Probe Hole Drilling and Pre-Excavation Grouting

2017 TUNNELING SHORT COURSE
10th Annual Breakthroughs in Tunneling
Short Course
August, 14-16, 2017
Agenda

1) Chattahoochee Tunnel, Atlanta, GA
2) South River Tunnel, Atlanta, GA
3) Rondout West Branch Bypass Tunnel, Newburgh, NY
Probe Hole Drilling and Pre-Excavation Grouting

Probe Drilling:
Drill, maintain, and monitor probe holes in the shaft and tunnel excavations to detect the presence of groundwater inflows

Pre-Excavation Grouting:
Injection of cementitious Grout through holes drilled in advance of the excavation to control water inflows.
Chattahoochee, Atlanta

Grouting to reduce water inflows – Pre-excavation & post lining installation

- Approximately 50,000 LF tunnel, 18’-4” diameter (excavated)
- Hard Rock, Main beam TBM excavation w/ rock bolt support
- Metamorphic rock – Schist and Gneiss, 20-30ksi.
- Groundwater inflow into tunnel controlled by fracture flow in hard rock
- 75% of the tunnel was lined with CIP concrete to final diameter of 16’
Chattahoochee - PEG

Probe Drilling - Eleven tunnel sections – 300lf to 1600lf
2ea 2-1/4” Probeholes 60-100lf/ea
PEG Grout criteria – 0.2gpm/lf of probe
If grout=>Two additional holes
Chemgrout grout plant - Type 3 Cement
Verification hole drilled after initial set of grout
PEG - Total 230hrs (2wks)

Water inflows:
  • Post mining steady state water inflow 1,410gpm
Concrete Liner 37,500lf w/ contact grouting
  • Water inflow post concrete 875gpm
  • Requirement <200gpm
Chattahoochee – Secondary Grouting

- Secondary grouting based on face mapping – focused on water bearing fractures in the rock.
- Duration:
  - 10.5mths - 2x10hr shifts covering 33,000lf of lined tunnel
- Equipment:
  - 2 grout gantries w/ Chemgrout CG600 grout plants
- Grout:
  - Nittetsu SuperFine Cement
  - US Grout Type V Standard Grout
- Total
  - Cement total 1,250,000lbs
- Water inflows:
  - Post secondary grouting
  - 185gpm
South River Tunnel, Atlanta

Grouting to reduce water inflows – Pre-excavation & modified contact grouting post liner installation
- Approximately 8,640 LF tunnel, 16’-4” diameter (excavated)

- Hard Rock, Main-Beam TBM excavation w/ rock bolt support
- 100% of the tunnel was lined with CIP concrete to final diameter of 14’
- Surface grouting in advance of tunnel drive
South River Tunnel, Atlanta
South River – Probe & PEG

Probe Drilling – 2x100-140lf (typical) – 100% of drive w/ 20ft overlap
Prediction un-grouted (w/o PEG) 2500gpm — 1500gpm after grouting
Trigger 10gpm/hole – 0.1gpm/lf
PEG Equipment: Grout plant on rail – Moyno progressing cavity pumps
PEG Material: Type III Cement – 94lbs bags
South River Tunnel, Atlanta

Total 14 grouting events:
  • Mob/Setup 57hrs
  • Drill Time 196hrs
  • Total Grout time 217hrs
  • Demob 61Hrs
    Total 530Hrs (22days=1mth)

Total 5,847 bags = 550,000lbs

Post Mining Water inflow – 700gpm (incl. shaft)

TBM Tunnel Max 930gpm – sustained 610gpm
South River Tunnel, Atlanta

Modified Contact Grout through concrete liner:
6mth modified contact grouting – 1845holes – 384hrs grout injection
Dayshift only
Modified contact grout pumped from surface
6,175bags (94lbs bags)
Post Modified Contact Grouting:
Final <100gpm
Contract <50gpm
Chemical Grouting:
Final 17gpm (after chemical)
Rondout, Newburgh, New York

Project Overview

Phase 1

Shaft 5A
Shaft 5B
Shaft 6
Shaft 6B
Rondout-West Branch Tunnel
12,500LF
Geology

Tunnel Reaches

- Reach 1 - 2,560lf – Shale (Normanskill Formation)
- Reach 2 - 3,900lf – Limestone & Dolomite (Wappinger Formation)
- Reach 3 – 3,500lf – Limestone & Dolomite (Wappinger Formation)
- Reach 4 – 2,540lf – Shale (Mount Merino Formation)
• Groundwater Head
  • Ranges from 675 ft to 875 ft

• Max. Heading Inflows
  • Ungrouted
  • TBM: 250 – 1300 gpm

• Solution Cavities
  • 3 – 30 lf, 5 – 30 Cy of flowing material
  • Reach 2: 3ea
  • Reach 3: 6ea

<table>
<thead>
<tr>
<th></th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaches 1 and 4</td>
<td>34,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Reaches 2 and 3</td>
<td>54,000</td>
<td>35,000</td>
</tr>
</tbody>
</table>
D&S PROBEHOLES

Section 31 71 17 – Excavation by Drill and Blast
3.07.A. Drill, maintain, and monitor probe holes in the shaft and tunnel excavations to detect the presence of groundwater inflows in accordance with Section 31 73 14

Section 31 73 14 – Shaft and Tunnel Grouting
Prior to probe or grout hole drilling, install standpipe/drill through packer
Probe and grout holes that do not stay open through the above techniques shall be downstaged to stabilize and advance the holes.
Shale Units: Min. 2 probeholes
Shale Units within 200’ of RWBT: Min. 4 probeholes
Wappinginger: Min. 4 probeholes
TBM Probeholes

