ASCE-NH SECTION LUNCH & LEARN

A TUNNELLED SOLUTION FOR THE CEMETERY BROOK DRAIN TUNNEL PROJECT
Manchester, NH

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Tunnels

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Agenda

- Tunnels for Stormwater Conveyance & Flood Control
- Overview of Tunneling
- Cemetery Brook Drain Tunnel Project
Tunnels for Stormwater Conveyance & Flood Control
Tunnels

- Underground horizontal excavation
- Excavated from a shaft, trench or portal
- Size (< 1 foot to 65 feet diameter)
- Water conveyance, mines, transportation, transit, utilities, and pedestrian
Why Tunnels

- Store & convey large volumes of stormwater
- Reduced construction related impacts
- Minimize real estate acquisitions
- Long-term and sustainable asset
Large Tunnel Projects

- Conceptual Planning
- Land Acquisition
- Program Controls and Reporting
- Permitting
- Engineering
- Initial technical investigations
- Delivery method analysis and selection
- Construction Procurement

- Project Administration
- Flexibility in reacting to external impacts
- Quality Control/Quality Assurance
- Commissioning and Closeout
- Secure financing and manage budget
- Interagency Coordination
- Construction Management and Support
Overview of Tunneling
Bored Tunnels

- Soft Ground
- Mixed Face
- Fractured Rock
- Competent Rock
Bored Tunnels

**Hard Rock TBM**

- Low permeability and good quality hard rock
- Relatively inexpensive
- Very efficient construction
- Cast-in-place lining
- Limited flexibility
Bored Tunnels

Soft Ground TBM

- Earth Pressure Balance (EPB):
  - Mixes excavated soil, foaming agents, water and polymers in the working chamber behind cutter head. The muck pressure is controlled by the pressure wall.
  - Screw conveyor takes the mud out of the machine as the machine moves forward.

- Slurry Shield (SS):
  - The cutter head is balanced by bentonite slurry.
  - Screw conveyor is replaced by two pipes circulating the slurry in and out of the working chamber.
Bored Tunnels

- Series of trailing gear modules
- 300 ft to 400 ft behind the shield
Bored Tunnels

- Sequence
  - Excavate launching/receiving shafts
  - Assemble and Launch TBM in launching shaft
  - Excavate tunnel / erect lining
  - Retrieve TBM from receiving shaft
  - Repurpose or backfill shafts
- Limits on alignment curvatures
- Cost effective for tunnels longer than 1 mile
- Fast construction
- Limited flexibility
**Mined Tunnels**

- Often Used in combination with Bored Tunnels (adits and connections)
- Very flexible
- Cost effective for tunnel shorter than 1 mile
- Multiple headings to increase productivity
- Each heading requires a full crew
- Fast mobilization
Subsurface Investigation

- Phased Investigations Often Work the Best

- Project focused exploration/testing Program
  - **Phase 1: Conceptual Stage**
    - Desk study plus project specific field and lab investigation
    - Alignment and profile; Shaft locations
    - Method of construction
    - Geophysical Methods
    - Typical boring spacing 500 ft – 1000 ft

  - **Phase 2: Preliminary Design**
    - Boring spacing 100 ft – 300 ft
    - Ensure adequate coverage at shaft locations
    - Develop a more refined subsurface profile
    - Design development and manage project geotechnical risks

  - **Phase 3: Final Design**
    - Conducts select additional investigations
    - Prepare documents that convey the tunneling conditions fairly to all knowledgeable bidders (fill in the data gaps)
Contracting for Underground Construction

**Geotechnical Data Report (GDR)**
- Presents all subsurface data
- Just the facts

**Geotechnical Baseline Report (GBR)**
- “Levels the playing field” for bids
- Interpretation of the conditions
- Baseline for change condition claims

**Differing Site Conditions (DSC)**
- Clause needs to be added to contract documents.
Tunnel Lining

- Purpose
- Initial / Final
- One-Pass / Two-Pass
- Dependent on tunneling method and tunnel use
Tunnel Lining

Precast Segmental

Load considerations
- Ground
- Groundwater
- Seismic
- Interior
- Installation
  - Jacking
  - Grouting
  - Deformation
- Stacking and handling
- Transportation
Tunnel Lining

- Structural design requirements
  - Project specific
    - ACI
    - AASHTO
    - AREMA
    - Waterproofing
    - Other
Tunnel Lining

- Reinforcement
  - Unreinforced
  - Deformed bar/wire mesh
  - Fiber Reinforced
Working Shafts & Drop Shafts
Working Shafts
Vortex Drop Shaft

- Anacostia River Tunnel Project
  - Launch shaft
  - Final large-scale vortex drop shaft
Baffle Drop Shaft

- Stormwater cascades down baffle
- Into deaeration chamber / Adit
- Feeds into the main tunnel
CEMETERY BROOK DRAIN TUNNEL PROJECT

