Different TBMs – different applications.

Dr. Karin Bäppler, Head of Geotechnics, Traffic Tunnelling, Herrenknecht AG
Content

- Motivation for Multi Mode TBMs
- Change between operation modes
- Milestones: Development of Multi Mode TBMs at Herrenknecht
- Variable Density TBM
- Conclusion
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 → optimized economy
- Best suitable mode of operation → increased safety
Change of operation mode.
Multi Mode TBMs.

Open Mode

Conversion
• modular
• integrated

Closed Mode

Single Shield TBM

Slurry Shield

EPB Shield
Change between Open Single Shield and EPB (1 ↔ 2).

EPB-Modes of operation.

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

**Closed Mode- Compressed Air**
- exceptional mode of operation
- control of water inflow
- max. 2.5 bar depending on soil condition

**Open Mode**
- stable face conditions
- atmospheric excavation chamber
- rapid chamber isolation possible (discharge gate)
- muck pile in chamber required (cutterhead wear)
Change between Open Single Shield and EPB (1 ← → 2). Katzenberg Tunnel, Germany.

- Railway tunnel
- 2x EPB Shield
- Diameter: 11,120mm
- Tunnelling length: 17,968m
- Limestone, sandstone, marl
Change between Open Single Shield and EPB (1 ⇆ 2).
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%)
- Moderate soil abrasivity
Change between Open Single Shield and EPB (1 ↔ 2).
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 Open Single Shield and EPB (1 ↔ 2). Tunnel de Saverne, 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 Open Single Shield and Slurry (1 ← → 3).

Center belt conveyor and slurry circuit 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 Open Single Shield and Slurry (1 ↔ 3). 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 Open Single Shield and Slurry (1 ↔ 3).
Lake Mead | Intake N°. 3 | Las Vegas.

- Sedimentary and volcanic geology
- Crossing fault areas and direct connection with lake
- Depth of the tunnel
- Potential for high groundwater inflows and high hydrostatic pressures of as much as 17bar.
Change between Open Single Shield and Slurry (1 ← → 3). Center Screw Conveyor and Slurry Circuit as primary mucking system (Special version for Lake Mead Project).

**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 120 seconds (screw discharge gate)
Lake Mead | Intake N°. 3.
Final breakthrough on 10.12.2014!

- S-502 Multi-Mode-TBM Ø7,180mm, Tunnel length 4,800m
- Breakthrough in a special cavern at the bottom of the lake
Change between Slurry Shield and EPB Shield (2 ↔ 3). Slurry Circuit and 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 Slurry Shield and EPB Shield (2 ↔ 3).
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…)

Herrenknecht. Pioneering Underground Technologies
Change between Slurry Shield and EPB Shield (2 ↔ 3).
Socatop Tunnel Project, France.

- Long tunnel (10km)
- Long single stretches within the alignment with clear preference for operation mode
- TBM size of 10m sufficient to install parallel systems
Change between Slurry Shield and EPB Shield (2 ↔ 3). Integrated concept for change of operation mode.

- Slurry and EPB specific modules or subassemblies permanently installed
- Change of operation mode in the tunnel
- Chamber interventions for “activation” of mode specific equipment required
Milestones: Development of Multi Mode TBMs at Herrenknecht.


- **Grauholztunnel**
  - Switzerland
  - Ø11.6m
  - Mixshield/ Shield TBM

- **Zürich-Thalwil**
  - Switzerland
  - Ø12.36m
  - Mixshield/ Shield TBM

- **Socatop**
  - France
  - Ø11.56m
  - Mixshield/ EPB

- **Zürich-Thalwil**
  - Switzerland
  - Ø12.36m
  - Mixshield/ Shield TBM

- **Metro Delhi**
  - India
  - Ø6.45m
  - Shield TBM/ EPB

- **Hallandsas**
  - Sweden
  - Ø6.11m
  - Mixshield/ EPB

- **Melen 7/ Istanbul**
  - Turkey
  - Ø10.82m
  - Mixshield/ EPB

- **Milen 7/ Istanbul**
  - Turkey
  - Ø10.82m
  - Mixshield/ EPB

- **Saverne**
  - France
  - Ø7.18m
  - EPB convertible

- **Weinbergtunnel**
  - Switzerland
  - Ø11.24m
  - Mixshield/ Shield TBM

- **Finnetunnel**
  - Germany
  - Ø10.82m
  - Mixshield/ Shield TBM

- **Lake Mead**
  - USA
  - Ø7.18m
  - Mixshield/ Shield TBM

- **Chengdu**
  - China
  - Ø6.25m
  - Shield TBM/ Mixshield

- **ATCOST**
  - Germany
  - Ø10.82m
  - Shield TBM/ EPB

**Herrenknecht. Pioneering Underground Technologies**
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 EPB Shield (2 ← → 3).
The Herrenknecht “Variable Density” TBM.

- 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. Modes of operation.
The Herrenknecht “Variable Density” ® TBM.
Successful completion at Kuala Lumpur

- Eight Variable Density TBMs were used in Kuala Lumpur for operation in slurry - and high density slurry mode
- The highly flexible Variable Density TBM concept proofed to be the perfect solution for the difficult ground conditions in Kuala Lumpur
Conclusion.

- More demanding tunnel alignments either relating to tunnel length, required face pressure or variation of ground conditions require more and more flexible TBM concepts.
- Custom-made machine solutions tailored to specific customer requirements and projects such as e.g. the Variable Density TBM
- Outlook: Development of new solutions related to safety and economy
THANK YOU FOR YOUR ATTENTION!