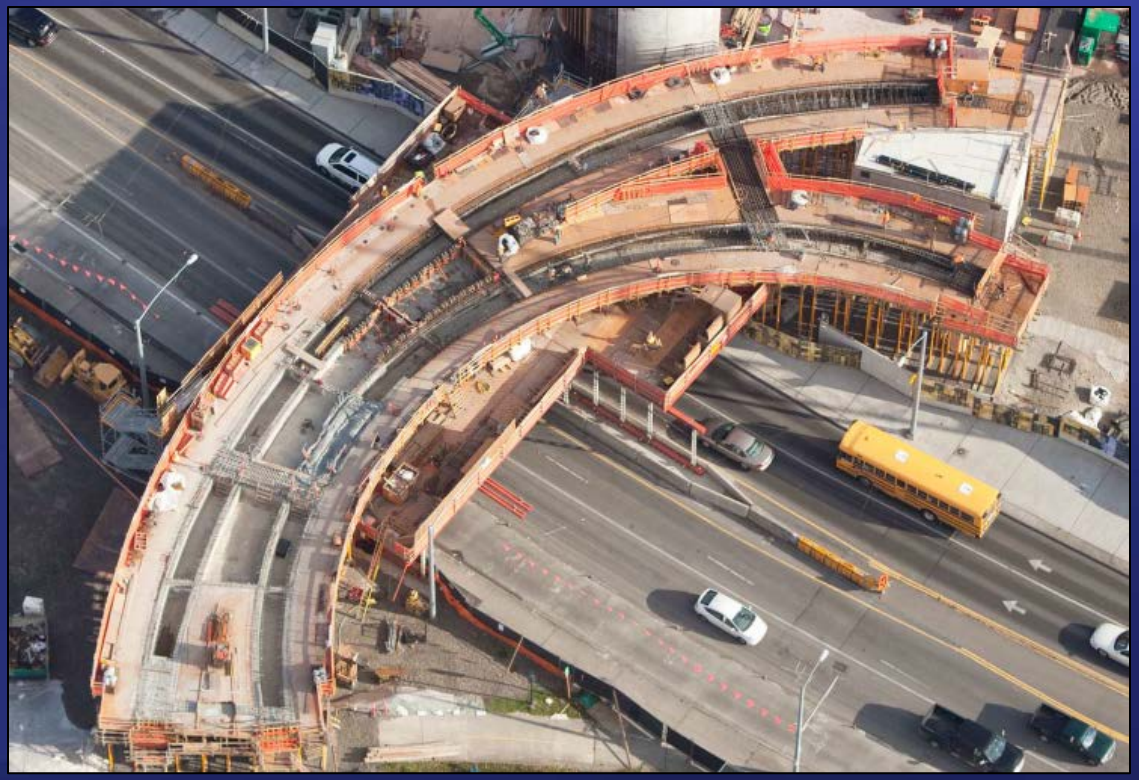
Landmark in the Making : Novel use of Post-tensioning in a Highly Curved Bridge



Claudio Osses, PE, SE – cios@b-t.com
Huanzi Wang, PE, PhD – huanzi.wang@aecom.com
Richard Patterson, PE, SE – rdpn@b-t.com

Acknowledgments

- Sound Transit, University of Washington, WSDOT, SDOT, and King County Metro

- Northlink Transit Partners Joint Venture

- Hoffman Construction Company

- Mike Dunn, Noah Brenner, Michelle Leviant, Randy Harlow, Mark Pickerill, Jeff Brown , Tanveer Sahoo, Steve Gleaton – Sound Transit

- Orin Brown, Luke Su, Noopur Jain, and Chris Jensen – AECOM

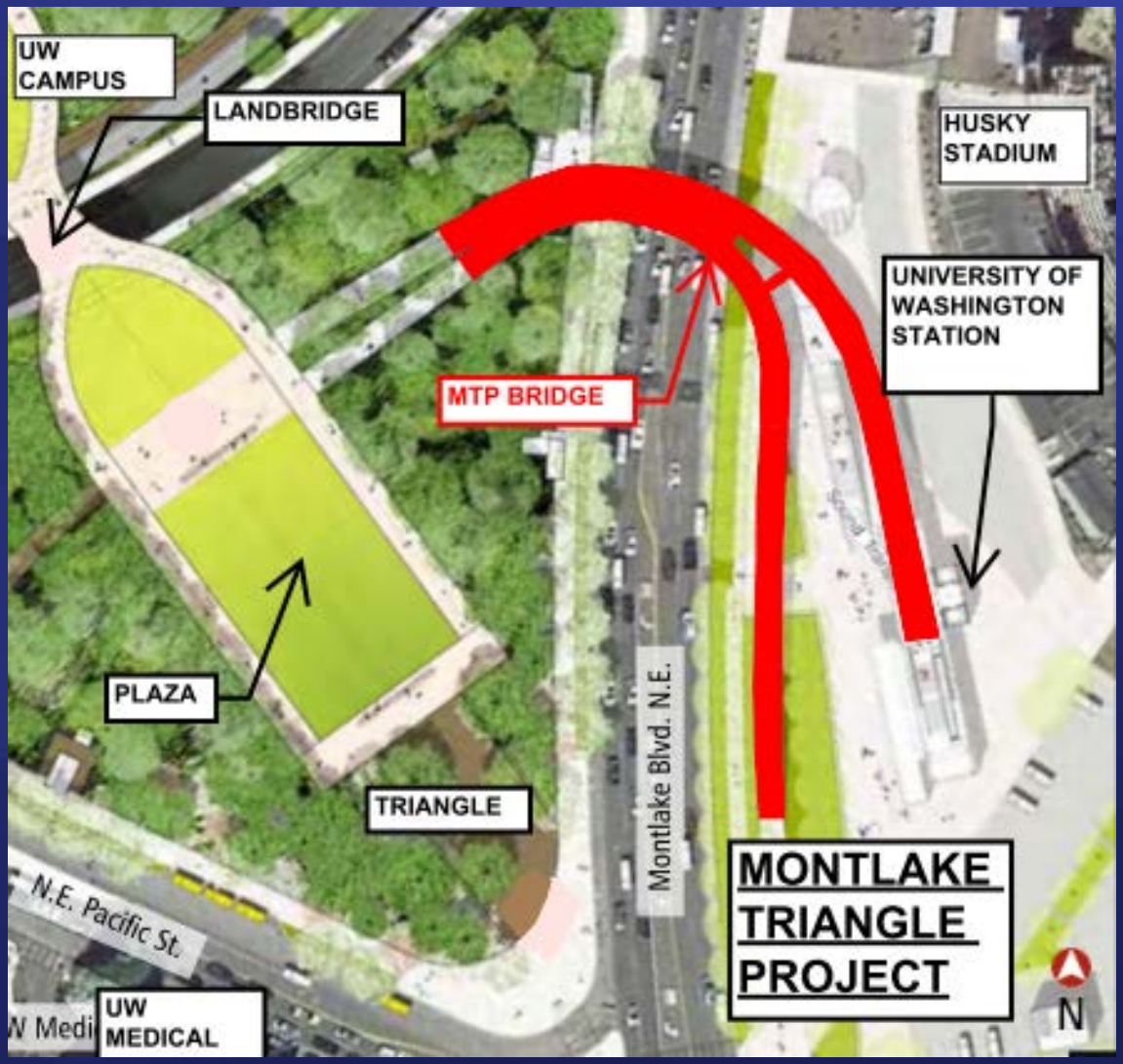
-Todd Schwisow, John Petterson – LMN

- Terry Lind – Hoffman Construction

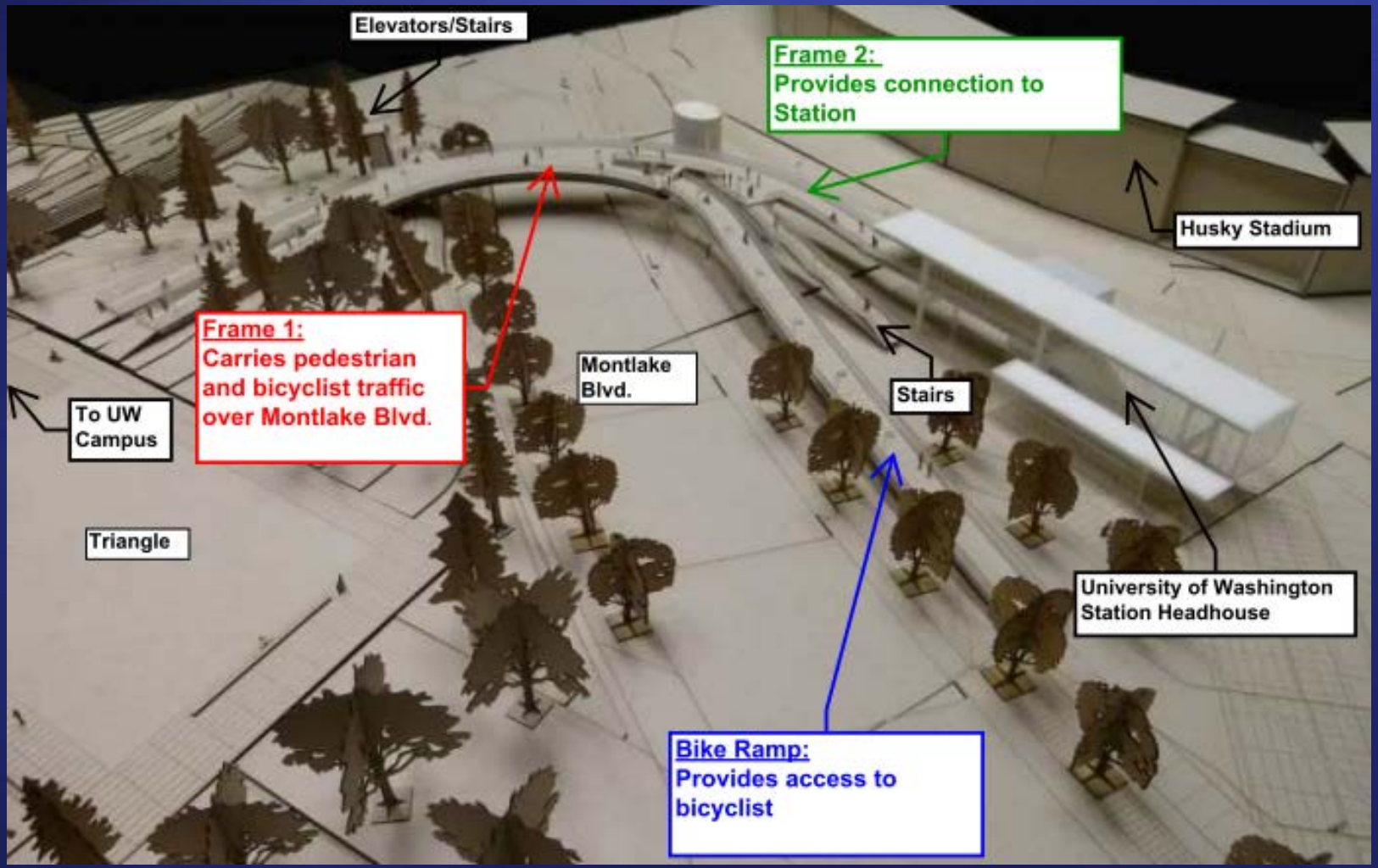
Part 1: Project Overview -

Sound Transit U-link project

Part 1: Project Overview -
Montlake Triangle Project



Part 1: Project Overview -
MTP Pedestrian Bridge

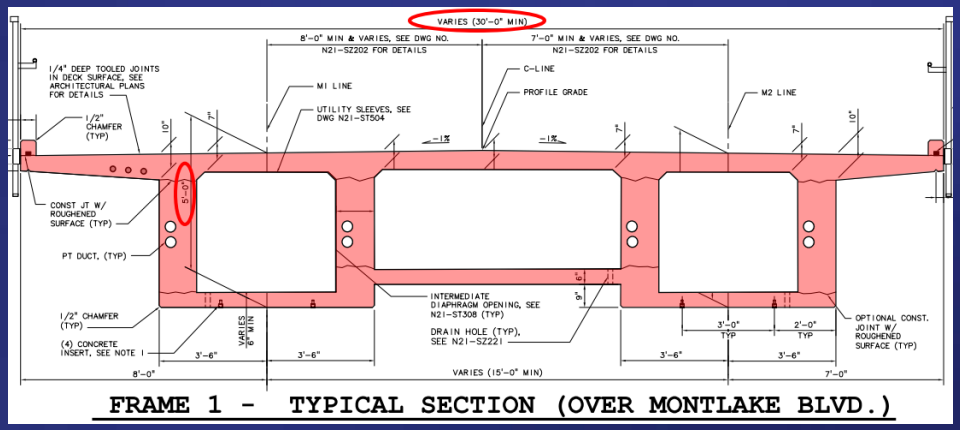


Part 1: Project Overview -

Montlake Triangle Project cont.

