Emergency Stabilization:
West Seattle High-Rise Bridge

Washington ACI Chapter & SEAW Joint Meeting

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Brett Commander, PE

February 16, 2022
Bridge Overview

• Operational July 14, 1984
• Segmental construction
• Approximately 100,000 ADT
• Cracking prioritized in 2013
• Preventative maintenance and more frequent observations started immediately
• Load rating analysis in 2019
Bridge Details

- Elevation (top)
  - Main span 590’
  - Flanking spans 375’

- Section (bottom)
  - Near Pier Table (left) h~30’
  - Near mid-span (right) h~12’
Bridge Details

Terminated at discrete bulkheads
- Joints 38 and 40 – main span
- Joints 12 and 14 – end spans

Segment Joint

Drag Steel

LONGITUDINAL SECTION AT BOTTOM FLANGE PT ANCHORAGE
Bridge Assessment

FAST ACT Federal Mandate

- Load Rating
- Known Main Span Cracking
- Data Gathering
- Field Observations

![Diagram of bridge components and observations](image-url)
Bridge Assessment

View – Behind End Diaphragm

End Diaphragm Cracking

View - Slide Plate In Front of Stops

PIER 18 END DIAPHRAGM ELEVATION
Bridge Assessment

Figure 9: Longitudinal elevation. Pier 15 to the mid-span (the west half).

Figure 13: The analyzed I-shape beam cross-section (red) and the original cross-section (dashed line) at segment 12.

Figure 22: Crack diagram at load factor 0.9 of Phase I.

Figure 23: Crack diagram at load factor of 1.0 from a previous analysis.
The Emergency
## Decision Matrix

<table>
<thead>
<tr>
<th>Activity</th>
<th>2020</th>
<th>2021</th>
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<tbody>
<tr>
<td>Inspection, Monitoring, and Testing</td>
<td>April: May</td>
<td>June: July</td>
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<td>Bridge Stabilization Measures</td>
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**Legend:**
- Blue: Design Activities
- Yellow: Construction Activities

**Decision Points**
- Based on condition findings
- Based on findings from the CBA and observed behavior

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Seattle Department of Transportation
Testing & Monitoring Overview

Providing information for the Decision Matrix

Nondestructive Evaluation (NDE) Testing (Condition)
- Examining condition at a material level
- Level of corrosion in mild steel and post-tension steel
- Concrete chemical properties – propensity for corrosion
- Depth of cracks

Structural Health Monitoring (Performance)
- Structural movement / deformation
- Change with respect to expectations
- Rate of change
- Safety
Testing & Monitoring

Confined space entry and air monitoring procedures

Ladders, removable bolts and fall protection to perform testing and material sampling (Photo Courtesy WSP)

SPRAT Ropes Access to obtain exterior concrete samples
Testing (Crack Depths)

Ultrasonic Pulse Velocity (UPV)
- UT probes above and below web-deck chamfer

Determine:
- Full-depth cracks (no signal)
- Depth of crack (time-of-flight)
Testing (Crack Depths)

Ultrasonic shear wave tomography
- Scans from top of deck above web
- Assess depth of crack plane
- Compare to UPV results
Testing (Condition of PT Tendons)

Impact echo

USW tomography

Ground truth

Intact grout

Voids in grout

Voids in grout
Monitoring

A suite of structural monitoring instrumentation

- Main span deflection – MEMS Shape Array
- Crack growth – vibrating wire crack gages
- End-span displacements – string potentiometers
- High resolution cameras
- Monitoring website with Alarms
Monitoring

Crack growth has slowed since the spring
• Manual Measurements of crack length
• Temperature-corrected measure of crack slip
Data Correlations - Predicted vs Actual

<table>
<thead>
<tr>
<th></th>
<th>(Deg F)</th>
<th>(W/m²)</th>
<th>Temperature (Deg F)</th>
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</thead>
<tbody>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg</td>
<td>53.3</td>
<td>129.5</td>
<td>0</td>
</tr>
<tr>
<td>Min</td>
<td>16.9</td>
<td>0</td>
<td>-36.4</td>
</tr>
<tr>
<td>Max</td>
<td>103</td>
<td>1355</td>
<td>49.7</td>
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— Predictions made using University of Washington weather station temperature and solar radiation data as input.


Worst combination TU + TG is Spring and Fall seasons
Data Correlations - Predicted vs Actual

Same process used to scale TU and TG midspan vertical displacements using weather station temperature and solar radiation data.

