Grout Use in Optimized Engineering Applications

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Large Problems could have simple Solutions using Knowledge, some Innovation and the Courage to think outside of the box.
Introduction

• Details of Construction Constraint
• Showcase Solution
Outline

• Project Background
• Execution Problems
• ACTS Proposed Solution
• Challenges of the Solution
• Execution of the Solution
• Lessons Learned
Project Background

- Two almost concentric buried pipes
- Micro Tunnel ID = 2.4m
- Cooling System pipe OD=1.2m
- Around 100m long between two shafts
- Shaft depth 15m from ground surface
- Filling the Annulus with Sand
Execution Problems

• Not possible to fill directly with sand:
  • No confinement from both ends
  • Difficult access to the central zone
  • Not possible to densify the sand due to access issues

• Initial proposed solution: use of sand as filling material

• Solution rejected by owner (possible main pipe damage & random density distribution)
ACTS Proposed Solution

• By filling the Annulus with a specially designed grout/mortar mix that will flow under gravity along the pipe length, without the need of special equipment:
  • The solution should be practical
  • Executable
  • Safe to personnel during execution
  • Does not damage the inner pipe
  • Serves the purpose/Filling to top
  • Cost effective
Challenges of the Solution

- Grout/mortar mix with high flowability (close to water)
- Maintain the flowability for the full duration of the shift
- Grout/mortar has to travel 100m filling evenly the full length
- Filling the whole space to the top
- Completing each lift in maximum 10 hours
- Have a strength that exceeds 25MPa
- No pumping, avoiding damage of the inner pipe
- Site conditions and safety
Execution of the Solution

- Practical
  - The solution comprised only the installation of a PVC pipe system and a reliable grout/mortar mix design
  - Pouring tanks at the top of the shafts
  - Vertical pipes 4 inch ID, with connections that can take the gravity pressure of a 15m high grout column
  - 80m long sacrificial pipes perforated at 15m interval, installed at five to six grout lifts, to distribute the mix
  - No need for personnel to go inside the annulus space
Execution of the Solution

• Executable
  • Grout/mortar mix design
  • Mock up trial
  • Site inspection
  • Risk assessment
Execution of the Solution

• Grout/mortar Mix Design
  • Sand (two gradations)
  • OPC
  • PFA
  • M/Silica
  • Optima 262 & Delvocrete
  • Water
Execution of the Solution

• Mock up
  • 70m long 4in PVC
  • 1m head
Execution of the Solution

• Site Inspection and Risk Assessment
  • The tanks were placed on top of the shaft, gravity advantage
  • Tanks equipped with filters to avoid random gravel entering the network system
  • Three networks were installed from both ends of the tunnels
Execution of the Solution

• Safe
  • Confined space third party training for the full working team
  • Entry inside the tunnel was forbidden at all times and especially while pouring and for at least 12 hours after
  • Working in night shift only to avoid heat stress (work was during summer)
  • Ventilation fans at all times while working at the tunnel ends
  • Special PPE: harness, headlights, etc...
  • Certified man-lift for network installation
Execution of the Solution

• Does not damage the inner pipe
  • PVC pipe installation had no contact with the main pipe
  • The grout/mortar mix is made of fine material (no gravel)
  • The poured layers were limited to 30cm, avoiding buoyancy
Execution of the Solution

- Serves the Purpose Cost Effectively
  - Was the cheapest safe solution
Execution of the Solution

• Fills the Void to the Top
  • Fluid mix (containing sand)
  • Long setting time, allowing homogeneous lifts
  • Successive lifts done after complete hardening of the first one
  • Sloped delivery pipes avoiding reverse circulation
  • Regular openings along the grout pipes for horizontal distribution
  • Shutters built gradually with each lift
  • The grout/mortar mix delivered by a batching plant, allowing a consistent delivery and non stop supply
Solution “Layout”
Solution “Layout”
Execution of the Solution
Execution of the Solution

• Summary
  • Equipment used:
    • Storage tanks for collection of grout/mortar from ready mix trucks
    • Filter within the tanks to capture any incidental gravel
    • 4in PVC pipes
    • Water pump for flushing clean the system on daily basis
    • Hand tools and power tools for the installation
  • Consumed around 350 cubic meter of mortar per pipe
  • The site team comprised only 4 technicians/labors and one engineer
  • Each pipe was completed in six working days
Lessons Learned

- Need for filter preventing gravel from entering the system
- Flexible pipes are needed at the corners of the main distribution line rather than a 90 degrees corners
- The tunnel was apparently horizontal, while it had 0.5% inclination
- The quantity of grout to order each time was challenging