Part 1: Project Overview -
Bridge Type Selection

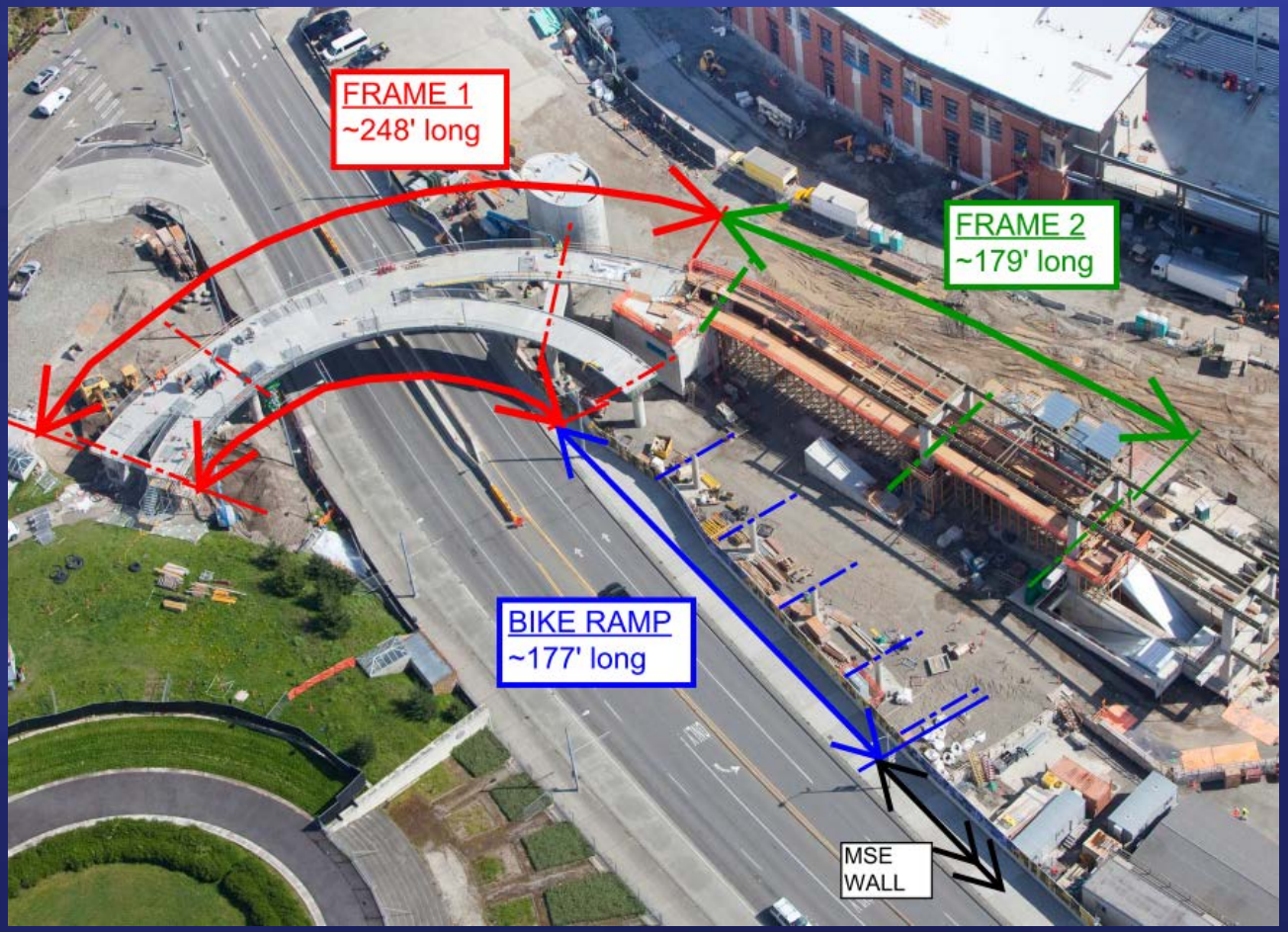
- CIP Post-tensioned double box
- 30' wide x 5' deep section spanning 130' ft over Montlake Blvd.
- Steel is more common for highly curved bridges.
- Durability and maintenance concerns with steel.
- CIP Post-tensioned Concrete →shallow section, low maintenance, and complex geometry



Part 2: Bridge Description –

Bridge Layout

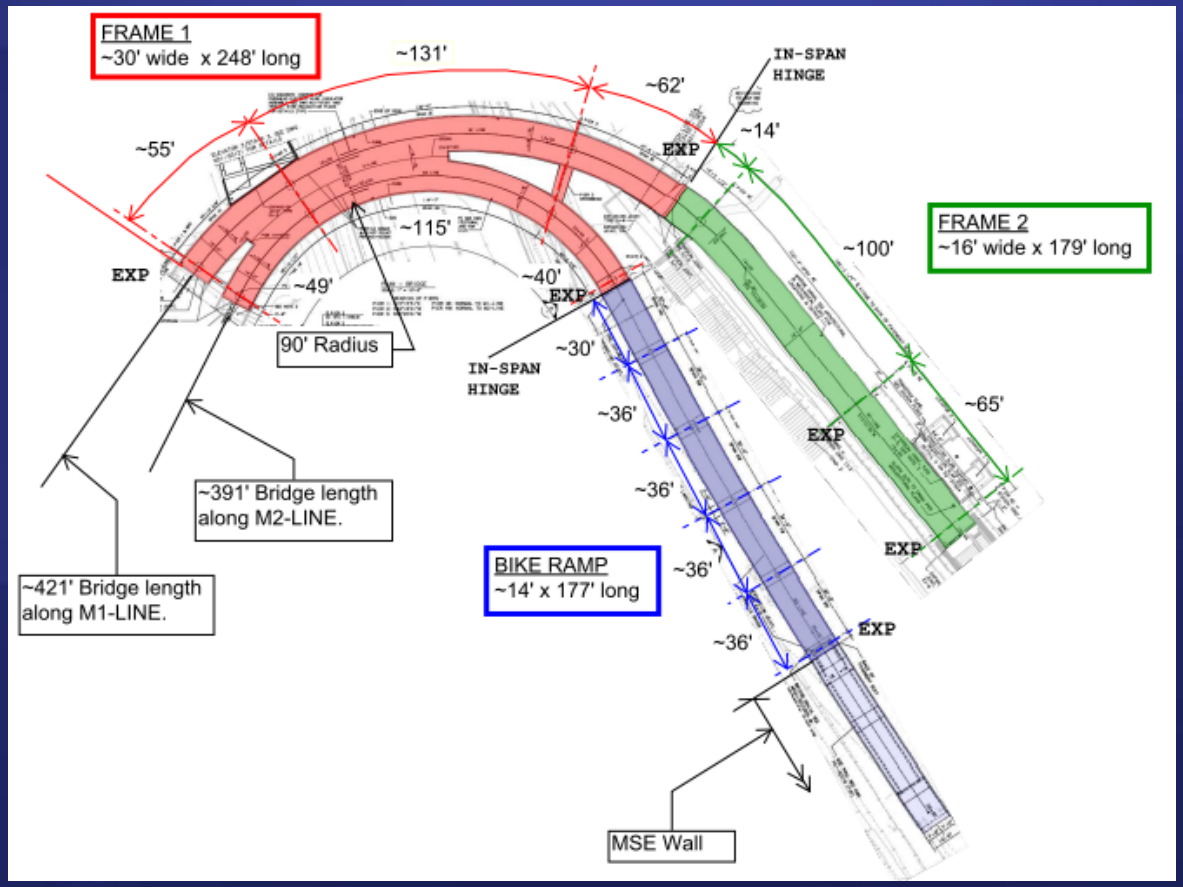
- Three segments: Frame 1, Frame 2, and Bike Ramp



Part 2: Bridge Description –

Bridge Layout cont.

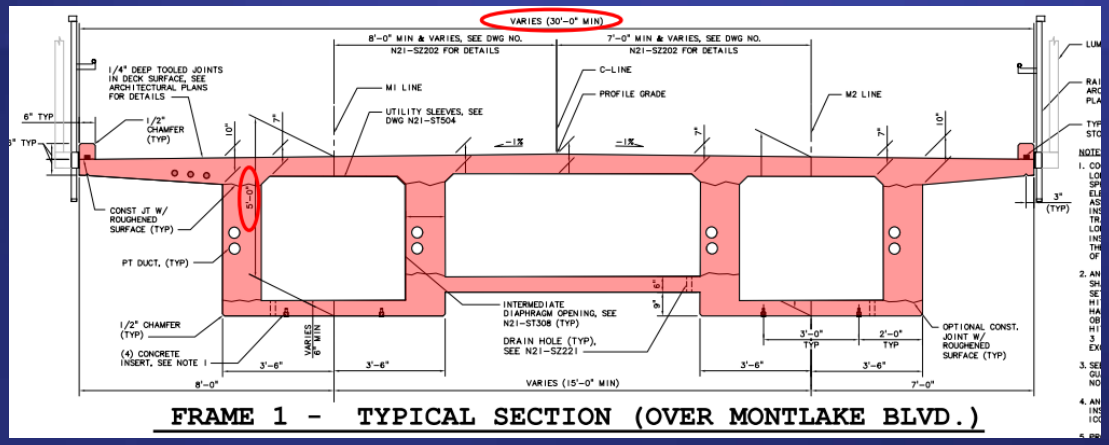
- Frame 1 – 3 spans, 130 ' max , short end spans, radial Pier layout, Exp at Pier 1 and hinges
- Frame 2 - 2 spans, 100' max span, exp at Headhouse frames and hinges
- Bike ramp - 5 spans, 36' max span, exp at abutment and hinge.
- Hinges split bridge into more regular segments improving behavior and simplifying design

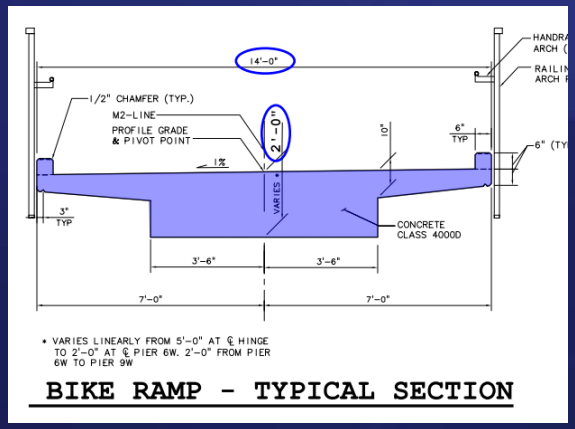


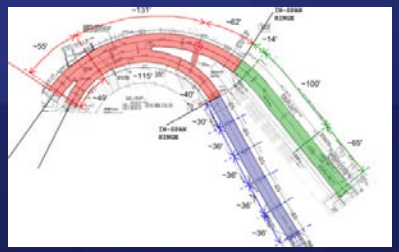
Part 2: Bridge Description –

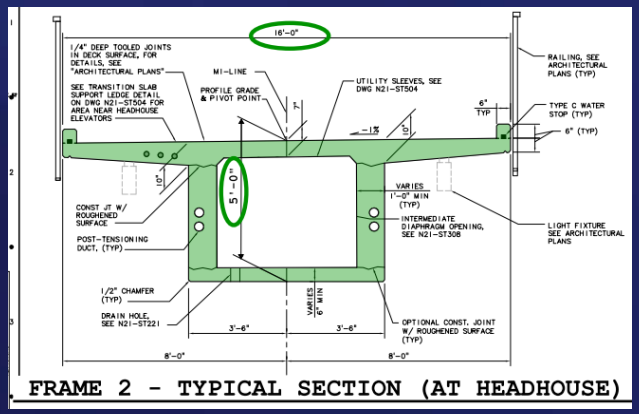
Typical Sections

- Three typical sections
- Frame 1 - 30 ' wide x 5 deep;
- Frame 2 – 16' wide x 5 deep (CIP PT Box)
- Bike Ramp - 14 ' wide x 2'ft deep (RC Slab)





