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Tuen Mun – Chek Lap Kok Link Northern Connection Sub-sea Tunnel Section Hong Kong

Presented by : Antoine Schwob





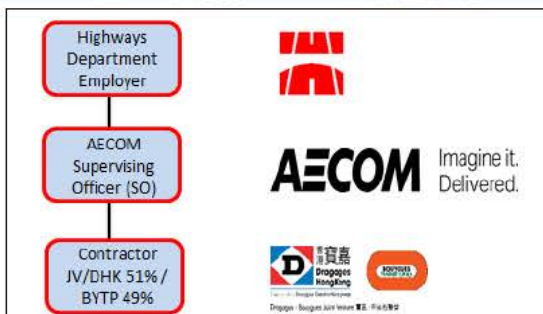
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TMCLK – Project General Information Location Map – Contract Information



Employer	The Government of HKSAR (Highways Department)
Contract No.	HY/2012/08
Contract Title	Tuen Mun – Chek Lap Kok Link – Northern Connection Sub-sea Tunnel Section
Contract Commencement Date	5 August 2013
Contract Completion Date	May 2020
Contract Duration	2,465 calendar days
Type of Contract	Design and Build Contract of the Government of HKSAR; 1999 Edition



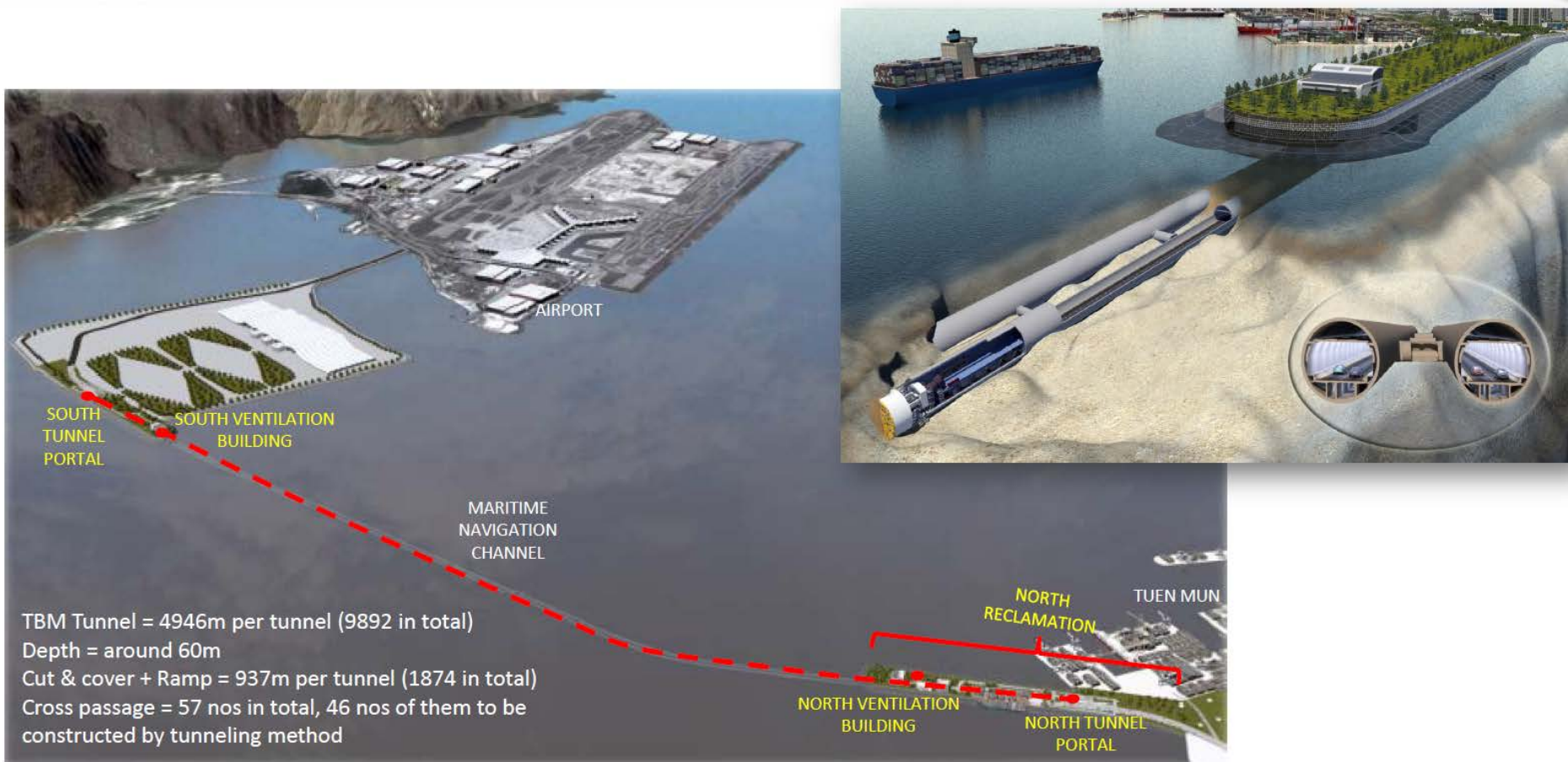


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TMCLK – Project General Information

