Considerations for Tunneling Water Pipelines through Rock Formations

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Overview

- Examples of water pipelines that will be discussed
- What is rock
- Tunnels in rock
- Tunneling methods
- Comparison of tunneling methods
- Other considerations
- How this applies to water tunnels
Example Water Pipelines

- Lake or river intakes
- Raw water transmission mains or water mains
- Sanitary sewers, CSOs
- Storm drains
- Generally ~16 – 96”, mostly 24 – 72”
  - Not large CSO tunnels, mega water tunnel projects
Example Tunnel Applications

- Tunnel can be the intake itself

- Tunnel for pipeline installation
  - Entire pipeline tunneled
  - Isolated segments tunneled – creek/river crossing, RR, highways, etc.
What is Rock?

- **Soft rock**
  - Highly weathered rock, saprolite, weakly cemented soil
  - Soil sampling equipment (RPSSS)
  - Earthwork tools - rippers
- **Hard rock**
  - Auger refusal, rock coring
  - Rock excavation methods
    - hoe rams, rock cutting tools
    - drill and blast
Tunnels in Rock

- Pipelines: ~24 – 72 inch => Relatively small tunnels
- Tunnel size in rock must consider constructability issues

- Tunneling methods:
  - Mechanical excavation
    - Roadheaders
    - TBM tunneling
      - Rock TBM, not microtunneling
    - Drill and blast
Rock Tunneling Methods – UCS strengths

UNCONFINED COMPRESSIVE STRENGTH (psi)

- CLAY SPADES
- IMPACT TOOLS
- SOFT GROUND TBM's
- DRILL & BLAST
- ROADHEADERS
- HARD ROCK TBM's
Tunneling methods – TBM Tunneling

Cutter discs

- Break rock in tension – “chipping”

TBM size

- TBM face large enough to fit cutter discs
  - 5.5”–19” range
  - 12”–17” more common
  - Larger discs more robust, last longer
  - Stronger rock => more discs, closer spacing
TBM size (continued)

- Normal force on cutters = TBM thrust
  - Stronger rock:
    - More thrust, more torque
      - Larger TBM
    - Increased wear on discs, bearings
      - Favors larger discs, larger TBM
- Maintenance - rear access to TBM face
  - 60-inch Dia. minimum
  - 72”–96” machines easier access
- Several considerations favor larger TBMs
  - Applies to rock microtunneling also
Additional considerations:

- **Starter and tail tunnels** –
  - Short tunnel to launch TBM
  - 50–100 feet
  - May need tail tunnel for trailing gear
- **Set up** = ~4 weeks on site
- **Feasible** < ~25,000–30,000 psi UCS for 8–10’ TBM
  - Larger TBM: 35,000–40,000 psi
  - Limited precedence in stronger rock
  - 8-ft water main in NoVA, diabase, > 50,000 psi: one TBM became trapped, v. low productivity

Tunneling methods – Roadheader

• Rotating cutterhead drums on extension boom
• Drums rotate
• Picks cut rock through grinding
• Size:
  - Tunnel must be big enough for equipment – drums, boom, etc.
  - Generally min 10-ft diameter (horseshoe shape)
Tunneling methods – Roadheader (continued)

- Considerations
- Relatively fast set-up (compared to TBM)
- Can be used for shafts (< ~ 8,000 psi)
- Can accommodate irregular tunnel shapes
- Can accommodate curves easily
  - Can start on a curve
  - No separate starter tunnel required
- Generally for rock < 10,000 psi
  - Stronger rock if fractured or if using larger, more powerful equipment (larger tunnels)
Tunneling methods – Drill & Blast

- Excavate rock by tension through blast forces
- Drill holes, load and shoot, muck, install supports
- Minimum size
  - large enough for man entry
  - 48”-60” minimum
Drill & Blast (continued)

• Drill methods influence productivity
  - Small tunnels – jack leg drills (by hand)
  - Larger tunnel (8-10 ft)
    • Can use drilling jumbo
    • More efficient drilling
    • Deeper rounds
    • More efficient excavation
  - Larger tunnel (8-10 ft) may be more cost effective than smaller tunnel
Drill & Blast (continued)

