Design of SR 99 Tunnel and Approach Structures
Western Bridge Engineers’ Seminar
Sept. 5, 2013
Jerry Dorn
Design-Build Team

Owner: Washington State Department of Transportation

Contractor: Seattle Tunnel Partners

Joint Venture: Dragados USA, TutorPerini

Designer: HNTB

Sub-Consultants: Intecsa-Inarsa, HartCrowser, Earth Mechanics, Inc.
Existing Alaskan Way Viaduct
SR 99 Tunnel

- Approximately two miles long.
- Two lanes with eight-foot safety shoulder in each direction.
- State-of-the-art safety systems.

- 1250 foot south approach
- 9300 foot bored tunnel
- 450 foot north approach
Tunnel Section

- Electrical rooms
- Egress corridor
- Equipment rooms
- Utility corridor
- Pump station
- Smoke extraction duct
Construction Bypass
Meet Bertha, the SR 99 Tunneling Machine

- 6700 tons
- 10 bar pressure
- 88M lbs thrust
- 24ea by 750 hp drive motors
- 0-2 rpm
- 24 Mw operating
Tunneling Machine Assembly in Japan

Screw Conveyor

Bottom of Muck Chamber
Tunneling Machine Assembly in Japan
Tunneling Machine Trailing Gear
Tunneling Machine Delivery to Launch Pit
SEISMIC DESIGN CRITERIA

Dual levels of design earthquakes:

- 2500-year return events (rare earthquake)
- 108-year return events (expected earthquake)

**Tunnel Liner**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Excavation diameter</td>
<td>57’3”</td>
</tr>
<tr>
<td>Internal diameter</td>
<td>52’</td>
</tr>
<tr>
<td>Segment thickness</td>
<td>24”</td>
</tr>
<tr>
<td>Grouting thickness</td>
<td>8”</td>
</tr>
<tr>
<td>Average ring length</td>
<td>6’5”</td>
</tr>
<tr>
<td>Number of segments</td>
<td>7+2+1</td>
</tr>
<tr>
<td>Tunnel length</td>
<td>9300’</td>
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Performance Objectives

- **Life Safety**
- **Operational**
Tunnel Liner Ring
Liner Design – Two Step Approach

**STATIC ANALYSIS**

**Step 1**
- Geotechnical Engineers
- **FLAC2D**
- Soil and Hydrostatic Loads (applied at each spring)

**SEISMIC ANALYSIS**

**Step 2**
- Structural Engineers
- **QUAD4M**
- Ground Deformations (applied at each spring)

**CSiBridge**
Seismic Models

2D Section Model

- Ovaling deformation
- Bending and axial in the liner for Extreme Event load combination

3D Spine Model

- Obtain seismic forces in the line
- Evaluate displacements at the interface between liner and south and north headwall

3D FE Model

- Predict the local behavior of the gaskets at the circumferential and radial joints
Seismic Results - Ovaling

$t = 0 \text{ s}$

Undeformed Shape

Deformed Shape

$t = 3.52 \text{ s}$

Dmax = +0.1019 ft

Dmin = -0.1077 ft

$t = 3.88 \text{ s}$

Dmax = +0.1056 ft

Dmin = -0.1321 ft

$t = 4.42 \text{ s}$

Dmax = +0.0163 ft

Dmin = -0.0179 ft

$t = 4.81 \text{ s}$

Dmax = +0.0356 ft

Dmin = -0.0437 ft

$t = 10 \text{ s}$

Dmax = +0.0328 ft

Dmin = -0.0359 ft
3D Spine Model – Differential Displacements

<table>
<thead>
<tr>
<th></th>
<th>2500 yrp</th>
<th>108 yrp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap Opening</td>
<td>6.6”</td>
<td>0.11”</td>
</tr>
<tr>
<td>Gap Closing</td>
<td>8.6”</td>
<td>0.14”</td>
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</tbody>
</table>
Ring Segments Pre-Cast Plant
Tunnel Liner Segment
Interior Structures

- CIP Frame
- Precast Slab
- Shotcrete Walls
Interior Structures Design

Freestanding concrete frame
650’ units
Construction Sequence
Approach Structures

- Southbound SR 99 on-ramp from Alaskan Way S.
- Connection from Alaskan Way S. to East Marginal Way
- New east-west connection at S. Dearborn Street
- Bike/pedestrian path
- Northbound SR 99 off-ramp to Alaskan Way S.
- Southbound SR 99 off-ramp to S. Royal Brougham Way
- Northbound SR 99 on-ramp from S. Royal Brougham Way
Cross-Sections at South Approach
Approach Structure
Tunneling Machine Launch Pit
Approach Structure Construction
South End Settlement Mitigation

Single Wall Shafts

Double Wall Shafts

Launch Pit

Main St.

King St.

Washington

Main

Jackson

King

Tunnel Alignment

N
Buoyancy Slab
The Start of Tunneling
Acknowledgements

WSDOT Structures: Tim Moore

Design Manager: Rich Johnson

South Approach: Tie Zong

Tunnel Liner: Yang Jiang

Tunnel Interior Structures: Tom Cossette

North Approach: Andrew Herten

Settlement: Carlos Herranz Calvo
Website:  
www.AlaskanWayViaduct.org

Twitter:  
@BerthaDigsSR99

Email:  
viaduct@wsdot.wa.gov

Hotline:  
1-888-AWV-LINE