Last experiences with tunnelling in the Netherlands, in particular the shield tunneling in the project Betuweroute

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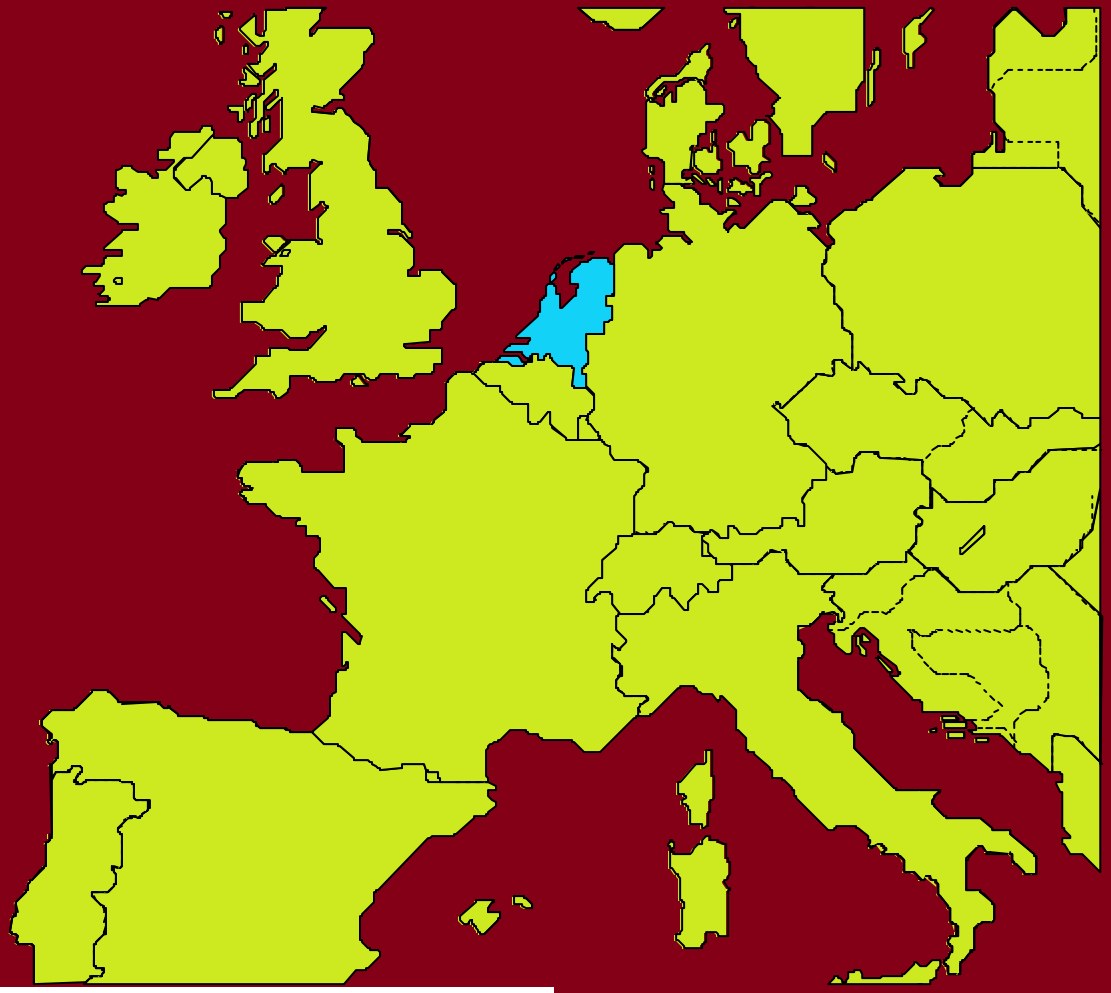
Betuweroute

Synopsis

- Development of shield tunnelling in the Netherlands
- The project Betuweroute
- Objectives tendering shield driven tunnels
- Offers contractors concerning the TBM's
- Experiences and results
- Conclusions
- Recommendations

the Netherlands



Open questions

by starting shield driving in the typical dutch underground conditions

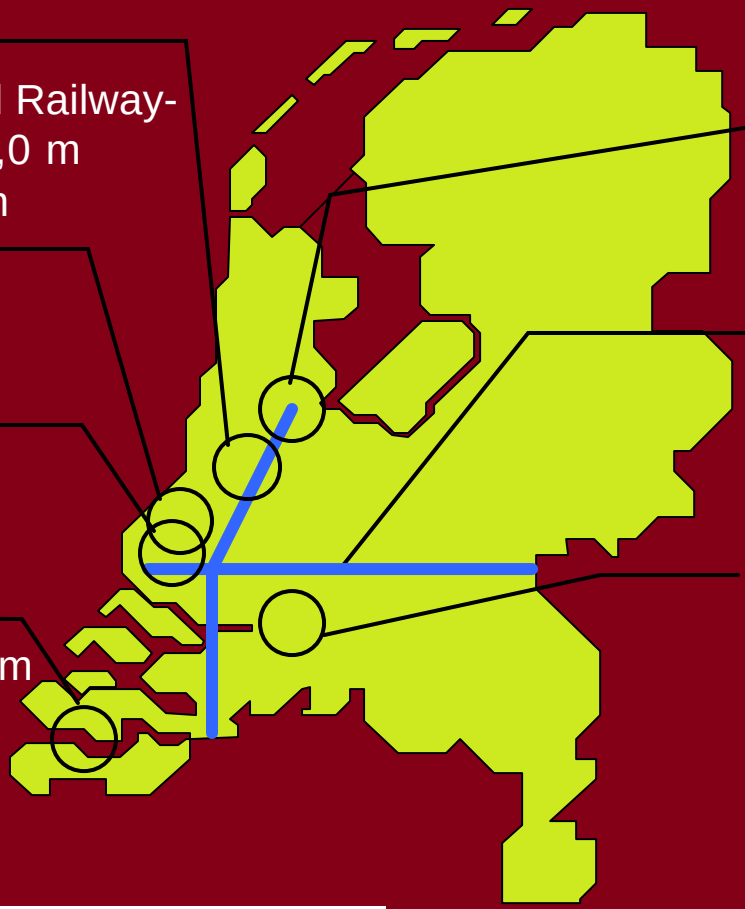
Underground conditions:

- soft and strong settlement holocene layers
- high water pressure

?

possibility of exact driving?
safety of the face stability?
safety for a long-term tightness?

Overview shield tunnels in the Netherlands



HSL - Zuid
High Speed Railway-
tunnel ø 15,0 m
1 x 6.570 m

The Hague
road tunnel ø 9.0 m
2 x 1.500 m

Rotterdam
metro tunnel ø 6.65 m
2 x 2.500 m

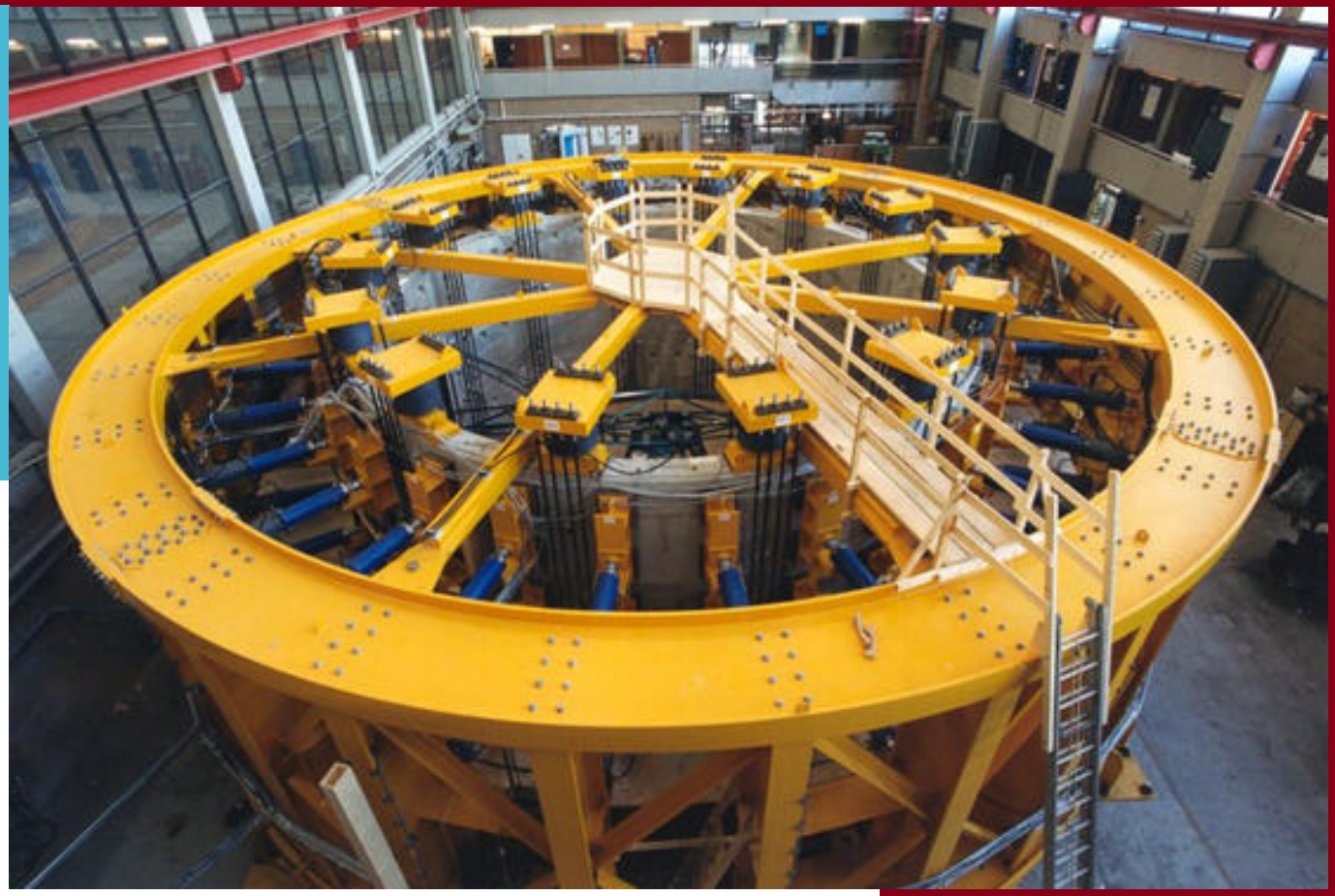
Westerschelde
highway tunnel ø 11,33 m
2 x 6.600 m