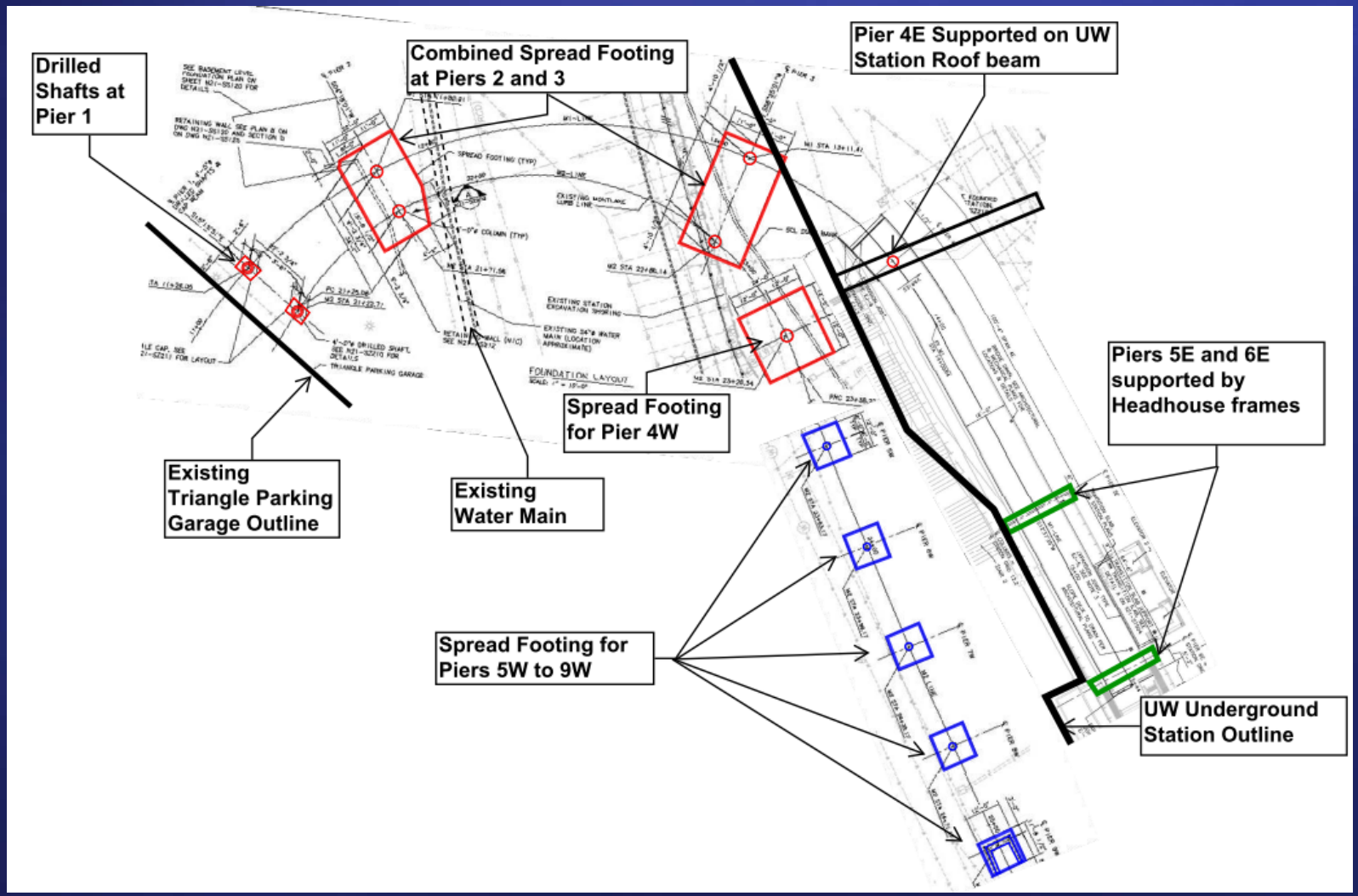




Part 2: Bridge Description –

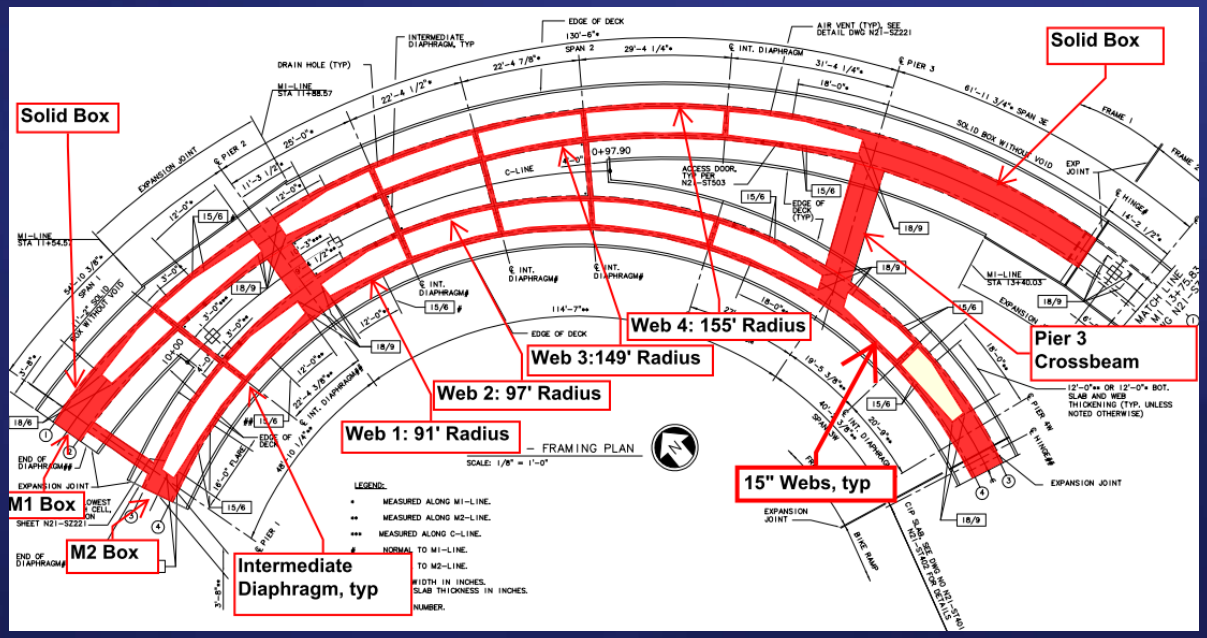
Substructure

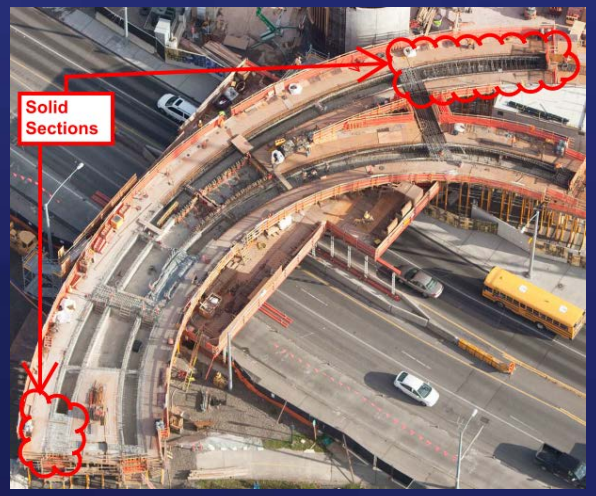
- Combination of drilled shafts, spread footings and the UW Station itself



Part 2: Bridge Description – Framing Plan – Frame 1

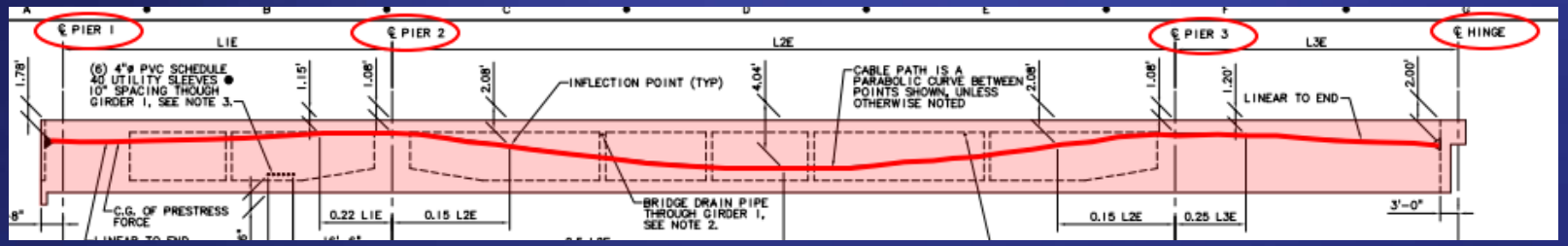
- M1 and M2 single boxes run together and separated along the bridge
- Pier 1 and Pier 3 crossbeam tie boxes
- Radius varies from 91 ft to 155 ft
- Radial orientation of Piers
- Solid box area

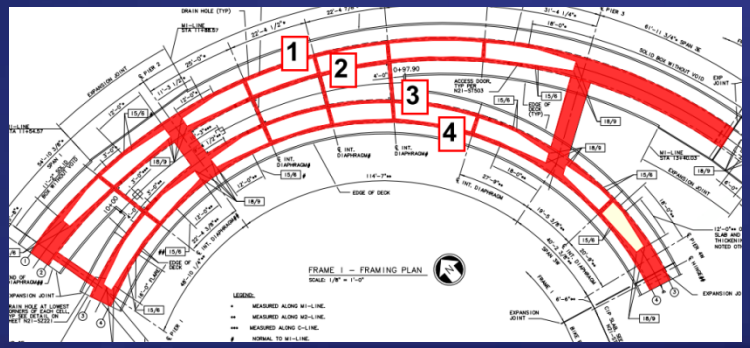




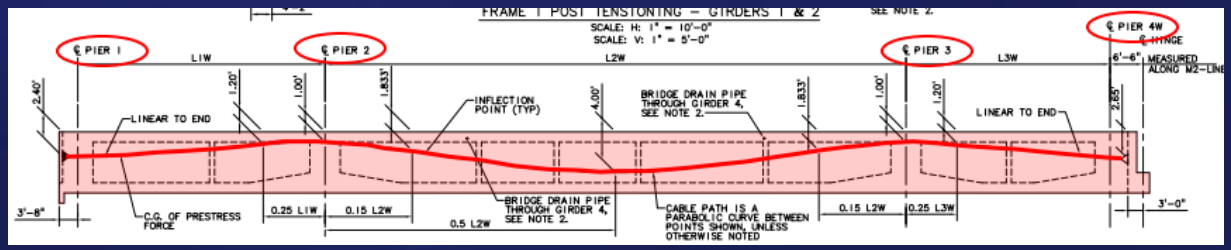
Part 2: Bridge Description – PT Layout– Frame 1

- PT Layout for each web is standard
- Jacking force varies per web
- Radial piers minimize in-plane horizontal forces due to PT





M1 Box
Web 1: 46-0.6"strands, 2000 kip Pjack
Web 2: 44-0.6"strands, 1900 kip Pjack



M2 Box
Web 3: 31-0.6"stands, 1350 kip Pjack
Web 4: 29-0.6"strands, 1250 kip Pjack

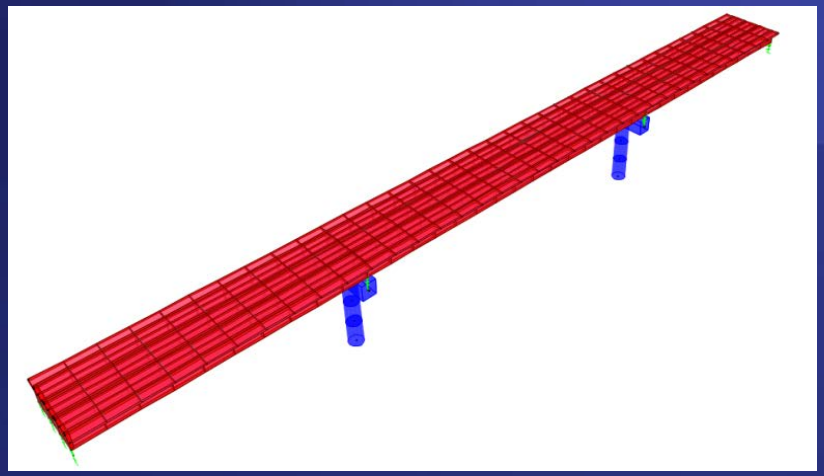
Part 3: Bridge Constraints

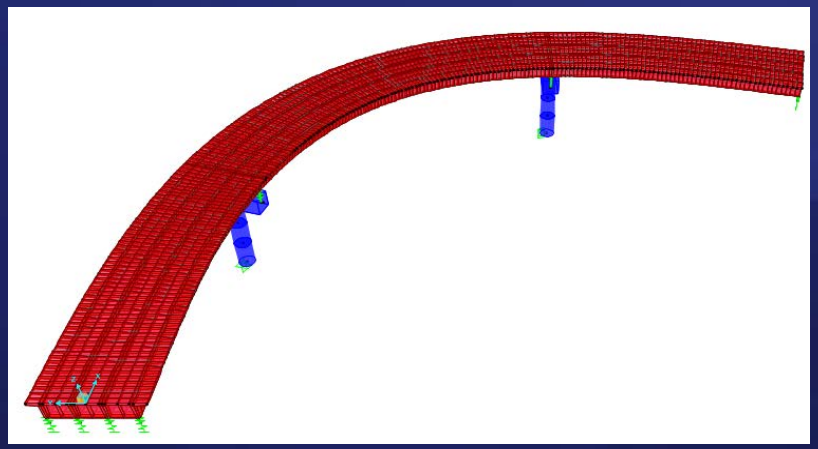
1. Highly Curved Plan Geometry
2. Limited Vertical Clearance
3. Long-Term Durability Requirement
4. Challenging Span Arrangement
5. Interface with Station Structures

