SLURRY, HYBRID AND LARGE TBMS

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Tunneling Consultant
SLURRY SHIELD COMPONENTS

1. Tunnel face
2. Cutterhead
3. Slurry
4. Excavation chamber
5. Bulkhead
6. Feed line
7. Air bubble
8. Submerged wall
9. Working chamber
10. Slurry line
11. Grid
12. Segments
13. Tailskin
SLURRY SHIELD TBM LAYOUT

- Compressed Air Plant
- Bentonite Mixing Plant
- Slurry Treatment Plant
- Muck Discharge
- Feed Line
- Discharge Line
- Slurry Circuit
- TBM
- Compressed Air Regulation
CRUSHER TYPES

jaw crusher  roller crusher
JAW CRUSHER CAPACITY

Crusher Capacity (Grain Size)
Shield Dia. < 20ft: 20"
Shield Dia. 20ft – 33ft: 32"
Shield Dia. > 33ft: 47"
SEGMENT ERECTOR OPERATION
MODERN DAY CUTTERHEAD DESIGNS

(Portland East Side CSO machines)
MODERN DAY SLURRY TBM

- Outer Diameter: 13.71m
- Length: 120.0m
- Weight: 3,300 ton
- Water Pressure: 13 bar
- Cutterhead power: 4900 KW
- Nominal Torque: 23,290 kNm (17,200 k-ft)
FACE PRESSURES EXPERIENCED DURING EXCAVATION

- HERA HAMBURG, Mixshield, Ø 6,0m
- SYDNEY, Mixshield, Ø 10,4m
- MÜLHEIM, Mixshield, Ø 6,9m
- GRAUHOLZ, Mixshield, Ø 11,6m
- HAMBURG, Mixshield, Ø 14,2m
- WESTERSCHELDE, Mixshield, Ø 11,4m
- HALLANDSAS, Mixshield, Ø 10,53m
- LAKE MEAD, Mixshield, Ø 14,0m
- ISTANBUL, Mixshield, Ø 13,71m
- HALLANDSAS, Mixshield, Ø 10,53m
- DIVERS ENGAGED
- LAKE MEAD, Mixshield, Ø 14,0m
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- DIVERS ENGAGED
CUTTING TOOL CHANGES
TYPES OF INTERVENTIONS

- Compressed air 0-3.6 bar, up to 4.5 bar in exceptional cases, short duration
  - decompression in TBM airlock
  - state of the art,
  - coverage by rules and regulations

- Mixed gas for short duration up to 6.0 bar
  - decompression in TBM airlock

- Saturation for long term interventions above 4.5 bar
  - above ground hyperbaric habitat
    (crew transfer shuttle)
MANLOCKS FOR SLURY TBM INTERVENTIONS
TYPES OF INTERVENTIONS

Mixed gas intervention

Submerged diving
CUTTING TOOL CHANGES UNDER ATMOSPHERIC PRESSURES

Access down into cutting arm spoke

Operator undertakes maintenance procedure's without the risk of having to work in the tunnel face

Back loading cutting tools
ATMOSPHERIC TOOL CHANGE at 12-bar PRESSURE
(Istanbul Strait Crossing Tunnel)
WEAR SENSORS AND MONITORING

- Wear monitoring of cutting tools
- Wear and rotation monitoring of disc cutters
- Wear monitoring of cutterhead structure
REMOTE VISUAL INSPECTION
CONVERTIBLE MACHINES

Open Mode

Conversion
• integrated
• modular

Closed Mode

Single Shield TBM

Slurry Shield

EPB Shield
**CHANGE BETWEEN OPEN SINGLE SHIELD AND SLURRY**

**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
HERRENKNECHT LAKE MEAD HYBRID TBM
(ROCK/SLURRY MACHINE)

- Hybrid rock/slurry machine
- Open/Closed mode operation
- Designed for 17 bar pressure
- Excavation diameter 23.5ft
- Hyperbaric intervention at high pressure
CHANGE BETWEEN SLURRY SHIELD AND EPB
(Integrated concept)