Amsterdam
metro tunnel ø 6,65 m
2 x 3.500 m

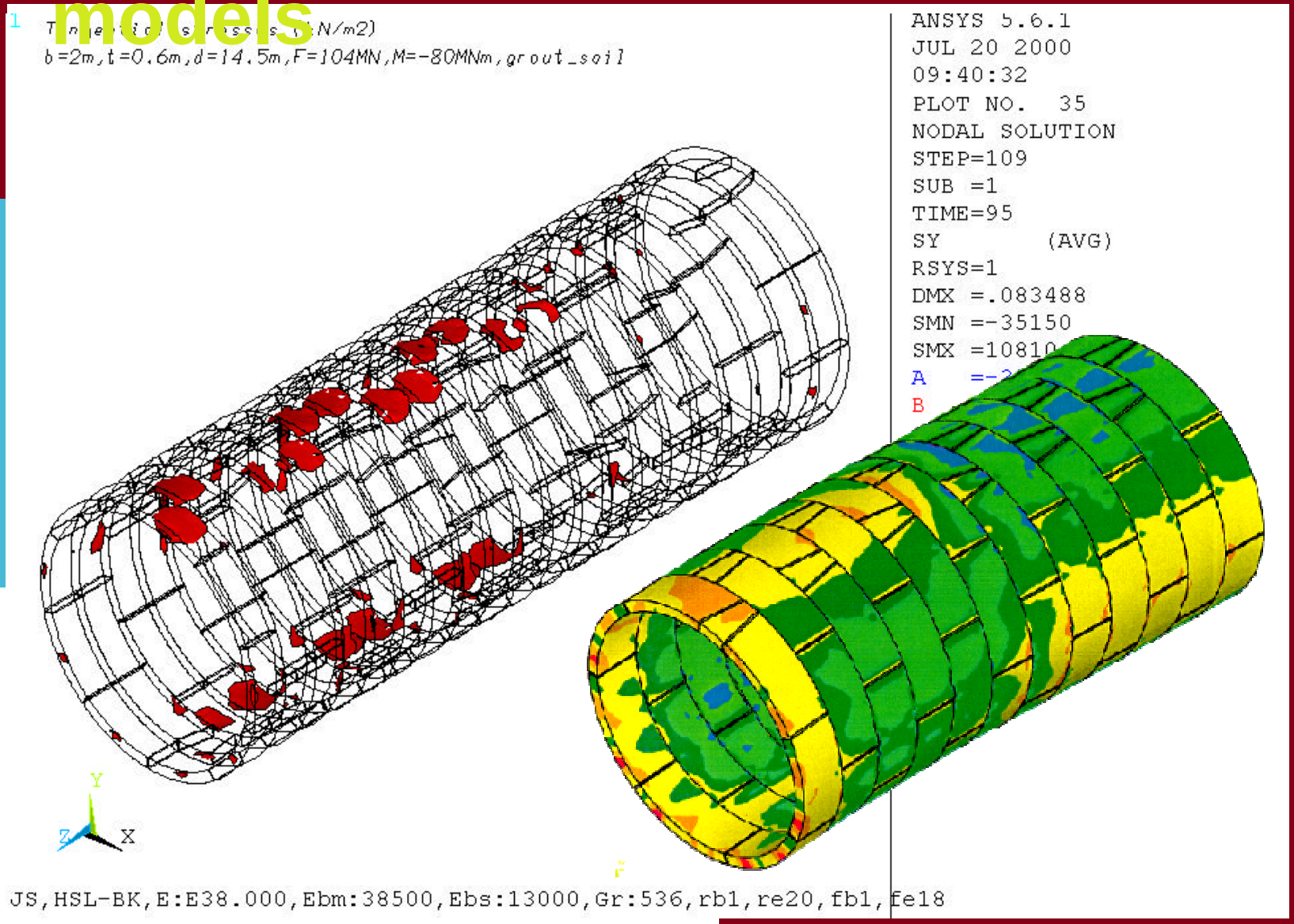
Betuweline
railway tunnel ø 10,0 m
3 shieldtunnels
Total 2 x 7.660 m

Heijnenoord
road tunnel ø 8,3 m
2 x 950 m

Full-scale laboratory test facility Delft



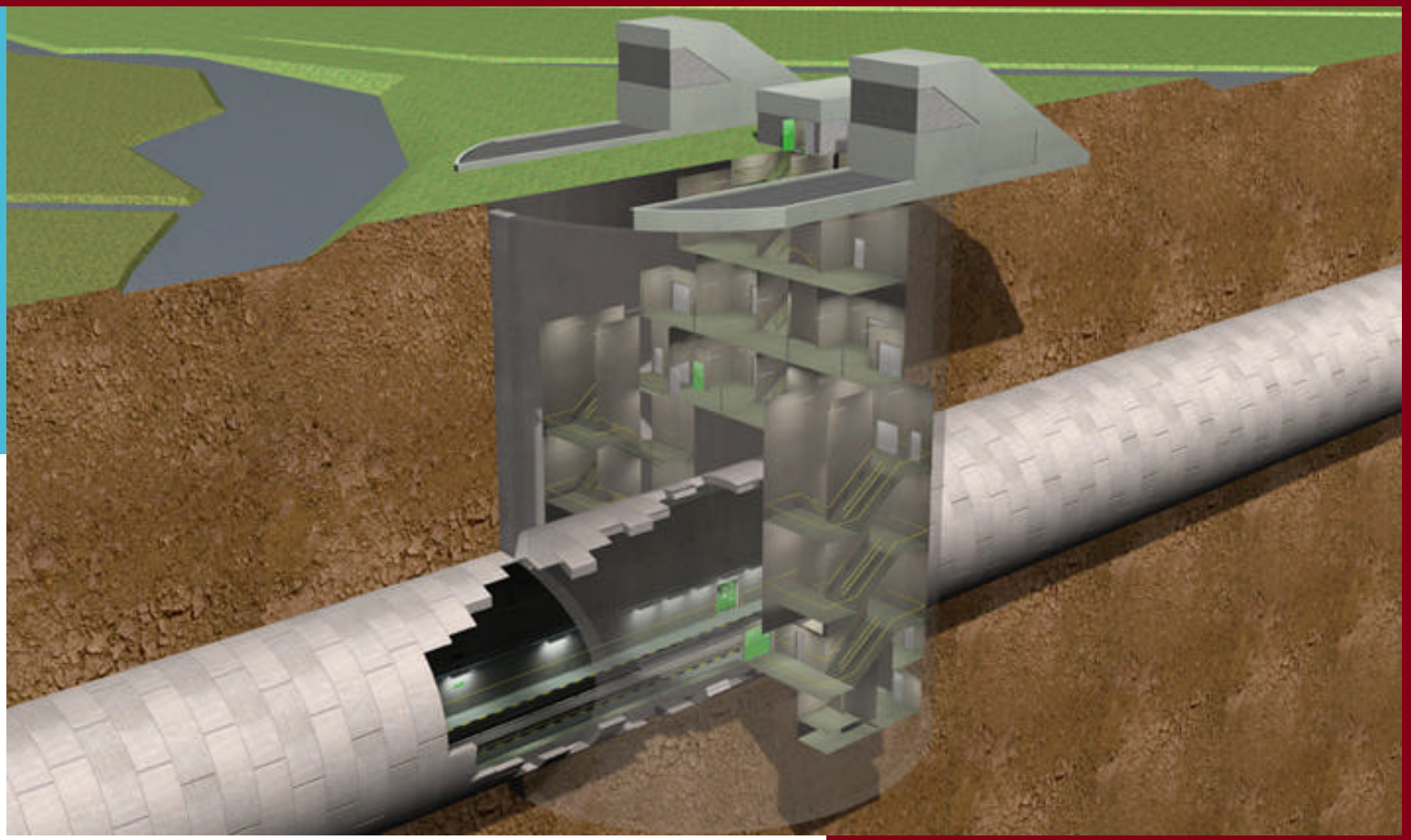
Damage Prediction with FEM models



Driving experiences in the Netherlands

- EPB-machine in sandy soil and 3,5 bar (water)pressure
- Continuous driving with a slurry machine
- Shield driving to a depth of 60 meters (changing tools by divers included)
- Shield driving with the world's largest diameter shield

