Trenchless technologies for small diameter tunnels.

Lutz zur Linde, Herrenknecht AG.
Bergen, June 07th, 2016
Herrenknecht  Tunnelling, Machine range Ø < 4.2m
Utility Tunnelling – Business Segments.

- **Utility Tunnels & Shafts**
  - Water & Sewage
  - Casing tunnels for pipelines and cables
  - Intake, outfall, landfall tunnels
  - Shaft construction

- **Pipeline**
  - Oil and Gas
  - High pressure lines
  - Fluid storage
  - Extraction of natural resources
  - Investigation and probe drilling

- **Energy**
  - Offshore foundations
  - Hydropower solutions
  - Offshore – Onshore connections
  - Onshore Network Expansion
Herrenknecht Group.
Small and large diameters.

Microtunnelling Machine AVN400 Ø 0,56m
Hong Kong Mixshield Ø 17,60m
Large Double Shield TBMs for Follo railway line Ø 9.96m
Herrenknecht Tunnelling.
Utility Tunnelling – Business Segments.

- Utility Tunnels & Shafts
- Pipeline
- Energy

- Machine range Ø < 4.2m.

- AVN & AVND
- EPB Shield
- Gripper TBM
- Single Shield
- Double Shield
- Auger Boring Machine
- HDD Rig
- Direct Pipe®
- Pipe Express®
- Partial-face Excavation Machine
- VSM

Herrenknecht. Pioneering Underground Technologies

- Guided by theodolite and monitor
- For compacted soil SPT > 35 and soft rock < 10MPa
- Different diameters
- Different cutterheads
Front Steer Auger Boring.
General functional principle.
Front Steer Auger Boring.
With Down-the-Hole Hammer (DTH) in rock.

- Guided by inclinometer, water level and side assist system
Front Steer Auger Boring.
With Down-the-Hole Hammer (DTH) in rock.

- Reference project, Switzerland
Front Steer Auger Boring.

Advantages.

- Low Capital Investment
- Short Setup Times
- Simple Operation
- Can be used in non-displaceable ground up to Rock
- Can be adapted to all Auger Boring Jacking Frames
- Can be equipped with a Down-the-Hole Hammer
- Control of Line and Grade with Inclinometer and Electronic Hydrostatic Water Level

Front Steer OD420 in soft rock

With hammer in rock up to 150MPa
Microtunnelling AVN 600 Citytunnelling.
AVN1200TB for hard rock tunnelling; L=165m

- M-1948M, AVN1200TB, OD1490mm
- Location: Huddinge, Stockholm, Sweden
- Geology: Swedish hard rock, granite
  - UCS: 150-223MPa / CAI 5,2
- Contractor: BAB Röhrtryckning AB
- Client: Stockholm Vatten
AVN1200TB for hard rock tunnelling.
Nissan River Crossing in Halmstad, South of Sweden. AVN1200TB used.

- M-1948M, AVN1200TB, extended to ID1400, OD1720mm
- 93m sewage tunnel built in only 10 days!
**Reference Project: Budapest, Hungary.**
Danube River Crossing in mixed geology.

- M-732M, reinforced concrete pipe ID1400/OD1720mm
- 1 x sewage tunnel installed under Danube river
- Deep Shafts: 23m
- Curved drive: long drive of 635m with horizontal curve
**Reference Project:** Budapest, Hungary.
Danube River Crossing in mixed geology.

- Mixed Geology: Limestone, Marl, Clay, Silt and Sand
Herrenknecht Premiere for AVN 1600TB.
First Microtunnelling Jobsite in Czech Republic: Sewer under the Royal Garden of the Prague Castle

- M-595M, AVN1600TB, OD1960mm
- Location: Prague, Czech Republic
- Tunnel length: 200m
- Contractor: Energie - stavební a bánská a.s.
- Tunnelling Duration: Nov 22nd – Dec 30th, 2013

AVN 1600 in 40m deep launch shaft in Prague.
Herrenknecht Premiere for AVN 1600.
First Pipe Jacking Jobsite In Czech Republic.

Hobas Jacking Pipes, ID 1800

Pipe Jacking equipment installed on jobsite under restricted surface conditions.
Trends in Pipe Jacking.

