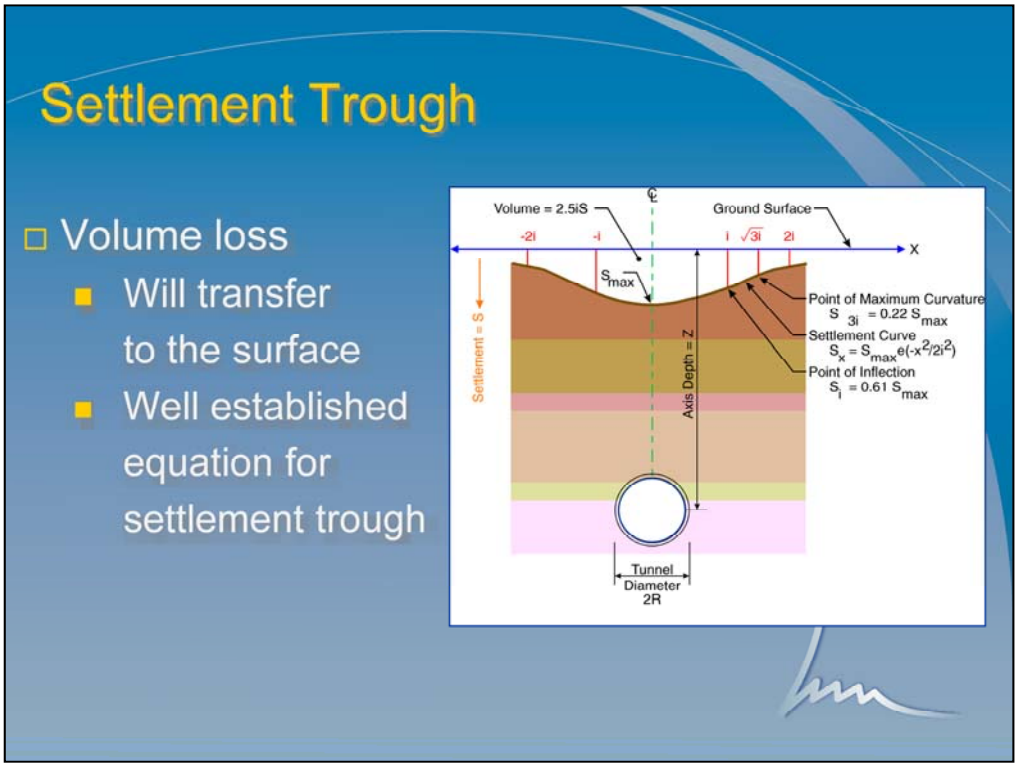


Effect on structures

Uniform settlement - no concerns

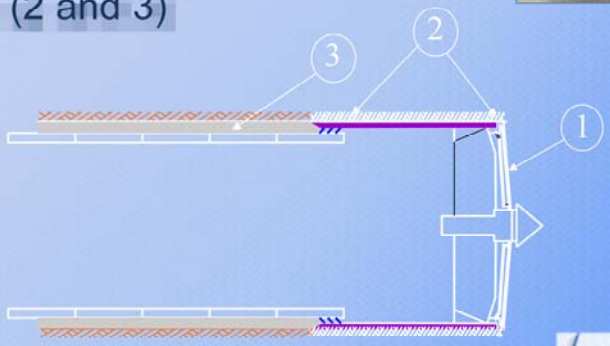
Angular distortion - causes damage due to tensile strain

1/500 - safe limit for no cracking of buildings

1/150 - potential structural damage

Sources of V_L during Tunneling

- Loss Through Face (1)
- Excessive Overcut for Steering (2)
- Filling of the Tail Void (3)
- Plowing (2 and 3)



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Instrumentation

- Measurement Objectives
  - Vertical displacements
    - Surface settlement monitors
    - Deep settlement monitors
    - Structure settlement / distortion
  - Lateral displacements
    - Ground – inclinometers
    - Structures – tilt meters
  - Water level indicators
  - Relative / absolute displacements
    - Tape / Rod Extensometers
  - Temperature effects
    - Gages / thermocouples

INSTRUMENTATION – AMSTERDAM

One of the most extensive ground monitoring surveys ever attempted is now under way in Amsterdam, years before tunnelling starts for the city's metro. David Hayward reports.