- Additional considerations
  - No starter tunnel
- Mobilization and set-up relatively quick
  - ~1 week or less
- Any strength rock
- Blasting may create additional concerns:
  - NoVA water main – blasting prohibited, proximity to fuel lines for Dulles Airport
  - Public Perception
Comparison of Roadheader, TBM and Drill & Blast

<table>
<thead>
<tr>
<th></th>
<th>TBM</th>
<th>Roadheader</th>
<th>Drill &amp; Blast</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Min: 60-inch</td>
<td>Min: ~10 ft</td>
<td>Min: 48-60 inch</td>
</tr>
<tr>
<td></td>
<td>More efficient: 8-10 ft</td>
<td>Larger for stronger rock</td>
<td>More efficient: 8-10 ft</td>
</tr>
<tr>
<td><strong>Rock UCS Strength</strong></td>
<td>Generally &lt; ~25-30,000 psi</td>
<td>Generally &lt; ~10-15,000 psi</td>
<td>All</td>
</tr>
<tr>
<td><strong>Set-up time</strong></td>
<td>~4 weeks (min)</td>
<td>1 week or less</td>
<td>1 week or less</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>~35-40 ft/day</td>
<td>~15-25 ft/day</td>
<td>~15-20 ft/day (w/ jumbo)</td>
</tr>
</tbody>
</table>

**Generally:**
- TBMs more cost effective for longer tunnels (3,000 – 5,000 ft)
- TBMs not *generally* used for short tunnels < ~500 - 1,000 feet.

Other considerations apply:
- Contractor’s crew and equipment availability
- Rock strengths
- Project location, access, restrictions
Other Considerations

- Shafts:
- Overburden requires SOE
- Excavate rock with Drill & Blast or Roadheader
  - Top of rock bench for SOE toe in (~2 - 5 ft)
- Construction/Access shaft:
  - Larger for excavation equipment
  - ~20-25 ft diameter min (in rock)
  - Bench, SOE thickness: Shaft = 25-35 ft min OD at surface.
- Recovery shaft smaller:
  - 10-12 ft ID in rock, 15-20 ft OD at surface
Other Considerations (continued)

- Shafts (continued):
  - Tunnel uphill for construction drainage
    - May dictate which is the construction shaft
  - Consider in shaft depth

- For pump station, raised bore shafts:
  - Requires ~8+ ft tunnel for connection
  - Pumps typically have casing
    - Need an oversized bore
    - Typically bore is >24” than casing
How does this apply to water tunnel projects?

- Generally impacts feasibility and cost estimates
- Examples feasibility studies
  - Reservoir intake shaft and tunnels
    - 48” intake tunnels in rock
    - Not realistic for either D&B or TBM
    - TBM costs – Not likely to use TBM
      - Tunnels too short
      - Too many set-ups
  - Pump station:
    - 36” dia pump shafts connect to 60” tunnel

Example feasibility study:
36” wells should have 60” (min) shafts
Connect to 96” tunnel
How does this apply to water tunnel projects?

Example creek crossing
- Modified by contractor
  - Deeper tunnel, slope to drain
  - Results in deeper shafts
How does this apply to water tunnel projects?

Case Histories

- **Little Patuxent Sewer, MD**
  - 42-inch FRP sewer
  - Rock UCS > 55,000 psi
  - 355-ft long
  - 8-ft Drill & Blast tunnel

- **Oregon Ave-Bingham Drive NW Sewer Rehab, DC**
  - 24-inch PVC sewer carrier pipe
  - 1866-ft tunneled drive
  - 60-inch machine used => access to cutter discs
How does this apply to water tunnel projects?

• Ensure shafts and tunnels are reasonable size
  - Diameter of tunnels
  - Diameter and depth of shafts

• Costs
  - Costs may not be reasonable if tunnel and shaft sizes are not correct
  - Especially important at feasibility studies and PE stage
• Sets the stage for the project design development, decisions, and budgeting
Thank you! Questions?