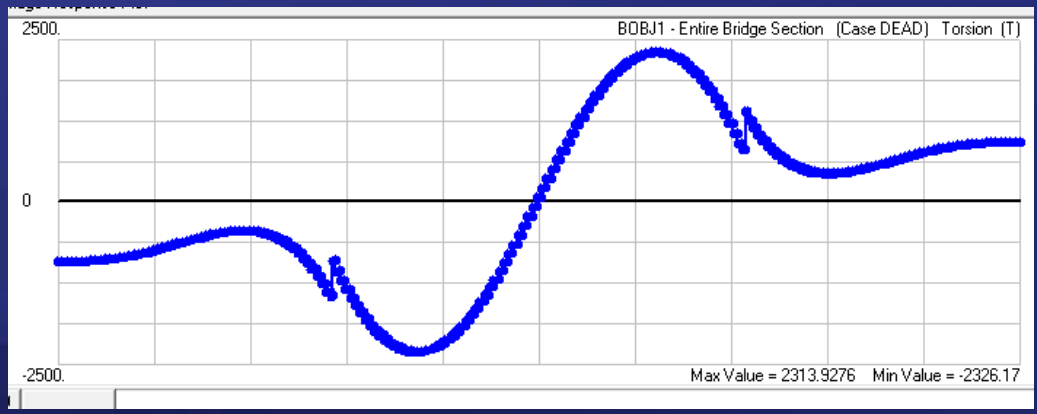
Part 3: Bridge Constraints –

Highly Curved Plan Geometry

1. Torsion induced by curved geometry;
2. Different bending moment distributions compared with straight bridge;

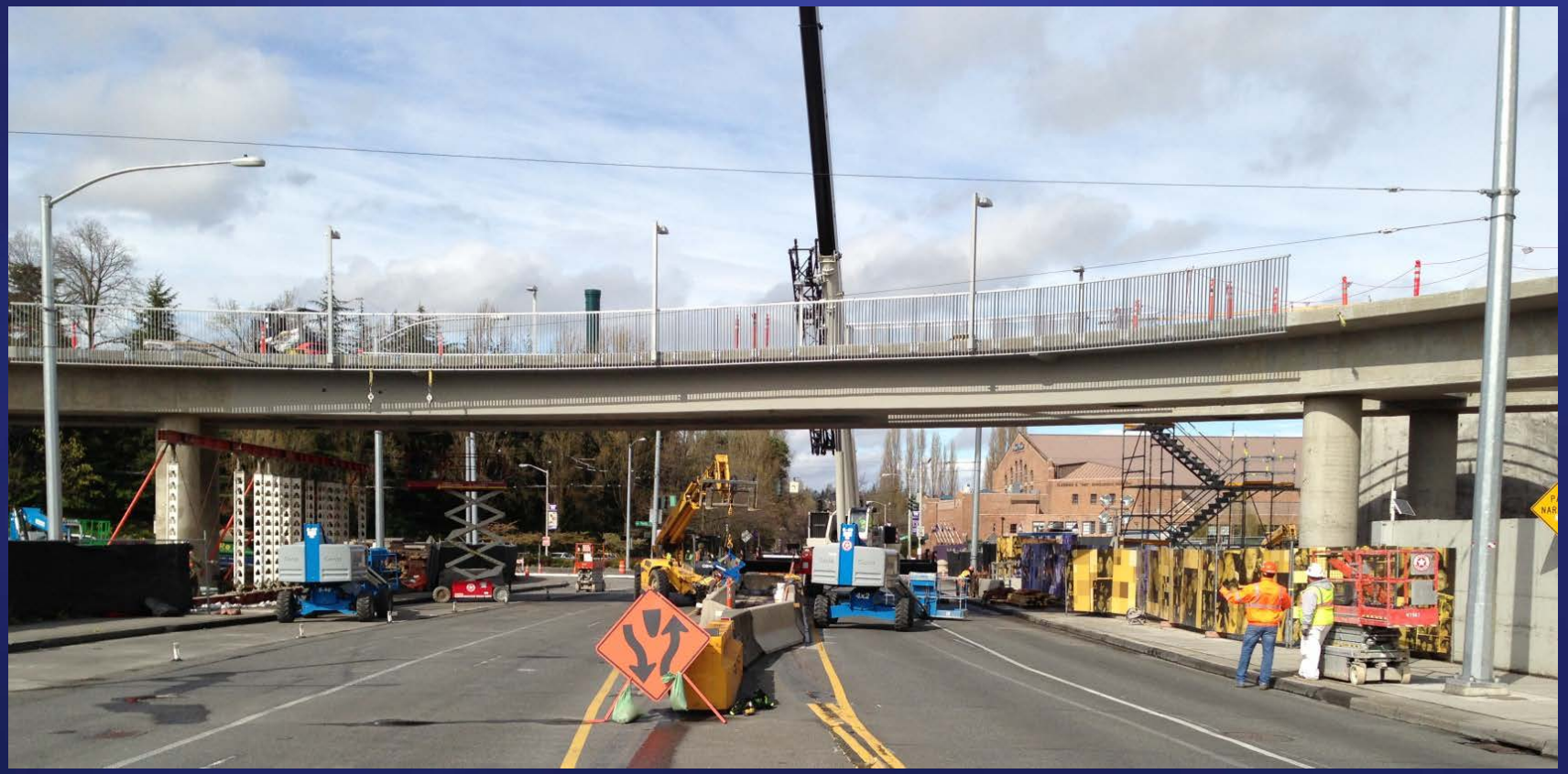






Part 3: Bridge Constraints –
Limited Vertical Clearance

- Bridge crosses over Montlake Blvd.
- Post-tensioned box girder allows shallower superstructure depth;
- Depth vs span = 5ft / 130.5ft = 0.038= 1/26;



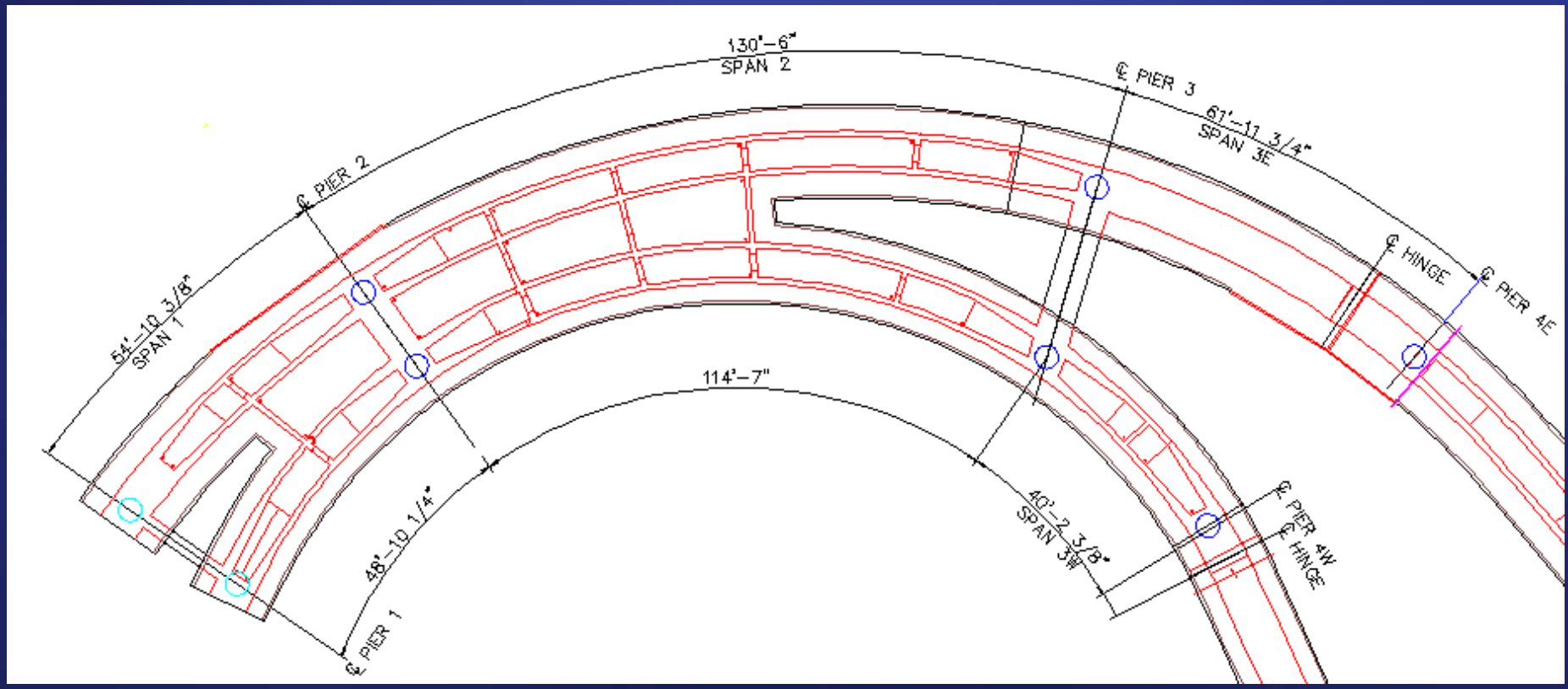
Part 3: Bridge Constraints –
Long-term Durability

- High long-term maintenance cost for steel structures;
- Concrete structure, especially prestressed concrete structure is durable;