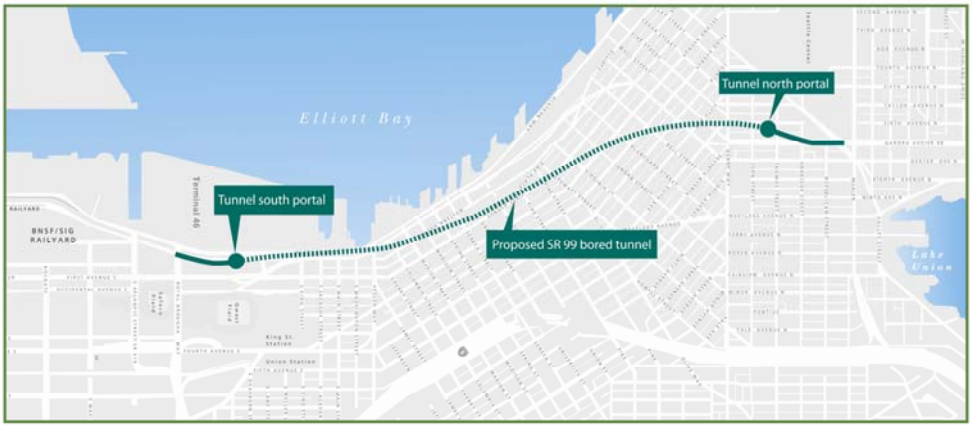
On the alert for settlement

DECEMBER 2001 Tunnels & Tunnelling International

Mitigation Measures

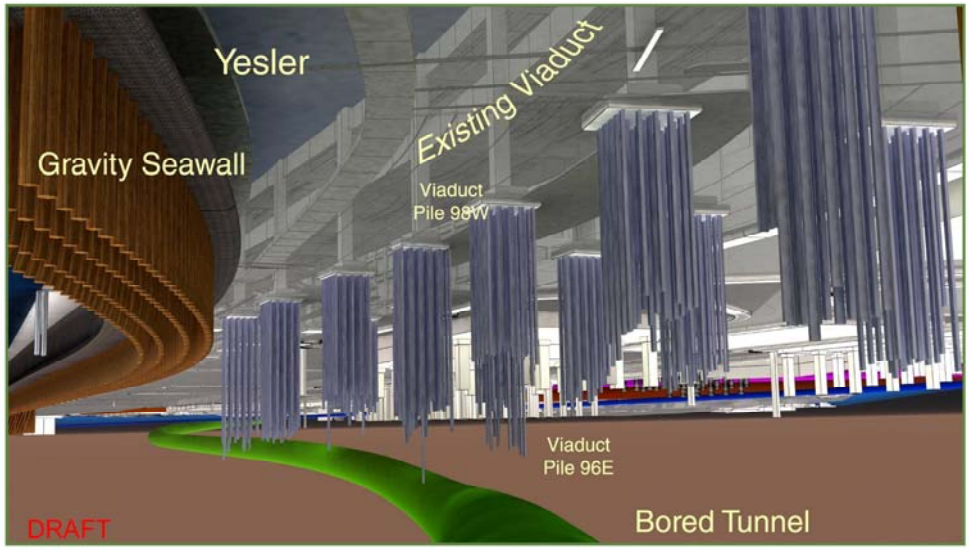
- Grouting Methods
- Freezing Methods
- Face Conditioning Agents