Project Layout



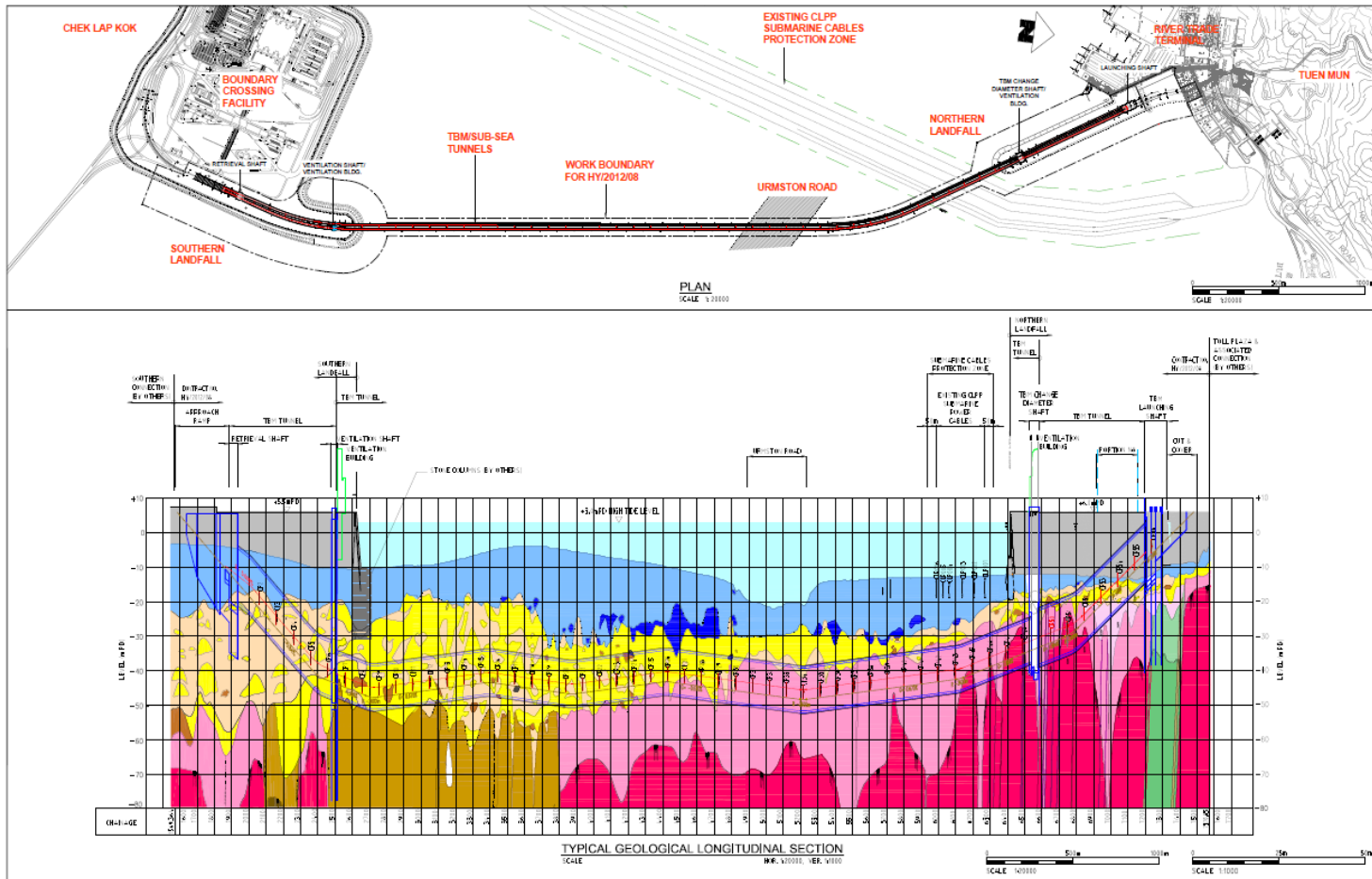


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TMCLK – Project General Information

Ground Conditions





TMCLK – Tunnelling at Northern Landfall

Construction of North Reclamation

Tunnelling at very shallow cover in freshly reclaimed land → Need for Ground improvement



1 - Plug made of CSM (Cutter Soil Mixing) and Jet Grouting required for:

- Gradual increase of confinement pressure for TBM Break-in
- Ground strengthening for Tunnel lining structural integrity at very shallow cover

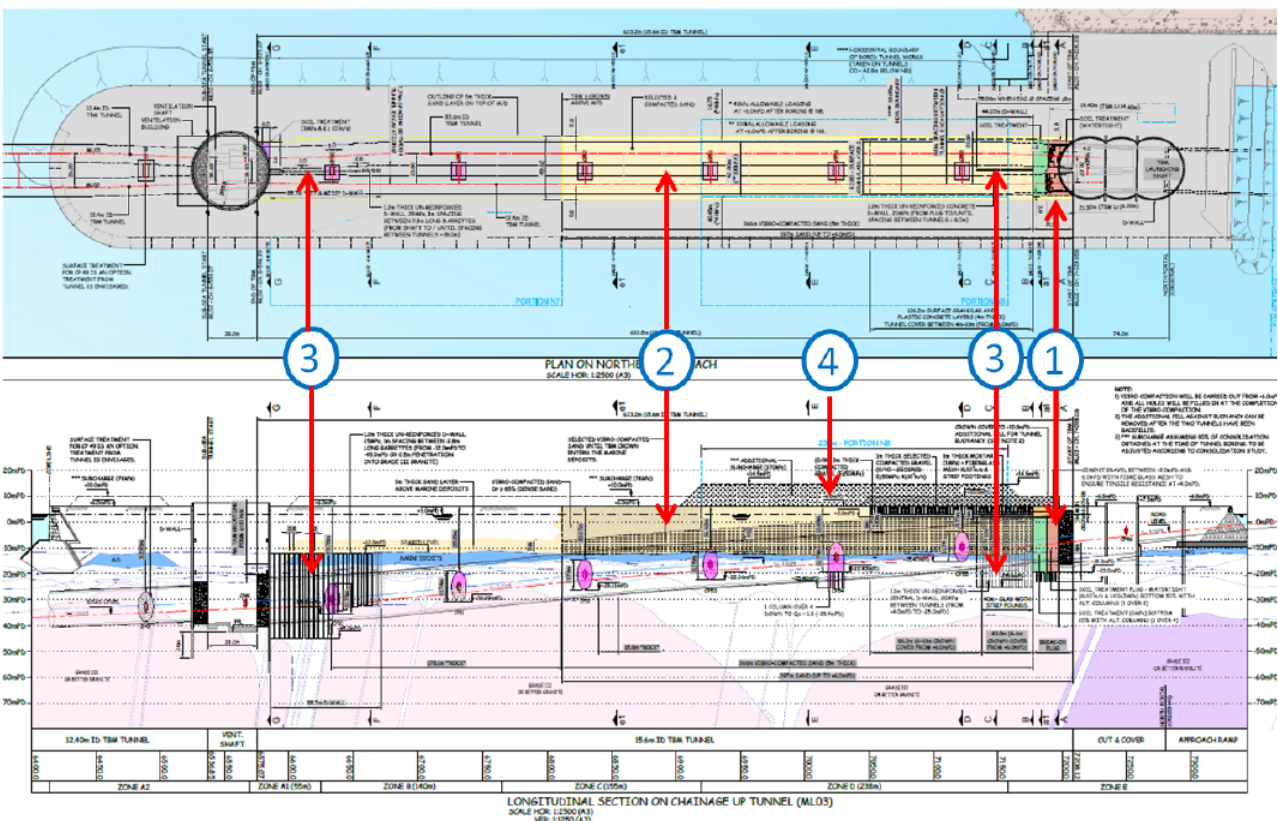
2 – Enhanced reclamation fill for tunneling in freshly reclaimed land:

- Use of vibro-compacted sand

3 – Central curtain D-Wall between 2 tunnels where spacing is close to avoid impact of confinement pressure of 2nd drive on 1st tunnel erected.

