Burlington Tunnel Emergency Repairs: A Case History

by: K. Pidgeon - ECI Rail Constructors, Inc.
M. Boscardin - Boscardin Consulting Engineers, Inc.
W. Riehl, III – Rail America, Inc.

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Presentation Organization

- Project Introduction
- Ground Conditions
- Original Tunnel Construction
- 2008 Rehabilitation
- The Emergency Repairs
- Lining Response/Performance
- Summary and Conclusions

Project Background

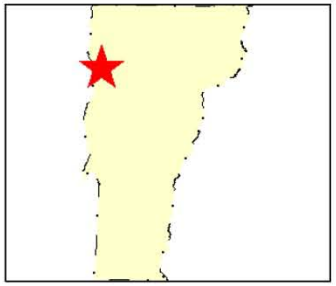
- 340 ft Long, Horseshoe-Shaped with Curved Walls
- 4º Horizontal Curve, 60 ft of Overburden
- Inside Dimensions - 17 ft High by 16 ft Wide
- Constructed by Vermont Central RR 1860 - 1861
- Brick Lining Supported on Limestone Block Footings
- Limestone Cobble Floor
- Owned by New England Central Railroad (Rail America)

VERMONT

Vermont Interactive Map Viewer

Vermont Center for Geographic Information (VCGI)

Burlington Tunnel



Legend

- Airports
- Mountains and Hills
- Interstates
- US Highways
- VT State Highways
- Rail Lines
- Town Boundaries

Roads

- Class 1-3
- Class 4
- Driveways

- Rivers and Lakes

Streams

- Intermittent
- Perennial
- Unassigned

- Cities
- VT State Boundary

0 375 750 1125 ft.

VT State Plane Meters (NAD83)

Scale: 1:3,929

Map center: 442200, 221184

URL: http://maps.vermont.gov/imf/sites/VCGI_basemap/jsp/launch.jsp

VCGI

6/17/11

4 Degree Horizontal Curve

Ground Conditions

- On the Shores of Lake Champlain
- Tunnel Through a 100-ft-High Sand Ridge
- Fine to Medium Sand
- Wind Blown Sand from Glacial Marine Deltaic Deposits
- Running Sand Conditions Below Ground Water
- Some Varved Clay Encountered During Repairs
- Ground Water Level Below Invert

Loose Fine-Medium Sand

Original Tunnel Construction

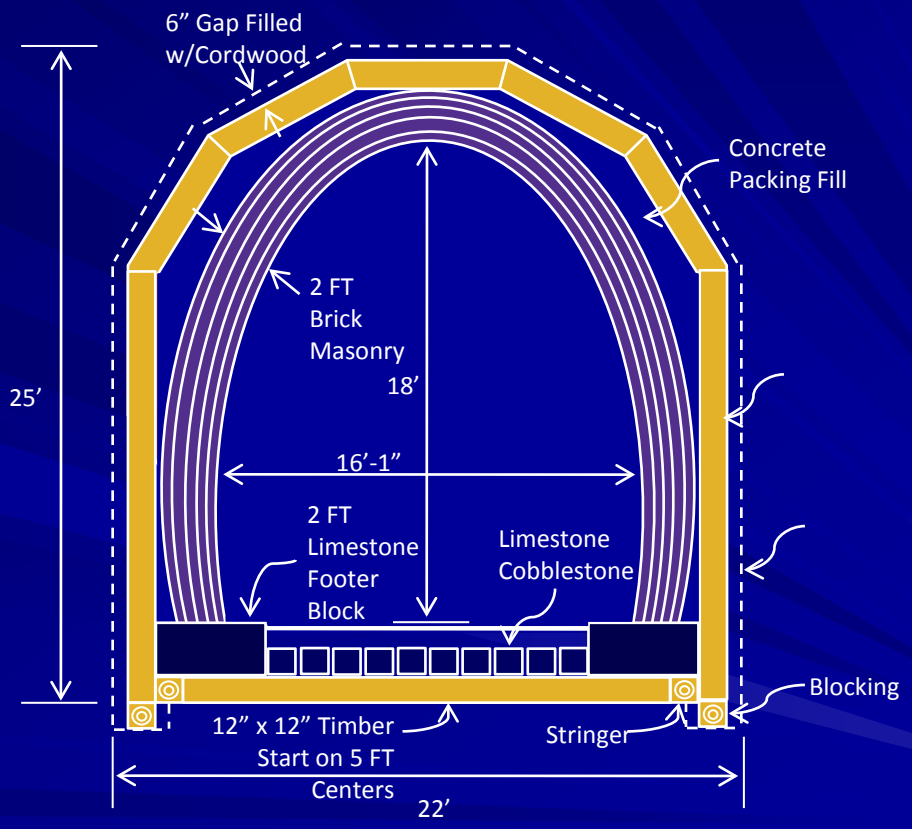
- Construction Started 1 November 1860
- Construction Completed 17 May 1861
- Ground Reported to be “Quick Sand”
- Vertical Wooden Shield with Top Heading and Bench Excavation, Forepoling
- Initial Lining Contiguous 12-in. x 12-in. Timbers, Backpacking with Cordwood, Timber Invert Struts
- Excavated Dimensions 25 ft High by 22 ft Wide