Model Comparison Midspan Shape Array Sensors

- Cracked Sections for Cols, J14, and J38
- Cracked Cols, Uncracked Superstructure
- Average Midspan Shape Array

Data from 4/24 to 6/16/2020
Data Correlations - Predicted vs Actual

Comparison of Joint 38 Behavior

Floor Gauge Deformation (in) vs Analytical Moment (kip-ft)

Platform Hoisting

Post-Tensioning

Pier 16 Side Joint 38 - NW_FLR1

Started Stressing

Ended Stressing
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### LEGEND:
- **Design Activities**
- **Construction Activities**

**Decision Point** based on condition findings

**Decision Point** based on findings from the CBA and observed behavior
Stabilization
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**LEGEND:**
- Design Activities
- Construction Activities
- **Decision Point** based on condition findings
- **Decision Point** based on findings from the CBA and observed behavior
How did we get here?
# Decision Matrix

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**Decision Point** based on condition findings

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# Further Rehabilitation

**Work Activities**

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<th>General Contractor/Construction Manager (GC/CM)</th>
<th>Design/Construction Contractor On-Boarding</th>
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<td>Intermediate Final 5. RFC</td>
<td>1. RFQ 2. SC 3. NTP CR &amp; Est. 4. MACC</td>
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**Design Activities**
- Installation of bridge interior illumination and electrical systems
- Removal of decommissioned utilities and relocation of existing in-service utilities
- Installation of inspection platforms

**Construction Activities**

-.Column 1:
  - Approach Superstructure
    - RR Clearance Window
    - See Dwg. S-206

- Column 2:
  - PIER 18
    - WSF STA. 96+75
    - ELEV. 195.46
  - PIER 18 Ground Improvements
    - See Dwg. S-204 & S-205
  - Channel Line
  - Waterway

- Column 3:
  - Approach Existing Ground Line along WSF Line
  - EXIST. RR TRACK

- Column 4:
  - CONSTRUCTION CLEARANCE ENVELOPE (SHOWN @ WSF LINE)
    - SEE DWG S-204
  - OHP POLE @ WSF LINE (TO BE VERIFIED BY CONTRACTOR)

- Column 5:
  - APPROX. EXIST. SIM SYSTEM Location (Typ.)
    - SEE DWG. S-201

- Column 6:
  - EXIST. SIM SYSTEM Location (Typ.)
    - SEE DWG. S-201
Roadway Structures Division

- Total Division Staff of 63 Permanent Positions
  - 3 Main Groups
    - Movable Bridge Operations
    - Structural Maintenance
    - Structural Engineering
- Work Type Split
  - Operation & Maintenance
  - Capital Programs (Levy/Non-levy)
  - Subject Matter Expertise
  - Emergency Response/Incident Management Team
  - Equity Initiatives
  - Reimbursable Work
Making the Decision to Close

- Bridge closed in March 2020 due to rapid growth of cracks
- Decision Driven By:
  - Public Safety
  - Preserve Integrity of the Bridge
- Growth of cracks continued, confirming immediate removal of traffic was essential
- This was not a maintenance issue
Pivot to ER, NDE & Stabilization
The Importance of Leadership & Community Support

- Mayor Jenny Durkan
- Deputy Mayor Casey Sixkiller
- SDOT Director Sam Zimbabwe
- SDOT Deputy Director Lorelei Williams
- Program Director Heather Marx
- SDOT Roadway Structures Division
- City Budget Office
- Seattle City Council
- Regional Stakeholders
- WSDOT/FHWA
- Community Task Force/Technical Advisory Panel
Reconnect West Seattle

2020 / 2021 Implementation Plan

• 15,000 Surveys and 1,700 meetings
• Online project dashboard
• 55 projects
• Completed 21 projects
• Low bridge access policy

Learn more:
www.seattle.gov/ReconnectWestSeattle
Planning for the future

Eventual High-Rise Bridge Replacement
• Rapid to 30% Design
• Long-term Off Alignment

Reconnect West Seattle
• Redundant modes of travel
• Increasing bike and transit capacity

High & Low Bridges
• Heavy impact to Budget for Instrumentation, Inspection and Maintenance
Predicting the Future

• Business Practices Upgrades
• Consistent and Clear Communication
• Move from Reactive to Proactive
• Future Levy Focus on Maintenance