HSL-Zuid emergency shaft



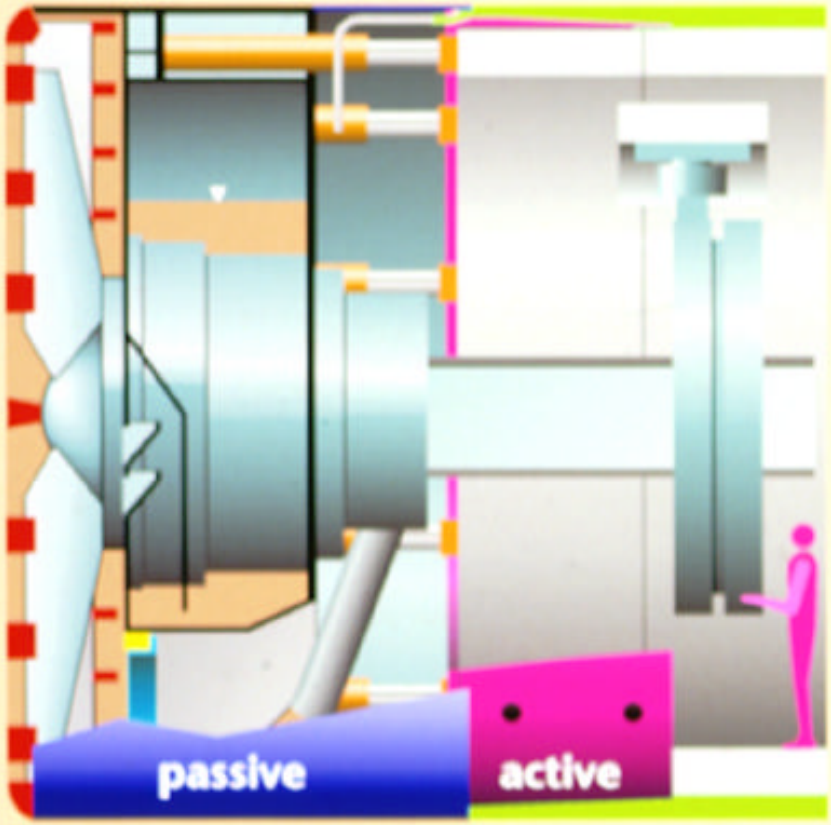
New development in TBM's in the Netherlands

- **Compact shield**
  (a very short shield to reduce settlements by driving between wooden pile foundations)

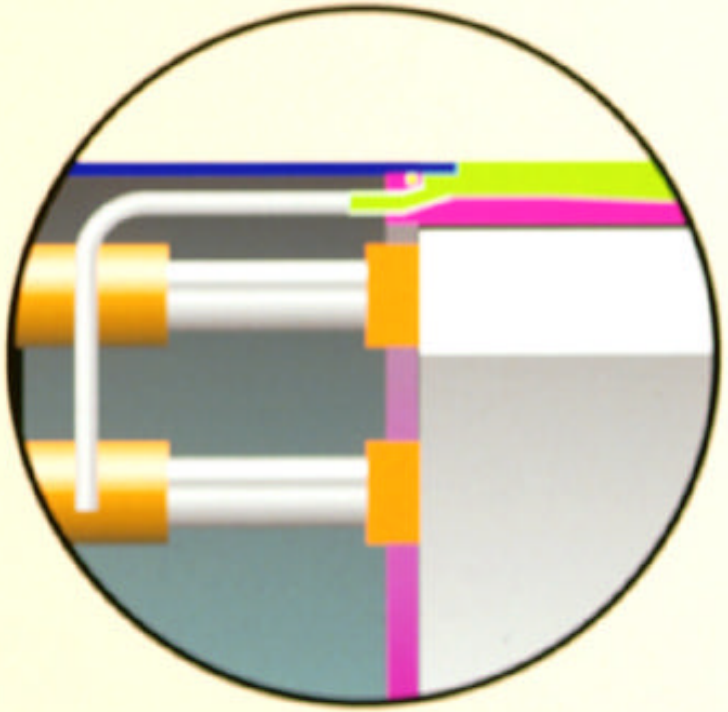
- **ITM-method: Industrial Tunnel Building method (continuous driving and extruded concrete lining)**

Vario-shield system

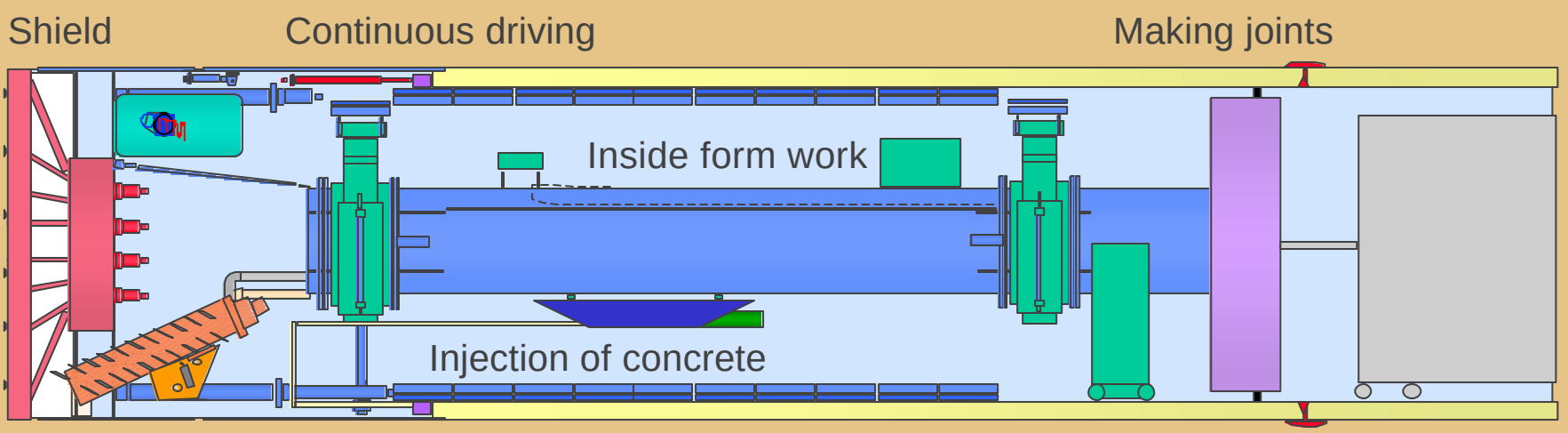
compact shield with active groundsupport around shieldtail



Metro Amsterdam



Industrial Tunnel building Method



Basic concept

Project Betuweroute

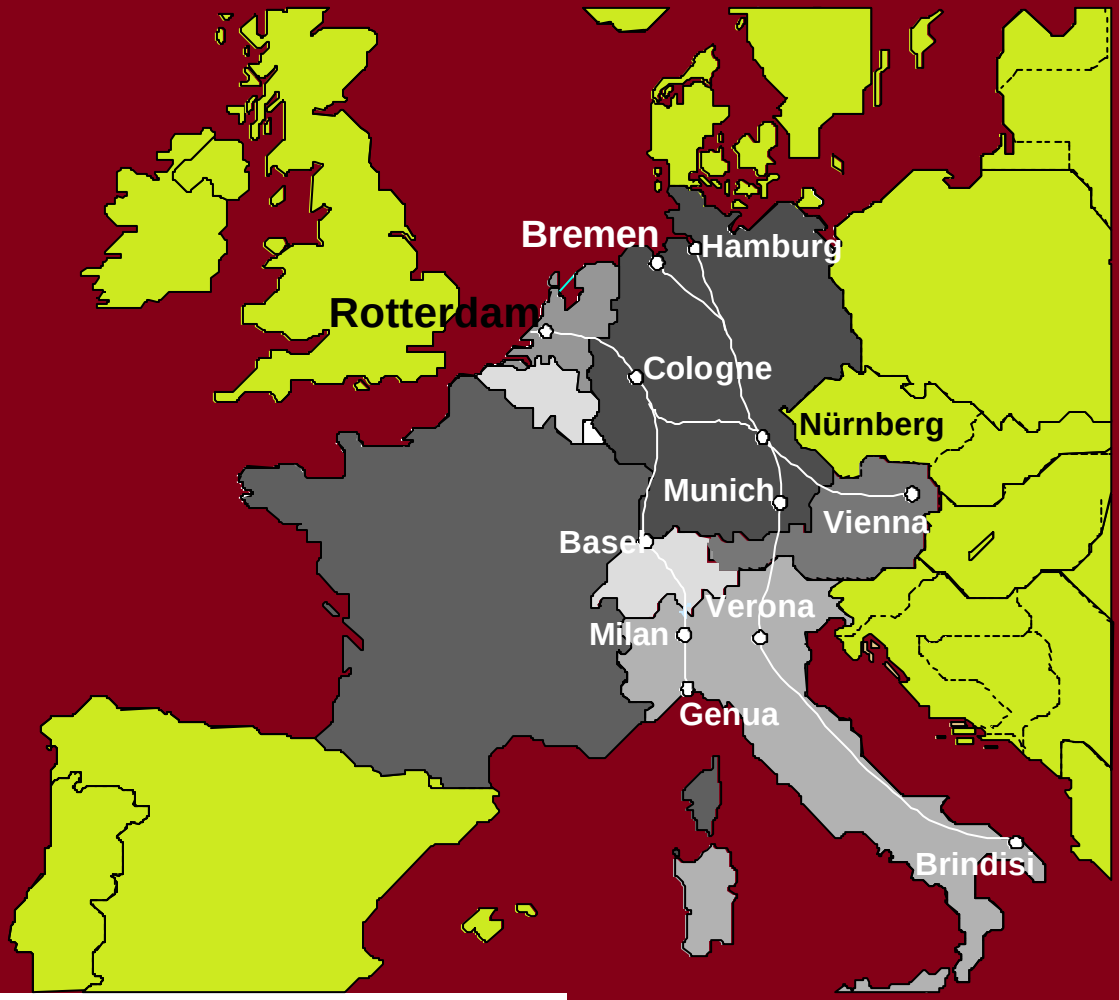
- New railway link from Rotterdam Harbor to German border
- Only for freight transport
- Total length 160 km
- Total 15 km tunnel
- Of witch 7.5 km shield driven