Original Tunnel Construction, Con't.

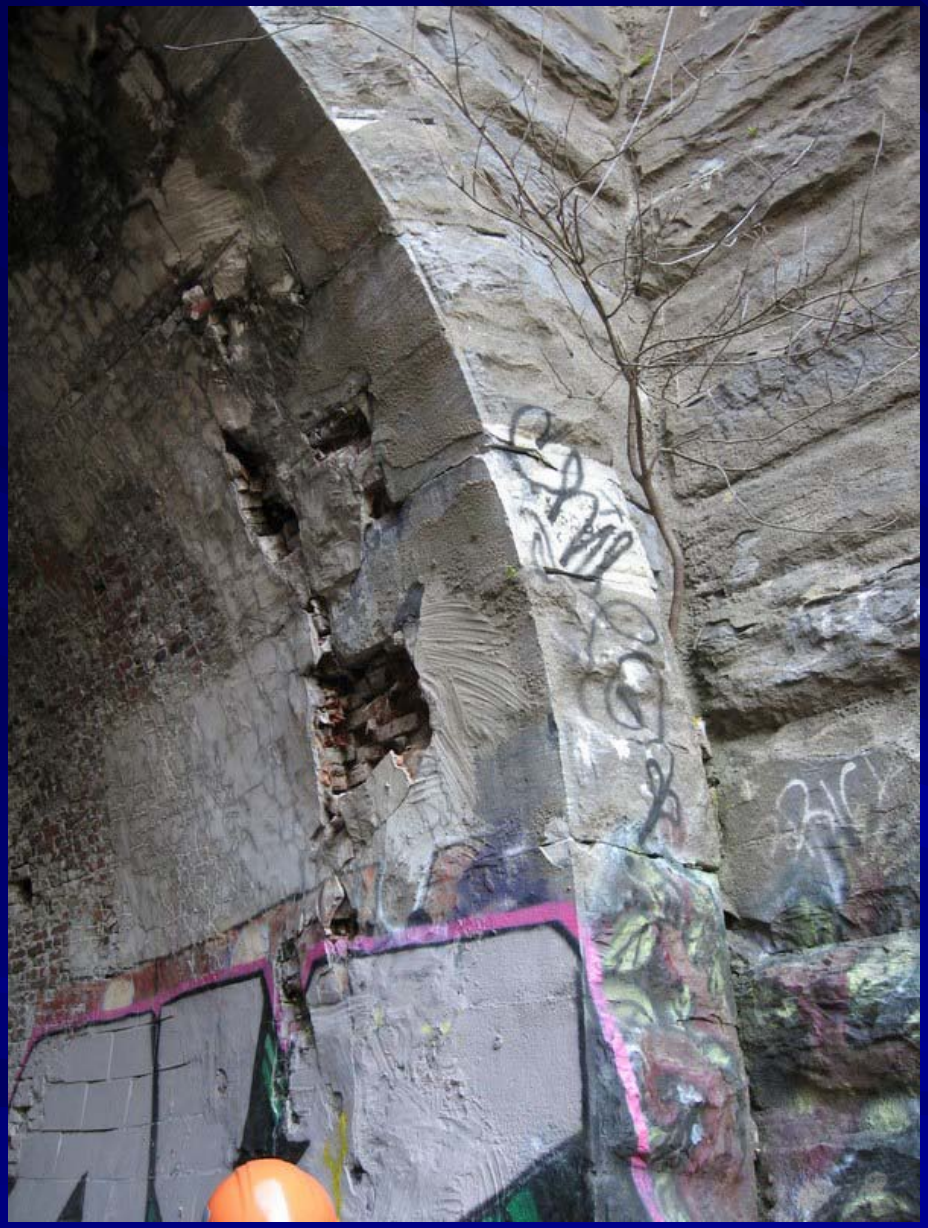
- Used 700,000 Board ft of Lumber
- 2-ft-Thick Brick Masonry Final Lining
- Concrete Fill Between Masonry Timber Linings
- Construction 24/7 – 85 Men in Two Shifts
- Average Tunneling Rate 3 ft per day
- Portals
  - Headwalls - 39 ft High Limestone Masonry 6 ft thick at Bottom
  - Wing Walls – 18 ft Thick at Bottom, 4 ft Thick at Top

