Tunnel Segment Backfilling with Double Shield TBMs
• Factors Determining Backfilling Annulus Gap
• Pea Gravel Backfill
• Pea Gravel Grout Injection
• Combination Pea Gravel & Mortar Backfill
Factors Determining Backfilling Annulus Gap
General Aspects about Annulus Gap & Backfill

- Ring build clearance
- Tail shield thickness
- Overcut for TBM steering and cutter wear allowance
- “Tapered” or “non-tapered” shield body construction
- Pea gravel injection through segments most common
Open Type Tail Shield
Annulus Gap, Annulus Volume

- Overcut for TBM Steering & Cutter Wear Allowance (Rock Tunnels)
- Tail Shield Thickness
- Segment Build Clearance Inside Tail Shield
Pea Gravel Backfill
Pea Gravel Backfill General Aspects

- Often used for PCC segments in rock tunnels
- Applied at full tail shield and open tail shield
- Open tail shield with pea gravel injection through segments is common method in rock tunneling
- Grout injection of pea gravel is often added

PCC = Pre Cast Concrete
Pea Gravel Backfill w/Open Type Tail Shield

- Invert segment placed on bored tunnel
- “Feet” on invert segment provides ring stability during ring build
- No tail shield brushes required; tail shield can be thinner
- No tail shield grease required
- Pea gravel backfill is simple and well proven
Pea Gravel Backfill w/ Open Type Tail Shield

- Segments with invert “feet”
- The feet allow the segment ring to be built directly on the rock tunnel invert
- The feet provide four point stability
Pea Gravel Grout Injection
Pea Gravel Backfill Injection via Segments

Rings Not Completely Backfilled

Pea Gravel Fill Via Hole...

No Tail Brushes

45° Angle of Repose
Pea Gravel Backfill Injection via Segments

Detail – hole for backfill injection pointed rearwards - no threaded insert

Detail – hole for erector pickup.
Pea Gravel Backfill Injection via Segments

Self-clamping injection nozzle. No threaded insert required.
Pea Gravel Backfill Injection via Segments

Insert must be minimum Ø70mm clear to prevent clogging
Pea Gravel Backfill Injection via Segments

Segment backfill via segment at crown
Pea Gravel Backfill Injection via Segments

Segment backfill via segment at invert area
Pea Gravel Backfill Technical Method

- Pea gravel is delivered into the annulus by means of dry type rotary shotcrete pumps (“blowing”)
- Shotcrete pump should be placed as far forward as possible to minimize hose length
- Insert opening Ø70mm clear to prevent clogging
- Hose size DN60 or DN70
- Pea gravel backfill takes place separate from TBM advance, thus no waiting is time required for annulus backfill to gain strength
- Pea gravel annulus is usually grouted as a secondary operation - theoretic gravel interstices have volume 30%, but 50% more realistic
Pea Gravel Backfill Injection Equipment

Dry type rotary shotcrete pump
Pea Gravel Backfill Handling in Large Tunnels

There is room for bulk material handling and bunkering of pea gravel.
Pea Gravel Backfill Handling in Small Tunnels

- Limited space for pea gravel handling systems
- Often times, there is not enough space to bunker a sufficient volume of pea gravel
- Pea gravel will be offloaded from a rail car during the TBM cutting stroke; this needs attention with respect to train movements
- Train operation cycle should be carefully considered to avoid “bottlenecks”
Pea Gravel Backfill Handling in Small Tunnels

- Pea Gravel Bunker and Conveyor
- Pea Gravel Pump
- Pea Gravel Transport Bin hauled on Flat Car
Pea Gravel Backfill Grout Injection

- Grout is injected in pea gravel as a secondary operation
- Theoretical interstices spaces in pea gravel at 30%
  - Realistically, it is 50% since pea gravel does not fill the gap completely
- Uses grout mixer, agitator, and piston or mono type pump for injection via segment holes
- Grout injection will be performed at a distance from the place of pea gravel injection
Combination Pea Gravel & Mortar Backfill
Combined Pea Gravel & Mortar Backfill

Pea Gravel Backfill

Invert Mortar Backfill
Combined Pea Gravel & Mortar Backfill

- Invert
- Mortar Injection
- pipes built into Tail Shield
Robbins Double Shield TBM with Pea Gravel Backfill

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Thank You