Proposed SR 99 Bored Tunnel Alignment

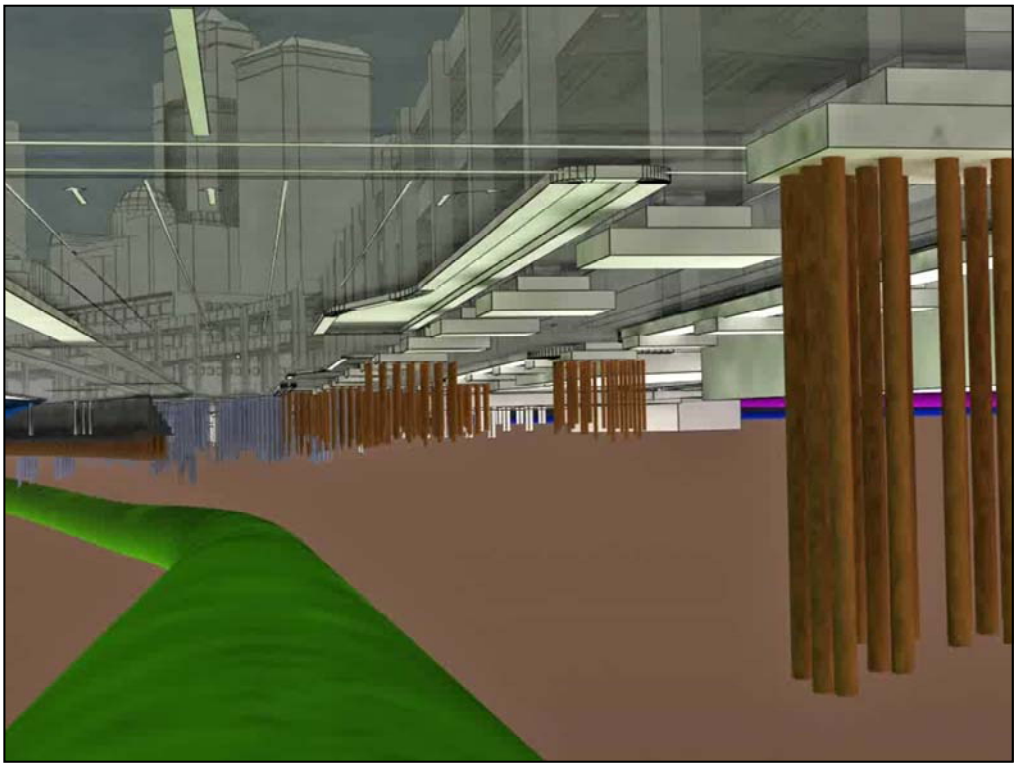


- Engineers continue to further refine the tunnel's preliminary design, including depths, grades and exact alignment.
- We anticipate the bored tunnel would be approximately two miles long connecting the stadiums area with Aurora Avenue North.
- The tunnel would have two lanes, with shoulders, in each direction and be between 60 and 200 feet underground.
- We used value engineering to evaluate a number of potential alignments for the proposed SR 99 bored tunnel.
- The proposed bored tunnel alignment begins on Alaskan Way, avoiding impacts on First Avenue through Pioneer Square, then moves toward First Avenue near Yesler Way, turns north near Stewart Street and ends at Sixth Avenue N. and Thomas Street.
- The south portal structure would be located in the vicinity of First Avenue S. between Charles and Dearborn streets.
- The north portal structure would be located in the vicinity of John and Harrison streets.
- Designed to 2,500 year earthquake standard.

Underground View



- This underground view shows the bored tunnel in green alongside the existing underground infrastructure.
- From this image, you can see that the tunnel is inland from the seawall and adjacent to the existing viaduct's structural supports, at one point crossing under them.



South Portal

- This image shows the updated portal with additional landscaping added as well.
- Describe the traffic movements – northbound, southbound, entering the tunnel, accessing downtown street grid, etc.

South Portal

- This image shows the updated portal with additional landscaping added as well.
- Describe the traffic movements – northbound, southbound, entering the tunnel, accessing downtown street grid, etc.

North Portal

- Current north portal design.
- Point out the Gates Foundation campus.
- Describe movements – connection to downtown grid, entrance to tunnel, ramps, etc.