Botlek Railway tunnel

Sophia Railway tunnel

Tunnel Pannderdensch Canal

Overview railways for freight transport



The three shield driven tunnels at the Betuweroute (1999 – 2002)

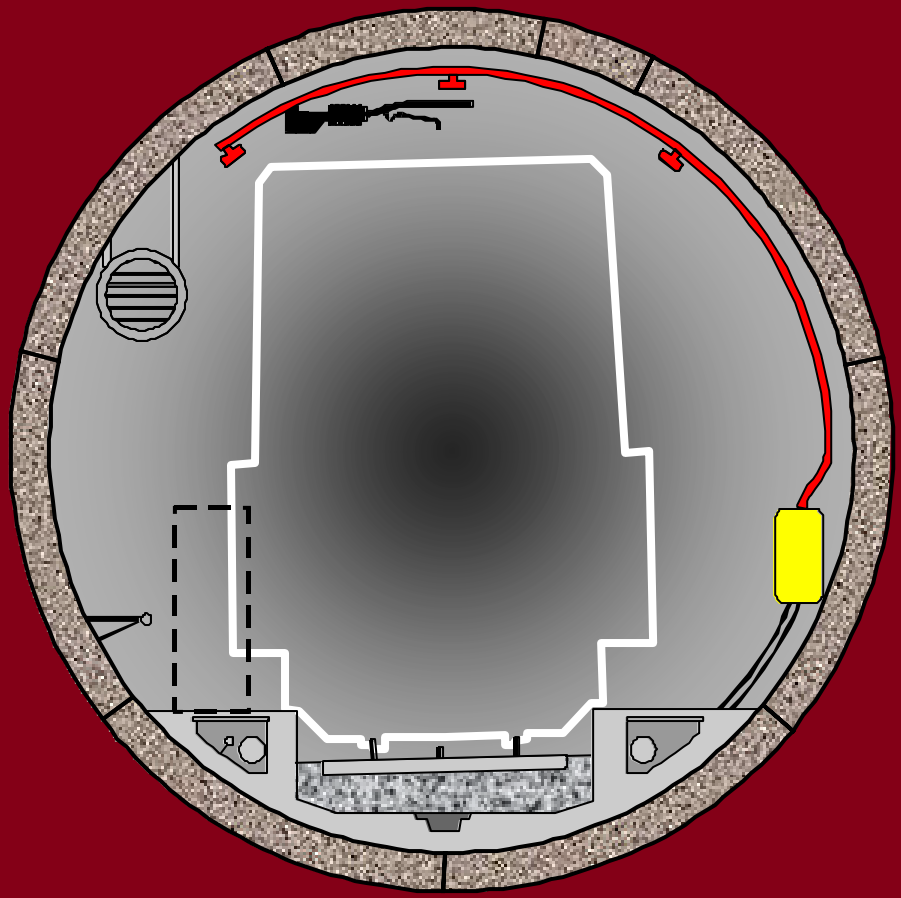
- Three times nearly the same (ins. Diameter 8.65 /crossing a river / twin tubes / max. slopes 2.5%)
- But still every time different and special

Botlek
Railway tunnel

Sophia
Railway tunnel

tunnel
Pannerdensch Kanaa

Cross section with sprinkler



Diameter (inside) 8.65 m

Tunnel suitable for double stack

Objectives tendering
(design and construct contracts)

- A TBM with a set of mitigating measures, to overcome critical situations that we could expect out of the reference design
- Incentives to the contractors to offer innovative TBM's / solutions (ref. design: slurry mode)
- We (client) want to know what happens during the shield driving
- To control the settlements (max. 25mm)

Client requirements in the tenderdocuments

– Mitigating measures:

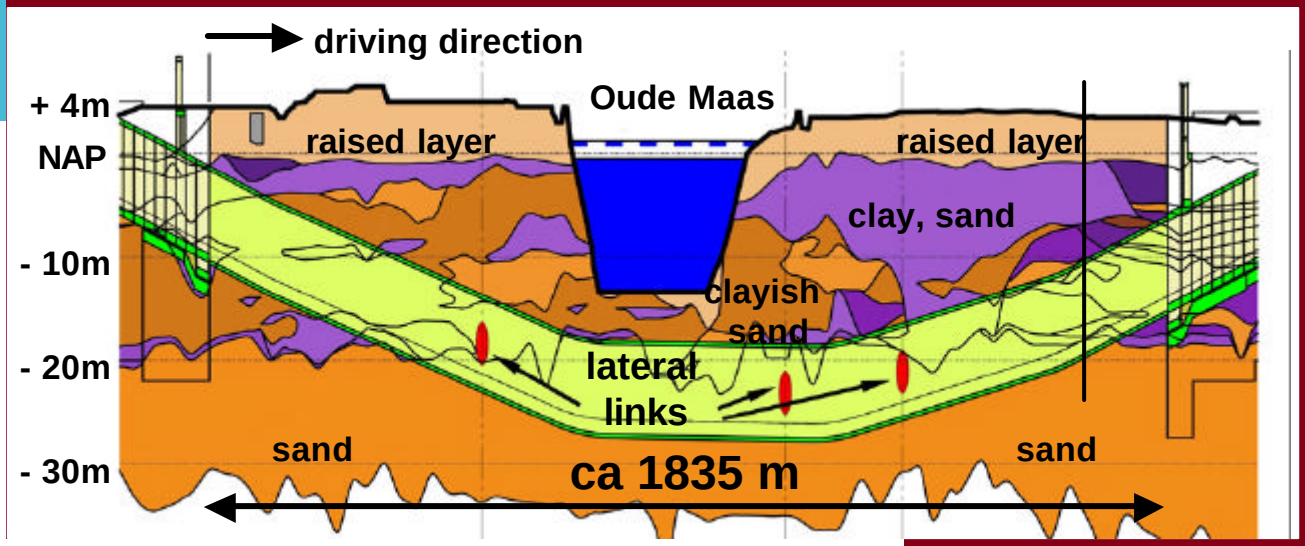
State of the art:
- cutterhead translation
- ground injectionpoints inside and around the shield
- variable overcutting
- extensive process control
- extensive monitoring

Innovations:
- ground investigation ahead the TBM (SSP
- mass-volume balance system
- measure wear on cutterhead tools

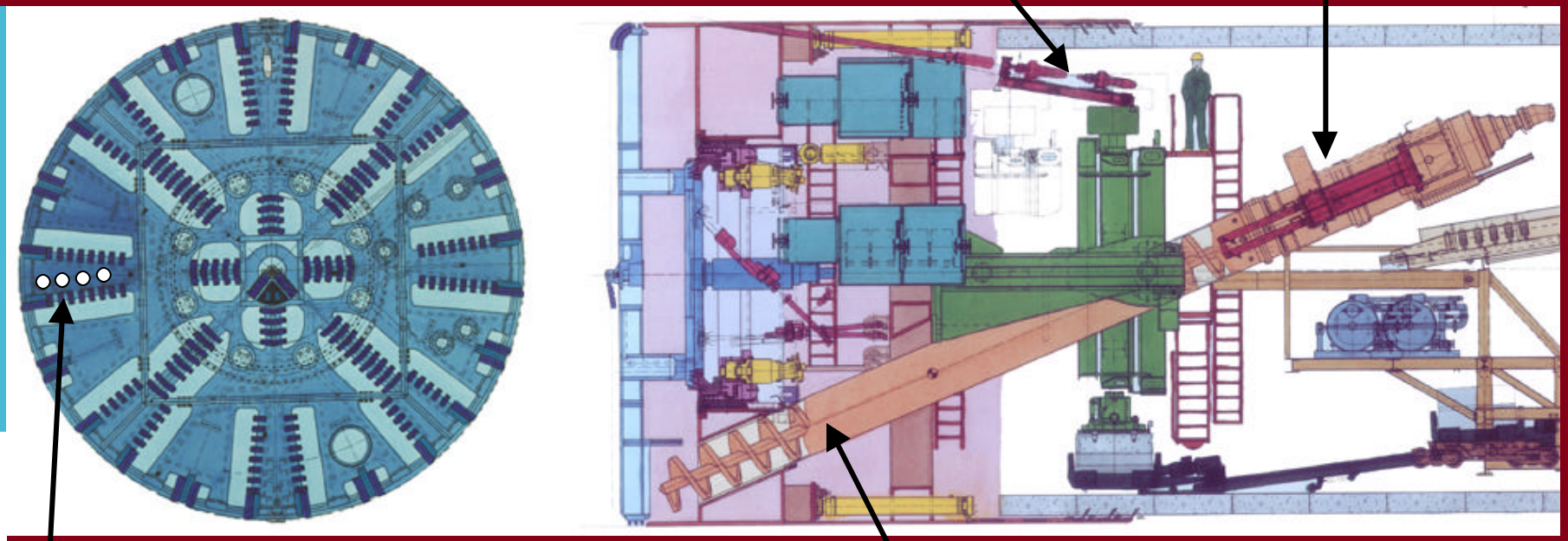
– Failure analysis

Offer contractor Botlektunnel (BTC v.o.f.)

