Multi Mode TBMs

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Multi Mode TBMs

- Basic Open and Closed mode TBM principals
- Motivation for Multi – Mode TBMs
- Change between EBP and Open single shield
- Change between Slurry and Open single shield
- Change between Earth Pressure Balanced shield and Slurry shield
- The Next Step: Herrenknecht “Variable Density” ® TBM
- Case Histories
Open Mode TBM principal

Open Single Shield
- Stable, usually non-water bearing ground conditions
- Atmospheric pressure
- Usual dry muck removal with belt conveyor
Earth Pressure Balance Shield and Slurry Shield Principal

Modes Of Operation

Closed Earth Pressure Balanced Shield (EPBM)
- Fine grained, unstable water-bearing soils
- Controlled pressure (screw and thrust)
- Thick-matter-type via screw conveyor

Closed Slurry Machine (STBM)
- Course grained, unstable water-bearing soils
- Controlled pressure (air bubble)
- Slurry circuit and above ground slurry treatment plant
## Multi – Mode / Convertible TBMs

### EPB / Mixshield Range

<table>
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<th>Sieve Size</th>
<th>Silt</th>
<th>Sand</th>
<th>Gravel</th>
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![Diagram showing the range of EPB / Mixshield with different sieve sizes for Silt, Sand, and Gravel.](image)

Sieve Size:
- Clay: 0-0.001
- Fine: 0.001-0.006
- Medium: 0.006-0.02
- Coarse: 0.02-0.2
- Fine: 0.2-0.6
- Medium: 0.6-2.0
- Coarse: 2.0-6.0
- Fine: 6.0-20.0
- Medium: 20.0-60.0
Motivation for Multi - Mode TBMs.

- Long sections of different ground conditions along the alignment
- Best suitable mode of operation for each single section
- Best suitable mode of operation $\Rightarrow$ optimized economy
- Best suitable mode of operation $\Rightarrow$ increased safety
Convertible Machines

- **Open Mode**
- **Closed Mode**

**Conversion**
- Modular
- Integrated

**Single Shield TBM**

**Slurry Shield**

**EPB Shield**
Change between EPB and Open single shield

Modes Of Operation

Closed Mode - Earth Pressure Balance
- regular mode of operation
- positive face support
- max. 6-8 bar depending on soil condition(ing)

Closed Mode - Compressed Air
- exceptional mode of operation
- control of water inflow
- max. 2,5 bar depending on soil condition(ing)

Open Mode
- stable face conditions
- atmospheric excavation chamber
- rapid chamber isolation possible (discharge gate)
- muck pile in chamber required (cutterhead wear)
Change between EPB and Open single shield

Katzenberg Tunnel, Germany

- Screw conveyor for primary mucking system
- No modification for open – closed mode change
- Short individual closed mode sections along the alignment (approx. 10%) – 8.9km
- Moderate soil abrasivity
Change between EPB and Open single shield

Center Belt Conveyor And Screw Conveyor As Primary Mucking System

**Closed Mode - Earth Pressure Balance**
- Screw conveyor in forward position for full capacity
- Center belt and muck hopper retracted, rotary installed
- Cutterhead muck transport channels partially removed

**Open Mode**
- Screw conveyor in retracted position (limited capacity)
- Center belt and muck hopper in forward position, rotary removed
- Cutterhead muck transport channels installed
Change between EPB and Open single shield

Saverne Tunnel, France

- Screw conveyor and center belt / muck hopper for primary mucking system
- Approx. four days required for open – closed mode change
- Two short closed mode sections along the alignment (approx. 5%)
- Very high rock/soil abrasivity
Change between Slurry and Open single shield

Slurry Circuit and Center Belt Conveyor As Primary Mucking System

Closed Mode – Slurry machine
- Submerged wall gate open
- Center belt and muck hopper retracted and sealed
- Slurry circuit and treatment plant in operation

Open Mode
- Submerged wall gate closed
- Center belt and muck hopper in forward position
- Closing / Mode change within 2 - 4 hours
Change between Slurry and Open single shield

Weinberg Tunnel, Switzerland

- Slurry circuit and center belt / muck hopper for primary mucking system
- Approx. one week required for open – closed mode change
- 10% of the tunnel length in closed slurry mode at the end of the drive for Limmat river crossing (transition from molasse rock in gravely material)
Change between Slurry and Open single shield

Center Screw Conveyor and Slurry Circuit as Primary Mucking System (Special Version for Lake Mead Intake No. 3 Tunnel)

Closed Mode – Slurry machine
- Submerged wall gate open
- Center screw and muck hopper casing retracted and sealed
- Slurry circuit and treatment plant in operation

Open Mode
- Submerged wall gate closed
- Center conveyor and muck hopper casing in forward position
- Closing in less than 20 seconds (screw discharge gate)
Change between Earth Pressure Balance Shield and Slurry Shield

Slurry Circuit or Screw Conveyor as Primary Mucking System, Different Method of Face Pressure Control

Closed Mode – EPB Machine
- Screw conveyor for primary muck discharge
- Advance speed and / or discharge volume regulation for face pressure control ➔ muck volume based face pressure control

Closed Mode – Slurry Machine (Mixshield)
- Slurry circuit for primary muck discharge
- Air bubble for face pressure control ➔ independent face pressure control
Change between Earth Pressure Balance Shield and Slurry Shield

Integrated Concept for Change of Operation Mode

- EPB and Slurry specific modules or subassemblies permanently installed
- Change of operation mode in the tunnel
- Chamber interventions for “activation” of mode specific equipment required
Change between Earth Pressure Balance Shield and Slurry Shield

Modular Concept for Change of Operation Mode

- Exchange / installation of system specific modules or subassemblies in intermediate shaft (e.g. slurry circuit – screw conveyor, air bubble regulation system…)
- Common modules for not system specific functions (e.g. ring erection, cutterhead drive, air lock systems…)

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Change between Slurry Shield and Earth Pressure Balance Shield

SOCATOP Tunnel, France

- Long tunnel (10km)
- Long single stretches within the alignment with clear preference for operation mode
- TBM size of 11.6m sufficient to install parallel systems
The Next Step – Frequent Changes.
Seamless Transition – Switching Between Modes of Operation

- Long sections of different ground conditions along the alignment
- High frequent changes of ground conditions along the alignment
Change Between Slurry Shield and Earth Pressure Balance Shield

The Herrenknecht “Variable Density” ® Concept

- Transformation between EPB face support and slurry face support in the tunnel without the need of modification or chamber intervention
- Full size and quality face support systems for EPB and slurry operation
- Safe and fully controlled conditions for face support during mode change
The Herrenknecht “Variable Density” ® TBM
Some of the Functional Principles Used for The “WCP – Mode” on the Port of Miami TBM

EPB Mode

WCP Mode
The Herrenknecht “Variable Density” ® TBM
Typical Layout for a Mid-Size TBM in Full Multi Mode Configuration
The Herrenknecht “Variable Density”® TBM
Modes of Operation

Open Mode

EPB Mode

Slurry Mode

High Density Slurry Mode
The Herrenknecht “Variable Density” ® TBM
Successful Completion at Kuala Lumpur

- Supplied a total of six Variable Density TBMs and two EPB TBMs for the project
- Greatly varying geology: Hard Granite Rock, mixed soft ground “Kenny Hill Formation” and extreme karstified limestone
- The highly flexible Variable Density TBM concept proved to be the perfect solution for the difficult ground conditions in Kuala Lumpur
- ITA Technical Innovation of the Year Award (2014)
THANK YOU FOR YOUR ATTENTION.

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