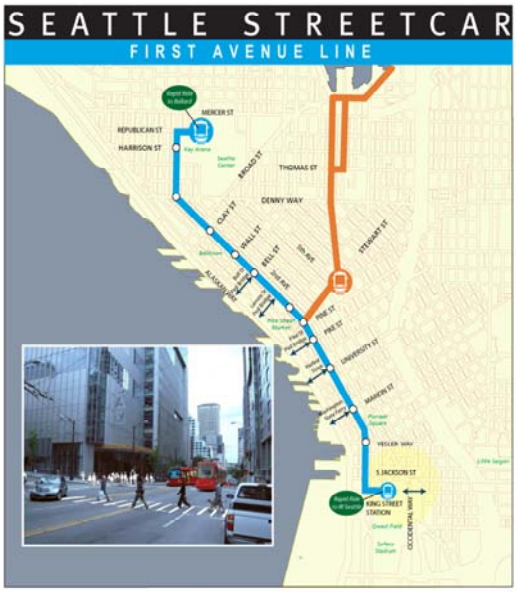
- The bored tunnel alternative is made up of more than just the bored tunnel.

- It includes a new Alaskan Way along the waterfront, as well as a pedestrian promenade. It also includes improvements to several city streets including Mercer and Spokane streets, and increased transit service.

Back Pocket

First Avenue Streetcar

- Connects to the First Hill Streetcar.
- Connects to Ballard and West Seattle RapidRide lines.
- Connects to Amtrak, Commuter Rail and Light Rail at King Street Station.
- Provides easy access to Colman Dock.
- Connects major activity centers: Seattle Center, Pike Place Market and the stadium area.



- Connects to the existing South Lake Union Streetcar and the Sound Transit-funded First Hill Streetcar.
- Connects to King County Metro's RapidRide bus rapid transit lines to Ballard and West Seattle.
- Connects to Amtrak, Commuter Rail and Light Rail at King Street Station.
- Easy access to Washington State Ferries.
- Connects major activity centers including Seattle Center, Pike Place Market and Seahawks/Mariners stadium area.
- Expected to carry 4 million riders per year, comparable to Portland Streetcar and San Francisco Embarcadero Line.
- $135 M, including 8-vehicle fleet capable of providing service every 6 minutes.

Transit Service Enhancements

Transit enhancements will provide important mobility during and after construction and are critical to the success of the bored tunnel solution.

- Enhanced service to accommodate demand
  - Additional bus service
  - First Ave. Streetcar
- Access to downtown
- Construction mitigation
- Environment

Transit is also critical to the success of this alternative.

Enhanced service to accommodate demand

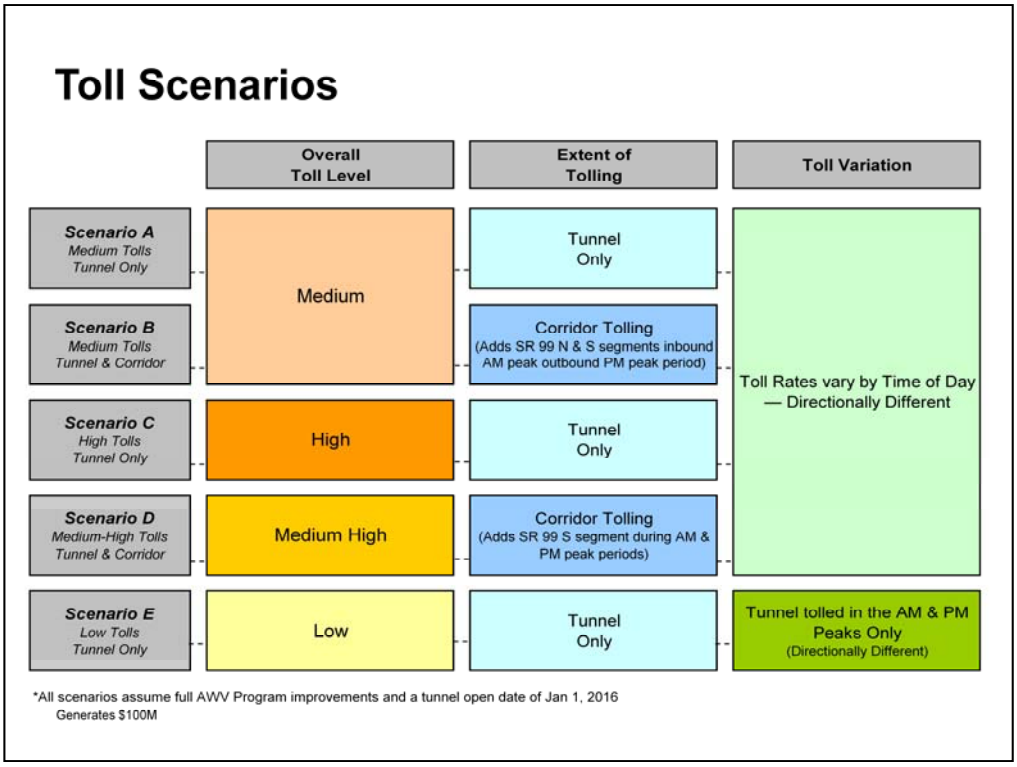
- Expanded transit will be needed to accommodate increases in travel demand that will come with the expected growth in the region. Buses are projected to provide between 34 and 39 percent of all morning peak period trips to downtown. Without improved transit, many of these trips will be taken by other means such as private vehicle. The increased transit service proposed is consistent with the city and region's growth policies.