Sketch of Initial Lining

- Excavation
  18.7 cy/ft
- Over Excavation
  1.3 cy/ft
- Concrete Packing
  1.35 cy/ft
- Cordwood Packing
  35 cy/ft
- Timber Lining
  838.2 Board ft/ft



Tunnel Lining Condition at 148 Yrs Old



2008 Pre-Rehab Condition

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2008 Rehabilitation Plan

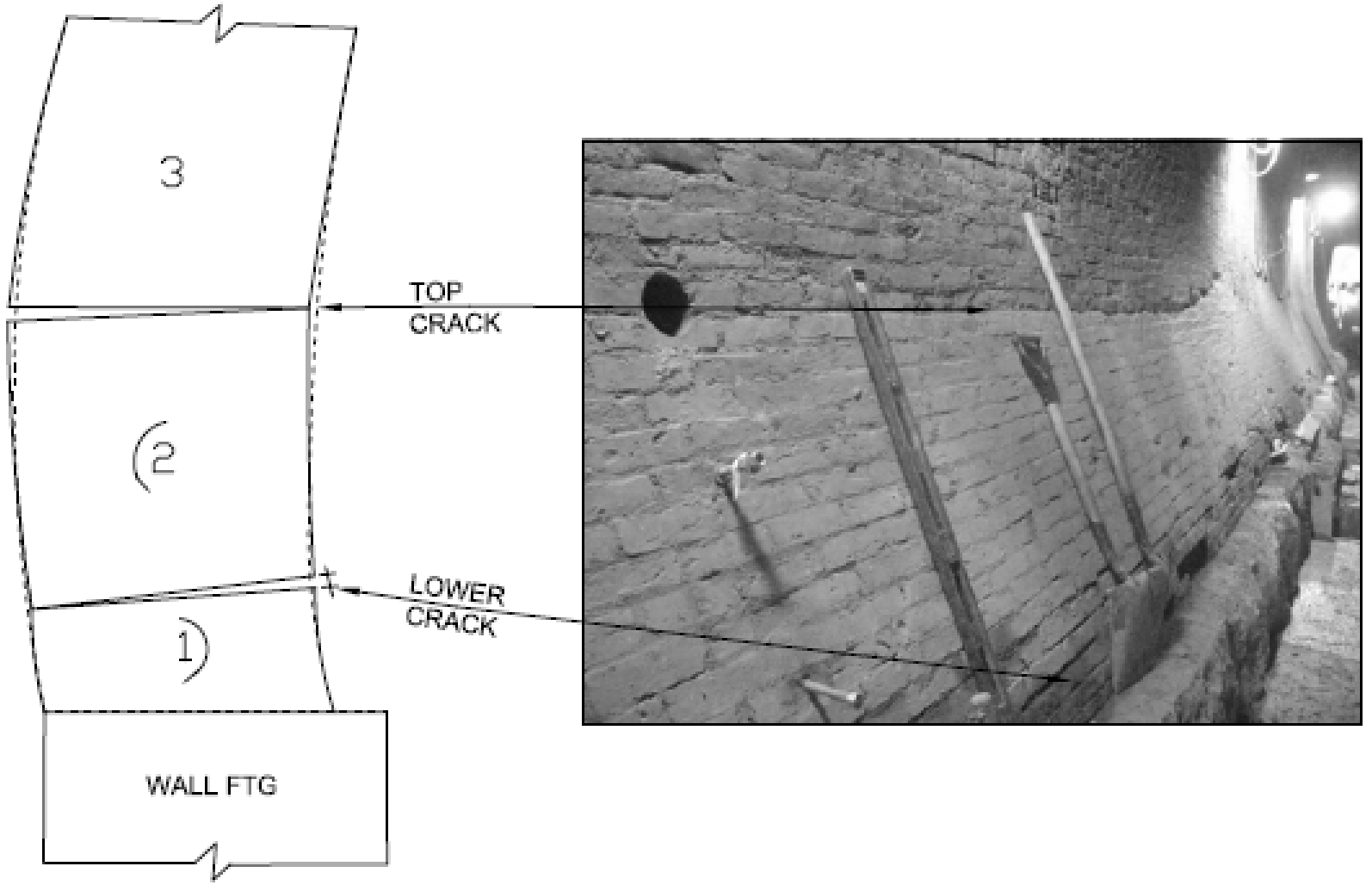
- Original Intent of 2008 Rehab
  - Mitigate Lining Distress Due to Weathering, Seepage, Freeze-Thaw, Age and Impacts
  - Apply 6-inch Shotcrete Internal Lining, with Weep Holes
  - Lower Tracks to Compensate for Shotcrete
- Pre-2008 Rehab Included:
  - Shotcrete, Bolting, Pointing, Insertion of Masonry

