Western Bridge Engineers

September 2013

Accelerated Bridge Construction – Fraser Heights Bridge

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Outline

- Introduction
- Problem Statement
- Solution
- Seismic Design
- Construction
- Conclusion
- Acknowledgements
Introduction

- Part of Port Mann Highway Project – a 37 km freeway widening: Vancouver – Langley, BC
- $2.5 Billion contract between the Province of BC and Design/Build Contractor Kiewit/Flatiron
- 450 m four-lane wetland crossing for the new South Fraser Perimeter Road
  - *Construction equipment prohibited in wetland*
  - *Total “footprint" restricted to 45 m²*
Problem Statement

- Wetland comprises highly compressible soils
- Challenging seismic performance requirement
- Construction schedule – limited to 12 months
- 4–5 m deck height results in stiff substructure
- Long segment lengths are desirable to minimize expansion joints and seismic interfaces, and improve vehicle ride quality

- Innovative solution required
Location

North Surrey, BC
Final design very similar to bid design

Parallel 436 m and 472 m long, 11 m wide superstructures

Typical span length 18 m – end spans 14 m

Bents: two steel pipe piles per trestle supporting box-section steel cap beams

302 identical reversible full-depth 250 mm precast deck panels – 3 m long, 11 m wide

100 mm membrane and asphalt wear surface
Wetlands and soil profiles
Eastbound: 436 m long – 26 spans
Westbound: 472 m long – 28 spans
Underside of Superstructure

Piles, caps, girders, precast deck panels installed
Seismic Design

Performance Criteria

- Minimal damage and immediate use by emergency vehicles for 475-year RP event
- Significant damage, return to full service following repairs for 975-year RP event
- No collapse, non-repairable damage acceptable, for 2475-year RP or Cascadia subduction events

*Criteria readily achieved by design selected*
Seismic Design – SAP Model

Northeast Quadrant
Seismic Design – Plastic Hinges

Hysteresis in piles
Seismic Design

Isolated Superstructure

- Base isolation accommodated thermal strains
- Segment lengths up to 250 m
- 224 bearings – only two types required
- Bearings: height – 144 mm; rubber thickness – 126 mm
- 975 year event displacement (non-linear time history analysis) – 109 mm max
Isolation Bearings

Typical single-bearing support

Double-bearing support – west end-span
# Seismic Response – Periods

<table>
<thead>
<tr>
<th>Mode</th>
<th>Natural Period (sec)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Westbound Bridge</td>
<td></td>
<td></td>
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<tr>
<td>Longitudinal</td>
<td>1.7</td>
<td></td>
<td>2.18</td>
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<tr>
<td>Transverse 1</td>
<td>1.49</td>
<td></td>
<td>1.67</td>
</tr>
<tr>
<td>Transverse 2</td>
<td>1.33</td>
<td></td>
<td>1.58</td>
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## Seismic Response – Displacement

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Displacement (mm) max.</th>
<th>W/B Bridge</th>
<th>E/B Bridge</th>
<th>Expected Yielding</th>
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</thead>
<tbody>
<tr>
<td>10% in 50 years</td>
<td>Transverse</td>
<td>154</td>
<td>165</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>109</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>5% in 50 years</td>
<td>Transverse</td>
<td>212</td>
<td>227</td>
<td>Several cap/pile joints</td>
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<tr>
<td></td>
<td>Longitudinal</td>
<td>154</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>2% in 50 years</td>
<td>Transverse</td>
<td>341</td>
<td>363</td>
<td>Several cap/pile joints</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>253</td>
<td>325</td>
<td>Several piles (minor)</td>
</tr>
</tbody>
</table>
**Top-down construction method**

- 250 tonne erection crane
- Two movable work platforms on WB trestle
- Crane drives piles, installs pilecaps, places concrete in piles and cap joints, erects girders, and installs deck panels
- Materials delivered over EB and WB trestles
- Girders and panels acting non-compositely designed for one lane of highway loading
Top-down construction method
Crane – Work Platform
Construction – Piles

- 112 open-ended steel pile piles
- 762 mm diameter x 19 mm wall thickness
- SLS – 2100 kN; ULS – 2700 kN
- Required geotechnical capacity – 5400 kN
- APE D80 hammer: 268 kNm; 31.4 tonnes
- Top 11.5 m concrete-filled; reinforcing ratio: 2.6%
- Rebar cage penetrates into joint in pile cap
- Rebar flexural yielding capacity-protects pile cap
Crane – Pile Driving
Steel Pilecap Installation

Joint formwork in place
Pilecap Joint
Pile rebar cage projects into pilecap joint
Accelerated Bridge Construction

**Time frame**

- 52 weeks available for construction
- Virtually all components critical path
- Span cycle:
  - Advance work platform and crane
  - Drive piles – clean out, fill with concrete
  - Place steel pier cap and cast pile/cap joints
  - Install bearings, girders and precast panels

*10-day average span-cycle achieved*
Challenges – Pile Installation

- East abutment piles 45 m long (35 m anticipated)
- Several piles encountered boulders:
  - Full-height HP 360x174 driven inside pipe to by-pass boulder (3 piles)
  - Shallow boulder excavated (west end)
- Six west-end piles drilled-in from outside wetland to achieve required embedment
- Final total pile length: 2306 m (108% of estimate)
- All 112 piles successfully installed
Challenges – Pile Installation

Pile tip damage
Girder Erection

Girders lifted in braced pairs
Deck Panels

All panels identical and reversible
Deck Panel Joints

- 350 mm wide joints
- Suspended forms
Deck Panels – Pockets

Clusters of thirteen 22 mm studs
Watercourse Crossing

*Bridge design accommodates existing wetland drainage*
Completed Bridge

- Minimal impact on wetland
- Open median reduces deck shadow effect
West Abutments

Wire-faced MSE median wall
Installation of Protecto Wrap preformed waterproof membrane

Surfacing: 40 mm Open Graded Friction Course over 60 mm Hot Mix Asphalt
Finished Deck Surface

Looking west from East Abutment
Conclusion

• Value achieved by:
  o Maximizing deck segment lengths and work repetition
  o All 112 pile sections were identical
  o Constant girder section – no butt welds
  o All 302 precast full-depth deck panels were identical
  o Non-composite bridge carries materials delivery trucks
  o Building tolerance on support location into design – no corrective action required
A custom solution was developed to solve a challenging bridging problem.

Bridging solution developed for bid design envisaged top-down, Accelerated Bridge Construction techniques.

Identical layout used for final design.

Work platform added to avoid 250 tonne crane loading on superstructure.

*Contractor estimated cost at $25 Million: $2500 per m²*
Acknowledgements

- **Owner:** BC Ministry of Transportation and Infrastructure
- **Design-Build Contractor:** A joint venture of Peter Kiewit Sons Co. and Flatiron Constructors Canada Limited
- **Onshore Design:** H5M – a joint venture of Hatch Mott MacDonald and MMM Group Limited.
- **Bridge Designer:** Brybil Projects, a subsidiary of Associated Engineering Group Ltd.
- **Geotechnical Engineer:** EBA Engineering Consultants Ltd.
- **Bridge Installation Contractor:** Gateway Infrastructure Group GP
Thank You
- for your attention
Questions?
Contact: harveyd@ae.ca