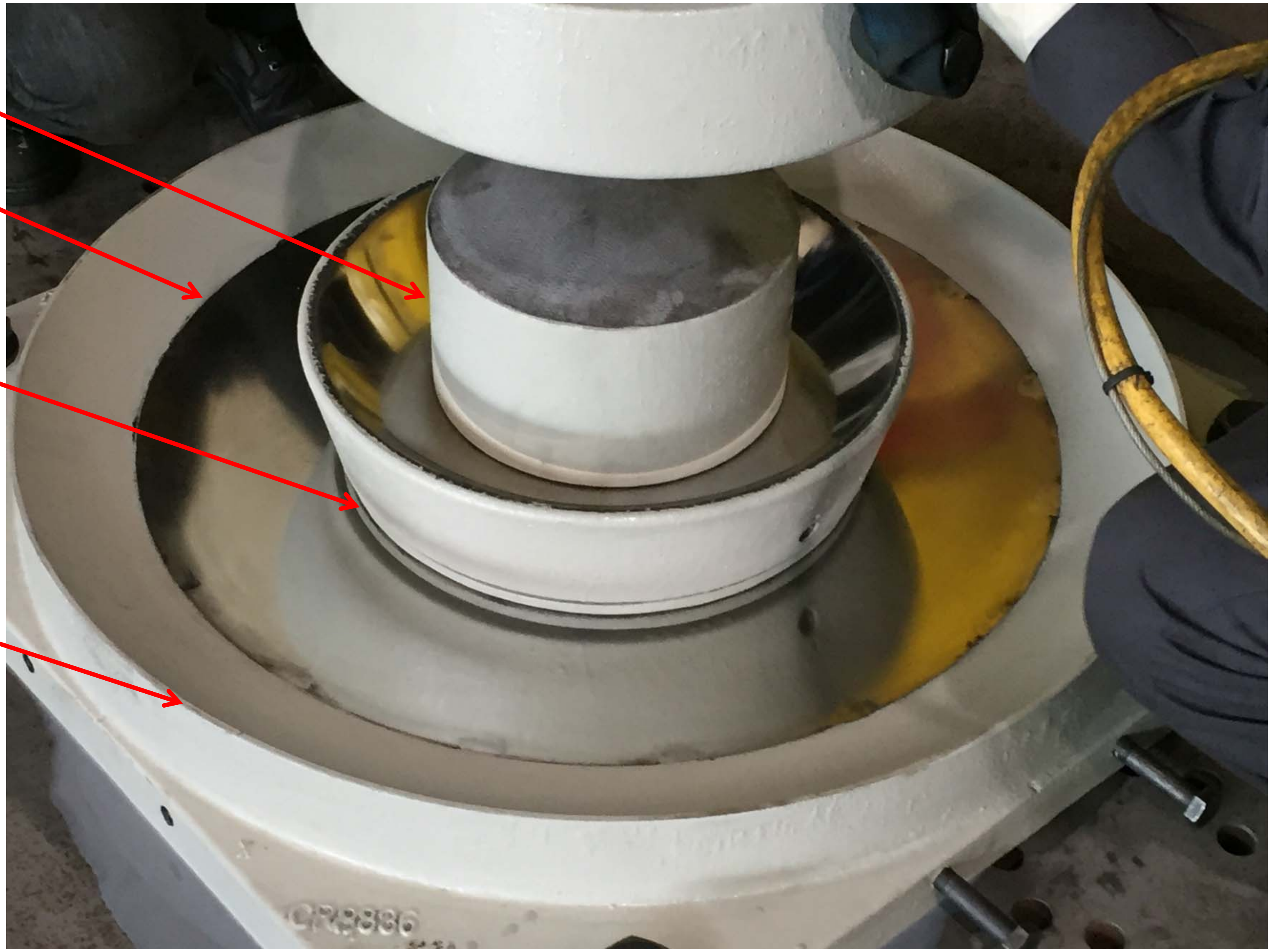
Inner slider

Limit of stainless steel liner

Yielding mechanism at inner concave slider

Outer concave plate – small 12½” radius used at exterior

Typical restraining ring not used