Alternative evaluation • Preliminary engineering
Open-cut • Tunnel • Trenchless technologies
12,000-ft • 12-ft ID
Soft ground • Mixed face • Rock
Environmental assessment • Permitting • Traffic management
Hydraulics engineering • Ground investigation • Community outreach
Structural engineering • Traffic management
Cemetery Brook Drain Tunnel Discussion

- Program Background & Importance
- Alternatives
- Design and Construction Considerations
- Hydraulic Modelling
- Project Status
Program Background & Importance
Program Background & Importance

- City of Manchester committed to solving CSO Issues
- 1995 LTCP agreement US EPA/NHDES/City
- Phase I Combined Sewer Overflow (CSO) Abatement Program
- 2010 LTCP updated
- Phase II Combined Sewer Overflow (CSO) Program
Program Background & Importance

- Wastewater Treatment Plan improvements
- System optimization
- Brook removal
- Sewer separation
Location

- Manchester, NH
- ~115,000 population
- Proximity to Boston, MA
Program Components
Project Goals and Objectives

- Brook removal
- Sewer separation
- System capacity
- Street flooding
- CSO discharge
Alternatives
Open Cut Alternative Alignment
Alignment – Queen City Avenue
Alignment – Rail Trail Corridor
Alignment – Massabesic Avenue & Elliot Hospital
Tunnel Alternative
Tunnel Alignment
TBM Launching and Main Construction Staging Area
TBM Receiving Area
Outfall Structures / Existing EIN / CSX Crossing
Drop Shaft 6 / Existing Storm Drain Intercept
Cemetery Brook Inlet
Construction Sequencing

SEQUENCE STAGE 1
1. Install support of excavation
2. Excavate soil to expose rock

SEQUENCE STAGE 2
1. Drill and blast shaft for vortex drop shaft and vortex approach structure
2. Install initial lining

SEQUENCE STAGE 3
1. Excavate diversion chamber and install intake screen
2. Install stoplog at intake and map initial lining

SEQUENCE STAGE 4
1. Install Buchanan block at the end of excavated area to allow flow to mine through
2. Raise bore or blind drill vent shaft

SEQUENCE STAGE 5
1. Install final lining in shafts and drainage chamber
2. Mount spherical annular space in shafts

SEQUENCE STAGE 6
1. Construct tunnel
2. Mine through Buchanan block

SEQUENCE STAGE 7
1. Internally mine tunnel lining
2. Permanently remove service
3. Test shaft
4. Install or concrete lining at Buchanan block and lift
Ground Investigation Program (GIP) Overview

- **Field Activities**
  - Soil Boring
  - Rock Coring
  - Packer Tests
  - Geophysical Survey
    - ATV/OTV Televiever Logging
    - Seismic Refraction

- **Laboratory Testing**
  - Soil
    - Index Testing
  - Rock
    - Uniaxial Compressive Strength
    - Tensile Strength
    - Point Load
    - CERCHAR
    - Drillability Index
    - Petrographic Analysis
Geotechnical Investigation (GIP) Program Overview

- Seismic refraction preceded borings
- 88 borings
  - 50/80-ft deep
  - 24 Monitoring Wells
  - Packer tests
- Geophysical Survey
  - 11000-ft
- GIP Phase 2
GIP Findings

- Subsurface strata
  - Fill
  - Glaciofluvial deposits
  - Glaciolacustrine deposits
  - Glacial till
  - Bedrock

- Groundwater varies – 6 ft to 20+ ft bgs

- Bedrock: 10-ft to 110 ft bgs
Laboratory Test Results - Rock

- **Tensile Strength**
  - 524 psi → 1,836 psi

- **UCS/Elastic Modulus**
  - UCS: 1,000 psi → 32,000 psi; Average 13.6 ksi
  - EM: 1,485 ksi → 9,687 ksi

- **CERCHAR (Abrasiveness)**
  - Very → Extreme

- **Point Load Test (Correlated UCS)**
  - 2,900 ksi → 23,300 ksi
Rock Quality

- High Rock Quality Designation (RQD)
- Low number of Joints & discontinuities
- Low permeability
- High strength
- Extremely abrasive
GIP Phase 1 Environmental Testing – Group 1
Tunnel Profile
Tunnel Profile
Machine Type

- Grain size distribution
- Pressurized face
- Soft ground / rock
- Segmental lining
Hydraulic Physical Model
Hydraulic Physical Scaled Model

- Evaluate design elements
  - Air movement
  - Venting
  - Connection criteria
- Two types of drop shafts
  - In-line drop shaft
  - Off-line drop shaft
- Outfall structures
  - Transition
  - Energy dissipation/Apron
Tunnel and Outfall Structures
Project Status
CEMETERY BROOK DRAIN TUNNEL PROJECT

Preliminary/Final engineering
12,000-ft ● 12-ft ID ● Segmentally lined tunnel
Design through Q2 2024
Bid late Q3 2024 (tentative)