Sound Transit Sounder Commuter Rail

The D-to-M Streets Track and Signal Improvement Project: Pacific Avenue Bridge

Western Bridge Engineers’ Seminar
September 4-6, 2013
Sounder System Map

Everett – Seattle

Seattle - Lakewood
Tacoma to Lakewood Corridor

- 8.2 Miles
  - 1.4 miles of new track
  - 6.8 miles of track and signal upgrades

D to M Street

Tacoma to Lakewood
Project Elements

- At beginning of project (10 - 15% level of design)
  - 3 walls in downtown area
  - 1 bridge (3-span)
  - 3,500’ of cut wall
  - 1 braced excavation

- At end of project (100% level of design)
  - 22 walls in downtown area & along cut
  - 3 bridges (2ea – 3 span, 1ea – 2 span)
  - 2,400’ of soil nail wall
  - 1 braced excavation
Wall Types: Soldier Pile, SP w/ Tiebacks, Concrete Cantilever, SEW, Soil Nails, Block walls
Tacoma Avenue Braced Excavation
B Street Gully Bridge - Rendering
B Street Gully Bridge
A Street Bridge - Rendering
A Street Bridge
Visualizations

- Used for:
  - Project stakeholder meetings
  - Open houses
  - City Council approval of Pacific Avenue Bridge aesthetics
- Originally limited within project scope
- Became the go-to deliverable to show engineering elements to non-engineers
Financials

- **Construction:**
  - Engineers Estimate = $66M
  - Low bid by Mid-Mountain Construction= $40.8M
  - Bid + Change Orders ≈ $69M
    - Bulk of CO cost related to contaminated material discovery

- **Design + DSDC: (PB + 6 Subconsultants)**
  - Total Team Budget = $14.5M
  - Design = $10.5M
  - DSDC = $4M
Pacific Ave Bridge Type Selection

- Bridge Type Study Undertaken in August 2008

  - General Criteria:
    - Feasible
    - Affordable
    - Attractive

Baseline 3-span TPG with PS Box side spans
Alternatives Considered

- Cast-in-Place Thru Girder
- Thru Plate Girder
- Tied Arch
- A-Frame
- Thru Truss (Pony Truss)
- Extradosed
- Thru Steel Box Girder
- Cable-Stayed
A few of the Alternatives Evaluated

- Single Span Tied Arch
Alternatives Cont’d

- Single Span A-Frame
Alternatives Cont’d

- Single Span Pony Truss
Alternatives Cont’d

- Single Span Extradosed
Bridge Type Cost Comparison

Sound Transit
D to M Street Track and Signal Project

Bridge Type Cost Comparison

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Total Cost (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 3-Span TFG/PS Box</td>
<td>$3.506</td>
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<tr>
<td>CIP Thru Girder</td>
<td>$2.810</td>
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<tr>
<td>Thru Plate Girder</td>
<td>$3.027</td>
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<tr>
<td>Tied Arch</td>
<td>$3.050</td>
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<tr>
<td>A-Frame</td>
<td>$3.122</td>
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<td>Thru Truss (Pony)</td>
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<tr>
<td>Cable Stayed</td>
<td>$4.590</td>
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IN-PROGRESS
Structure Type Evaluation Matrix

A weighted criteria approach was taken using the following categories:

a) Aesthetics
b) Impact to Roadway Profile
c) Gateway Potential
d) Cost
e) Schedule
f) Structural Behavior
g) Constructability
h) Durability
i) Inspection and Maintenance
j) Geotechnical / Foundations

Weighting ranged from 1 – 5:
1 – Does not meet minimum criteria
2 – Meets minimum criteria
3 – Exceeds criteria
4 – Clearly exceeds criteria
5 – Significantly exceeds criteria
# Structure Type Evaluation Matrix

## D to M Street Track and Signal Project

### STRUCTURE TYPE EVALUATION MATRIX

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score Weight</th>
<th>Baseline 3-span</th>
<th>A-Frame</th>
<th>Steel Through Girder</th>
<th>Concrete Through Girder</th>
<th>CIP Through Girder</th>
<th>Cattle Stayed</th>
<th>Extradosed</th>
<th>Tied Arch</th>
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### Ranking

1 – Does not meet minimum criteria
2 – Meets minimum criteria
3 – Exceeds Criteria
4 – Clearly Exceeds Criteria
5 – Significantly Exceeds Requirements

Highest score indicates most preferred structure type
Final Alternative Selection

- The single span Thru Plate Girder was preferred based on:
  - Least cost
  - Most constructible
  - Least impact to roadway
- Ultimately due to urban design concerns in the downtown area a 3-span TPG structure was selected.
Public Workshops (July 2009)