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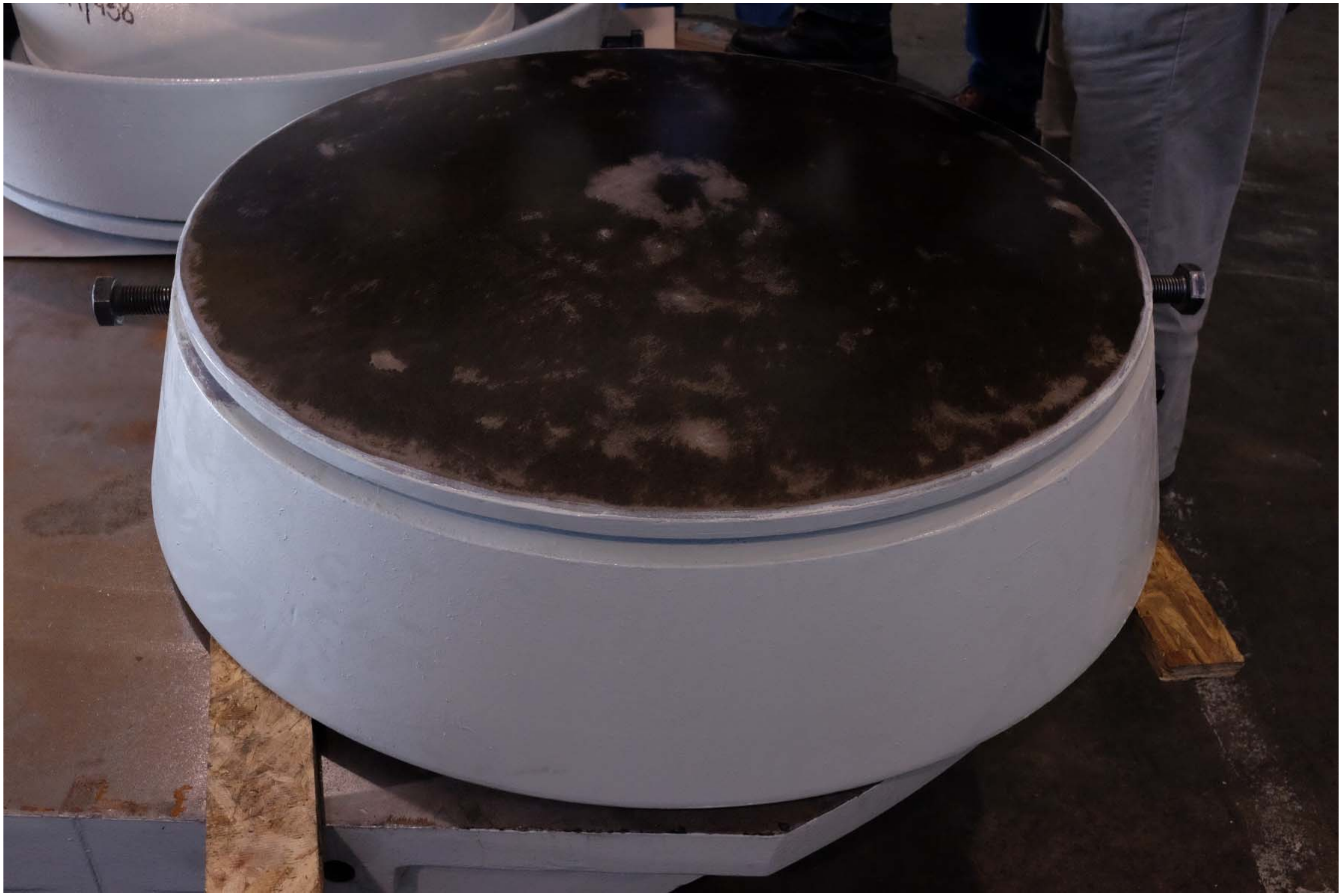
Isolation Bearing Yielding Mechanism



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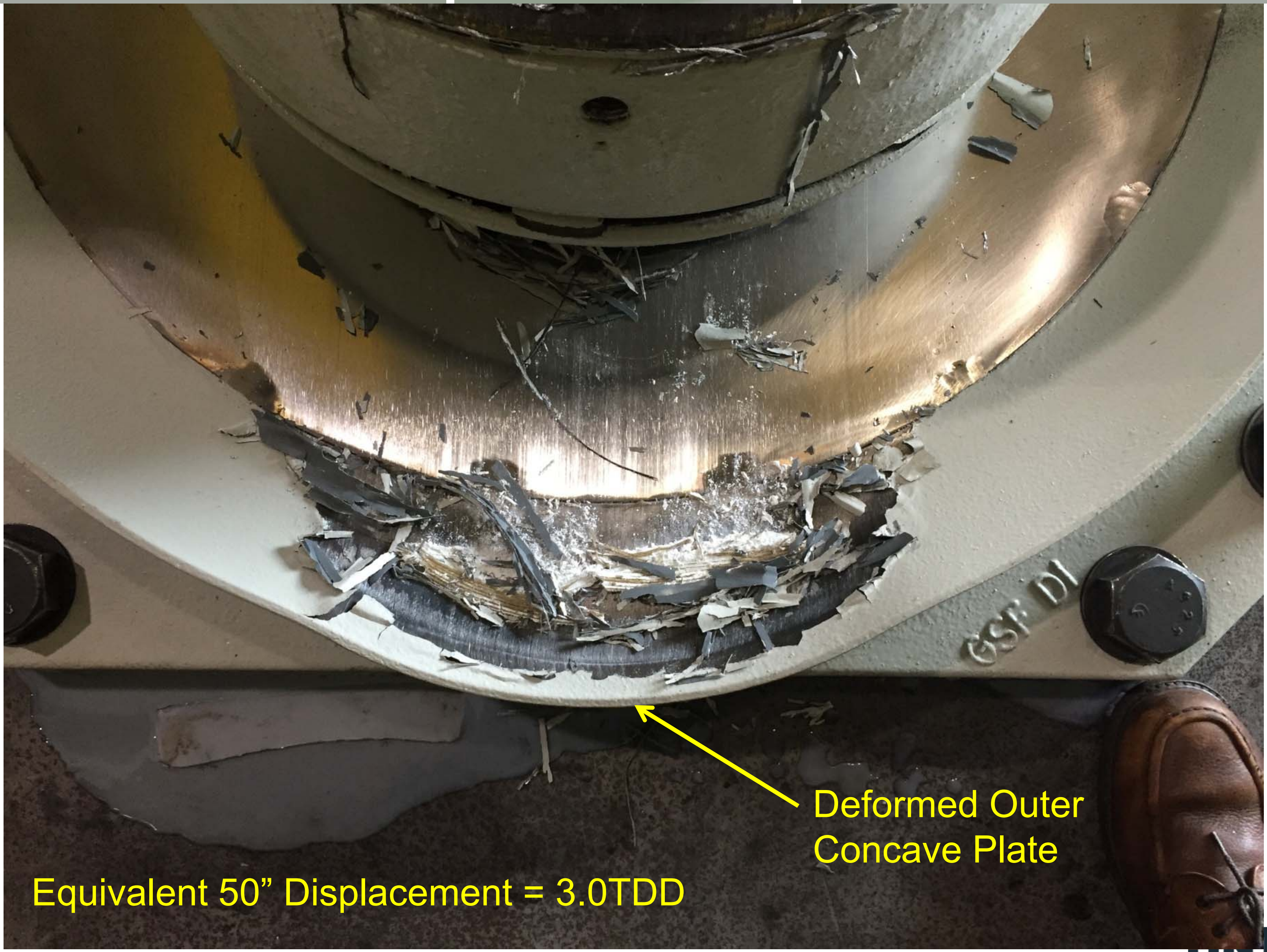
Actual Full-Size Bearing