Access to downtown

- The bored tunnel will provide a through route for traffic to bypass downtown Seattle. With this alternative, SR 99 will no longer have mid-town ramps at Seneca and Columbia or at Elliott and Western. The AWV transit package includes capital projects such as transit priority pathways to help transit provide fast, reliable service to and from downtown Seattle. These capital improvements along with expanded bus service are needed to provide the public with quick reliable options traveling to and from downtown.

Construction mitigation

- Transit is essential to keep people moving during construction. As part of the Moving Forward projects, King County Metro received $32 million for transit service to keep people moving during construction in particular the south end construction. The construction impacts of the central waterfront and the other elements such as the seawall are not determined at this time.



Paananen

•Five scenarios looked at various toll rates from low to high.

•We also analyzed tolling only the bored tunnel and potentially segments of SR 99 north and south of the tunnel.

- Segments were from the Aurora Bridge, south to the bored tunnel, and from Spokane Street, north to the bored tunnel.

•In addition to capital costs, this also covers maintenance and operations.

•*Note: The date in the footnote is Jan. 1, 2016 for revenue generation purposes. The tunnel would open to drivers in late 2015.*

Relocate Electrical Lines

- Relocated electrical lines to locations east of the viaduct between Massachusetts and Railroad Way.
- Installed two man-hole vaults between Atlantic and Royal Brougham.
- Installed conduit between Atlantic and Royal Brougham.

Construction: September 2008 – December 2009

Status: Complete

- As the city has grown up around the viaduct, so has the web of utility lines that weave around and under it. These lines need to be moved to better protect downtown's power supply in the event of an earthquake, and to prepare us for taking down the viaduct south of S. King Street.
- The project began in September 2008 and will take a little more than one year to complete.
- We do not anticipate any power outages for this work. The electrical systems are redundant. Even if one line must be shut down temporarily, it would not affect the city's power supply.
- Currently, ELR construction crews have work happening at all areas of the project site. The site runs between S. Massachusetts Street to the south and Railroad Way, S. to the north and between the viaduct to the west and to about a half a block east of the viaduct.
- Crews are currently trenching along Colorado Avenue S. between S. Massachusetts Street and S. Atlantic Street. Crews have built a temporary by-pass road for freight traffic which will be opened starting Monday, March 2. Colorado Avenue S. will be closed to through traffic, but drivers will still be able to access the Bemis Building parking lot. Southbound freight traffic must use the temporary bypass road and northbound freight traffic must use Utah Avenue S. Drivers will notice a series of traffic revisions on Colorado Avenue S. for the next three months and should pay close attention to the signed detour.
- In the staging area between S. Atlantic Street and S. Royal Brougham Way, crews are installing conduit and have also already installed two manhole vaults.
- Crews have relocated water lines and installed conduit under S. Royal Brougham Way and will repave that section of road this week.
- WSDOT suspended work between S. Royal Brougham Way and Railroad Way S., until further design is complete on the southern portal for the bored tunnel section of the central waterfront section of SR 99. However, crews have already shored and excavated for one vault and have removed abandoned railroad lines from the old WOSCA property.
- Additional work will be needed to relocate some of the remaining lines between Railroad Way S. and Union Street and others between Railroad Way South and electrical vaults on S. Washington Street and Yesler Way. The exact location, method and schedule for relocating these electrical lines will depend on the solution chosen for the viaduct's central waterfront section.

