# LARGE TO VERY LARGE TUNNEL BORING MACHINE DIAMETERS FOR THE CONSTRUCTION OF TODAY'S INFRASTRUCTURE SYSTEMS

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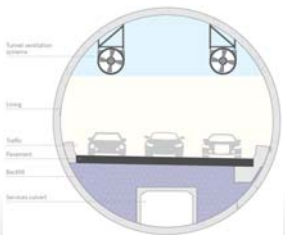
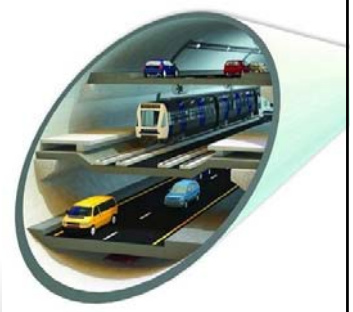
## MOTIVATION FOR LARGE TO VERY LARGE DIAMETER TUNNELS

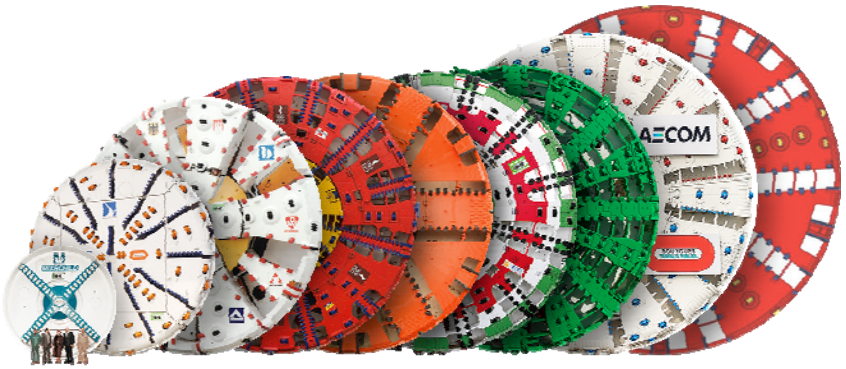
- Multi lane road tunnels
- Multi deck designs
- Combined tunnels
- Alternate safety concepts (cross passages)





## SUPERSIZE³

Going bigger step by step



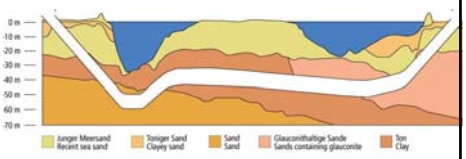

| 1985 | 1996 | 1997 | 2006 | 2006 | 2010 | 2016 | 2013 | Concept |
|---|---|---|---|---|---|---|---|---|
| **HERA** | **Sydney** | **Hamburg** | **Madrid** | **Shanghai** | **Sparvo** | **Santa Lucia** | **Hong Kong** | **St. Petersburg** |
| 5.95 m | 10.70 m | 14.20 m | 15.20 m | 15.43 m | 15.62 m | 15.87 m | 17.6 m | 19.25 m |



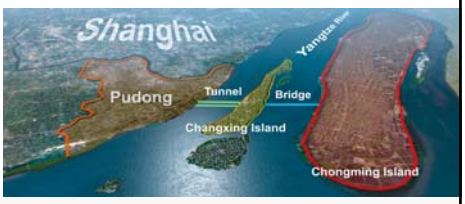
## LARGE-DIAMETER PROJECTS

References: Mixshields

- Westerschelde Tunnel, The Netherlands
  - 2 x Mixshield Ø11,340mm
  - 7.5 bar pressure



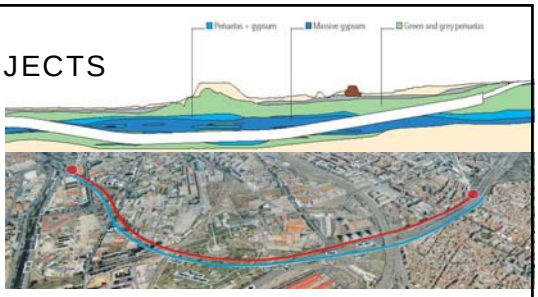
- Shanghai Changjiang Under River Tunnel Project, China
  - 2 x Mixshield Ø15,430mm
  - Pressure of up to 7 bar
  - Breakthrough 10 and/or 12 months ahead of schedule