Prototype Testing to 42” Equivalent Displacement

Outer Concave Plate after 50” Equivalent Displacement



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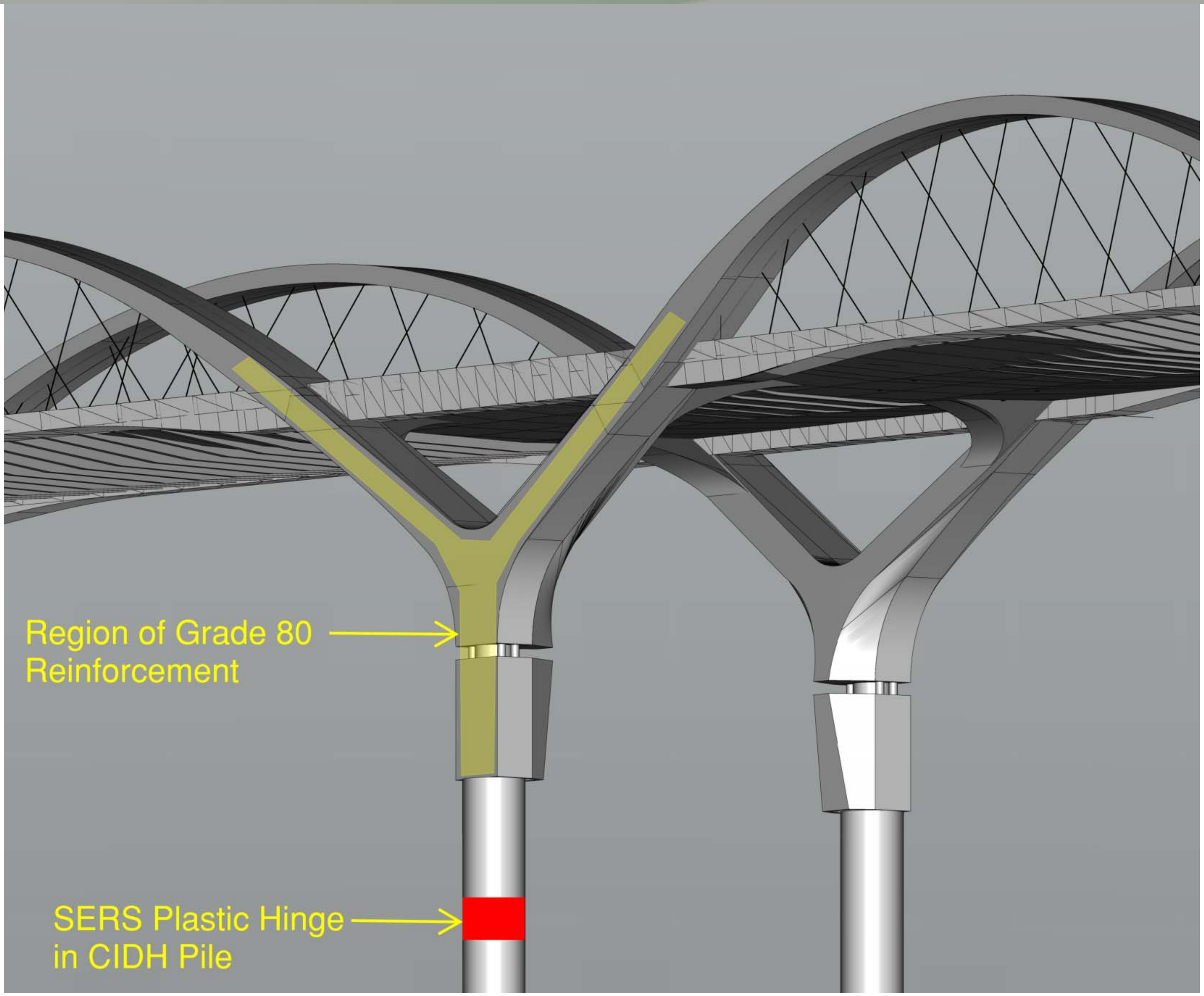
Grade 80 Reinforcement