Separation Plant

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Earth Pressure Balance Machines

- Developed by Japanese in mid 1970's
- Needed to broaden the range of applicable ground conditions
- Much simpler than the Slurry Machine
- Face supported by conditioned excavated material
- Excavated material removed from the face with a screw conveyor and transported by train or conveyor.
- Has to some extent replaced the use of Slurry Machines

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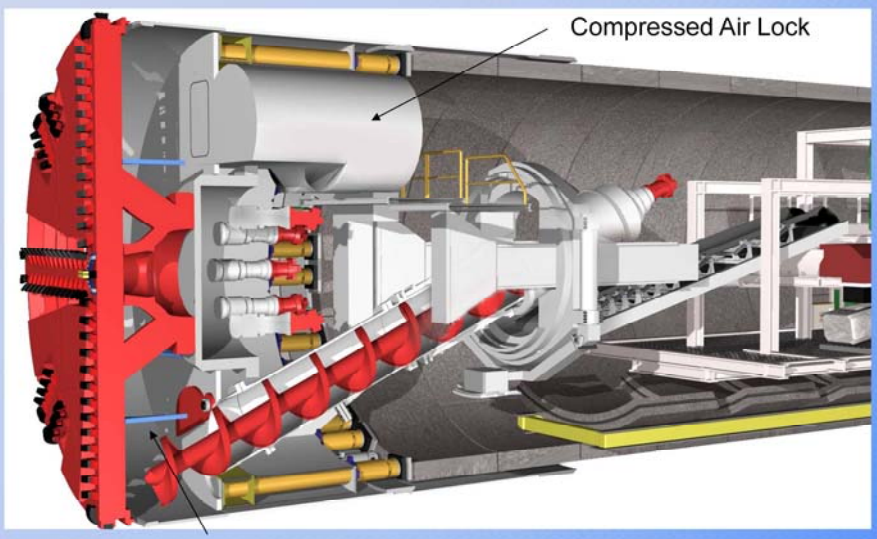
Access to Chamber and Cutter Head



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Installing the Gaskets

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Mechanical Segment Erector

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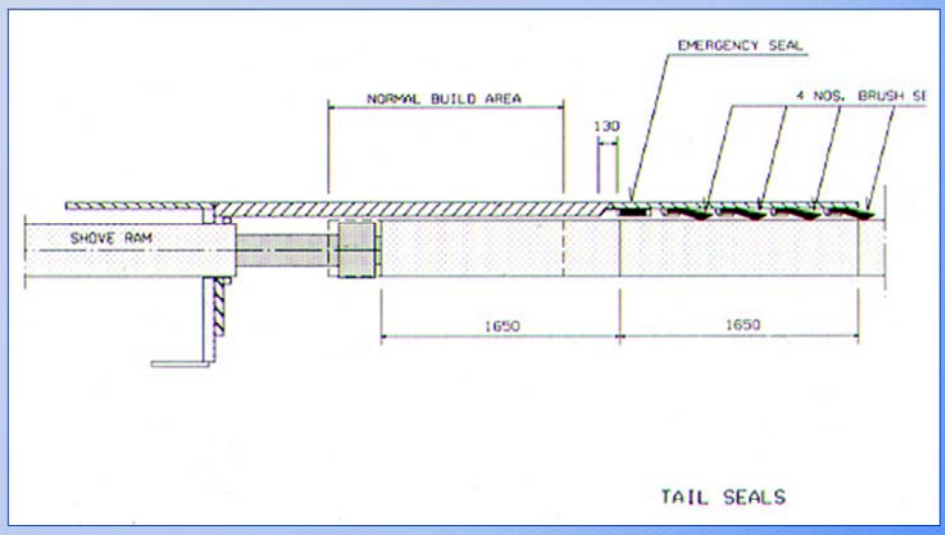
Vacuum Segment Erector