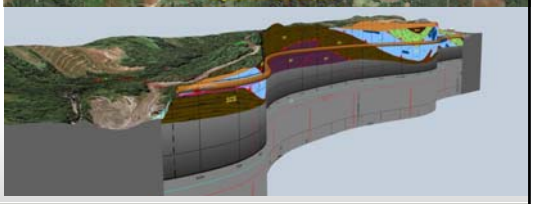
## LARGE-DIAMETER PROJECTS

References: EPB Shields

- Madrid M30, Spain
  - Inner-city road tunnel
  - 1 x EPB Shield Ø15,200mm
  - Breakthrough 4.5 months ahead of schedule



- Galleria Sparvo, Italy
  - 1 x EPB Shield Ø15,550mm
  - Explosion protection



## CROSSING UNDER THE BOSPORUS

Istanbul Strait Road Tunnel Crossing Project – Project Location

## CROSSING UNDER THE BOSPORUS

Istanbul Strait Road Tunnel Crossing Project

- First road tunnel (3.34km) under the Bosporus
- Single-tube, double-deck road tunnel (ID= 12m)
- Up to approx. 100m below sea level

**Challenges:**

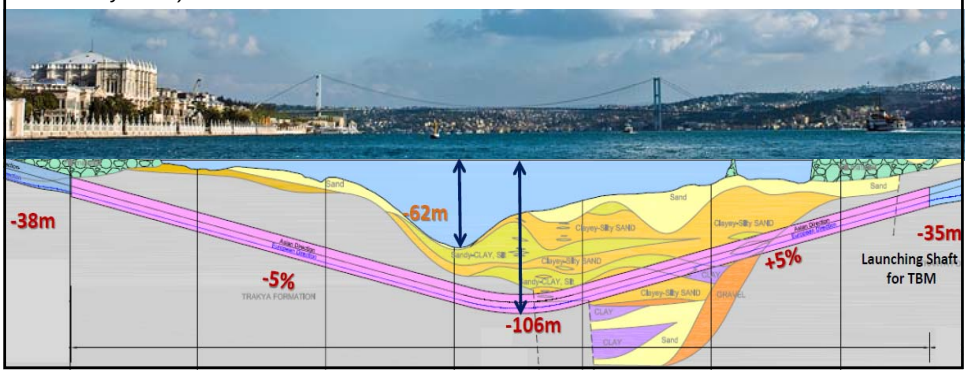
- Very large diameter TBM ($Ø_{exc.}$= 13.71m)
- Variable ground conditions:
  full face rock & soft ground with cobbles and boulders and transition zones
- Anticipated face pressures above 11 bar
- Surface access to create “safe havens” or “access shaft” no realistic option



## CONNECTION BETWEEN EUROPE AND ASIA

Istanbul Strait Road Tunnel Crossing Project

- Mixshield Slurry TBM Ø13.66m
- Mixed face cutterhead (rock and soft ground excavation)
- Fully articulated cutterhead, accessible for atmospheric cutter change
- Full preparation for saturation diving (above ground habitat, crew shuttles, shuttle transport and transfer systems)



## ISTANBUL STRAIT ROAD TUNNEL CROSSING

Cutterhead Features

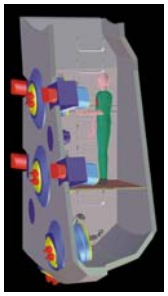

- Main spoke, atmospheric accessible
- Auxiliary spoke, conventional
- 19” twin disc cutter, atmospheric exchange with monitoring system
- Scraper tools, atmospheric exchange
- Scraper tools, conventional
- Multi level sectorized wear detection loops
- Bucket lips, conventional