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Grade 80 Rebar Limitations

- Members must be Capacity Protected
- Yield Strength of 80 ksi only Considered for SERS
- Expected Yield Strength of 87 ksi
- Strength and Isolated Seismic Limits Assumed 60 ksi
- Grade 80 Couplers to be Approved Through Testing
- WSDot Memo used for Splicing and Development Length

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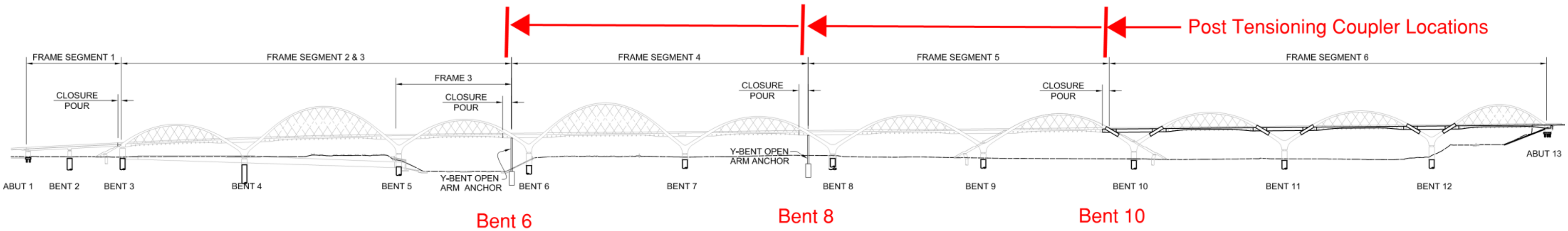
Post Tensioning Couplers



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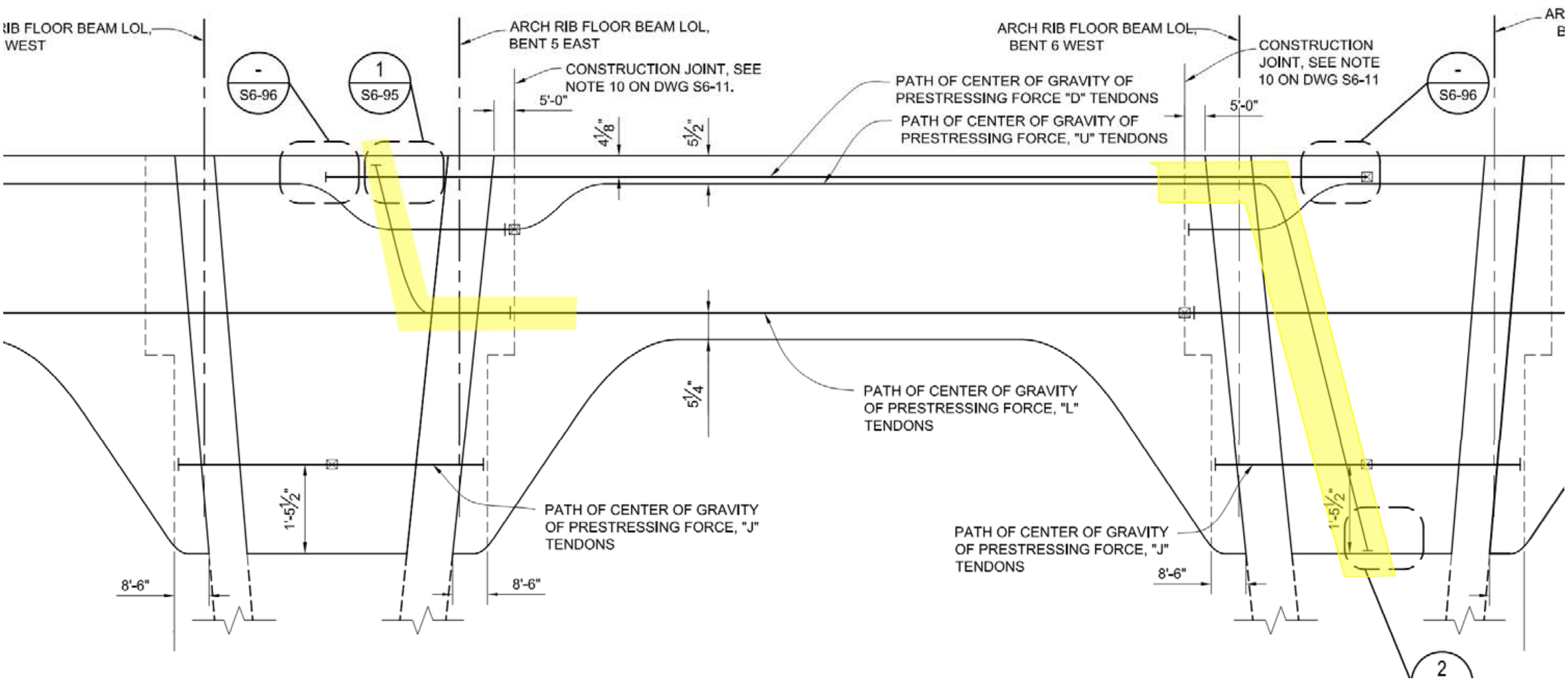
Couplers Avoids Post Tensioning Lapping