4 – Enhanced Ground Consolidation measures for tunneling through clay layers below freshly reclaimed land:

- Extra height of surcharge
- Reduced spacing of Band drains





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TMCLK – Tunnelling at Northern Landfall

Site set-up at North Reclamation





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TMCLK – Tunnelling at Northern Landfall Tunnel Boring Machines



TBMs

- Supplier Herrenknecht, Germany
- Type: Slurry Mixed Shield TBM
- Boring Diameters: **17.63m** / 14m
- Design Pressure: 5 / 7 bars max
- Nominal Torque: > 28/23 MN.m
- Max Power on C/H: > 5600kW/4900 kW





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TMCLK – Tunnelling at Northern Landfall Launching Shaft and TBM Assembly



Dimensions of Shaft: Length 85m / Width 44m / Depth 22m



Miami, USA, 18th November 2019

Antoine Schwob, Technical Director



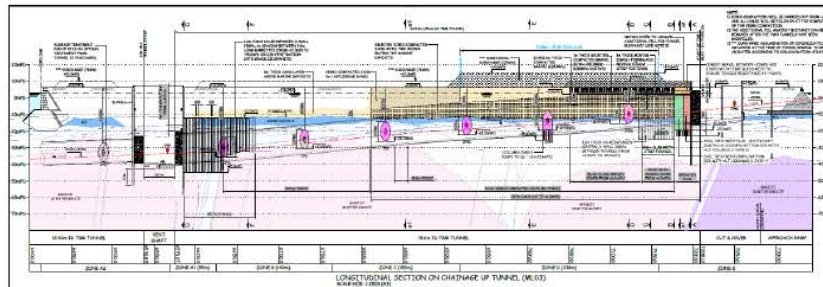
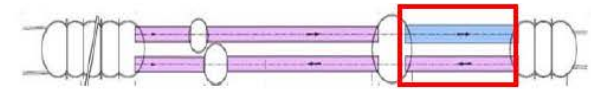
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TMCLK – Tunnelling at Northern Landfall North Approach Tunnels



- 640 m of tunnels
- 5% gradient
- Tunneling within freshly reclaimed land
- 8m spacing between tunnels
- Shallow cover at North launching shaft: 4m
- Tunnel depth at North Ventilation Shaft: 35m





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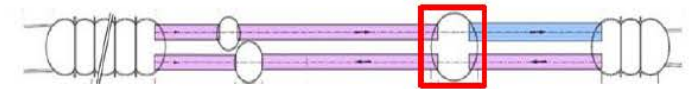
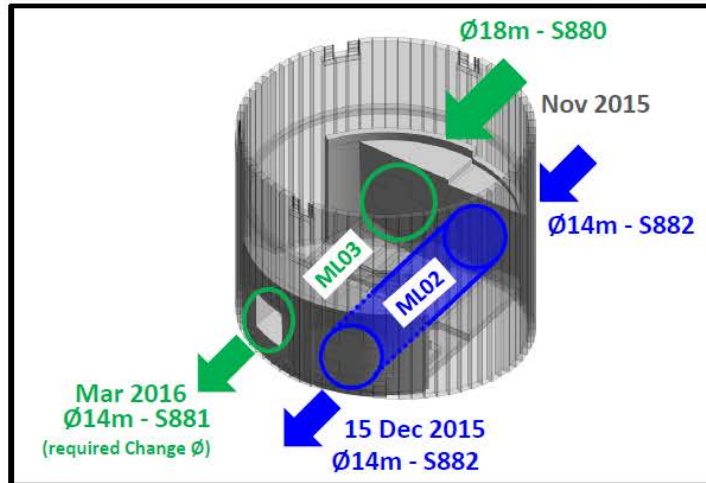


TMCLK – Tunnelling at Northern Landfall

North Ventilation Shaft – TBMs Crossing

2 TBMs have to cross NVS with different constraints:

- S-880 Break-out and change diameter (from 17.63m to 14m)
- S-881 crossing without reconfiguration



Shaft Flooding for S880 B/O



Shaft dewatering after S880 B/O





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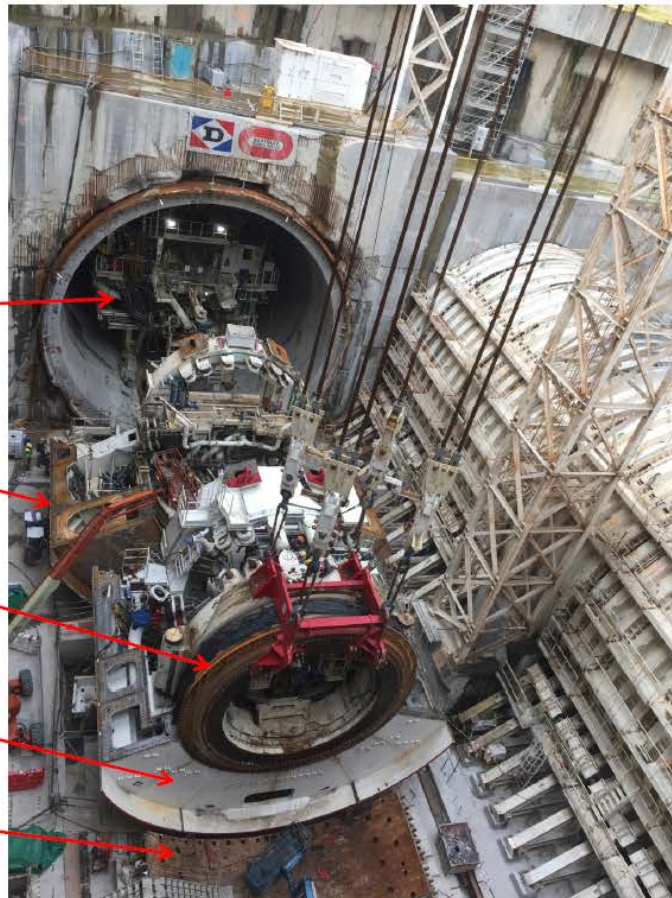


TMCLK – Tunnelling at Northern Landfall North Ventilation Shaft – TBMs Crossing

S-880 → S-881:

Change Diameter Operation

Change of TBM Cutterhead and Shield Diameter to 14m before break in to sub-sea section



Back-up gantries to be reconnected on S-881 Shield

S-880 Shield under dismantling

Main Drive transferred from S-880 to S-881

S-881 Shield under assembly

Launching Steel bell under assembly

S-882 crossing with no TBM reconfiguration

Use of crossing steel bell:

- Continuity of the tunneling operation and other activities inside tunnels
- 1 week for crossing (including cutterhead intervention) → 2 months programme saving compare to traditional Break-out / Break-in scheme
- No disturbance to adjacent change diameter operation





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TMCLK – TBM Intervention Strategies TBM Cutterhead Monitoring System

Background / Context:

- TBM drive in adverse ground conditions: Rock / CDG
- TBM sub-sea drive at depth greater than 50m below sea level



**Need for Daily Maintenance works in hyperbaric conditions
(up to 6.0bars) in TBM Excavation Chamber**

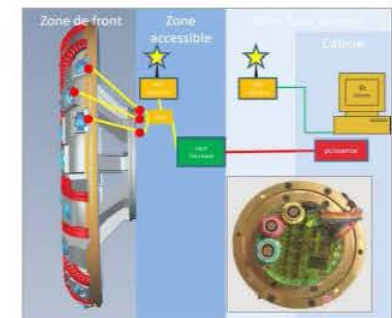
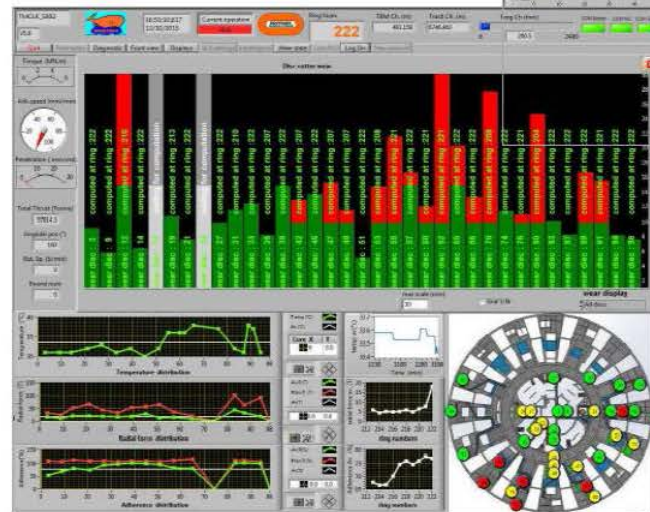
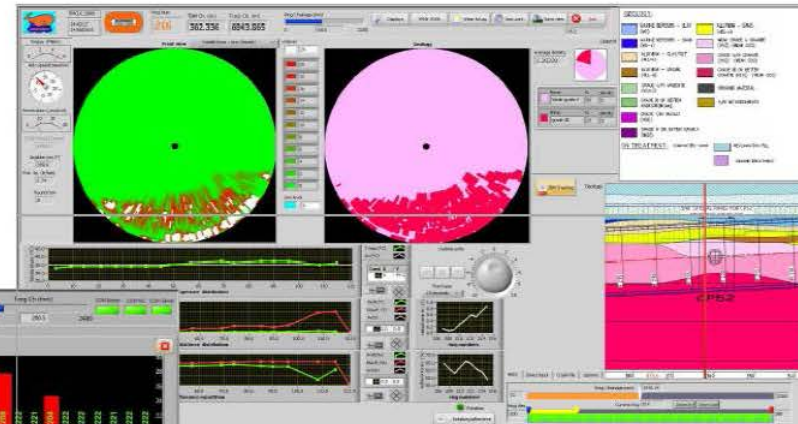
TBM Cutterhead Monitoring System:

MOBYDIC (BYTP)

- Real time geological face mapping
- Real time cutter disc wear status

→ Allows TBM driving parameters to be adapted

→ Helps to prepare and focus Hyperbaric interventions





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TMCLK – TBM Intervention Strategies

Saturation Technique

Daily Compression/Decompression cycle at high pressure constitutes :

- Increased **health and safety risk** for Divers
- **Less efficiency** due to limited working hours and long decompression time

→ Use of Saturation technique

- Keep Divers in hyperbaric environment during **longer cycle**: typically 28 days
- **Living habitat**: dedicated facilities with pressurized living chambers in surface



Surface living habitat



People involved

- 6 Doctors
- 3 Nurses (Day / Night)
- 45 Professional hyperbaric workers
- 12 live support technicians
- 3 Hyperbaric Operation Supervisors



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TMCLK – TBM Intervention Strategies

Saturation Technique

Pressurized shuttle transferred daily to TBM and directly connected to TBM hyperbaric chambers



Total Saturation Dives since Dec 2015:
> 300

Total discs changed in Saturation:
1000

The best dive:
13 discs changed

Maximum Intervention Pressures:
5.8 bars

No DCI or other health problems since the commencement in December 2015





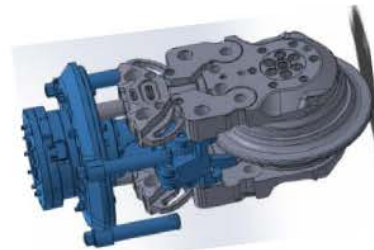
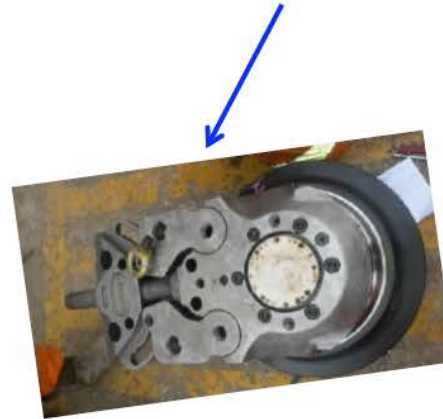
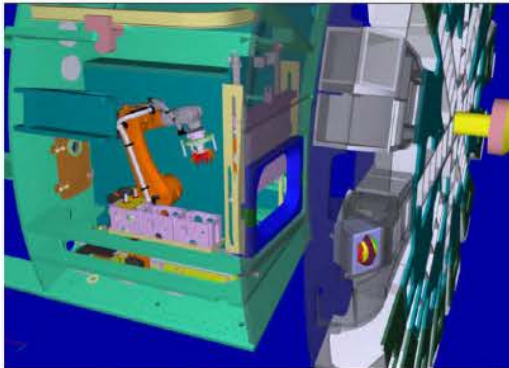
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TMCLK – TBM Intervention Strategies

Use of Robotic Arm to limit human intervention

- Limit human intervention under high pressure conditions
- Limit heavy handlings
- Cutterhead declogging and cleaning
- Cutter disc wear measuring
- Robotic arm in the TBM shield
- New cutter disc fixation (BYTP patent)