- Higher hydrostatic pressures (river crossings / outfalls)
- Larger tunnel profiles
- More heterogeneous ground conditions
- Longer tunnel drives

Lower overburdens (inner-city)
Elbe Crossing in Hamburg, Germany.
Pipe Jacking for gas pipeline.

- M-1439M, AVN2500, OD3000
- Casing for 2 gas pipelines for Gasunie
- 1,580m advance in 112 days
- Up to 4 bar groundwater pressure
- Breakthrough: December 4, 2014
Sea Outfall Project Sochi, Russia.
Two pipe jacked outfalls in the Black Sea.

- 2 Sewage tunnels installed under the Black Sea, 1,411m + 2,014m.
- 2,014m = Long distance record in ID 2000 | First Sea Outfall in Russia.
- Geology: clay, limestone, argillite
- Performance: 2,014m tunnel installed in 100 days.
Reference Project: Europipe, Germany.
2,535m Pipe Jacking in the North Sea in 1994.

Tunnel length: 2,535 m
Hard Rock Pipe Jacking TBM.

1. Cutting wheel
2. Muck ring
3. Winch
4. Electric motor
5. Stabilizer
6. Target/Gyro
7. Belt conveyor
8. Telescopic Station
9. Gripper
10. Muck Skip
Hard rock TBMs for Pipe Jacking.
TBM 1200.
Advantages of TBM Technology

- Lower investment compared to Slurry Equipment
- Lower operational costs / no separation plant
  - No water, no disposal cost, no wear in slurry equipment
- Designed to cut the hardest rock (11" discs – max. 250 MPa)
  - high thrust capacity
- Easy and fast maintenance of cutting wheel (change of cutters)
- Simplified equipment → lower maintenance and repair cost
- High penetration rates
- Fast set-up and Launching times
TBM1600 for Hard Rock Tunnelling in Madinah / KSA. Jobsite Setup.
TBM1600 for Hard Rock Tunnelling in Madinah / KSA.
Launch shaft with Muck Skip for Soil removal.
TBM1200 for Hard Rock Tunnelling in Madinah / KSA.
Launch Shaft.
TBM1200 for Hard Rock Tunnelling in Madinah / KSA.

Excavated Soil.
Tunnel Lining in rock conditions.
Depending on Rock Classification we use different TBM types.

- without Lining
- Rock Bolting
- Mesh & Beam
- Shotcrete
- Rib & Lagging
- Segment Lining
Machine types for rock conditions.

Non-Shielded TBMs
- Mainbeam Gripper TBM
- Cutting Ø > 3600mm

Partly-Shielded TBMs
- Micro Gripper TBM
- Cutting Ø > 2580mm

Shielded TBMs
- Single Shield TBM
- Cutting Ø > 2800mm
- Double Shield TBM
- Cutting Ø > 2800mm
Mainbeam Gripper TBM.
Main characteristics.

- Suitable for stable rock
- Temporary lining: roof bolting, mesh & beam, shotcrete
- Min. cutting diameter: 3600mm
- Production: 300-600m/month
- Lining close behind the Cutterhead
Bärenwerk Hydropower Plant.

- S-800, Gripper TBM
- Diameter: 3,830mm
- Location: Fusch, Austria
- Application: Headrace tunnel
- Tunnel length: 2,818m
- Geology: Alpine rock
- Contractor: Marti Tunnelbau
- 5.5 months from kick-off meeting until factory acceptance test on February 15, 2013
- Start of tunnelling: April 2013
- Breakthrough: September 10, 2013
Micro Gripper TBM.
Main characteristics.

- Suitable for stable rock
- Temporary lining: roof bolting, mesh & beam
- Min. cutting diameter: 2580mm
- Production: 250-500m/month
- Compact design
- Suitable for tight curves ($r = \sim 150m$)
Micro Gripper TBM.
Reference Project: Rio Vermelho HEPP.