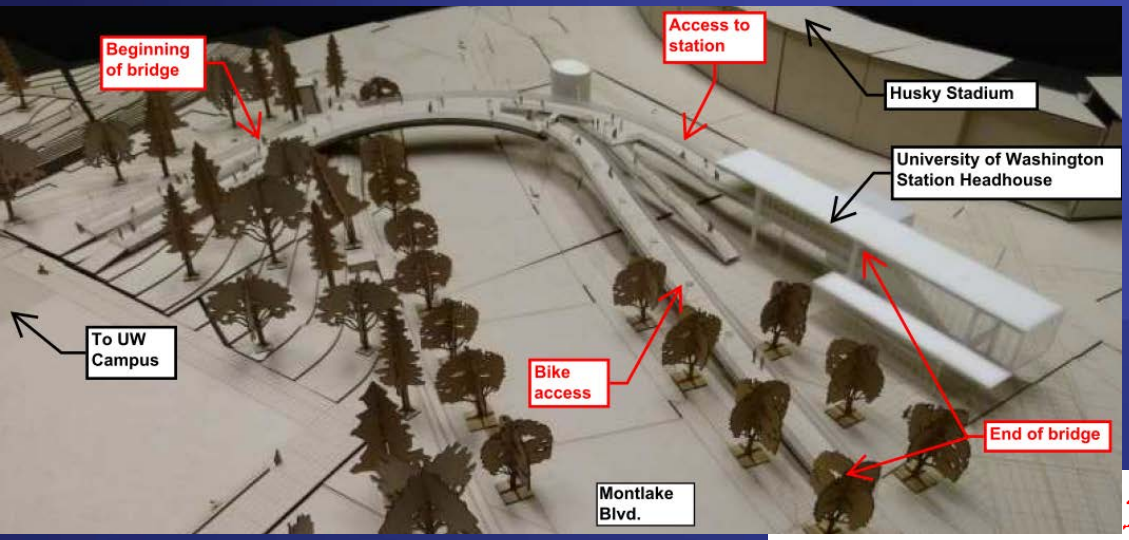
Part 3: Bridge Constraints –

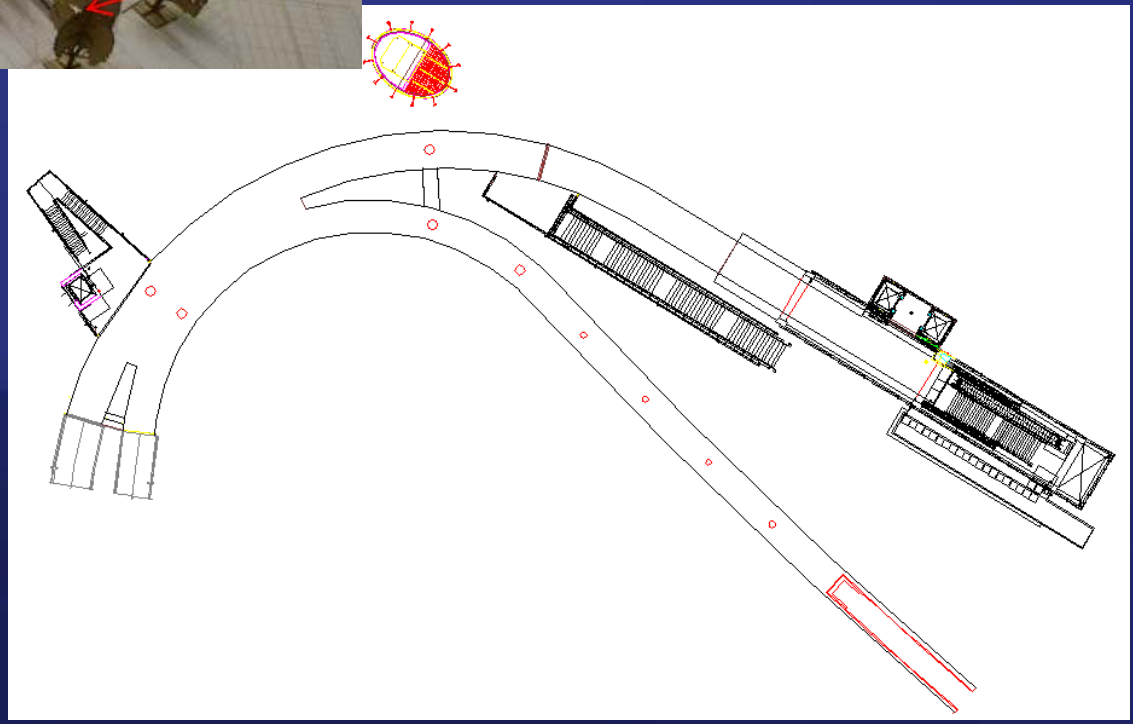
Challenging Span Arrangement

Uplifting at the bearing becomes a concern due to unbalanced span arrangement



Part 3: Bridge Constraints –
Interface with Station Structures



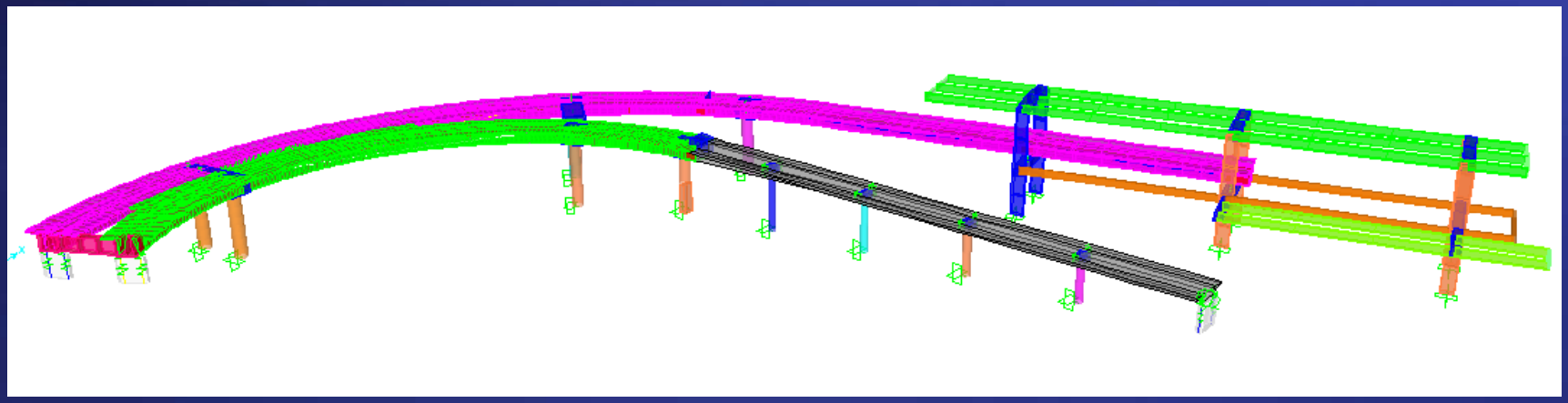


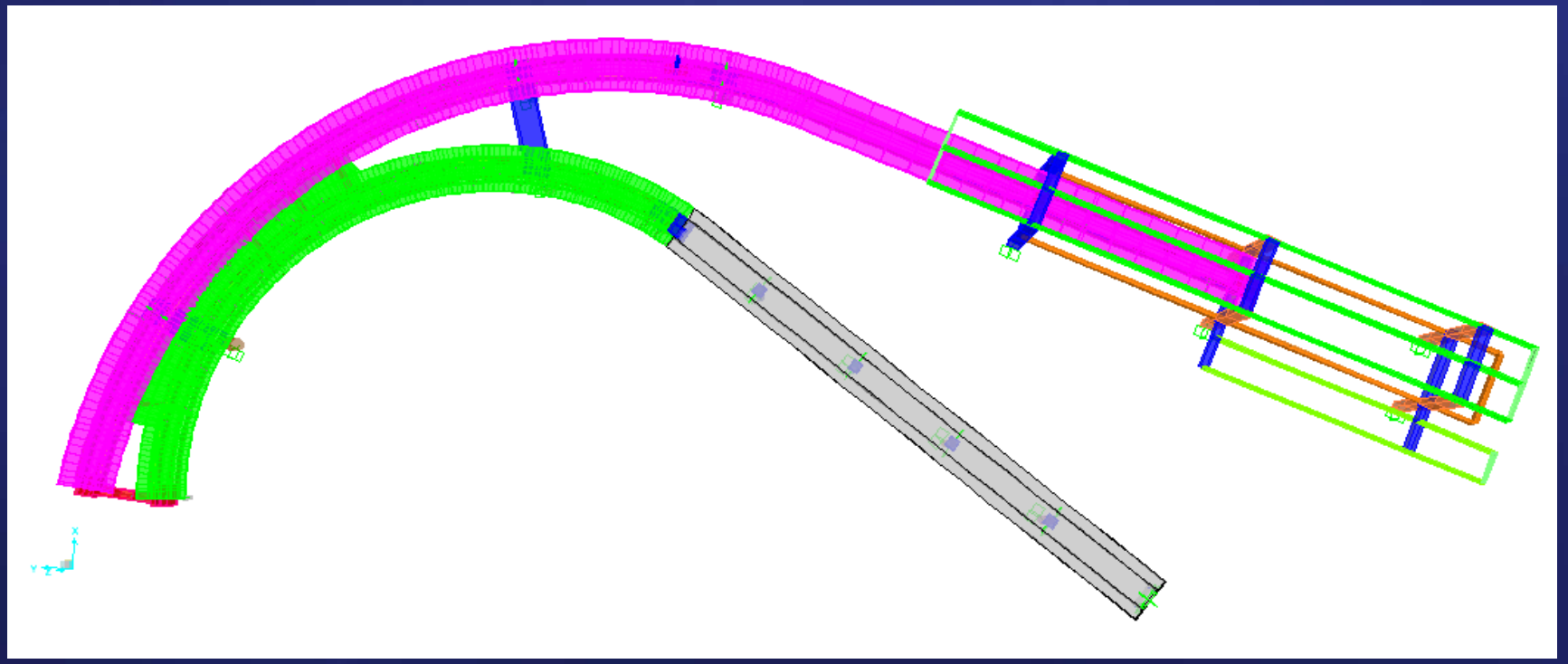
Part 4: Bridge Analysis and Design Challenges

1. Global FE Model
2. Frame Arrangement
3. Bearing Uplifting
4. PT Local Effect
5. PT Jacking Sequence

Part 4: Bridge Analysis and Design Challenges

– Global FE Model





Part 4: Bridge Analysis and Design Challenges

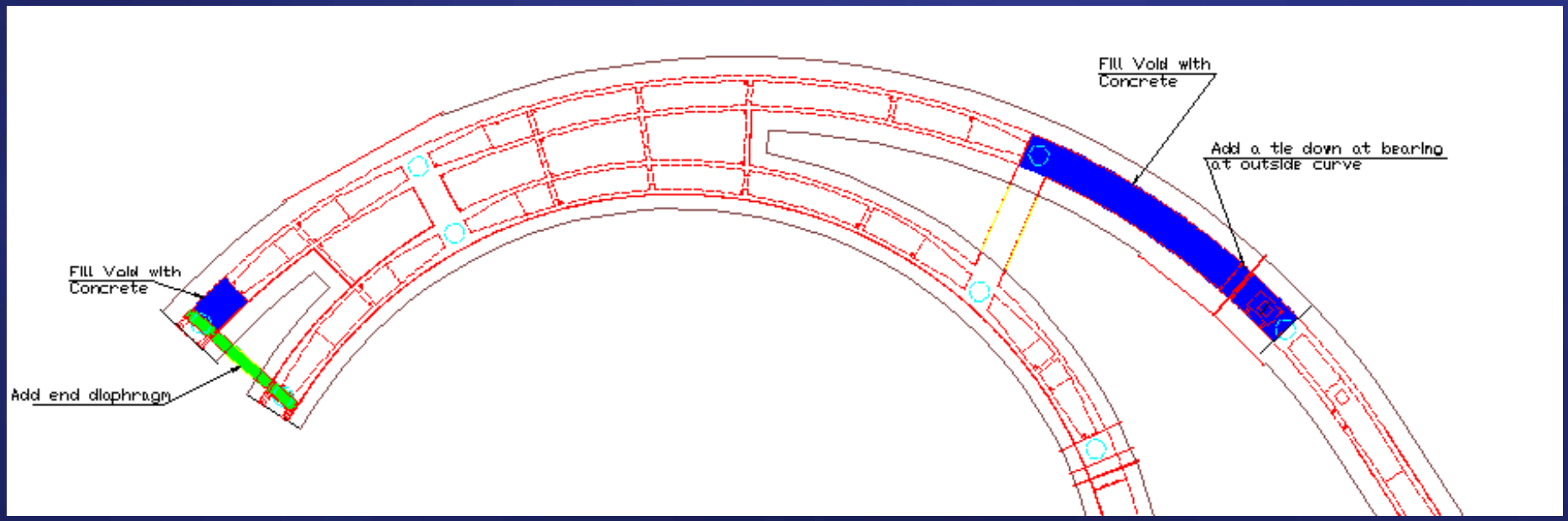
– Frame Arrangement

1. In-span hinges ;
2. One pier column is directly founded on station roof;
3. Two pier columns are supported by headhouse structure;
4. No longitudinal expansion joint

Part 4: Bridge Analysis and Design Challenges

-- *Bearing Uplifting*

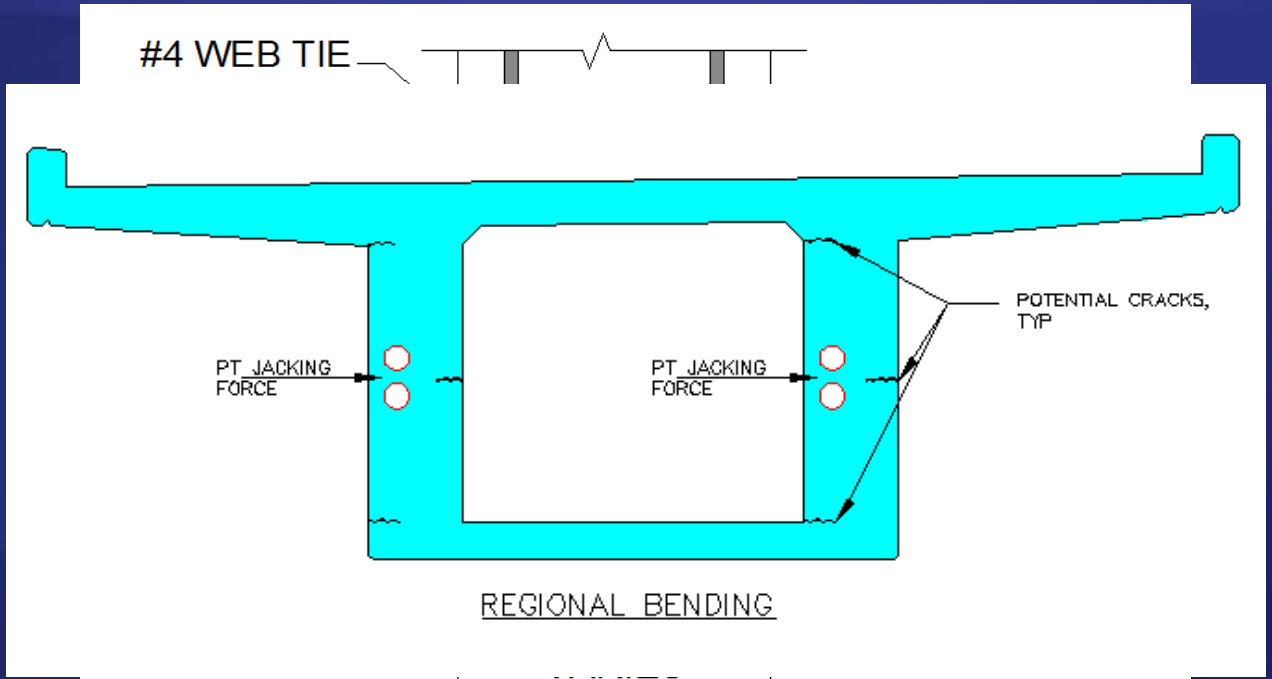
1. Filling up the box of side spans
2. Use end diaphragm
3. Provide a tie down