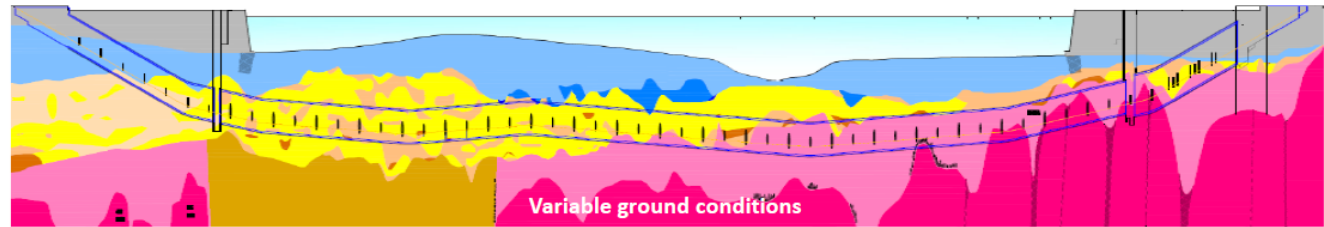
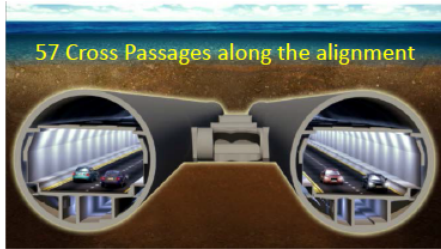




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TMCLK – Mechanized Cross Passages Construction of Cross Passages with Mini-TBM



Design development after contract awarded:

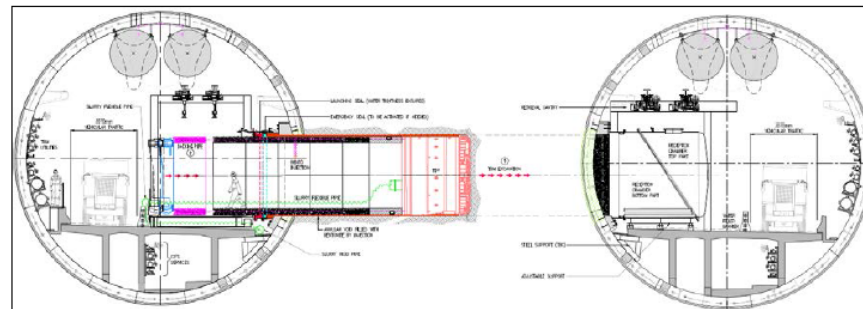
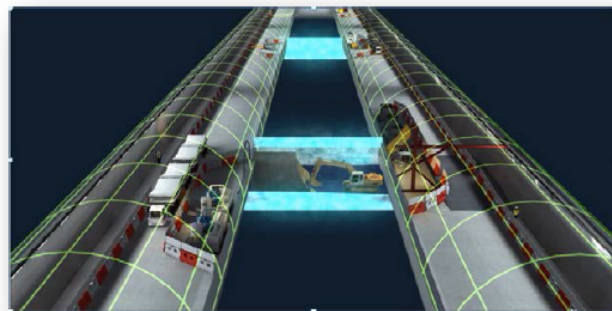
Change ground freezing method by pipe jacking TBM method

Purpose:

- Risk mitigation,
- Key Date to be fulfilled

Main Challenges:

- Launch/receive mini TBMs inside the main TBM tunnels under construction
- Strengthen/stabilize main tunnel segmental lining at CP locations
- Temporary & permanent sealing system to prevent water ingress/leakage under high water pressure



46 Cross Passages excavated with Pipe Jacking TBM

Target: 20 days/CP

2 TBM Ø3.665m launched from one Tunnel to another

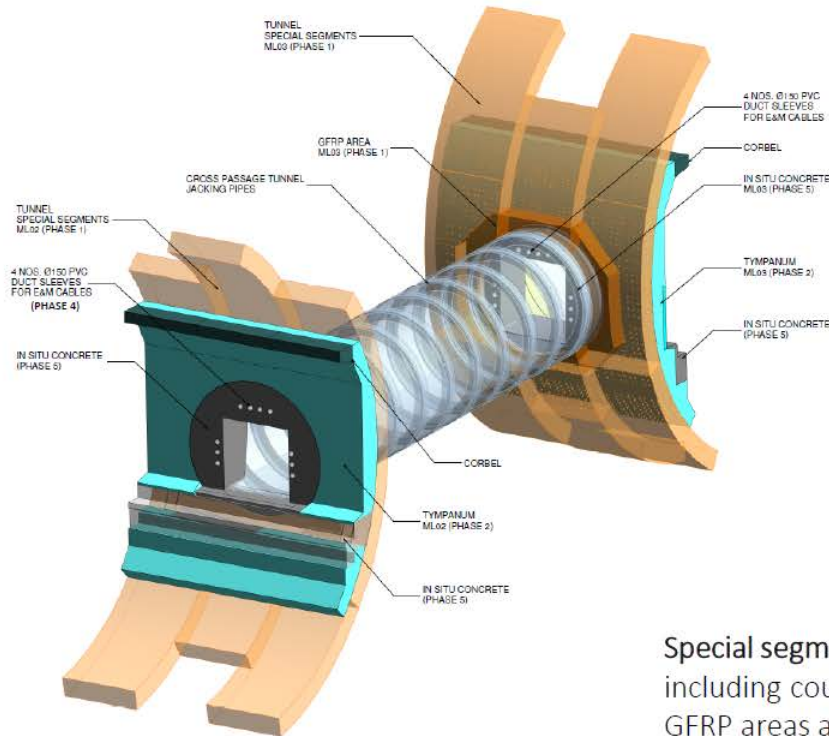


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TMCLK – Mechanized Cross Passages Structural Components

RC tympanum to reinforce the tunnel structure at CP opening and secure the tunnel



Precast jacking pipes creating the permanent lining as the TBM excavation progressing (PHASE 3)

Special segments including couplers and GFRP areas at tympanum location to prepare the break-in area in tunnel lining