Emergency Condition

Developed Rapidly After Floor Removal

- Tunnel Sidewalls Moved Inward
- Additional Cracking Observed
- Immediate Response - Stabilize and Assess

Wall Movement



Cracking Caused by Rehab Construction

15 Sept – Emergency Concrete Bracing

Emergency Bracing Slab

Technical Approach to Repairs and Emergency Response

- Immediately Stabilize Wall Movements
- Monitor Further Wall Movements
- Investigate Causes of Movements
- Evaluate Lining Loads, Stresses, Cracking
- Design Permanent Invert Struts
- Complete Emergency and Original Rehab
- Monitor During and Following Construction

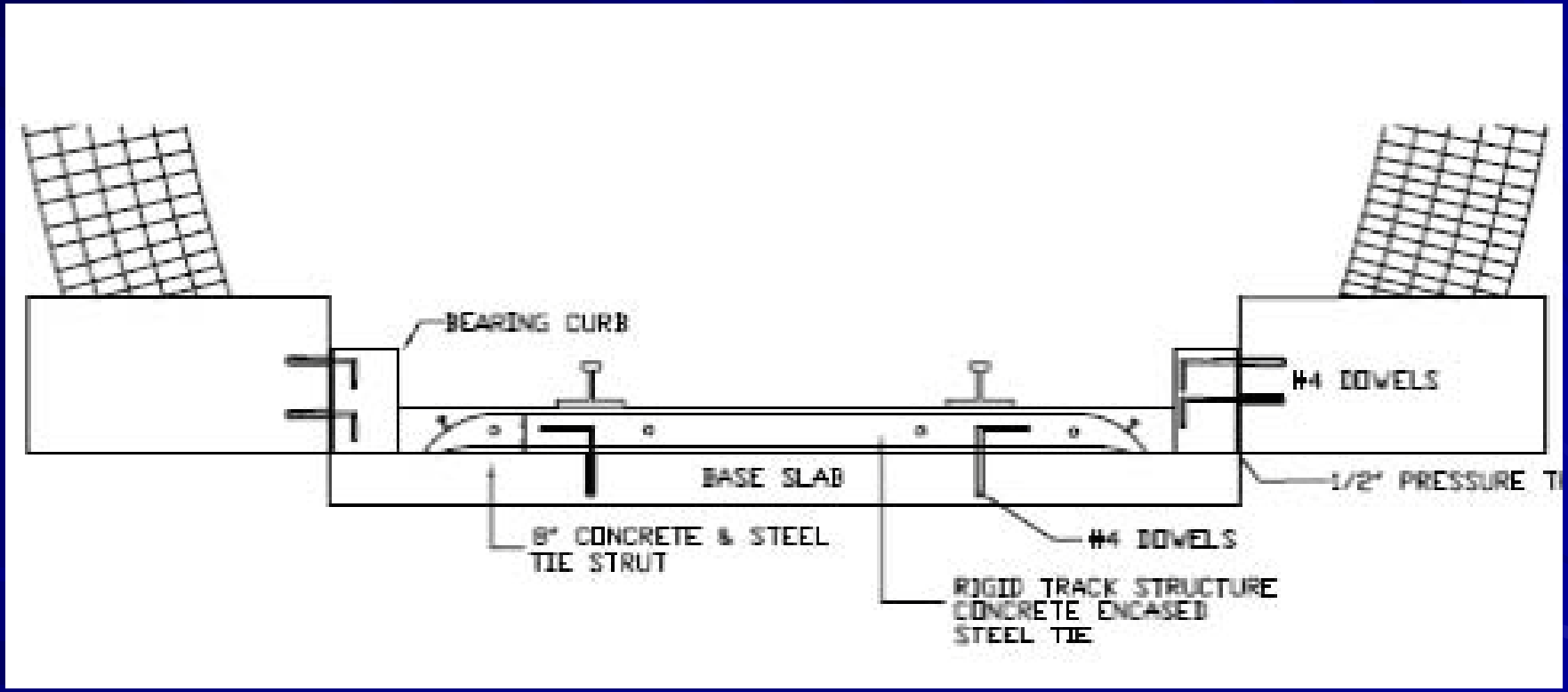
Lining Coring

Crack and Survey Monitoring

Shotcrete Work

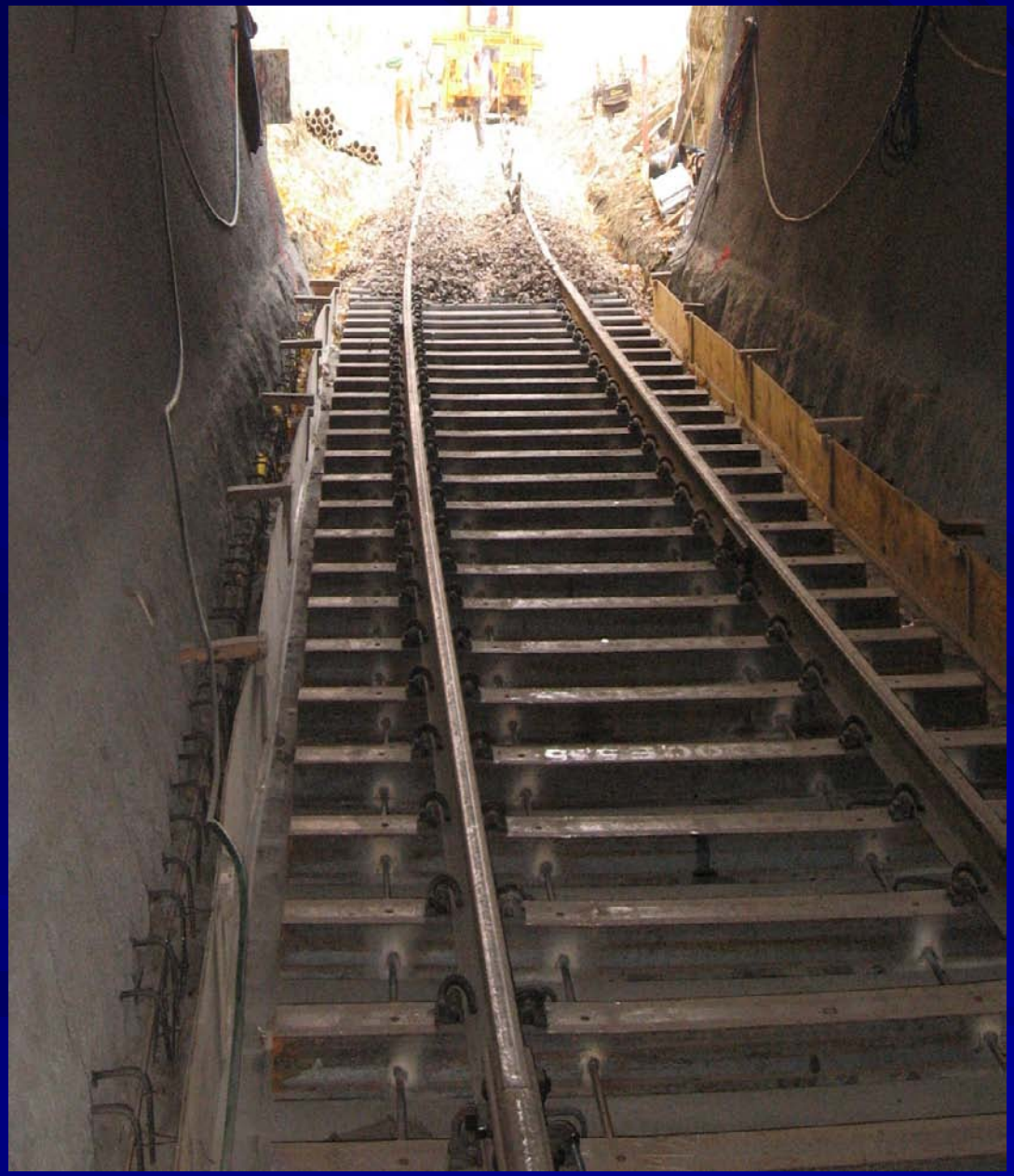
Cross Section of Rigid Track System