Part 4: Bridge Analysis and Design Challenges

– PT Local Effect

1. In-plane force
2. Strut-and-tie method
3. Regional bending



Force Transfer Mechanism

Part 4: Bridge Analysis and Design Challenges
– PT Local Effect

4. Cracking of concrete cover
5. Out-of –plane force effect

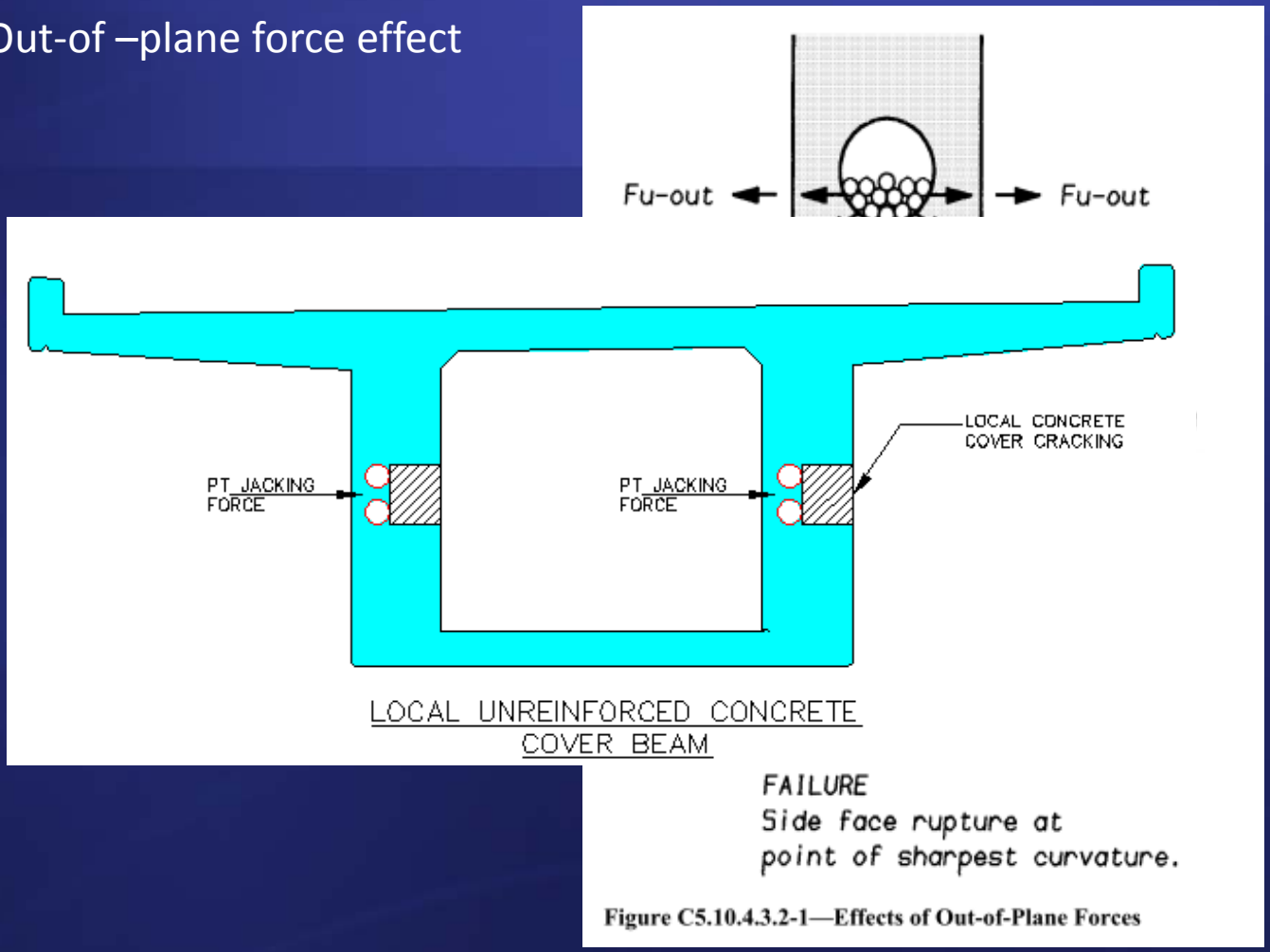
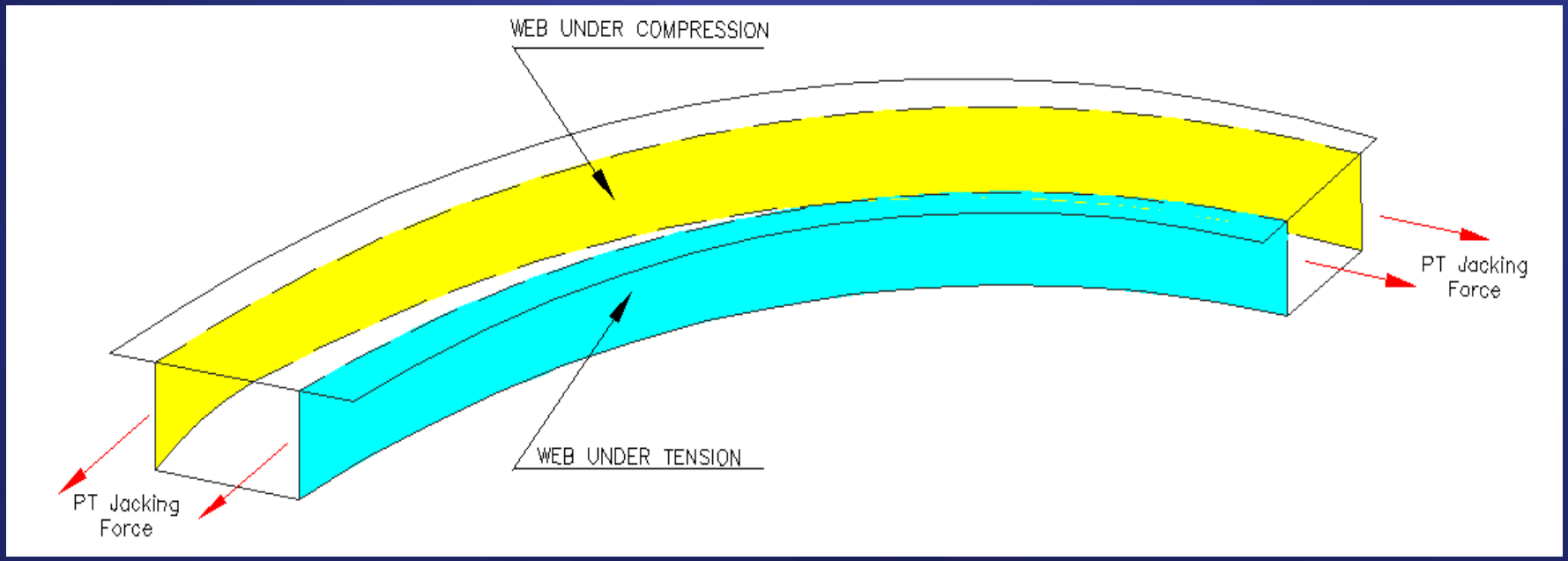


Figure C5.10.4.3.2-1—Effects of Out-of-Plane Forces

Part 4: Bridge Analysis and Design Challenges

– PT Jacking Sequence

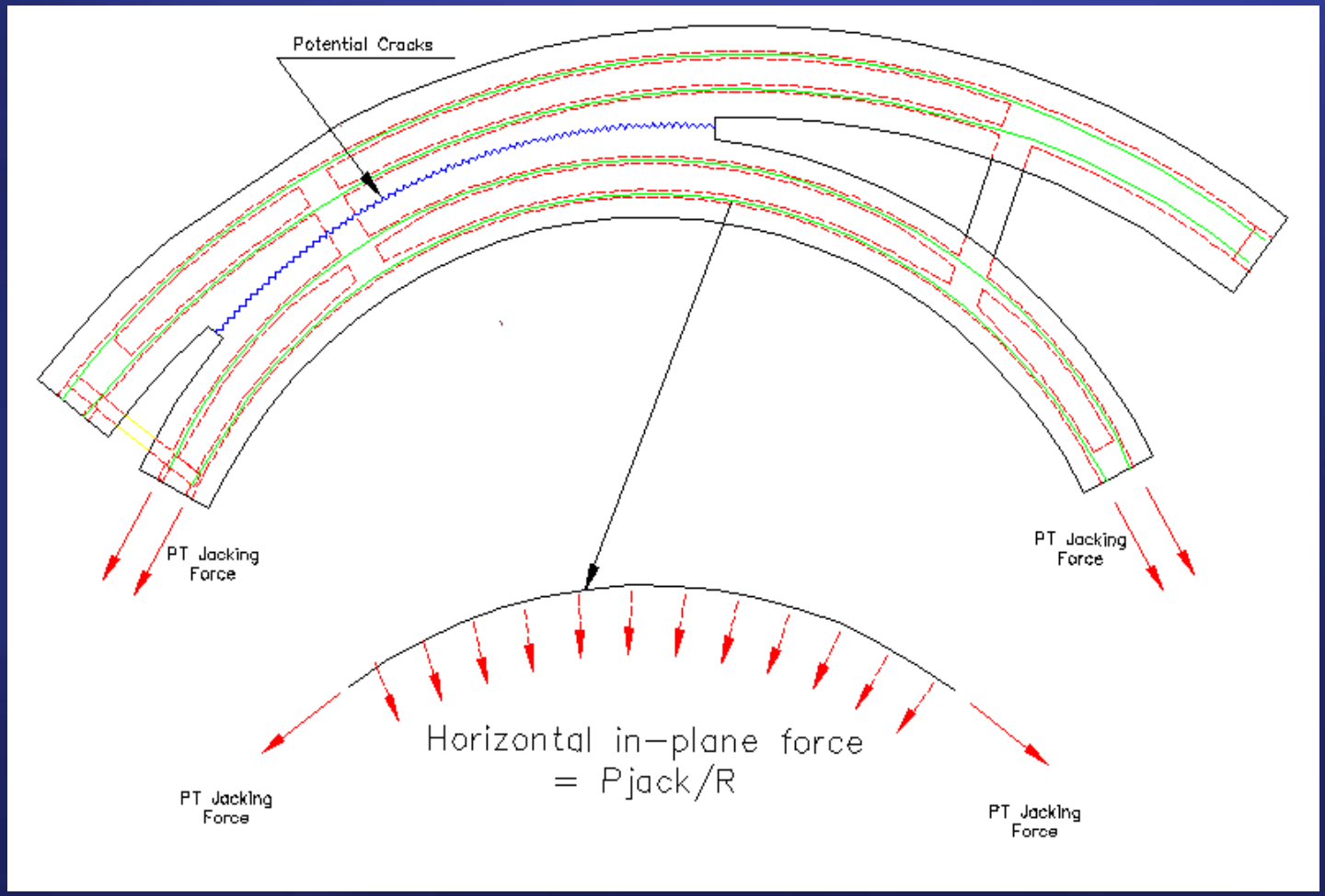
1. Tension on the inside of the curve and compression on the outside of the curve.



Part 4: Bridge Analysis and Design Challenges

– PT Jacking Sequence

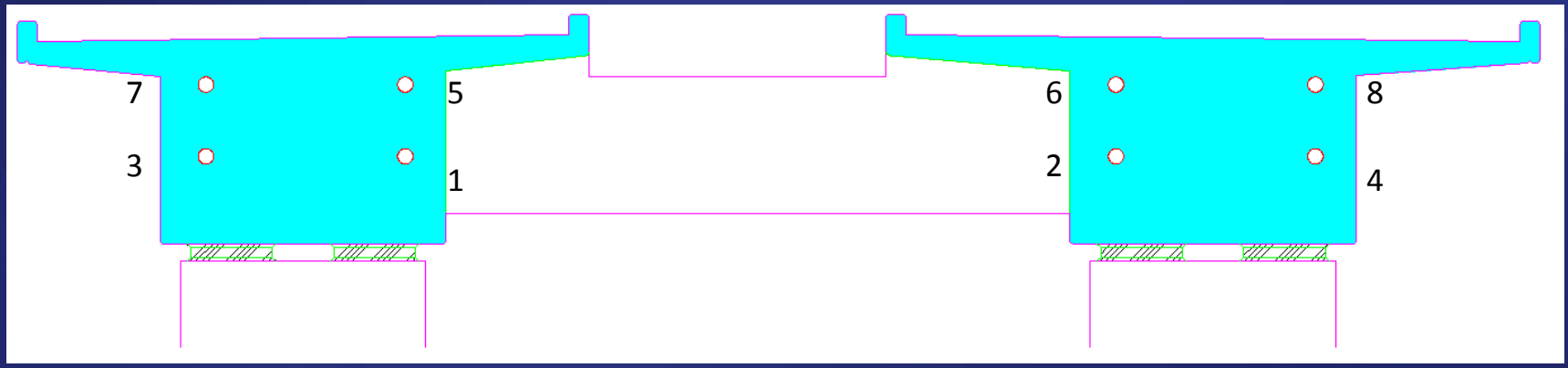
2. Differential lateral force can cause transverse tension in the slabs;