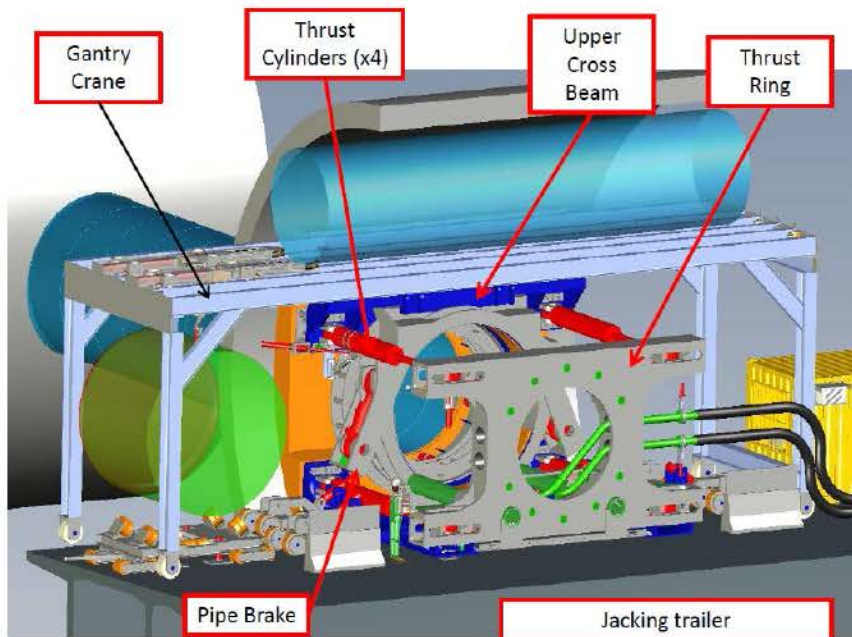




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TMCLK – Mechanized Cross Passages Launching Side – Pipe Jacking Equipment



Main Challenges:

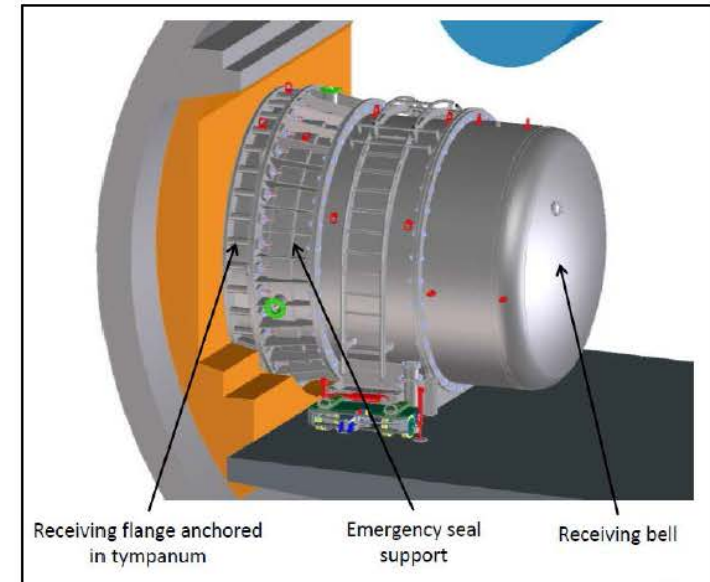
- Structural: Spread the TBM thrust loads to the Main Tunnel Lining
- Watertightness and ground stability to be maintained at any stage
- Logistics: compact equipment in order to always keep 1 lane for construction traffic



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TMCLK – Mechanized Cross Passages Receiving Side – Steel bell



After TBM Break-out in Steel Bell:

- Temporary watertightness ensured by Grouting at CP/Main Tunnels Interface
- Bell pressure lowered
- Bell opening and TBM retrieval





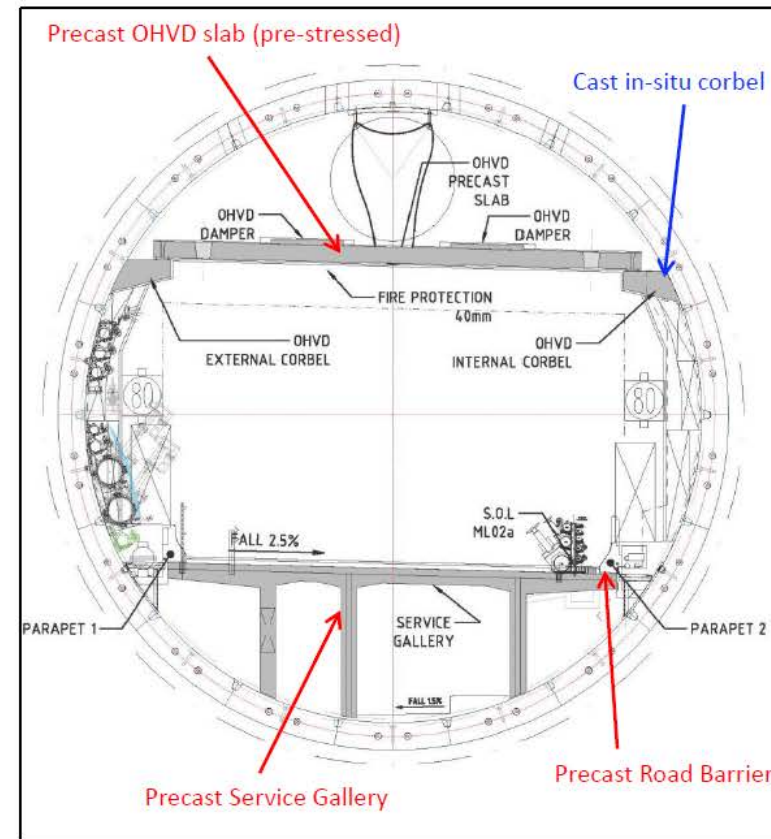
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TMCLK – Use of precast solution for TBM Internal Structures

Background

- **Very tight construction programme** for Tunnels Internal Structures (IS)
 - **Access to TBM to be maintained** during IS construction
 - Total length of tunnels \approx **10km**
 - Easy delivery of precast elements by barge (seawall available for berthing)
- Development of **precast solutions** for Tunnel Internal Structures
- Development of **specific tools** for each type of structure in order to make the installation as fast and efficient as possible





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TMCLK – Use of precast solution for TBM Internal Structures



Use of ISIG for Road structure installation

Extensive use of **DfMA**:
Precast Structural elements **Designed for Manufacture and Assembly**

Dedicated equipment for increased productivity and minimizing disturbance to construction traffic