TBM:
- EPB mode (in spite of sandy soil (60%) and 3.5 bar water pressure)
- Hydraulic mud transport, even with pumps at the end of the screw conveyor

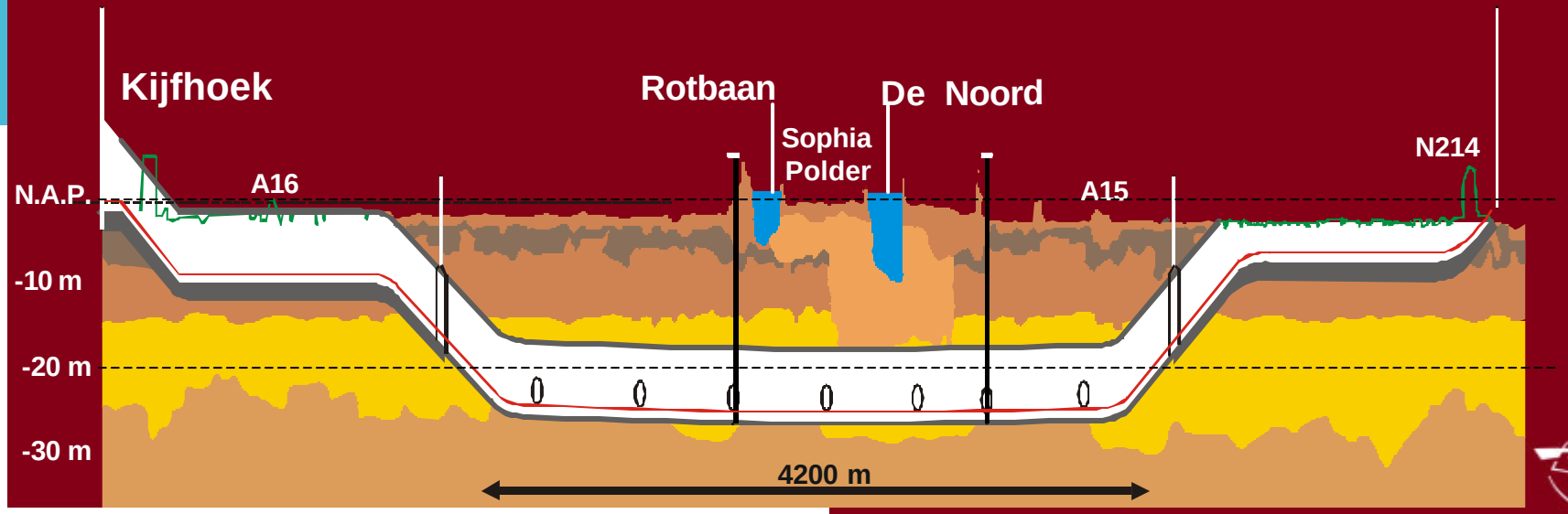


EPB-shield Botlek tunnel



Offer contractor Sophia tunnel (Tubecon v.o.f.)

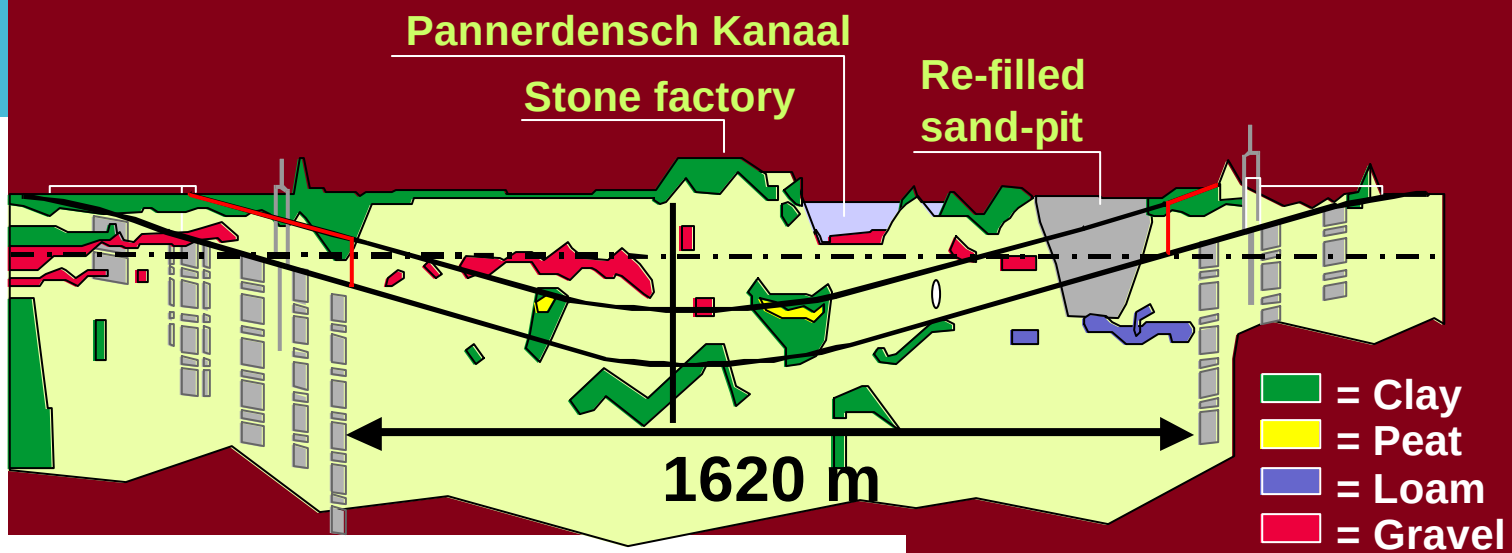
Innovation:
- one TBM - slurry mode - designed for the normal and Continuous drive mode
- Logistics design: 40 m/day




Soil-breasting plates
Sophiaspoortunnel
TUBECON I

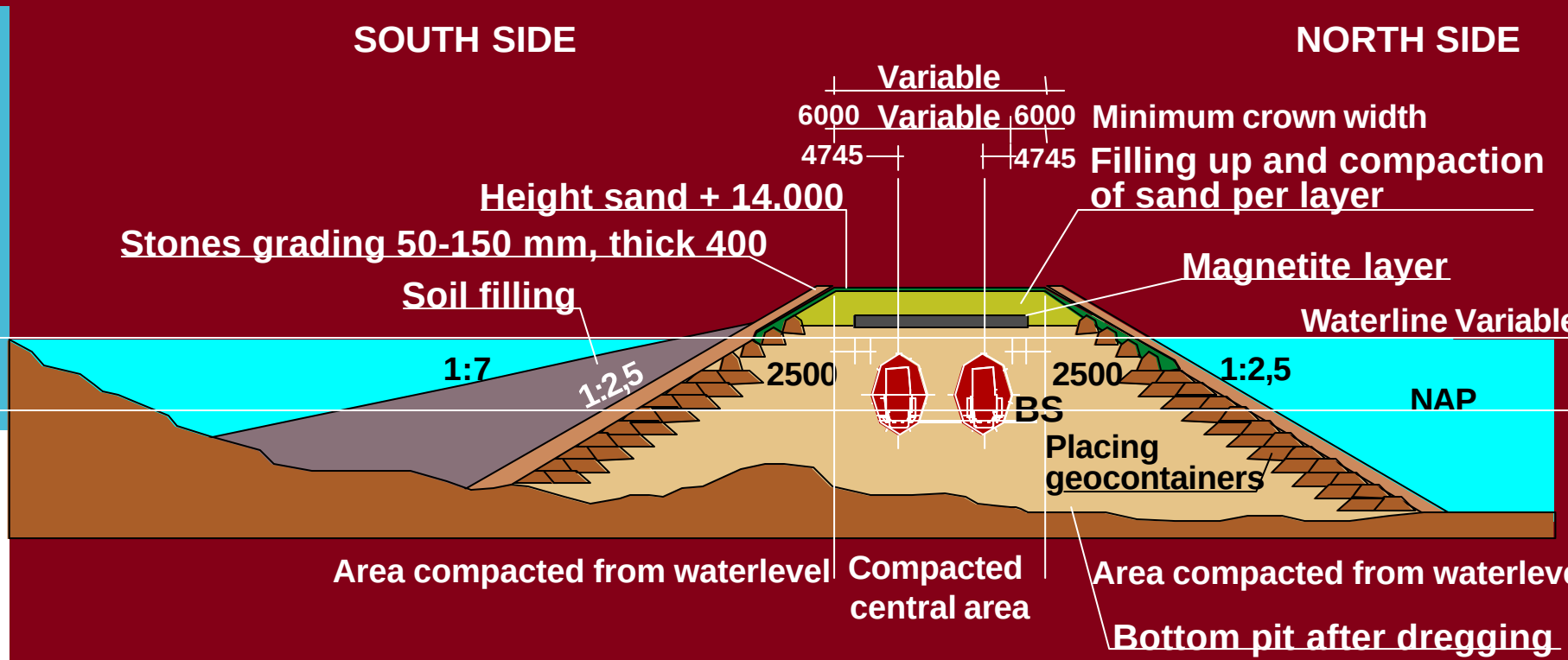
Offer contractor Pan. Canal (Comol v.o.f.)

