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
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Part 1: Project Overview - Sound Transit U-link project
Part 1: Project Overview -
Montlake Triangle Project
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MTP Pedestrian Bridge

Frame 1:
Carries pedestrian and bicyclist traffic over Montlake Blvd.

Frame 2:
Provides connection to Station

To UW Campus

Triangle

Elevators/Stairs

Montlake Blvd.

Stairs

Bike Ramp:
Provides access to bicyclist

Husky Stadium

University of Washington Station Headhouse
• 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
• 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 – Bridge Layout cont.
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" strands, 1350 kip Pjack
- Web 4: 29-0.6" strands, 1250 kip Pjack
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;
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
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
1. Filling up the box of side spans
2. Use end diaphragm
3. Provide a tie down
1. In-plane force
2. Strut-and-tie method
3. Regional bending
4. Cracking of concrete cover
5. Out-of-plane force effect

Figure C5.10.4.3.2-1—Effects of Out-of-Plane Forces
1. Tension on the inside of the curve and compression on the outside of the curve.
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**

- **Existing parking garage**
- **Pier 1 Drilled Shaft**
- **Existing Garage Roof**

Remove 4 ft of soil before drilled shaft construction starts.
Part 5: Construction Challenges -
Pier 2 Footing Construction next to Water Main
Part 5: Construction Challenges -

*Pier 4E Column on UW Station Roof beam.*

- Couplers, away from plastic hinge region, staggered
- Beam designed for the plastic moment capacity of the column
- Pier column founded on UW Station Roof Beam

PIER 4E
Part 5: Construction Challenges -

*Bridge connection to UW Station Headhouse*

- Elastomeric bearings
- Headhouse Frame crossbeam
- Frame 2
- Shear Key
- UW Station Headhouse Frame
- Shear key for Frame 2
- UW Station Roof Beam
- PIER 5E
Part 5: Construction Challenges - Formwork

- Adjustable bracing
- Side form shim
- Camber shims
Part 5: Construction Challenges - Falsework

- Protected temporary pier
- 14'-6" clearance
- King County Metro overhead line

FALSEWORK OVER MONTLAKE BLVD.
Part 5: Construction Challenges - Post-tensioning construction

- Duct tie
- Web ties
- Plastic duct
- Flexural reinforcement
- PT Spiral reinforcement around anchorage
- Bursting reinforcement
- Duct tie and Web Tie reinforcement
Questions

Claudio Osses, PE, SE – cios@b-t.com
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