- M-1848M, Gripper TBM 2850 retractable
- Location: Sao Bento do Sur, Brazil
- Use of tunnel: Water tunnel for Mini-HEPP Project
- Tunnel length: 7.7km in 6 drives
- First 800m drive: completed in 2015
- Geology: rock
- Contractor: KM26 - Caldeiraria e Madeireira LTD
- First 2 Multi-Service-Vehicles in use for Utility Tunnelling machine
  - Most “slim” version of MSV ever built
Rio Vermelho Hydropower Project.
Retractable Gripper machine.

- Drives overview:
  1. drive 800m straight, 0.4% uphill
  2. Tunnel: 550m, straight, 5% uphill
  3. Tunnel: 3000m, 300m curve radius, 0.4% uphill
  4. Tunnel: 750m, 5% uphill
  5. Tunnel: 280m, straight
  6. Tunnel: 2350m, >300m radius, 4.3% downhill, TBM retraction through tunnel

- Well suitable for stable hard rock
- Compact machines for small HEPP
- Small curves Min. R = 150m
- 14” discs – max. UCS ~ 350 MPa
Rio Vermelho Hydropower Project.
First 2 Multi-Service-Vehicles in use for Utility Tunnelling machine

- Most “slim” version of MSV ever built
Double Shield TBM.
Main characteristics.

- Suitable for instable rock
- Permanent lining: Concrete segments
- Min. cutting diameter: 2800mm
- Production: 400-600m/month
- Excavation+lining can be done simultaneously
- Multifunctional use as Gripper, Single Shield and Double Shield possible
- High advance rates in gripper and double shield mode
Double Shield TBM.
Reference Project: Inelfe HDVC Link France - Spain

- M-1619M+M-1620M, 2 x TBM 3500, OD 4265mm, „Alberas & Canigou“
- High-voltage cable tunnel
- Tunnel length: 8,261m (from South: 7,026m, from North: 1,235m)
- Geology: abrasive rock, schist, Gneiss, Diorit, Granite, 150 MPa
- Contractor: JV Eiffage-Dragados
Double Shield TBM.
Reference Project: Inelfe HDVC Link France - Spain

- Best daily performance: 53.5m (M-1620M, 24.06.2012)
- Best monthly performance: 1.040m (M-1620M, September 2012)

- Breakthrough of M-1620M in finished tunnel of M-1619M on April 17th, 2013.
- Special machine design for disassembly of both machines in the tunnel, without cavern. Machines reusable
Double Shield TBM.

- M-1684M, M-1685M, 2x TBM3600XH, OD 4240 mm
- Location: Uva Province, Sri Lanka
- Tunnel length: 3.3 km Trailrace + 15.6 km Headrace
- Geology: hard rock with max. 250 MPa compr. strength
- Contractor: Farab
Tuenn Mun-Chek Lap Kok Link.
Hong Kong. Cross Passages with AVN 3000.

- M-2001M + M-2003M
- 2 x AVN 3000, OD 3605
- 44 Cross passages will connect the two road tunnels
- Length: 14m each
Tuenn Mun-Chek Lap Kok Link.
Hong Kong. Cross Passages with AVN 3000.

- First breakthrough: March 31st, 2016
- Tunnel length: 10.82m
- Max. confinement pressure: 5.5 bar
**GongBei Pipe Arch. Hong Kong - Zhuhai - Macao Bridge.**

Road tunnel along the border Macao - Zhuhai.

- Connection of the 30km long bridge to the mainland
- 4 x AVN1200TC | OD 1640 + 2 x HKS 300 Separation plants
- Geology: sand, fine sand, clay
- 36 drives of 255m length each
- Curve radius = 250m
GongBei Pipe Arch. Hong Kong - Zhuhai - Macao Bridge.
Road tunnel along the border Macao - Zhuhai.

- All 36 drives finished in May 2015
Slant Directional Drilling Rig.
Reference project Mongstad, Norway.

- H-026, HK250T
- Entry angle: 45°
- Landfall of a gas pipeline
- Borehole diameter: 14"
- Final depth: 234m (below sea level)
- Drilling length: 416m
- Geology: Basalt, 276MPa
- Contractor: Visser & Smit Hanab
Full Face Hole Opener & DHJP

Hole Opener and Down Hole Jet Pump (DHJP)
Thank you!