Part 4: Bridge Analysis and Design Challenges

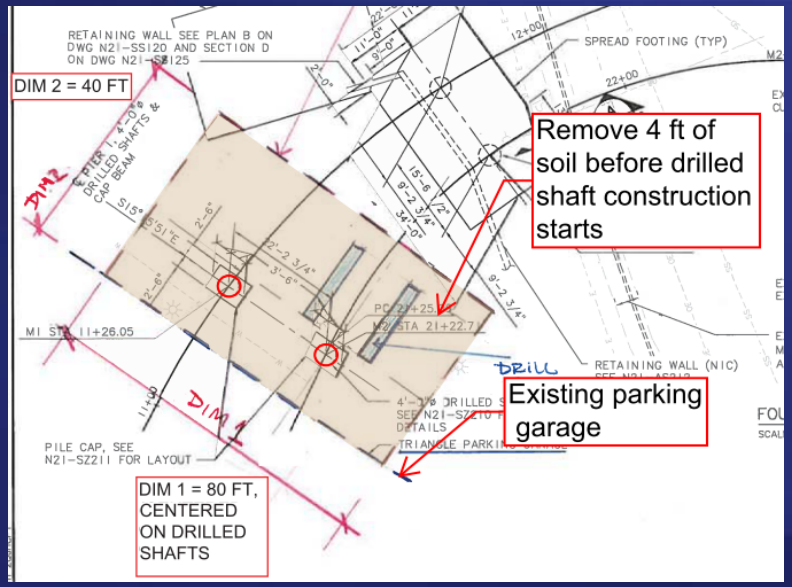
– PT Jacking Sequence

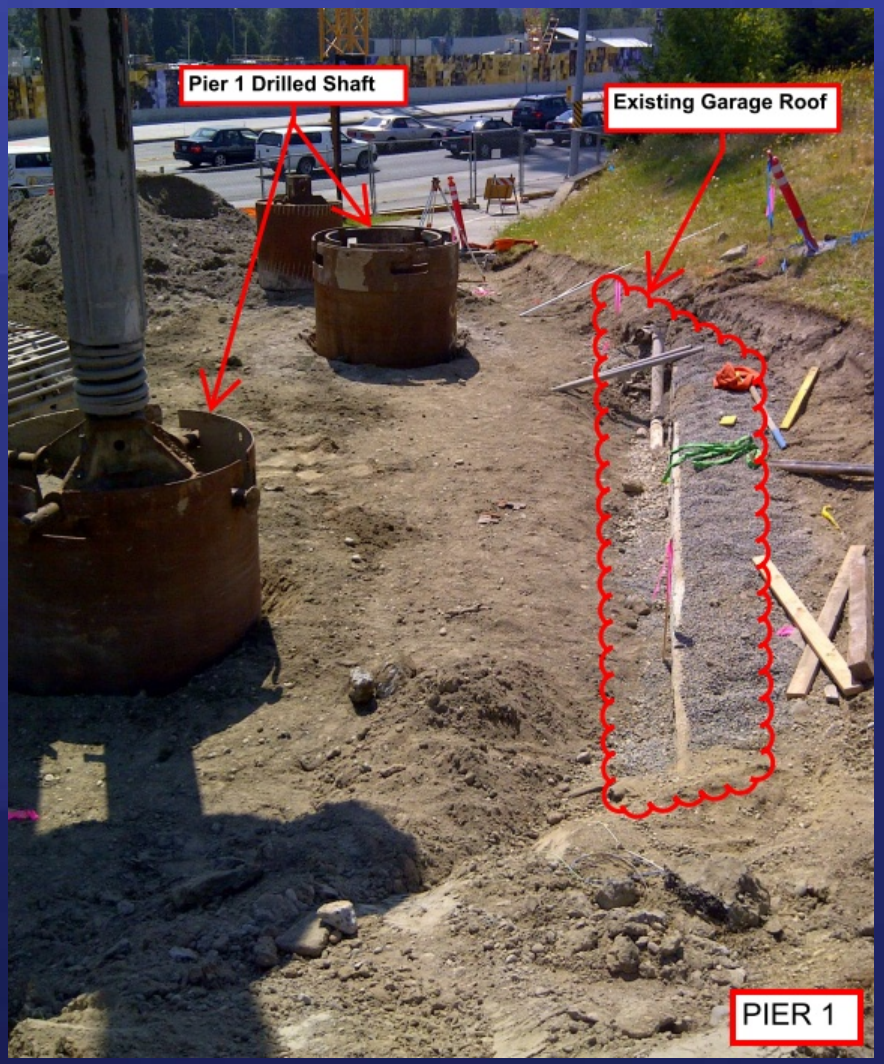
Final PT Jacking Sequence Selected :



Part 5: Construction Challenges -

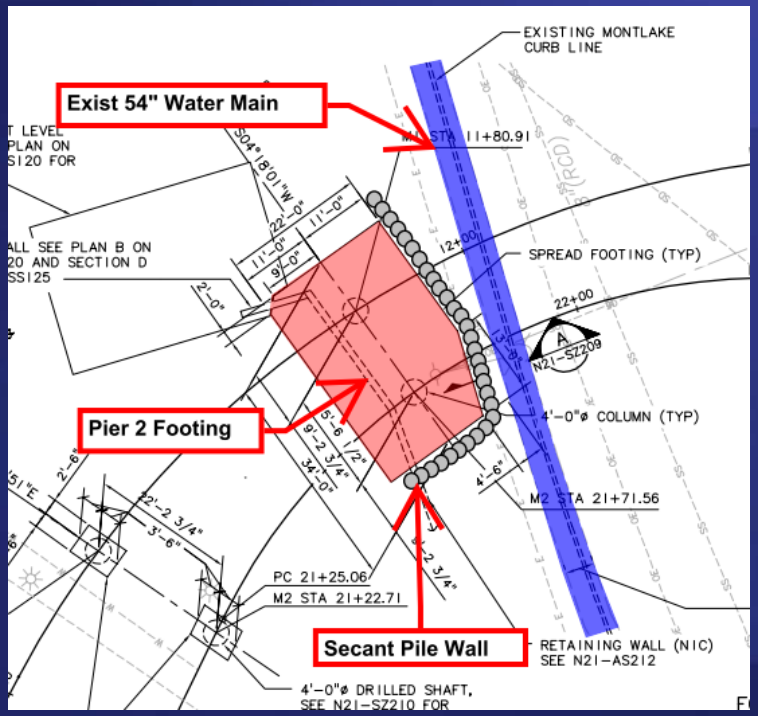
Pier 1 Drilled Shafts next to Existing Garage





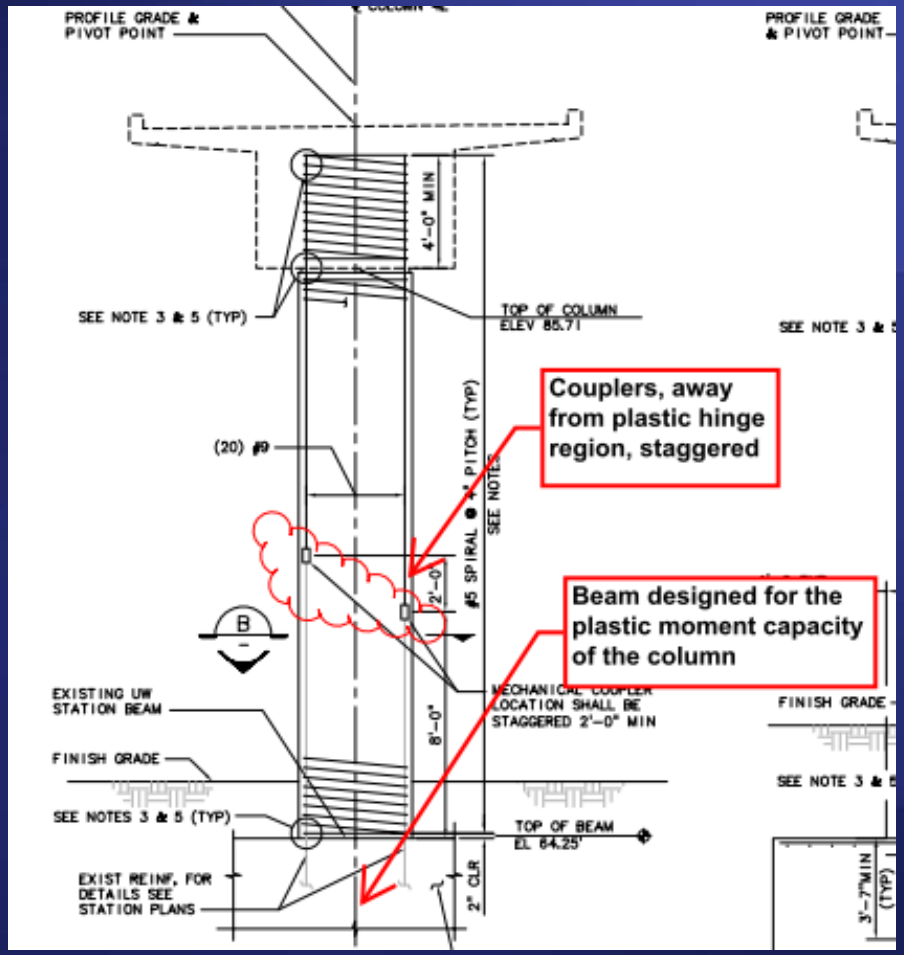
Part 5: Construction Challenges -

Pier 2 Footing Construction next to Water Main



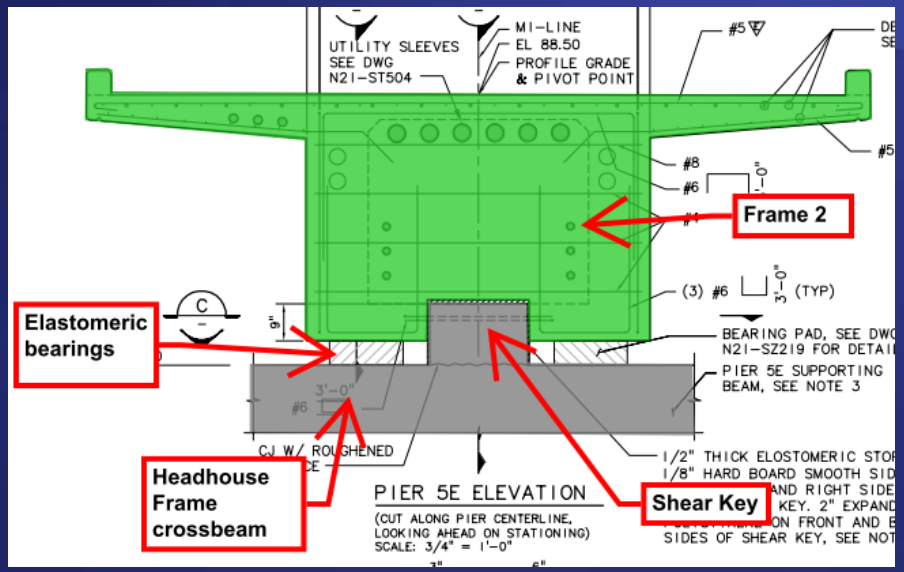
Part 5: Construction Challenges -

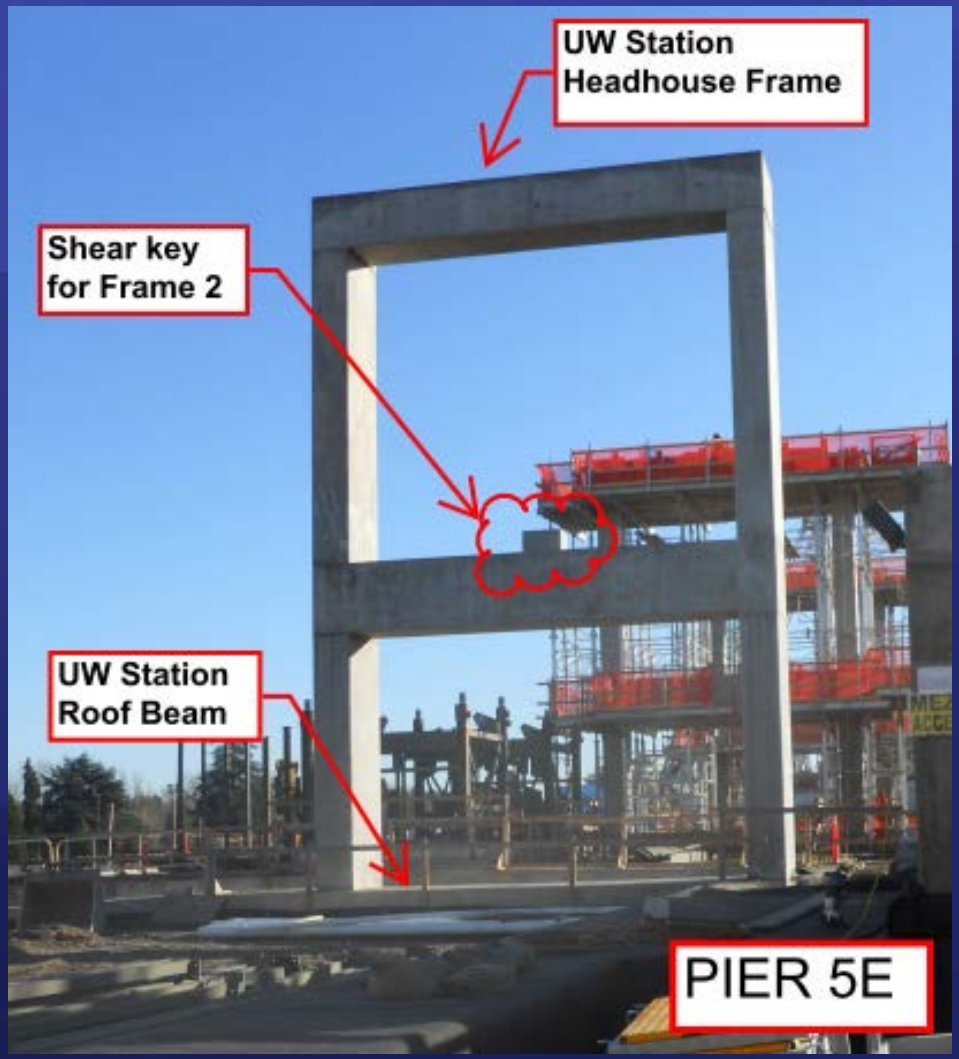
Pier 4E Column on UW Station Roof beam.