- 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
CHANGE BETWEEN SLURRY SHIELD AND EPB
(SOCATOP tunnel, 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
EPB Mode: Machine uses a screw conveyor to maintain face pressure and to remove muck

Slurry Mode: In slurry mode, muck empties into an enclosed slurry box where boulders are broken up using a crushing mechanism in the box and then fed into the slurry pipes.
Crossover XRE

- Mixed ground cutterhead: with disc cutters & soft ground tools or a combination of tools (interchangeable).
- Two-speed gearboxes: provide high torque at low RPM under soft ground conditions and high RPM under hard rock conditions.
- Cutterhead rotation: Single direction is more efficient in hard ground conditions and bi-directional is more efficient in soft ground to prevent roll.

Crossover XSE

- Equipped with both screw conveyor and slurry system for muck removal.
- Ground conditions: soft ground containing water under pressure (particularly for water pressures > 5 bar).
- The most universal of the Crossover machines, the XSE can bore in most types of ground.

Crossover XRS

- Highly adaptable to variable ground conditions; suitable for rock tunnels with water pressure > 5 bar.
- Hard rock machine with a rock cutterhead and slurry system in place.
- Capable of mining rock through high water pressure without grouting off water flows.
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
LARGE DIAMETER TUNNELS
## LARGE DIAMETER TBMs SINCE 2011

<table>
<thead>
<tr>
<th>Start date/launch</th>
<th>Country</th>
<th>Project * = TunnelTalk reference article - See References below</th>
<th>TBM manufacturer</th>
<th>Diameter</th>
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<tbody>
<tr>
<td>2017 In planning</td>
<td>USA</td>
<td>Los Angeles I-170 Highway Tunnel*</td>
<td>Yet to be procured</td>
<td>16 m plus</td>
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<td>2017</td>
<td>Japan</td>
<td>Tokyo Outer Ring Road Kan-etsu to Tomei*</td>
<td>4 machines</td>
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<td>1 Kawasaki, 3 JIM</td>
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<td>2017</td>
<td>China</td>
<td>Shanghai Zhuguang Road Tunnel</td>
<td>1 Herrenknecht Mixshield</td>
<td>14.41 m</td>
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<td>Ex Auckland Waterview TBM</td>
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<tr>
<td>2016</td>
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<td>Shanghai Yanjiang A30 Motorway</td>
<td>2 Herrenknecht Mixshields</td>
<td>15.43 m</td>
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<td>Ex Shanghai Changjiang under river project</td>
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<td>Santa Lucia Highway Tunnel, A1 near Firenze*</td>
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<td>Hong Kong</td>
<td>Tuen Mun - Chek Lap Kok subsea highway link*</td>
<td>1 Herrenknecht Mixshield</td>
<td>17.6 m</td>
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<td>Ex-Nanjing Machine</td>
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<td>Welsan Road Tunnel, NanJing*</td>
<td>2 IHI/Mitsubishi/CCCC slurry TBMs</td>
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LARGE DIAMETER TBM over 14-m.
VEHICLE FOR TRANSPORT OF A COMPLETE LARGE SEGMENT RING
TOOL SPEED LIMITATIONS IMPACTING TBM ADVANCE RATE

![Graph showing TBM advance speed versus TBM diameter for rock and soft ground conditions.](image-url)
Tuens Mun-Chek Lap Kok Link
Northern Connection Sub-sea Tunnel Section
Project Background
Tuen Mun-Chek Lap Kok Link
Northern Connection Sub-sea Tunnel Section
TBM Design and Operation

**TBM S880**
- 19” single disc cutter 117 Nos.
- 19” double disc cutter 6nos.
- Scrapers 200 nos.

**TBM S882**
- 19” single disc cutter 97 Nos.
- 19” double disc cutter 4 nos.
- Scrapers 114 nos.

- Slurry type TBM
- TBM fabrication was in both Germany and China by Herrenknecht AG.
- TBM S880 launched on 24 April 2015
- TBM S882 Launched on 12 June 2015