Use of ISSG for OHVD Slab Installation





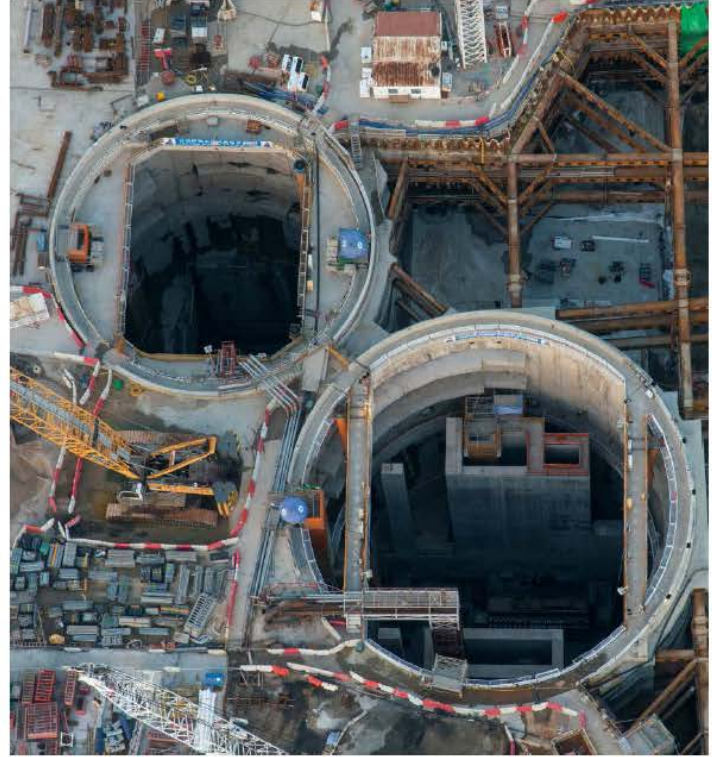
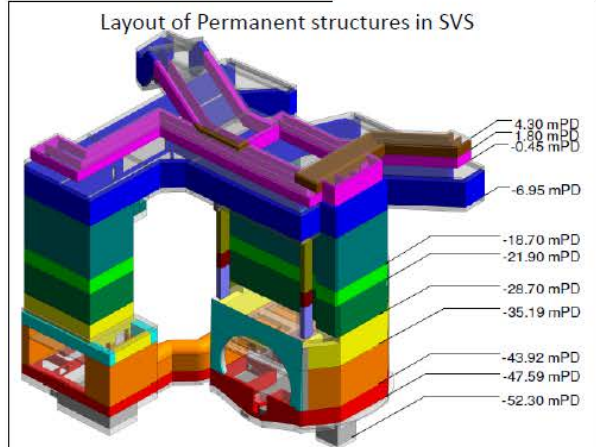
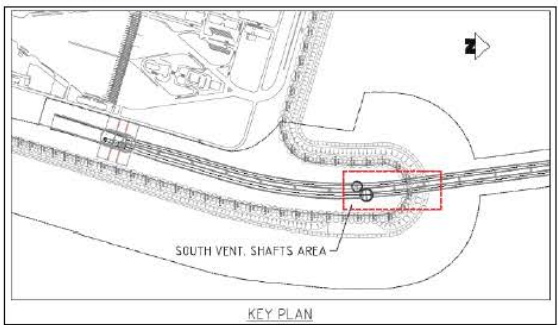
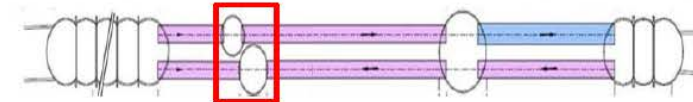
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TMCLK – Southern Landfall Challenges

South Ventilation Shafts

- ❑ 2 Circular Shafts – 33m/26m diameter
- ❑ 60m deep – 1.5m thick D-Walls
- ❑ Each shaft to be crossed by 1 TBM
- ❑ Permanent Ventilation ducts connecting Tunnels to adjacent South Ventilation Building





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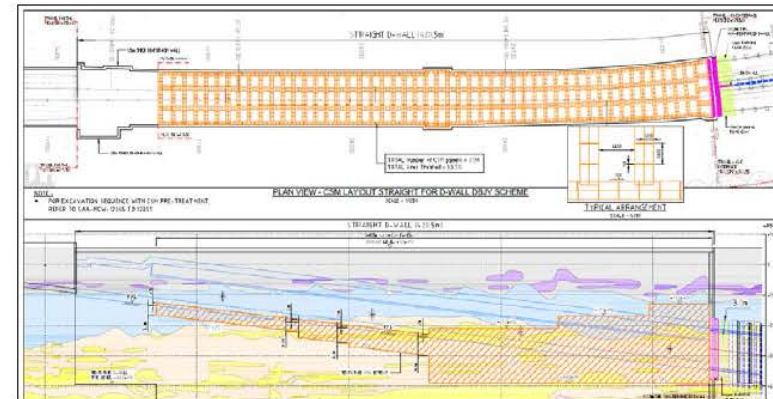
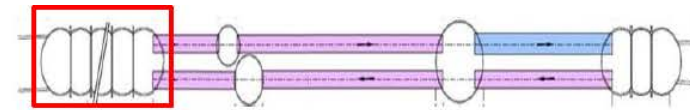


TMCLK – Southern Landfall Challenges

South Cut & Cover

Cut and Cover Section – Straight D-Walls Option

- Extreme density of strutting layout
 - 9 layers – 6m horizontal spacing
 - Huge loads with no extra capacity
- High risks associated to existing lateral movements of the reclamation



- Need for **extensive Ground Treatment** (CSM – Cutter Soil Mixing) to compensate lack of consolidation in Clay layers
 - ELS stability relies upon Ground treatment