EPBM Tail Seal



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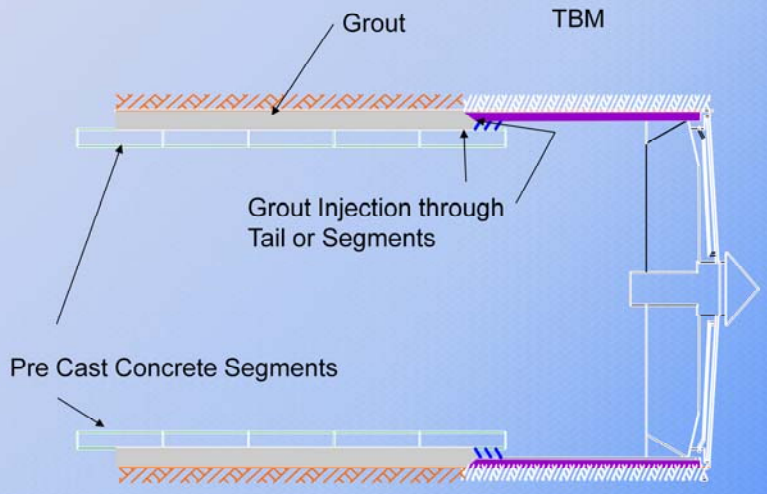
Tail Grouting



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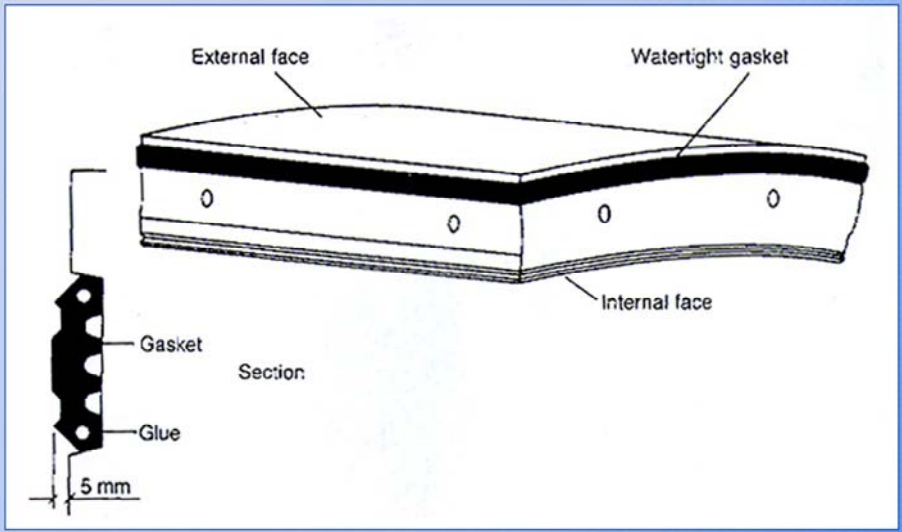
Precast Concrete Segment



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Volume Loss Magnitudes

- Historical Standards — Volume Loss, V_L
  - Good practice in firm ground — 0.5%
    - better soils and excellent ground control
  - Good practice in slow raveling ground — 1.5%
    - considered good ground
  - Fair practice — 2.5%
    - More face and tail loss
  - Poor practice — 4.0%
    - Yet more face loss
    - Tail void mostly unfilled

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Slurry Machines

- Slurry Machines were initiated by John Bartlett's patent of 1964
- Developed for use in soft ground
- Mainly used in granular materials below the water table
- Face supported by a mixture of excavated material and bentonite slurry
- Excavated material transported in a slurry pipeline
- Separation plant required

TBM - Key Components

- Cutter Head
  - Main Bearing
  - Head Access
- Muck Removal System
  - Screw conveyor to trains or conveyor
  - slurry line
- Push Rams
  - Sufficient to overcome:
    - Face pressure
    - Friction
- Tail Seals
  - Tail Grouting
- Tunnel lining
  - Erector system
  - Pre-cast concrete segments
  - Watertight Gaskets

Engineering Analyses

- Ground Characterization
- Volume Loss, V_L at tunnel depth
- Settlement Trough at surface
- Condition Assessments
- Effects on Structures