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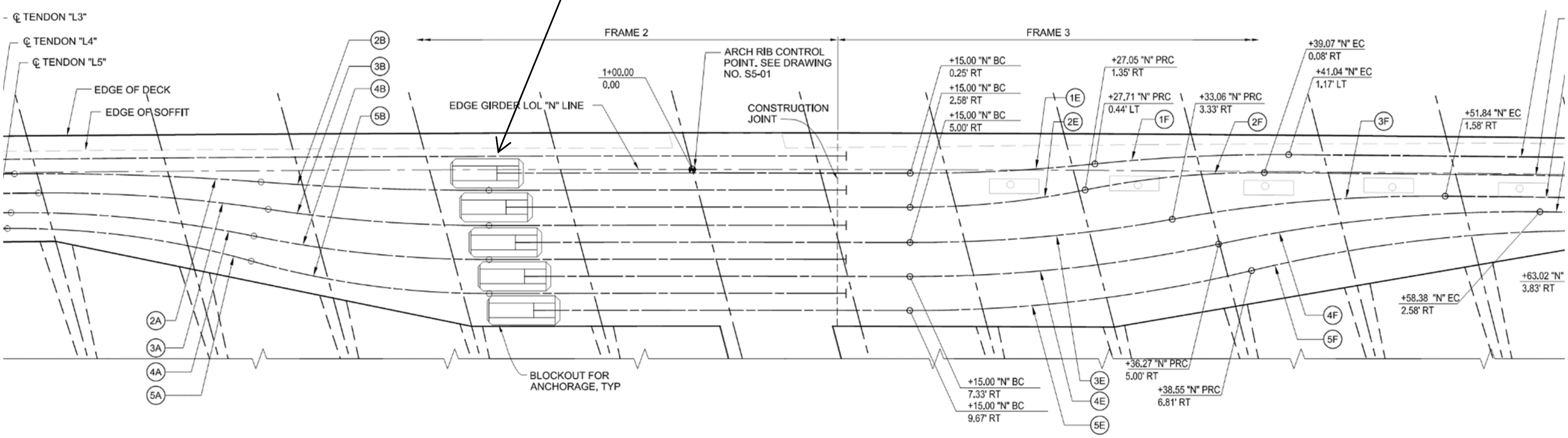
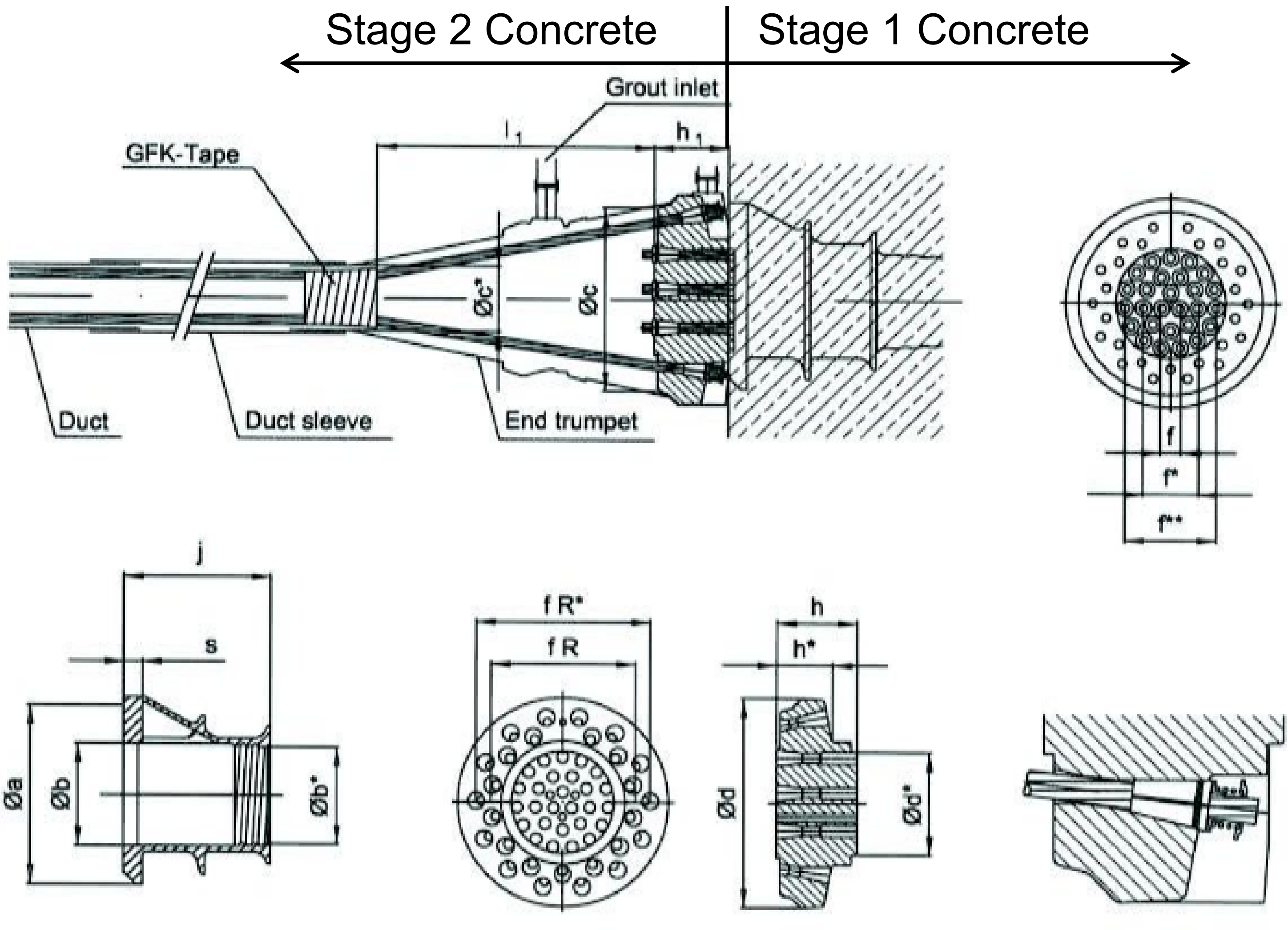
Post Tension Lap Splicing at Edge Girder