- Using an overhauled TBM completed with clients requirements
  (in the past used in Caïro and Dusseldorf)
- A familiar slurry machine



Kandiadam

Basic plan Kandiadam



The experiences with the TBM's learns

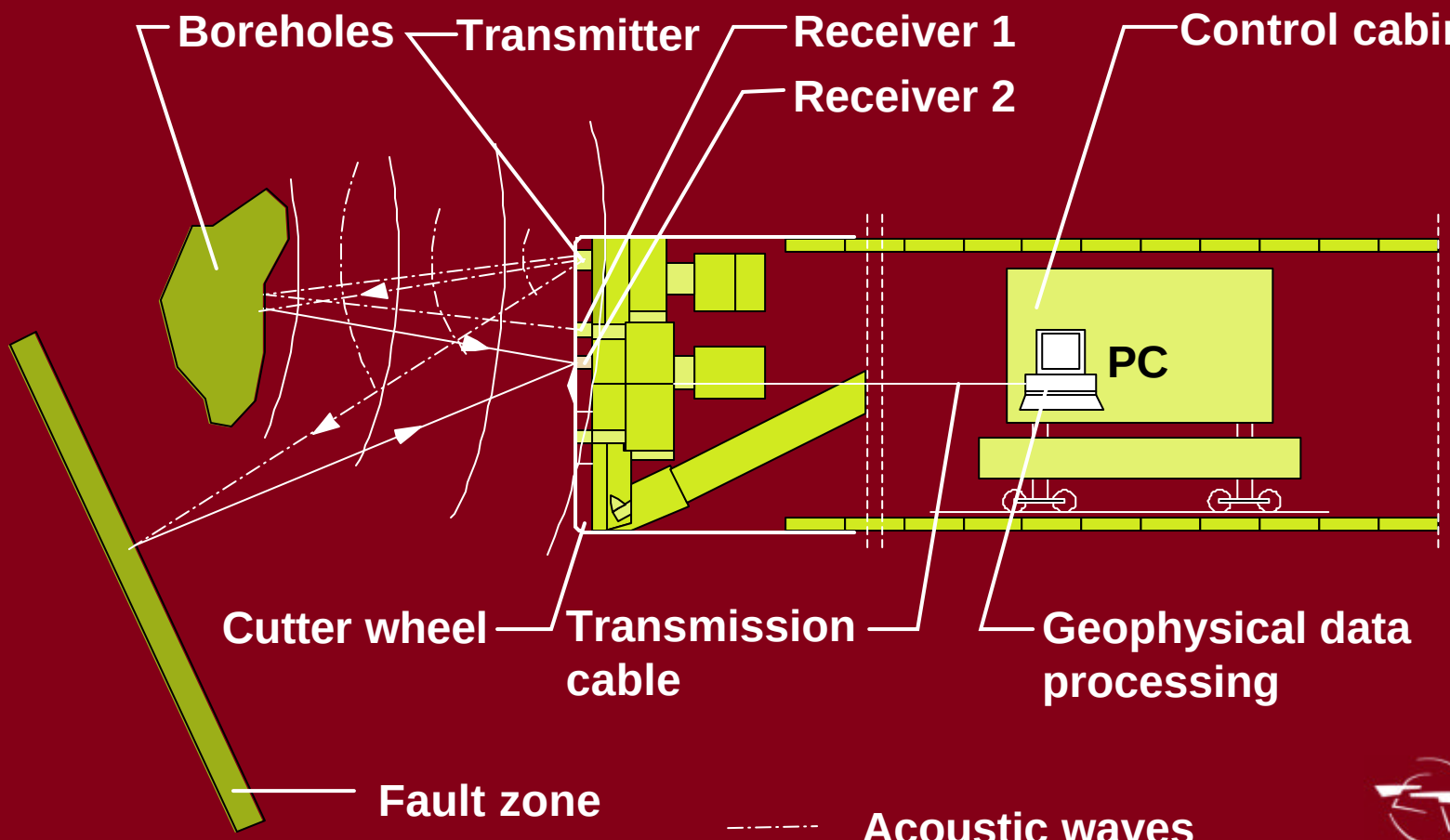
Botlek: The choice of the right foam makes the EPB technique widely usable, also in coarse sands.

Sophia: The tunnel is build in the normal drive mode. The executed tests with the continuous drive mode have showed that the system works. Further development is necessary

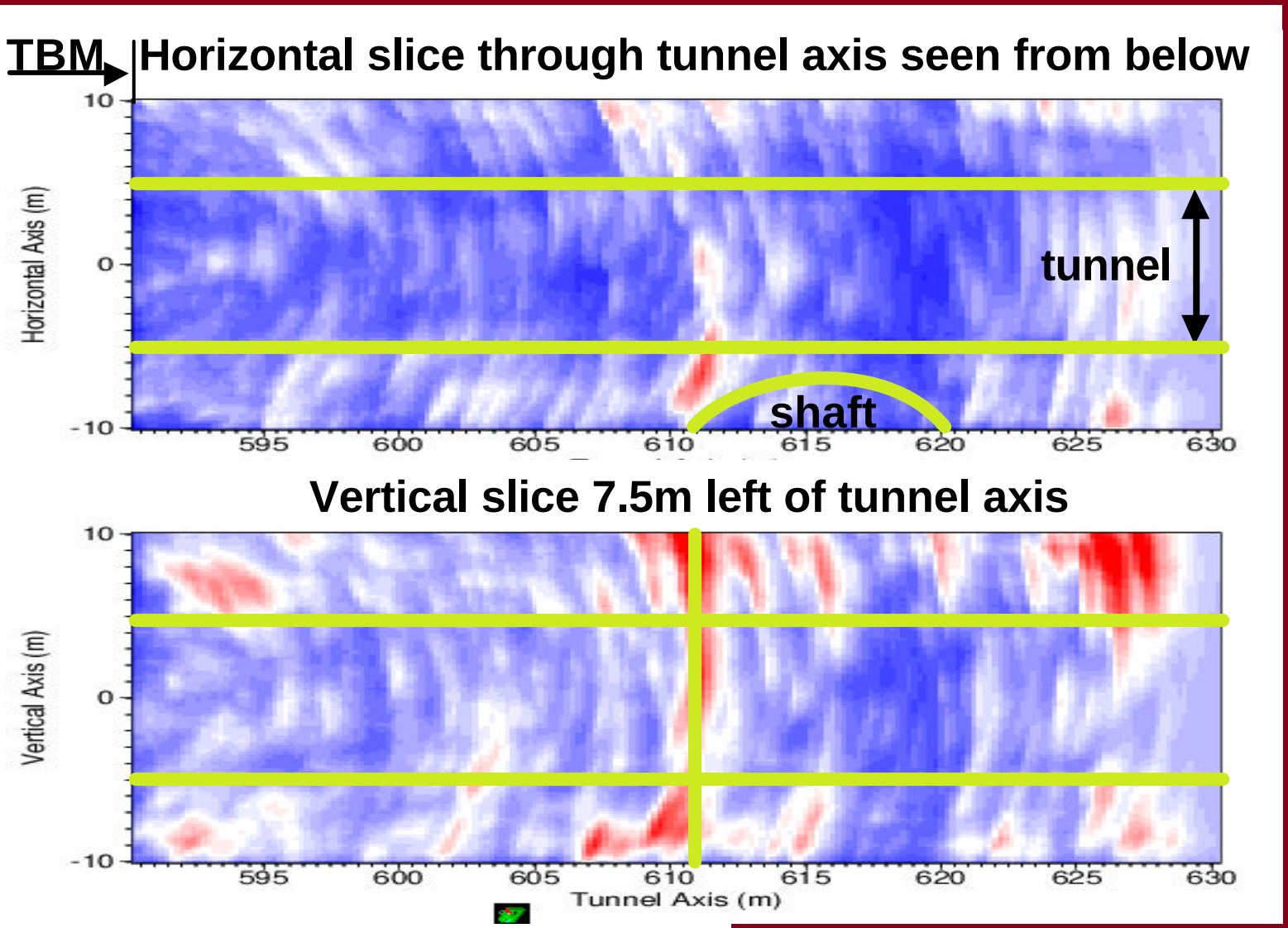
Pan. can.: Not many technical breakdowns. The use of mass-volume balance systems was successful.

Sonic Soft ground Probing

target: receiving information about changes of the geological formations or potential obstacles at a distance of 40 m in front of the cutterhead (on line)