Section 31 71 19 TBM Excavation
Probe holes overlapped minimum of 20 feet.
Probe holes outside the tunnel perimeter shall be backfilled with grout.
Probe holes shall be monitored and recorded by the Contractor:
  o 1. Hole ID;
  o 2. Start/end time for each drill rod;
  o 3. Water inflows encountered by hold depth;
  o 4. Rod drop or rapid advancement due to voids or open apertures;
  o 5. Bound or stuck drill steel and depth of occurrence;
  o 6. Plugged steel;
  o 7. Collapsing hole;
  o 8. Flowing ground.
31 73 14 Shaft & Tunnel Grouting

- Shale Units: 0.3gpm/ft or 30 gpm/feature
- Shale Units within 200’ of RWBT: 0.2gpm/ft or 20 gpm/feature
- Wappinger Group: 0.3gpm/ft or 30 gpm/feature
- PEG – Materials: Type III Cement, Ultrafine Cement
- Double-acting piston pump: Max pressure capacity of 1,000 psi with maximum pumping capacity of 400 cubic feet per hour (50 gpm) at a pressure of 350 psi.
- Two (2) pumps and plants available to treat two (2) holes simultaneously.
- Refusal: less than 0.5 cubic foot of Grout injected over a two (2) minute period at the specified maximum injection pressure and Grout consistency.
- Max. 30,000#/100ft length of grouthole
- 6hr grout cure before advancing excavation
Drill & Blast – Grout Hole Layout

24 ea GROUT HOLES

NOTE: LOOKOUT TO BE 7.5 deg
HOLE DEPTH TO BE 72 - 75 VERTICAL FEET

Shaft Layouts
Drill & Blast – Grout Hole Layout

TAIL TUNNEL

GANTRY CHAMBER
TBM PEG Port Openings

- Two drills capable of drilling through CHD
- Single Drill for shield ports

**Forward Drills**
- Two independent drill systems
- Drilling through 16 drilling positions through cutter head

**Aft Drill**
- Drill mounted to segment erector
- Storage position on erector during boring
- Drill through 14 positions in forward shield
TBM Cutter Head
Drill Positions

- Drilling positions
- Two cutter head positions allow drilling through all 16 cutter head drill ports
TBM PEG – Hole Layout
Drill & Shoot Grout Equipment

- Triplex Pump
  - Gear 1 = 725psi @ 52 gpm
  - Gear 2 = 942psi @ 39 gpm
  - Gear 3 = 1450psi @ 26 gpm
Packer, Flow Meter
TBM Drilling Positions
TBM Drilling Equipment

W50 & W70 DTH Hammers
TBM PEG Equipment

- Hany Agitator HRW1200
- Hany Mixer HCM 610
- Hany Grout Pump ZMP 726V

**Hany Agitator HRW1200**
- Usable content: 1 m³
- Electric motor 50 Hz: 1.5 kW
- Electric motor 60 Hz: 1.8 kW
- Speed 50 Hz: 20 mm/min
- Speed 60 Hz: 31 mm/min

**Hany Mixer HCM 610**
- High Shear Colloidal Mixer
- Mixing Pump: TMP 22
- Production approx. (W/C = 1): 6 m³/h
- Circulation capacity: 1400 l/min
- Usable content: 1.55 m³
- Max. particle size: 8 mm
- Electric motor 50 Hz: 9 kW
- Electric motor 60 Hz: 11 kW

**Hany Grout Pump ZMP 726V**

**Specifications Table**

<table>
<thead>
<tr>
<th>Grout pump</th>
<th>ZMP</th>
<th>726V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plunger Ø</td>
<td>mm</td>
<td>85</td>
</tr>
<tr>
<td>Capacity max. (W/C = 1)</td>
<td>m³/h</td>
<td>6.5</td>
</tr>
<tr>
<td>Pressure, max.</td>
<td>bar</td>
<td>100</td>
</tr>
<tr>
<td>Pressure, min.</td>
<td>bar</td>
<td>8</td>
</tr>
<tr>
<td>Max. particle size</td>
<td>mm</td>
<td>8</td>
</tr>
<tr>
<td>Electric motor 50 Hz</td>
<td>kW</td>
<td>30</td>
</tr>
<tr>
<td>Electric motor 60 Hz</td>
<td>kW</td>
<td>36</td>
</tr>
</tbody>
</table>
Pre-Excavation Grouting

Trigger 0.3gpm/ft-probe, 30gpm/feature
Less than 200ft from RWBT - Trigger 0.2gpm/ft-probe, 20gpm/feature
Drilling & Grouting thru Stand Pipe/Collar pipe
Down-stage grouting at high flows
Max. injection pressure 1.5psi/vf of cover (Pump max. 1,000 psi), Min. 50psi above hydrostatic
Grout Mixes

Portland Type III Cement
Microfine Cement
Ultrafine Cement
Admixture—Rheobuild 1000
Sodium Silicate

Figure 5.8 Grain size distribution of various ultrafine cements.
Rondout D&B Pre-excavation Grouting Status August 2017

- Shaft 5B D&B excavation 95% complete
- Total of 8 holes grouted
- All holes injected located in Tail Tunnel
- Max. take 17,000lbs in one hole
- Total Cement Type III  56,000 lbs
- Total Ultrafine 4,400 lbs
Project Status

Starter and Tail Tunnel
Excavation complete August
TBM Assembly underground start September
Questions?

2017 TUNNELING SHORT COURSE
10th Annual Breakthroughs in Tunneling Short Course
August, 14-16, 2017