Tunnels, Tiebacks, and Piles: A Design Case History of Dealing with Obstructions

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Presentation Outline

- Introduction & Background
- Geotechnical Conditions Along the Alignment
- Discovery of Potential TBM Tunnel Conflicts
- Mitigation Options & Precedence
- Final Solution
- Summary & Conclusions
Introduction & Background
Baltimore Red Line Project

Project Owner

MTA
Maryland

Program Management Consultant (PMC)
Joint Venture

Jacobs
Gannett Fleming
STV

General Engineering Consultant (GEC)
(Designer)
Joint Venture

Parsons Brinckerhoff
RK&K
AECOM
Baltimore Red Line Alignment

- New ~14-mile LRT line through Baltimore City & County

- 3.4 Mile Downtown Tunnel
  - ~22 ft OD TBM Tunnels
  - 5 underground stations & pedestrian tunnel
    - Cut & cover using slurry walls for temp & permanent support
    - Proposed Inner Harbor Station connects to existing Charles Center Metro Station
Inner Harbor Station, Connector, & Charles Center

- Existing Charles Center Metro Station
- Proposed Light Street Pedestrian Connector Tunnel
- Proposed Inner Harbor Station

Charles Center = 2 levels
To meet ADA design grades, IHS = 2 level
Geotechnical Conditions

- Fill
- Post Cretaceous Sediments
  - includes soft organics
- Cretaceous Sediments
- Residual Soil & Transition Group
- Rock – amphibolite & gneiss
- Groundwater depth: 5 – 15 ft
At Inner Harbor Station:
- Rock depth = 65-85 ft
- Two level station = above rock
- Three level station requires:
  - Excavation in rock & rock support
  - Slurry wall toe in
  - Tiebacks & rock supports
  - Blasting
Discovery of Potential TBM Obstructions

- **Central Business District**
  - High rise buildings, basement garages

- **Research for:**
  - Assessment of Construction Impacts
  - Case histories of similar work

- **Available information:**
  - Record building plans
  - Available shop drawings
  - Published case histories

- **Potential Obstructions**
  - East & west station approaches
  - TransAmerica Building
  - Gallery at HarborPlace
3 level basement garage

External SOE (Schnabel Fndn Co. 1970):
- Driven soldier piles & lagging
  - Outside building line, in City ROW
  - 38 piles within Lombard Street
- Soil tiebacks
- No as-builts

Possible conflicts:
- Soldier piles: ~ 4 ft from EB TBM
- Considering possible deviations
  - Piles ~1.8 - 4 ft from TBM
  - Anchors 6- 10 feet from TBM
4 level basement garage

Discovered by researching slurry wall precedence

Published Paper (Gifford & Wheeler, 1992):

- Slurry walls for temp & permanent support
- Temporary soil tiebacks
  - Multi-strand anchors
  - “Lost point” installation method

No additional info

- No SOE drawings, tieback records
- Contacted companies for SOE, no records
- Only record was conceptual figures in paper

Possible conflicts:

- Multiple rows of anchors within EB TBM
Additional Investigations

- **Site visits**
  - TransAmerica – no access to verify SOE
  - Gallery – tieback ports visible behind architectural walls
    - Survey of tieback ports
Mapping of Tiebacks
- Independent calcs to estimate lengths, variability
- Overlay on alignment profile

Results:
- 122 anchors within EB TBM path
- Spacing as close as 2.5 feet along bottom row

Longitudinal Profile of EB TBM tunnel
Mitigation Options & Precedence

- **Issue:**
  - 122+ Anchors w/in TBM tunnel east of IHS
    - Cannot mine through
    - Focus of mitigation options
  - Also soldier piles with ~2 – 4 feet of tunnel west of IHS

- **Investigation options for anchor removal**
  - Evaluate all possible options
  - Investigate feasibility
  - Successful precedence is a must
Mitigation Option 1

- Remove anchors from within tunnel heading during mining
  - Precedence: Seattle Bus Tunnels (Critchfield & MacDonald, RETC 1989)
    - 450 anchors from within tunnel heading
  - Comparison with BRL:
    - Seattle = open face tunnel shield
    - BRL = closed face TBM
      - High groundwater, compressible soils
      - Compressed air interventions
  - Baltimore Precedence:
    - Metro section C (two blocks north)
      - Tunnel shield w/ compressed air & limited dewatering (~10-15 ft)
      - Dewatering settlements, face instability, contaminants
Mitigation Option 2

- Remove anchors from within Gallery basement ahead of TBM mining
  - Drill around/adjacent to each anchor and remove it
- Tiebacks for underground garage removed ahead of transit tunnel
- Recovery of anchors using compressed air open face pipe jacked tunnel
Mitigation Option 2