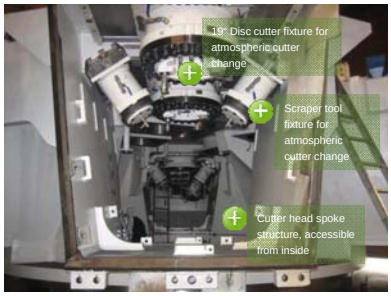


## PROJECT-SPECIFIC SOLUTIONS

For hydrostatic pressure of up to 12 bar

› Accessible cutter head, atmospheric cutter change at 12 bar face pressure (Istanbul Strait Road Tunnel Crossing Project)





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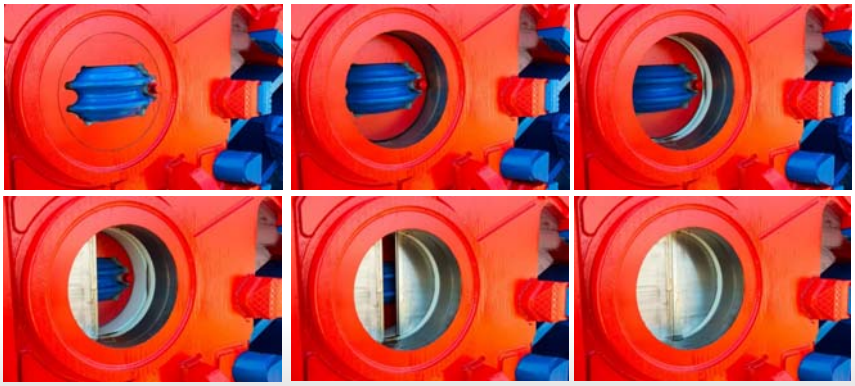



## NON-EXPOSURE MAINTENANCE SOLUTIONS

On-site cutter change Eurasia Tunnel Istanbul

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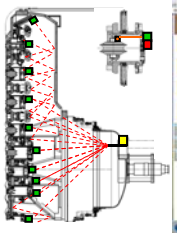
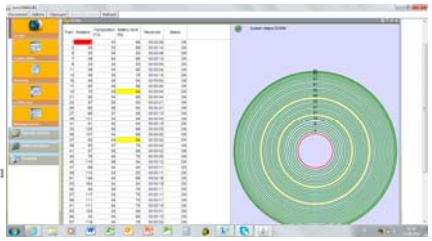
On-site cutter change Eurasia Tunnel Istanbul





## TBM FEATURES

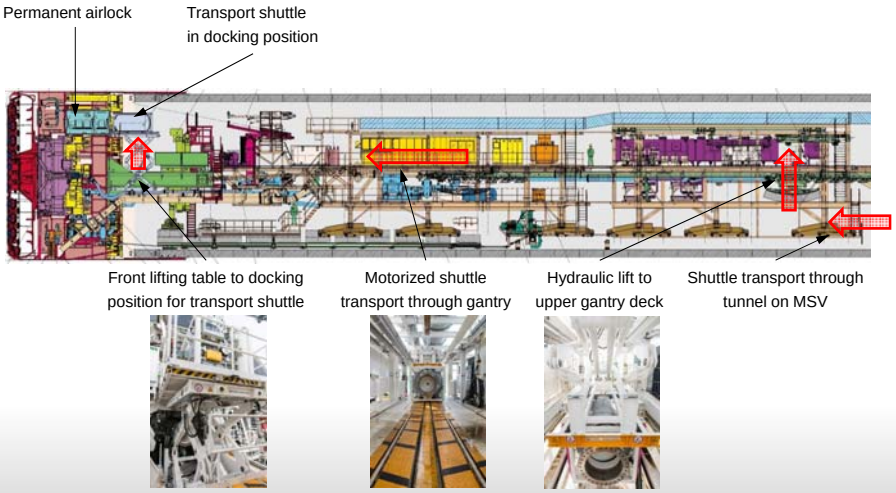
Cutterhead and Cutter Sensor Systems

- Structure wear detection systems for face periphery and backside
- Rotation and temperature sensor for each disc cutter
- Real time information on cutter conditions in control cab and site office (data recording system)