**REVISED “CLASSIC” BRIDGE ENHANCEMENT CONCEPT**

- Classic" Concept is Preferred Concept for Final Design
  - The concept incorporates elements that echo Boyle
  District historic character
  - Column shape and pier cap reminiscent of historic archi
  tecture in the area
  - Railing has simple, regular pattern
  - Walls have repeating classical"toffee" pattern

- Concept Refinements after Bridge Workshop #1
  - The pilasters are taller and topped by globes to mark ends
    of center bridge span
  - Column bases were reduced in size

**NIGHT LIGHTING CONCEPT**

- Bridge spans are lit to provide downtown
  gateway and to accentuate the bridge architecture
  - The sidewalks and bridge substructure
    are brightly lit for visibility and safety
Aesthetic Studies

Color, Railing Type, and Surface Treatments

Aesthetic Lighting
Pacific Ave Bridge - Rendering
Pacific Ave Bridge - Photo
Pacific Ave Bridge Characteristics

- Steel through plate girder superstructure with reinforced concrete ballast pan
  - 106’ Main Span with 11’-3” deep plate girders
  - 46’-0” Approach Spans with 5’-4” deep plate girders
Pacific Ave Bridge Characteristics

Piers

- Reinforced concrete cap on 5’-6” square columns
- 8’-0” diameter drilled shafts
Pacific Ave Bridge Characteristics

- **Abutments**
  - Reinforced concrete cap on 6’-o” diameter drilled shafts
Design Challenges

- Substructure design must accommodate initial single track and future double track superstructures
  - Initial single track for Sound Transit’s Sounder commuter train
  - Future additional track for Amtrak passenger train
- Liquefaction potential in 10’ layer of soil overlain by 30’ of fill
  - Downdrag on drilled shafts due to overlying material
  - Balance ductility with rail structure stiffness requirements
Designing for Future 2\textsuperscript{nd} Track

- Two column/shaft substructure designed for eventual third symmetrical column/ shaft

Initial – Single Track

Final – Two Tracks
Designing for Future 2\textsuperscript{nd} Track

- Top of bent elevations established for two-track superstructure
  - Floorbeams 70\% greater in height for future structure
  - Bearings 70\% greater in height for future structure
  - Temporary pedestals for initial structure elevation
Designing for Future 2nd Track

- Cap reinforcement designed with internal headed anchorages to minimize service disruption during cap extension.
Liquefaction Hazard

- Drilled shafts designed for additional 600 kip downdrag burden
- 45’ permanent steel casing required for drilling
Pier 3 Drilled Shaft Conflict

- 72” diameter culvert 30’ below grade at pier 3
Pier 3 Drilled Shaft Conflict

- Perceived conflict of drilled shaft installation with existing storm sewer at Pier 2
Pier 3 Drilled Shaft Conflict

- Larger auger size vs. tolerance for plan location and plumbness for shaft resulted in potential conflict
- Explore shaft construction tolerance to avoid culvert
Pier 3 Drilled Shaft Conflict

- Culvert still too close for comfort. Eventual use of a gyroscopic theodolite below surface provided the desired confidence in location.
Pier 3 Drilled Shaft Conflict

- City GIS vs. surface survey vs. gyroscopic theodolite survey
- Theodolite investigation revealed actual conflict at Pier 3
Pier 3 Drilled Shaft Conflict

- Redesign pier 3 using grade beam to avoid culvert
Pier 3 Drilled Shaft Conflict

- Design revision utilized existing 8’ diameter drilled shaft reinforcing cages.
- Reinforcing cages were extended approximately 50’ using mechanical couplers

Initial – Single Track

Final – Two Tracks
Pier 3 Drilled Shaft Conflict

- Excavation for grade beam installation
Pier 3 Drilled Shaft Conflict

- Shaft and grade beam reinforcing
Abutment Misalignment

- Bent 4 placed incorrectly
Abutment Misalignment

- Abutment 4 bearing stiffeners offset from bearing

North Misalignment

South Misalignment
Abutment Misalignment

- Web stress comparison between design and as-constructed for north girder
Abutment Misalignment

- Web Compressive Stress Detail

9.5 ksi Design Stress (Aligned)

15.1 ksi As Constructed (Misaligned 3”)

17.5 ksi Allowable Okay
Abutment Misalignment

- Rocker Plate Weld Stress Investigation

Misalignment created increase in weld stress for fatigue loading
Abutment Misalignment

- Increase flange to rocker plate weld size to $\frac{3}{4}''$
Pacific Ave Bridge - Construction
Pacific Ave Bridge - Final
Thanks to:

- Sound Transit
- Parsons Brinckerhoff
- D to M Streets Team:
  - Shannon & Wilson
  - Cosmopolitan Engineering
  - AHBL
  - GHL
  - Enviroissues
- William Ott Construction Consultants
Questions?