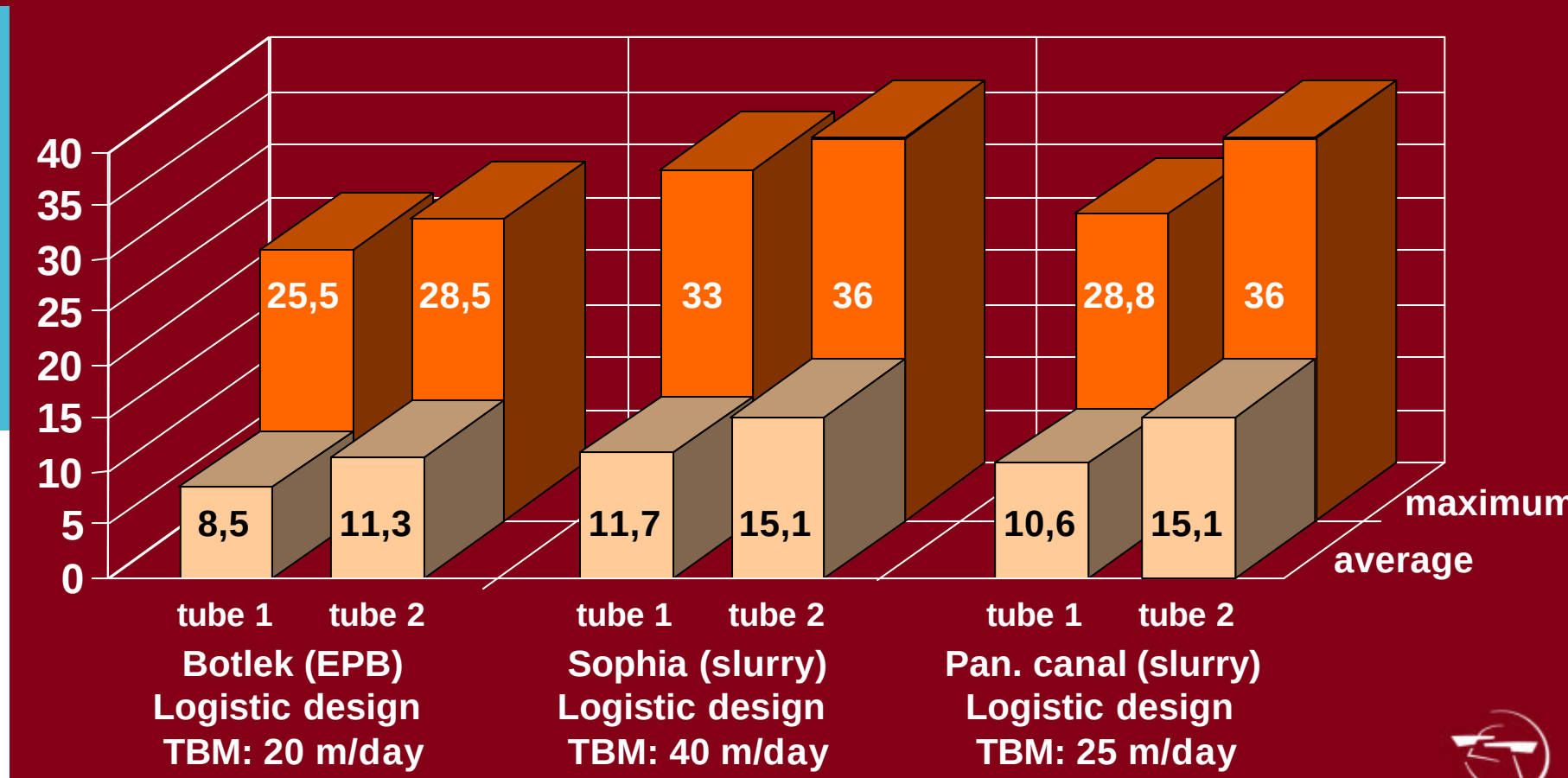
Shaft cross connection



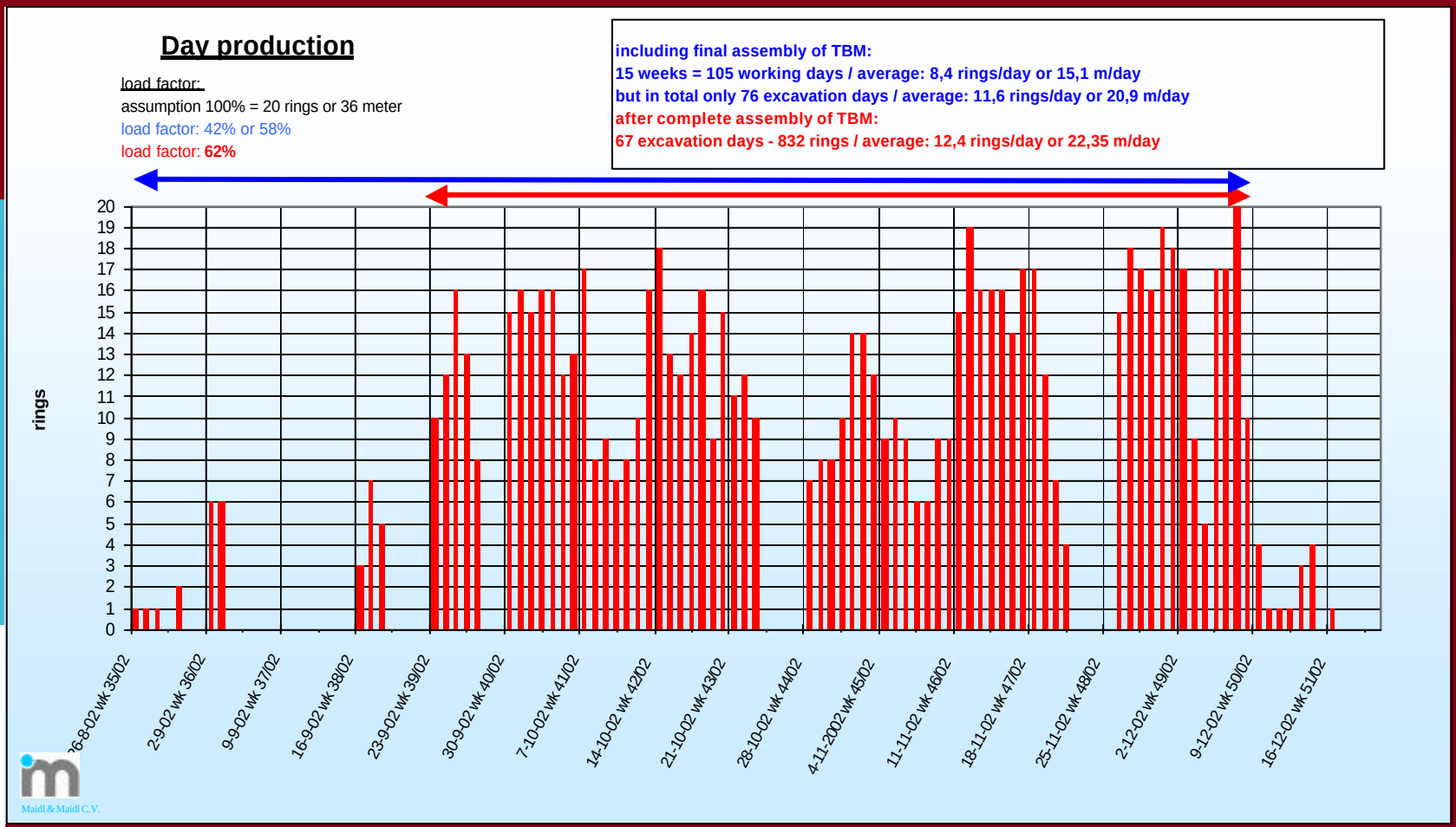
Tunnel lining

	Botlek	Sophia	Pan.Canal
			
system:	7+1	7+0	7+1
keystone:	small	large	small
thickness:	40 cm	40 cm	42 cm
length:	1,50 m	1,50 m	1,80 m
jointmaterial:	kaubit/plywood	kaubit/plywood	kaubit/none
ring coupling:	sock/dowel	sock/dowel	sock/dowel

Day performance TBM

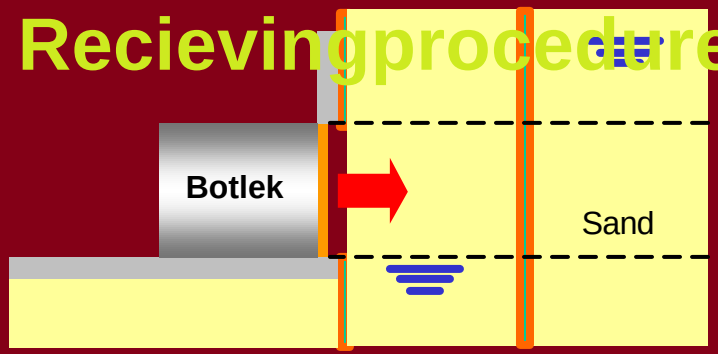


Construction time Pan.Canal Northtube

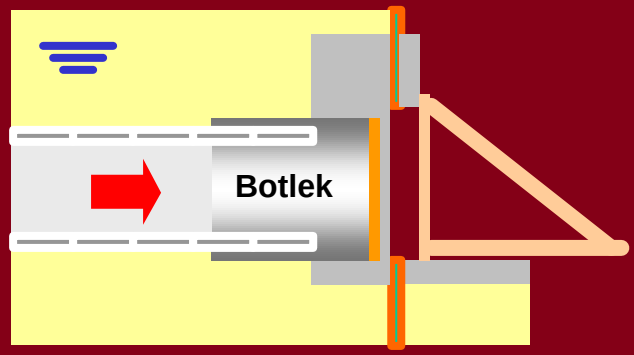


After complete assembly of TBM:
average 22,35 m/working day

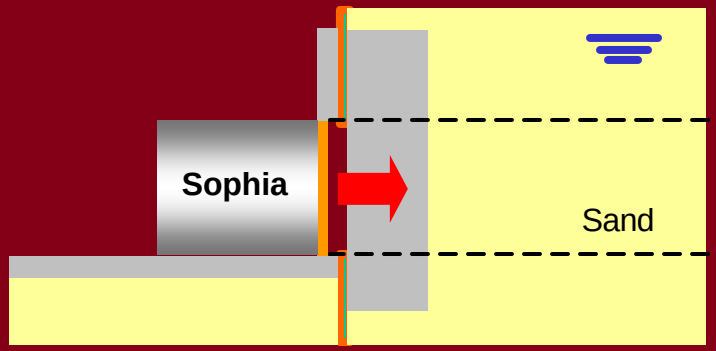
Startingprocedure
Recievingprocedure



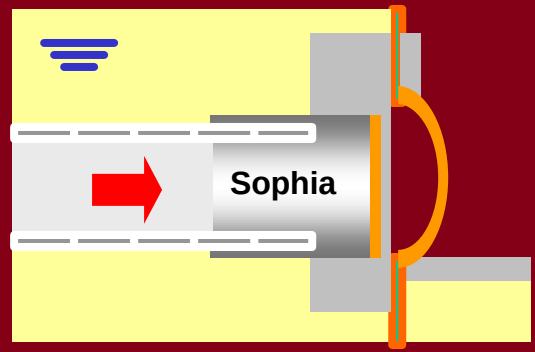
Polderconstruction



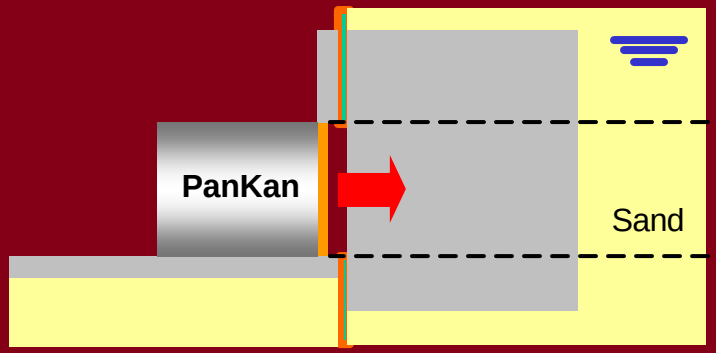
Shorter Dichtblock / closing by a steel construction