## SATURATION PROCESS

Crew shuttle transfer systems through trailing gear for saturation diving

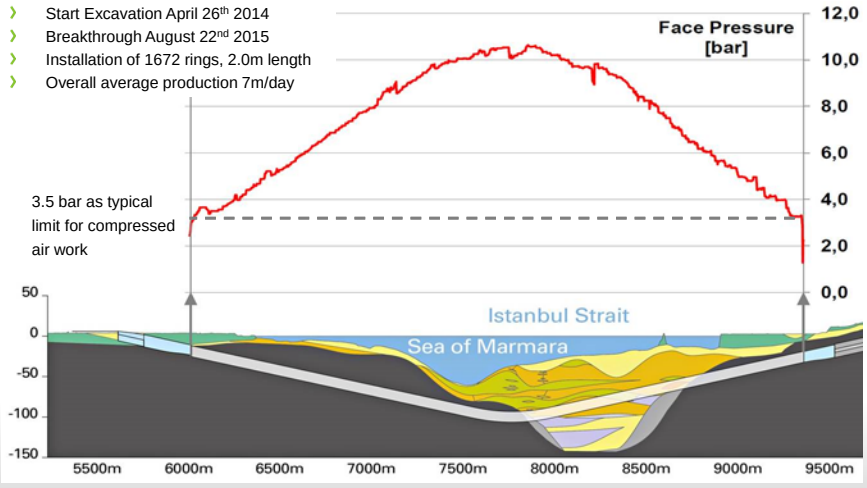





## ISTANBUL STRAIT ROAD TUNNEL CROSSING

TBM face pressure along the drive

- Start Excavation April 26th 2014
- Breakthrough August 22nd 2015
- Installation of 1672 rings, 2.0m length
- Overall average production 7m/day



## ISTANBUL STRAIT ROAD TUNNEL CROSSING

Lessons learned

- Best case scenario for possible open mode chamber access in Trakaya rock sections did not happen, closed mode operation at full rated pressure was inevitable for entire tunnel length
- Investment in multi level equipment preparation for worst case conditions was key for success (accessible cutter head, cutter sensor systems, preparation for saturation diving)
- Close cooperation of all involved parties (contractor, consultants, manufacturer, divers…) starting from a conceptual design stage is mandatory
- Full shop assembly, test and operator shop training is mandatory
- Accessible cutter head with atmospheric cutter change was key for project completion
- A trustful partnership of the complete team: Owner, Contractor and TBM supplier was the essential key to the success of such a difficult, challenging project.



## OPENING EURASIATUNNEL

20. December 2016


## WORLD RECORD IN TBM DIAMETER

Hong Kong: Tuen Mun-Chek Lap Kok Link (TM-CLKL)

- Road tunnel for connection of the Hong Kong-Zhuhai-Macao Bridge
- 2 x 4.2km of road tunnel by mechanized tunnelling
- Mixshield S-880, Shield-Ø17.6m
- High pressures exceeding 5 bar associated with highly unstable ground conditions
- About 50% mixed face conditions, 50% full face alluvium

## TUEN MUN – CHEK LAP KOK LINK

The largest machine world wide

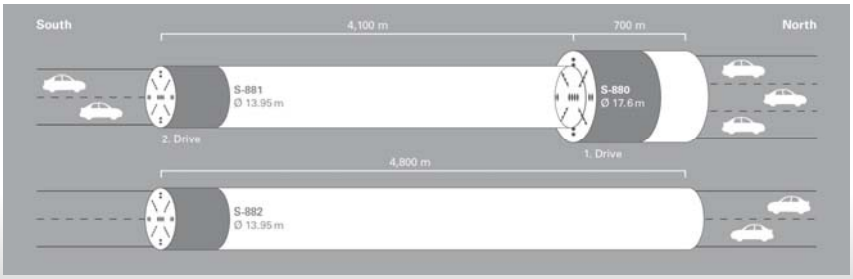
- S-880, Mixshield, Excavation diameter 17,630 mm
- Breakthrough in the ventilation shaft beginning of November 2015
- 2 parallel 2-lane road tunnels
- Important transport axis for the Hong Kong region to connect the airport



## HONG KONG:

Tuen Mun–Chek Lap Kok Link (TM-CLKL)