Part 5: Construction Challenges -

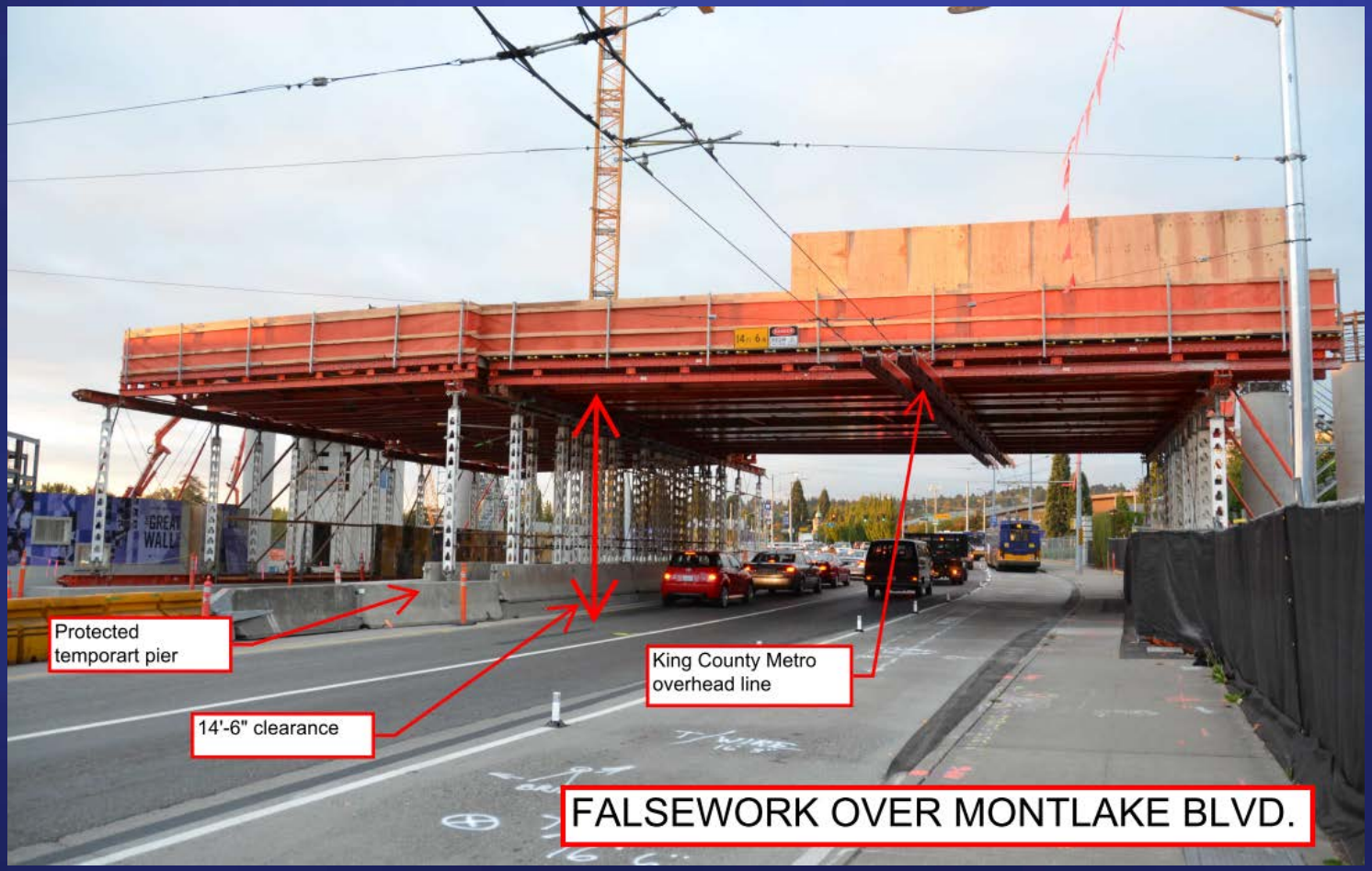
Bridge connection to UW Station Headhouse





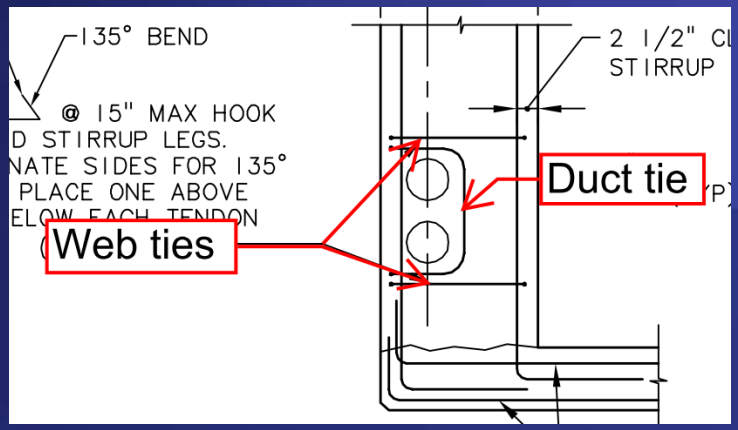
Part 5: Construction Challenges - *Formwork*

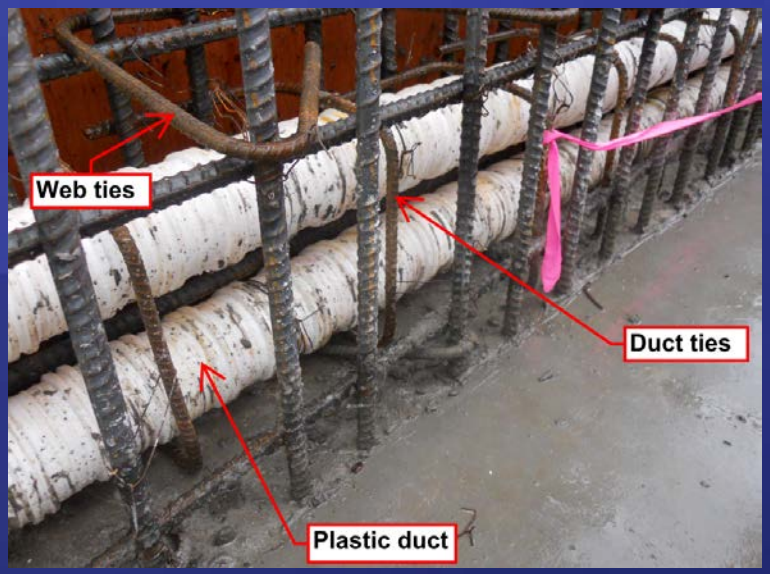
Part 5: Construction Challenges -
Falsework

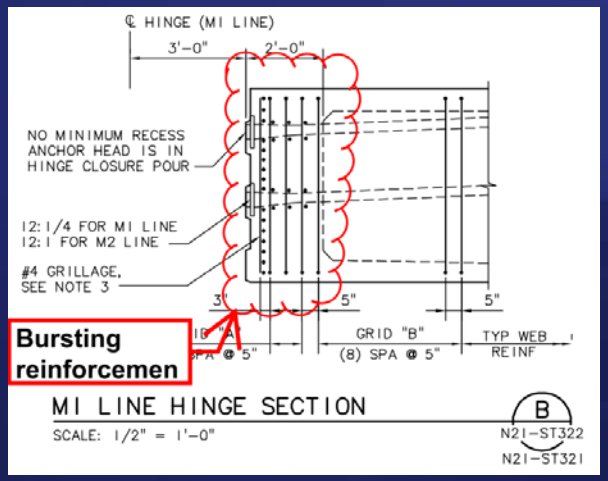


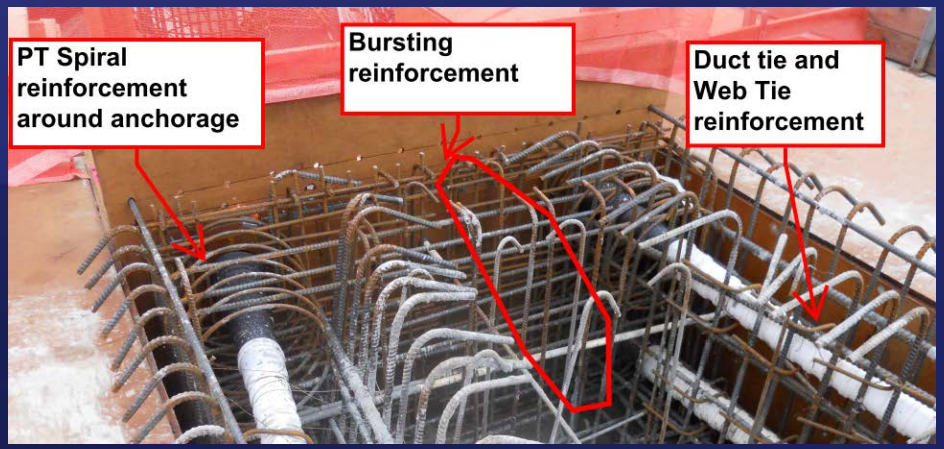
Part 5: Construction Challenges -

Post-tensioning construction

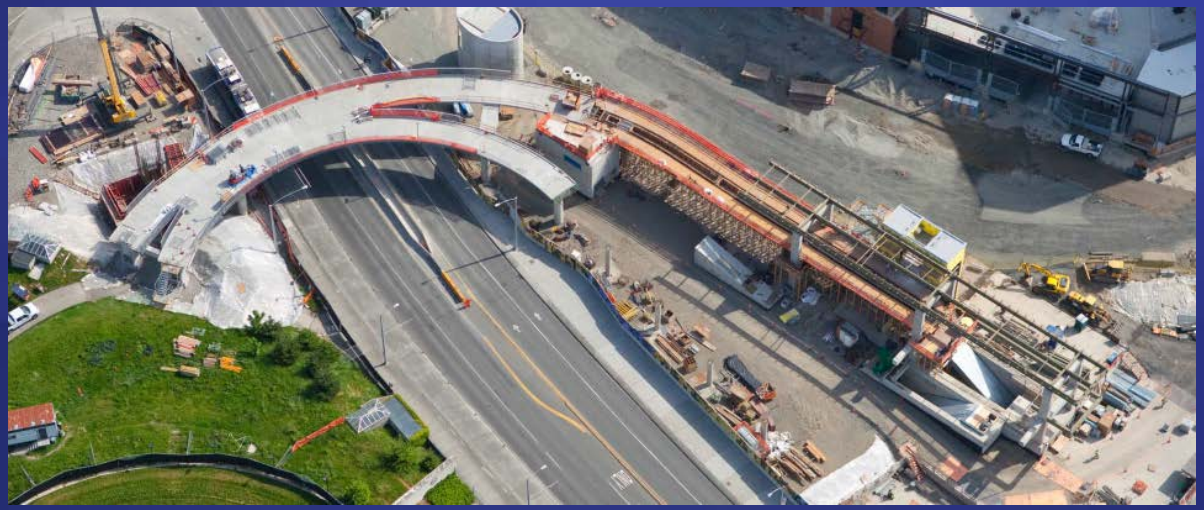








Questions



Claudio Osses, PE, SE – cios@b-t.com
Huanzi Wang, PE, PhD – huanzi.wang@aecom.com
Richard Patterson, PE, SE – rdpn@b-t.com