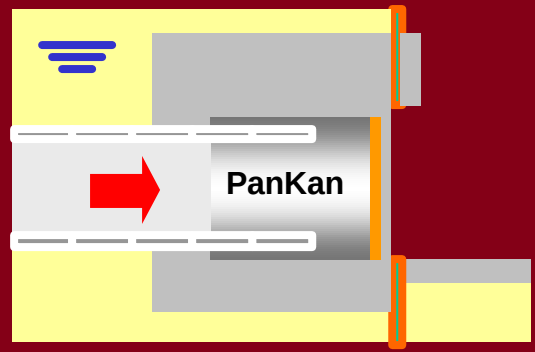
Shorter Dichtblock



Shorter Dichtblock / membrane topf



Longer Dichtblock



Longer Dichtblock / without closing


Comol
Tunnelbouw
Doorbraak
TBM
12-12-2002

Improvement of the soil of the holocene layers with the “Deep Soil Mixing“ method

Principle

- **improvement of the soil by mixing it with ca. 350 kg/m³ cement**
- **4845 pillars with a diameter of 800 mm**
- **compression strength s £ 5 Mpa**
- **elasticity module E ³ 20 MPa**

The grouting procedure using a two-component mortar, the so-called ETAC at the Botlektunnel in Rotterdam

Principle:

- Two-component mortar at the starting shaft
- Components are pumped by way of two separate pipes to the TBM
- Mixing and hardening take place inthe annular gap of the shield tail

Experience with using the two-component mortar at the Botlek tunnel

Advantages

++ Controlling the pressure and the mixture is more simple.

++ Transporting the mortar through pipes is logistically advantageous.

++ The number of injection lances can be reduced.

++ Pipes and pressure chambers need less cleaning

Drawbacks

- The quantity of mixture was considerably above the required value.

- The mixing of components is uncertainty.

- The long term influence of the air bubble forming component is uncertain.

- Higher cost of materials.

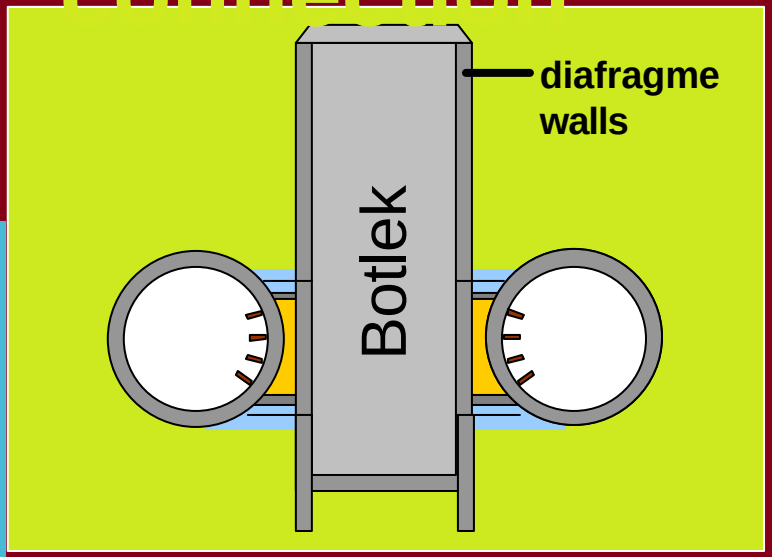
The shield driving process was successful

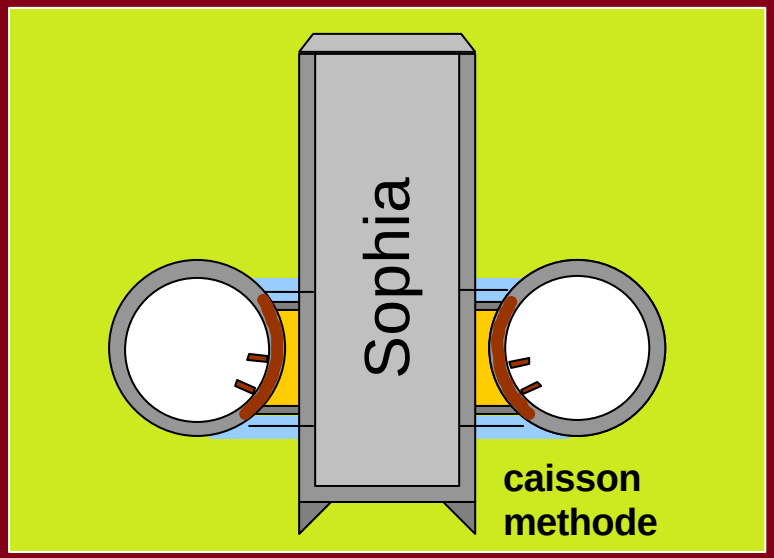
But

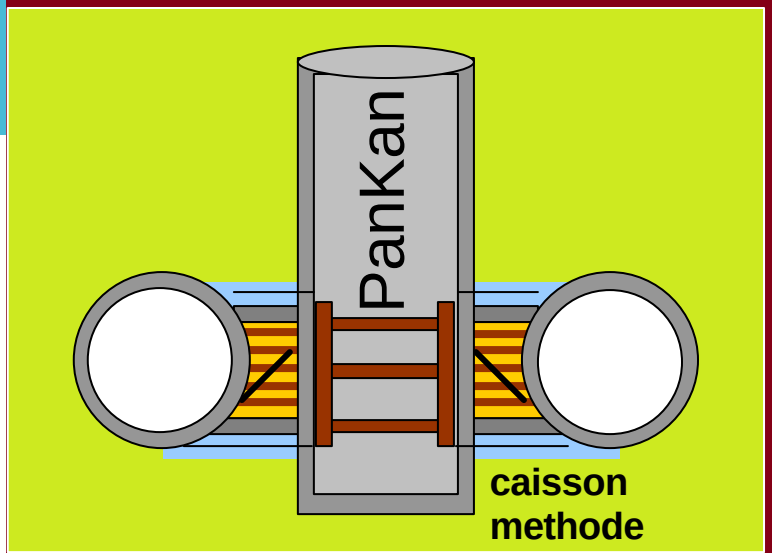
What happened too…

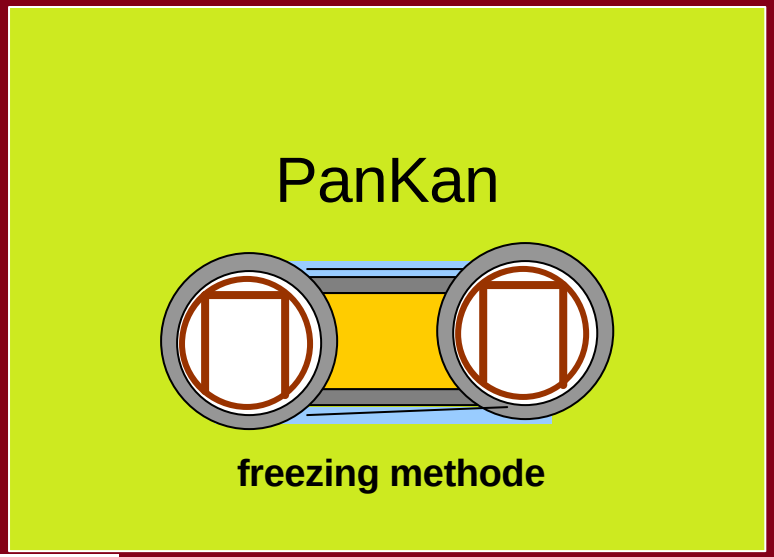
- **Foam / grout on the surface**
- **Confined blow-outs /cave-in's**
- **A crack in the screw conveyor-tube (wear)**
- **Damage on the over cutter (cost three months)**
- **Damage on the sealing in the shield joint**
- **Cracks in the lining**

Construction principle cross connection







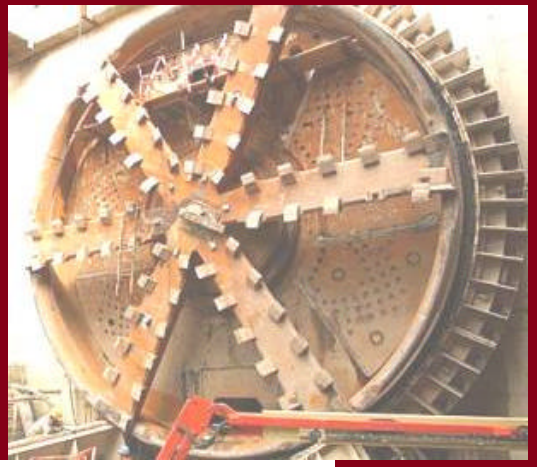


The cutterheads before and after the process

Botlek

Sophia

Pan.canal



Conclusions

- Shield driving in Dutch soft soil successful
- Always there happens something
- Control of settlements needs a lot of attention
- The cooperation between the management on site and TBM-crew makes the success and the quality

Recommendations

- Make a reference design to get the right tender specifications
- Monitoring is important for the improvement of the process, risk management and claim settlement
- Let us have the ambition to make the process less dependent on the people
- The client have to invest too in innovations to bring the shield driving to a higher level