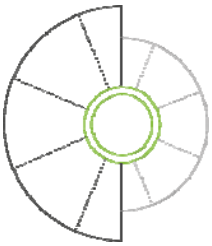
- 2 x 4.2km of road tunnel by mechanized tunnelling
- 2 x Mixshields:
  - Diameter 13.95m
  - Diameter 17.60m



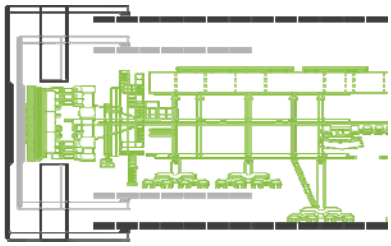
## TUEN MUN-CHEK LAP KOK LINK

Diameter change from 17.6 meter (S-880) to 14 meter (S-881)

17.6 m
**S-880**



14 m
S-881



**S-880**
S-881

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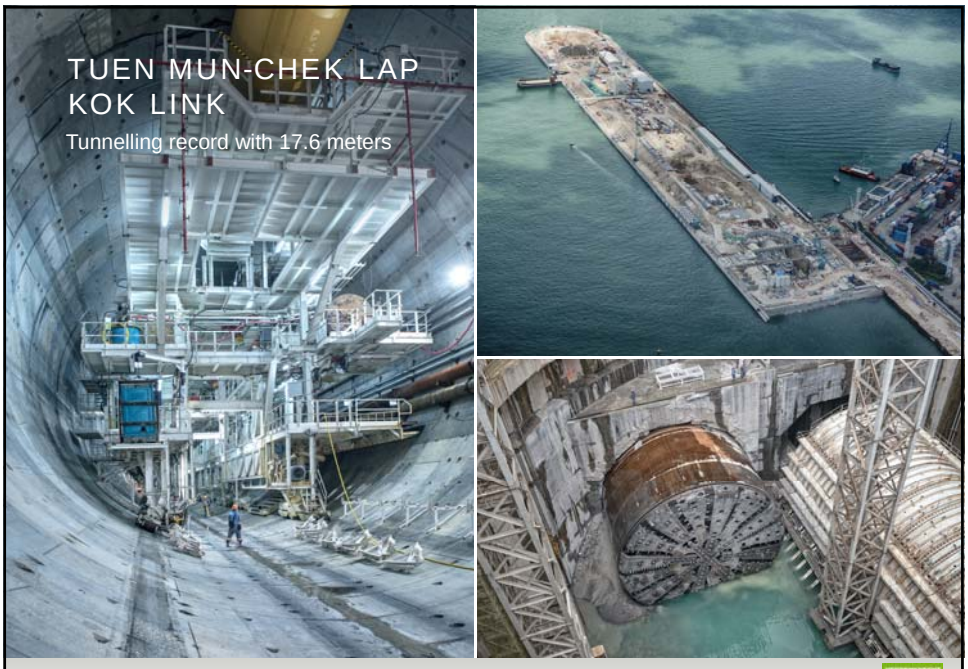


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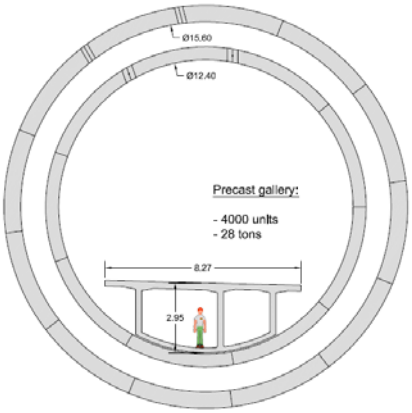
## TUEN MUN-CHEK LAP KOK LINK

Universal ring design

- Tunnel ID= 12.40m
  - 9 segments per ring
  - 14 tons each
  - 4000 rings
  - Ring length 2.20m
- Tunnel ID= 15.60m
  - 12 segments per ring
  - 12 tons each
  - 300 rings
  - Ring length 1.60m