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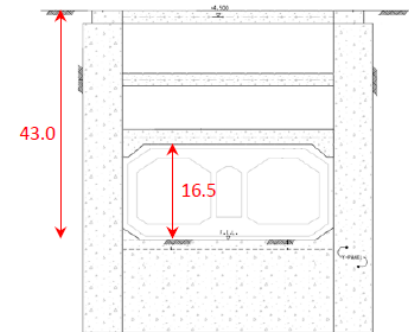
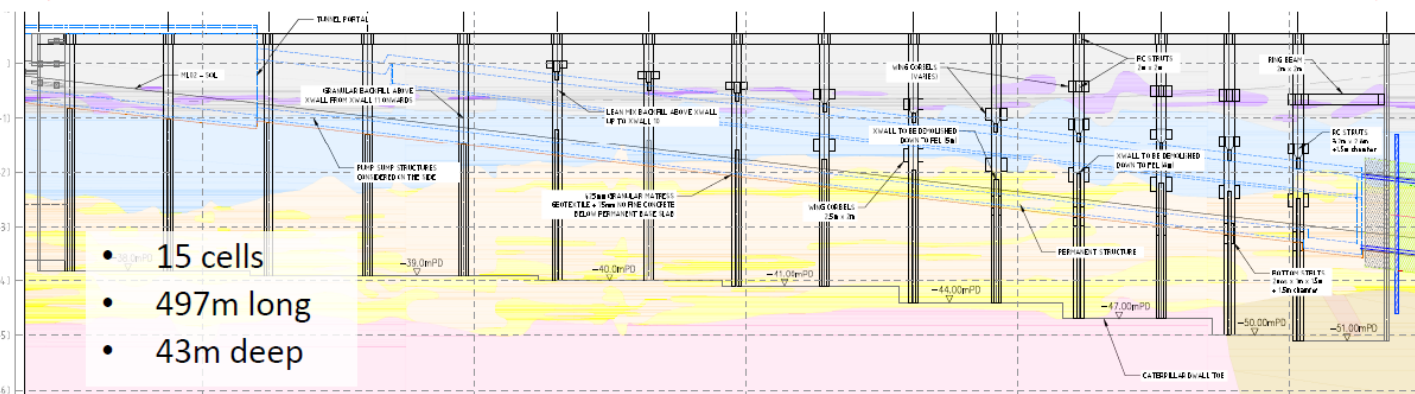
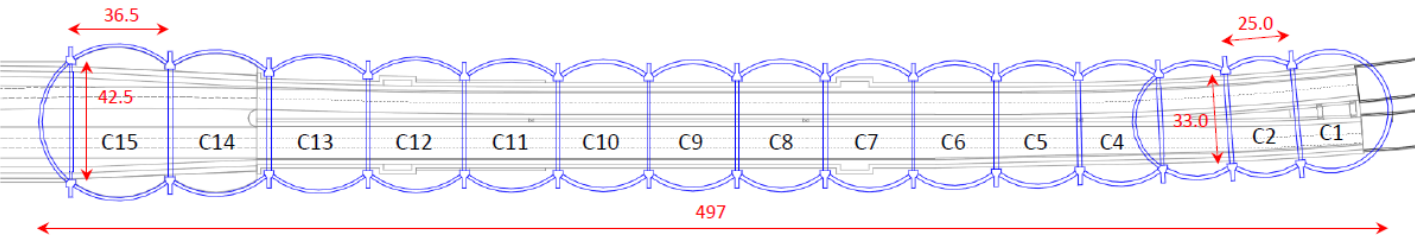


TMCLK – Southern Landfall Challenges

South Cut & Cover

Cut and Cover Section – Caterpillar Scheme

- Final scheme : 15 cells caterpillar cofferdam – 432 D-wall Panels
- Only 14 numbers in total of intermediate RC strut allowing for **fast excavation**
- Virtually **no lifting window restriction** due to strutting scheme
- No repropping at all, **continuous and smooth permanent structure construction**





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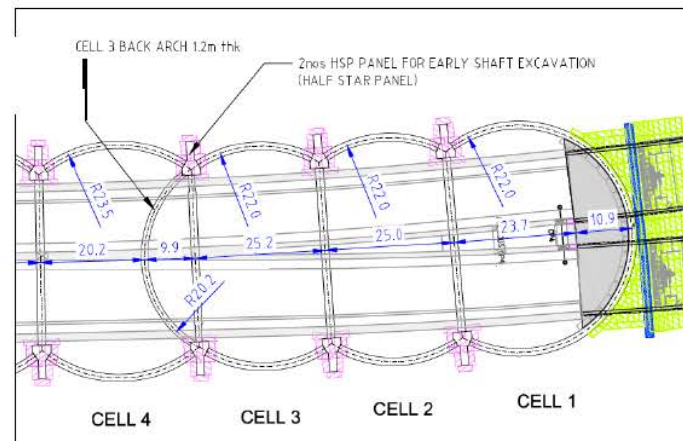
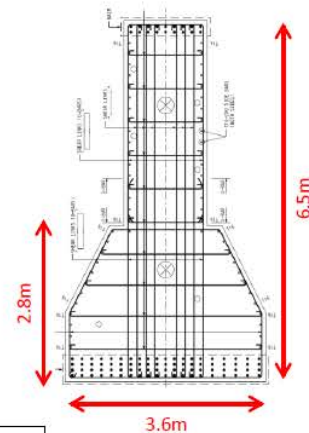
TMCLK – Southern Landfall Challenges

South Cut & Cover

Cut and Cover Section – Caterpillar Scheme

Main Technical Challenges:

- Y-panel construction:
 - Special panel with extra large dimensions
 - Requires in-situ steel fixing
 - Trench stabilized with Cutter Soil Mixing panels
- Staged excavation:
 - closing of 3rd cell with additional arch to allow early excavation of Cells 1 to 3 for TBM break-out





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TMCLK – Southern Landfall Challenges South Cut & Cover

Cut and Cover Section – Caterpillar Scheme





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Environmental Efforts : Sustainable Construction

➤ **Chinese White Dolphins :**

Hong Kong emblematic specie (Protected)

- 250m Dolphin Exclusion Zone
- Dolphin watchers / Hydrophones / Cetacean Detectors
- 0 incidents



➤ **Coral translocations:**

Hong Kong emblematic specie (Protected)

- 56 colonies to be translocated
- 100% transplantation successful
- Quarterly monitoring after translocation
- 0% mortality



➤ **Innovative construction solutions with reduced footprint:**

- Mechanized CP : 80% energy reduction compared to freezing
- Tunnel DfMA Approach : less site pollution and waste
- TBM alternative for Northern Ramps : -61% spoil / -12% MD
- Caterpillar for Southern Ramps : saving of 21'000 T of steel / 80'000m3 of ground treatment





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Safety, Health and Welfare :

➤ **A forward-thinking approach to Safety:**

- Holistic involvement from Executive Management to workers
- Technical innovations driven by safety considerations from the start (automation, robots, temp. works, full time technical ergonomist)
- Genuine safety incentives and day-to-day safety animations
- Track record of 0.39/100k m.hrs (industry target : 0.6/100k) for a total of 20 million man-hours
- Recognized safety strategy with more than 10 safety awards

➤ **Truly caring about employees health and well-being:**

- Canteen with 6 daily menus
- Fully equipped Gymnasium
- R&R zones
- Stretching exercises
- free medical exams
- Health promotion campaigns





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Working as a Community :

➤ A real emphasis on our communities:

- A site by definition within as a cross-boundary project
- Strength in diversity : more than 10 different nationalities working together, regular cultural gathering, events and animations
- Proactive liaison groups to understand our neighbors and to address their concerns
- Heavily invested in the local economy (85% of the works done with local companies)



➤ A spirit of Partnership:

- A collaborative approach with client and stakeholders
- Sharing events with our partners and interfacing contractors





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THANK YOU