PT Anchorage Threaded Through
Continuous PT to Deck



Post Tensioning Coupler Details
DSI Coupler P



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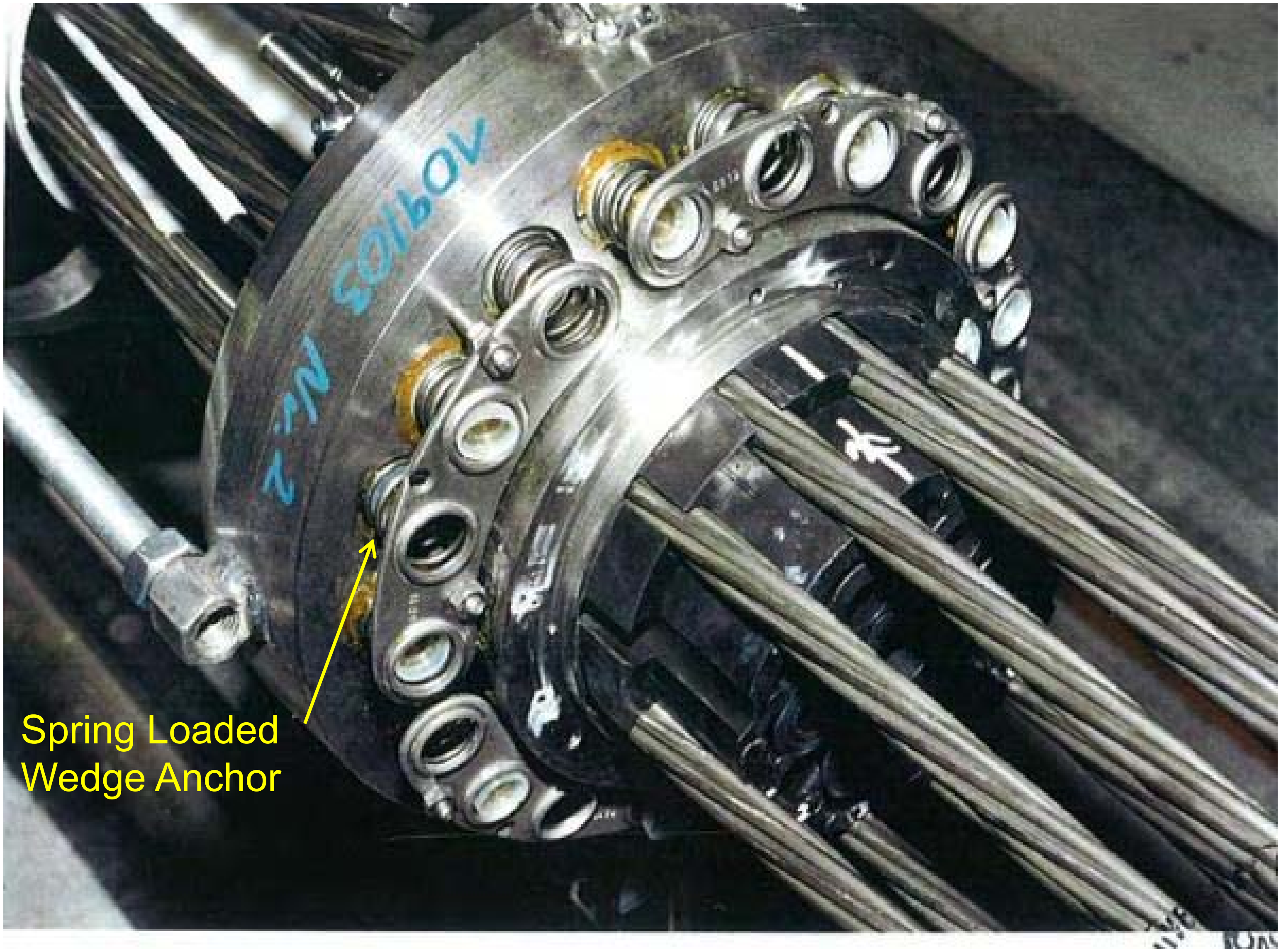
Coupler P Photograph