- Remove anchors from within Gallery basement ahead of TBM mining

Comparison with BRL:
- Leipzig, Germany:
  - Building owner’s responsibility, transit planned ahead of building
  - 5 anchors removed
- BRL:
  - >100 anchors
  - Logistics:
    - Anchor spacing – as close as 2.5 ft
    - Garage floors, limited headroom for some ports
    - Recovery of “lost points”? 
    - Take garage out of service
    - Removal of architectural wall
    - Impact integrity of slurry wall? (48” pipe jack)
Mitigation Option 3

- Remove anchors using surface based excavations
- Option 3A: Remove anchors with bored piles & slurry wall equipment
- Leipzig, Germany:
  - Careful inspection of each bucket
    - How many strands, elevation?
    - Map out tiebacks to verify full recovery
  - Removed 15 anchors total
- Comparison with BRL:
  - 122 anchors within tunnel
  - Additional anchors above, total 180 anchors
  - Difficult to verify full recovery
Mitigation Option 3

- Option 3B: Remove anchors w/ cut-and-cover section
- Install Support of Excavation (SOE)
- Excavate and internally brace
- lowest anchor level = 60 feet deep
  - High confidence of full removal
  - High groundwater, compressible soils
  - Requires impervious SOE – secant piles or slurry walls
- Precedence – LA Regional Connector (Hansmire & Roy, 2014, NAT)
  - Ground Conditions differ
  - Piles & lagging, dewatering feasible
    - Work around piles to cut out anchors
Mitigation Option 3B

- Considerations for BRL:
  - Additional cut-and-cover excavation close to IHS & Connector
    - Length ~330 ft (more than station)
    - MOT issues, disruption to CBD
  - Feasibility of secants/slurry walls through 180 anchors?
    - Delays will impact TBM schedule
  - LA Connector not built as of BRL design
    - Successful precedence not clear
Mitigation Option 4

- Remove anchors using SEM ahead of TBM mining
  - Construct an SEM “starter tunnel” to remove anchors
  - Backfill, mine with TBM
  - High confidence of anchor removal
  - SEM Mine from Inner Harbor Station
Mitigation Option 4

- **Precedence:** “Alternative Tunnel Design with SEM for Seoul Metro Lot 703”. (2009, June 24)
  - TBM tunnels changed to SEM
  - Reportedly successful, but no details

- **Considerations for BRL:**
  - 330 ft SEM tunnel,
  - 130 ft starter tunnel from IHS
  - Ground improvement or freezing from Lombard St
    - Significant surface disruption
  - Uncertainty with respect to precedence

- **Diagram:**
  - Ground Improvement or Freezing needed’
Design Mitigation Options

- **Options 1 – 4:**
  - Overall feasibility / viability not certain, conditions not as severe as BRL
  - None address potential for soldier piles on west side of IHS

- **Design Change Options:**
  - Horizontal alignment - Cannot shift far enough, cannot change streets
  - Vertical alignment
    - Cannot “drop” alignment enough to miss tiebacks
    - **Change IHS Station to 3 levels, lower entire alignment**
Design Mitigation Options

- Change IHS Station to 3 levels, lower entire alignment
  - Precedence: Central Subway, SF
    - Lowered alignment to avoid tiebacks for Moscone Convention Center
  - Lowers alignment on west and east approaches
  - Station invert lowered 20 feet
  - Ped. Tunnel Connection to be reconfigured, maintain ADA grades
  - Station will require rock excavation (added $)
  - Increases amount of mixed face excavation for TBM tunnels
  - Avoids all anchors & piles
Final Solution

- Discussed mitigation options with MTA
  - Best to avoid additional disruptions to public
  - Avoid potential for TBM breakdown
    - Section C Metro shut down
    - Other high profile TBM breakdowns

- Lower Inner Harbor Station to 3 levels
  - No change to overall design schedule
    - Do not delay project
    - Approaching 65% design
    - Accelerate design of IHS to “catch-up”
    - Performed add’l review of alignment for obstructions
      - Develop conceptual tieback SOE schemes for bldgs with basements
  - No additional conflicts identified
Two locations of potential obstructions were identified
- Both could significantly impact the TBM operations

Multiple options & precedents considered
- Precedence for many options, however
- Ground conditions, depths, means & methods are not comparable to BRL
- Best option was to lower the alignment

Lessons learned:
- Review all possible record sources
- Perform outreach to parties for adjacent or similar projects
  - Info regarding obstructions included shop dwgs & published paper
  - Info regarding precedence from published papers & personal communication
Thank you!

Questions?