Capacity = 28.5k/ft



Invert Slab Replacement

Completed Base Slab



Rigid Track Structure Before Concrete

Test Car

Concreting New Track Structure

Grouting Cracks

2008 Timeline of Events

- 15 Sept - Install Emergency Invert Brace, ECI Engaged
- 15-22 Sept - Assess Tunnel, Core Lining, Install Monitoring
- 20 Sept - Mill up to 18” off Emergency Concrete Brace
- Mid Sept –Mid Oct – Shotcrete Work
- 14-27 Oct – Replace Emergency Brace Slab in Segments
- Late Oct - Install 18-ft-Long Approach Slab at Each Portal
- 27 Oct – 3 Nov - Construct Rigid Track System
- 3 Nov - Run Test Car for Clearance Check
- 6 Nov - Install Concrete for Rigid Track
- 10 Nov - Pass Test Train
- 10-13 Nov - Finalize Alignment and Surfacing, Turn Over to RR
- 14-21 Nov - Install Grout Tubes and Grout Cracks

Summary and Conclusion

- Emergency Repair & Rehab Work Completed in 2 Months
- Rapid Response to the Emergency Condition Allowed Completion of the Originally Planned Repairs Close to the Original Schedule
- Flexible, Coordinated and Innovative Construction Approaches Contributed to Success
- Construction of the Original Repair Scheme May Have Been Possible with Low Pressure, Low Vibration Equipment, But Long-Term Performance of the Tunnel May Have Been Compromised without a Permanent Invert Strut.

Nov 2010 Inspection

Crack Monitor Nov 2010

- Wall Convergence 0 to ¼ inch Since November 2008
- Typically 1/8 inch Convergence
- Approximately Equal Estimated Shrinkage of Invert Struts
- No New Cracking or Widening of Cracks Observed


Questions?