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- Questions?

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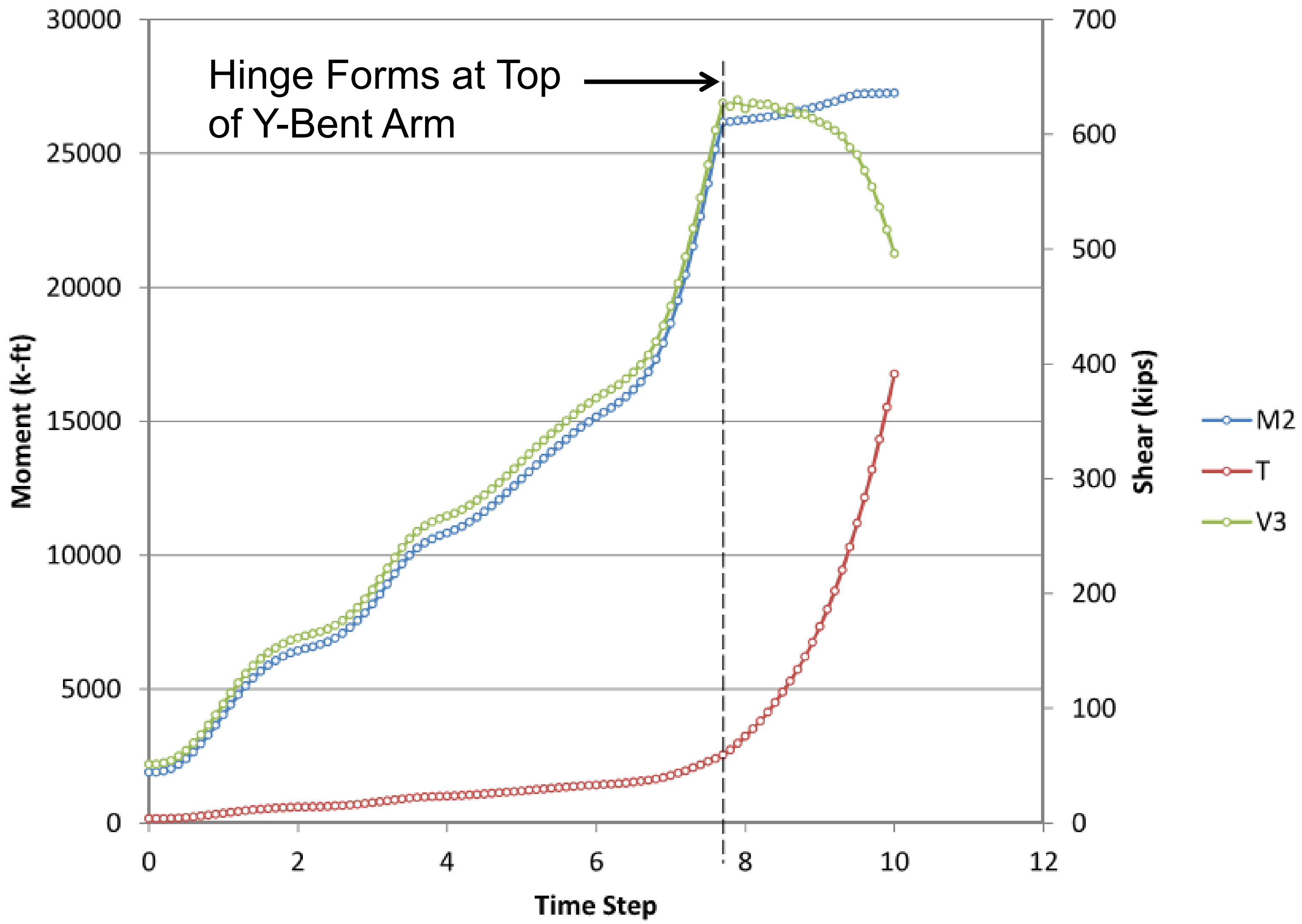
SERS Analysis – Y-Bent Arm Shear/Torsional Failure