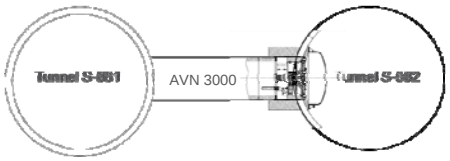





## TUEN MUN-CHEK LAP KOK LINK

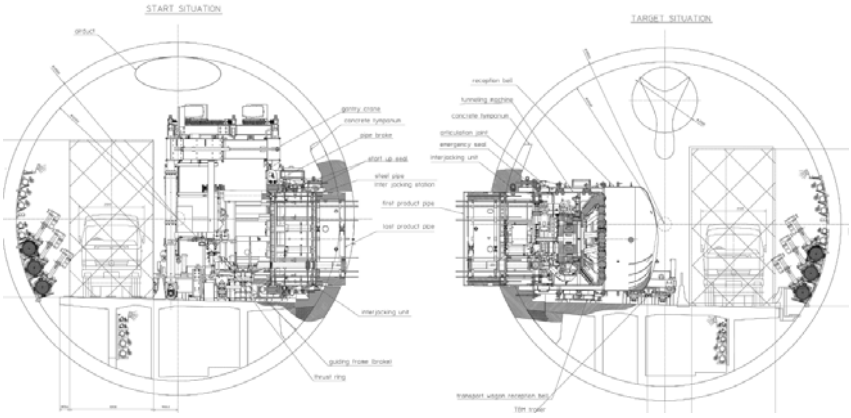
Cross passages with AVN 3000

- M-2001M + M-2003M
- 2 x AVN 3000, OD 3605
- 44 cross passages will connect the two road tunnels
- Length: up to 15m each
- Groundwater pressure of 5.5 bar




## TUEN MUN-CHEK LAP KOK LINK

44 tunnel cross sections with AVN-Technique






## TUEN MUN-CHEK LAP KOK LINK

AVN 3000 recovery in the tunnel, after breakthrough into reception bell

## TUEN MUN-CHEK LAP KOK LINK

AVN 3000 recovery in the tunnel, after breakthrough into reception bell



## TUEN MUN – CHEK LAP KOK LINK

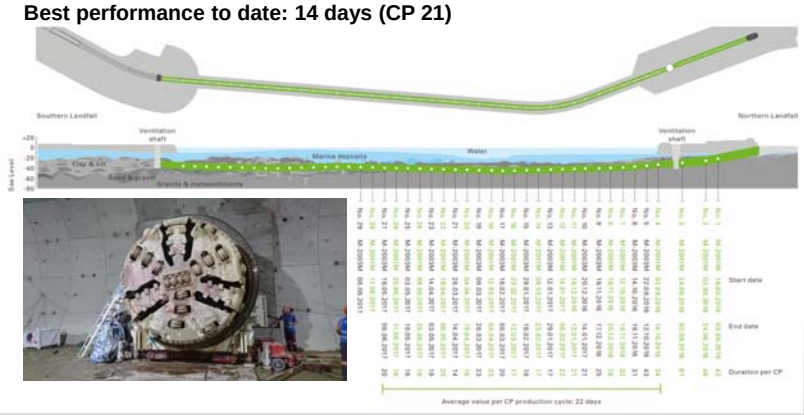
Tunnel cross sections with AVN technique

- 2x AVN3000
- Excavation length of 10-15 meter
- Water pressure of 5.5 bar
- Logistics in the tunnel can be maintained
- First use of TBM technology to construct cross sections under high pressures

## TUEN MUN-CHEK LAP KOK LINK

Cross passages with AVN 3000

- M-2001M + M-2003M, 2 x AVN 3000, OD 3605
- Performance continuously improved to Ø22 days construction time per cross passage
- **Best performance to date: 14 days (CP 21)**






## CONCLUSION AND OUTLOOK

- Mechanized tunnelling is the first choice to construct large-diameter infrastructures underground – safely, in time and in budget.
- Large diameters require up-to-date and project-specific solutions, e.g., to master high hydrostatic pressure when crossing under rivers and straits.
- Close and trusting teamwork tunnelling is fundamental for a project‘s success.
- The latest innovations underscore the high potential of future developments in mechanized tunnelling.


THANK YOU VERY MUCH FOR YOUR ATTENTION
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