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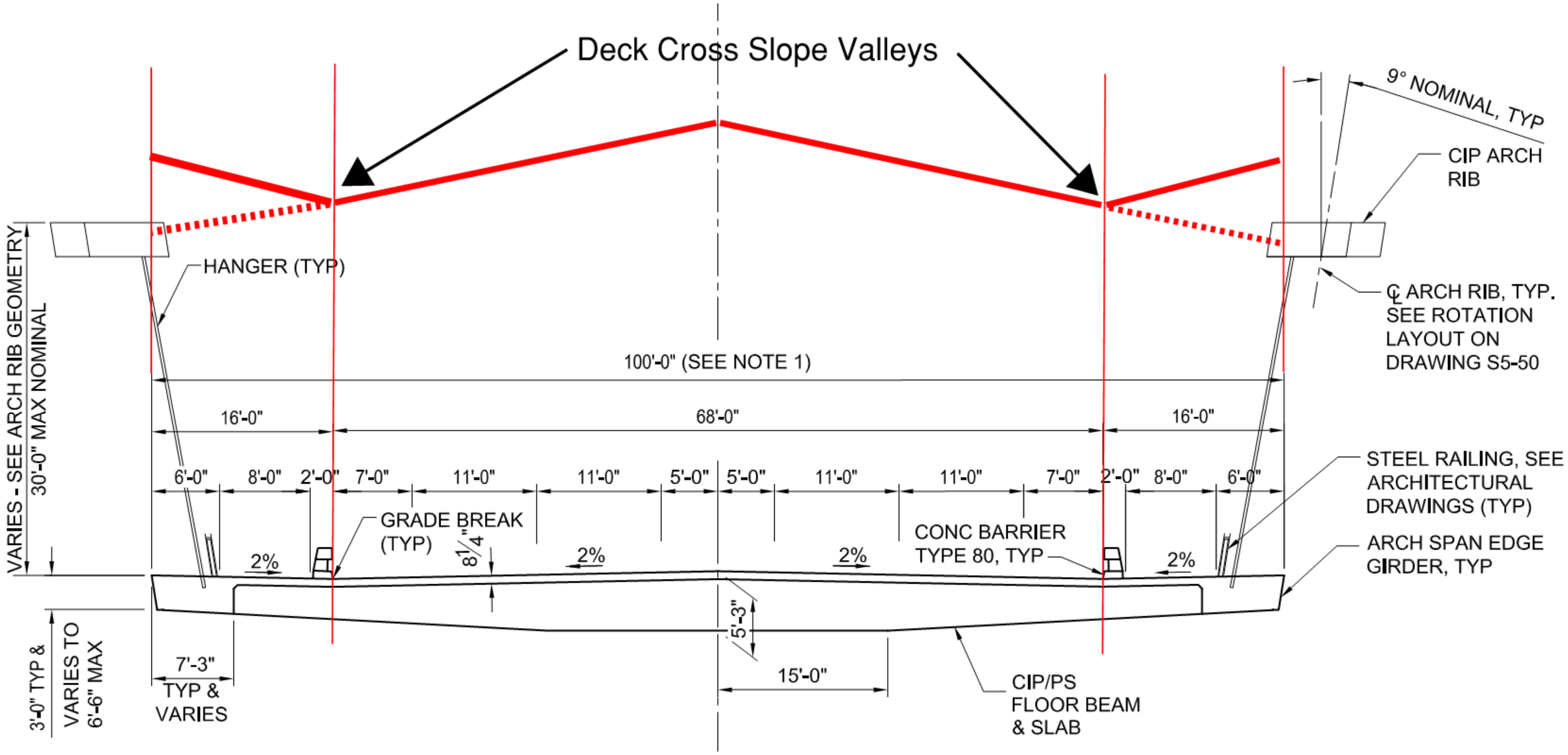
Y-Bent Arm Push-Over Study

Model	Stiffness – Igross Ratio			Δ	M	T	Axial
	Torsion	I22	I33	(ft)	(ft-kips)	(ft-kips)	(kips)
Y-Bent Only	1.0	1.0	1.0	0.440	33,687	12,930	4907
Y-Bent Only	0.2	1.0	1.0	0.735	48,850	4756	4907
Y-Bent Only	0.2	0.5	0.5	1.34	46,156	8558	5023
Y-Bent Only	0.01	1.0	1.0	0.900	57,125	296	4907

- Observations:
  - When in Elastic Range, Y-Bent Arm Torsion is Compatibility Torsion
  - After Plastic Yielding of Y-Bent Arm, Torsion becomes Equilibrium Torsion
- Conclusion:
  - Y-Bent Transverse Geometry Undesirable for Ductile Response
  - Must Prevent Plastic Hinging at Y-Bent Arms
  - Limit Plastic Hinging to Drilled Shafts

Caltrans Type 2 Joint Applied to "V" Cross Section



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