Tunnels content of the lecture

1st Hour

Tunnels

- Immersed tunnels
- Comparison Bored Tunnels (short)
- Land tunnels

2nd Hour

Introduction in Shield tunnelling

- Pipe jacking & tunnelling
- Slurry & hydroshield
- Slurry versus EPB
- Principles of support pressure

Delft University of Technology, faculty of Civil Engineering

Ir. S. van der Woude

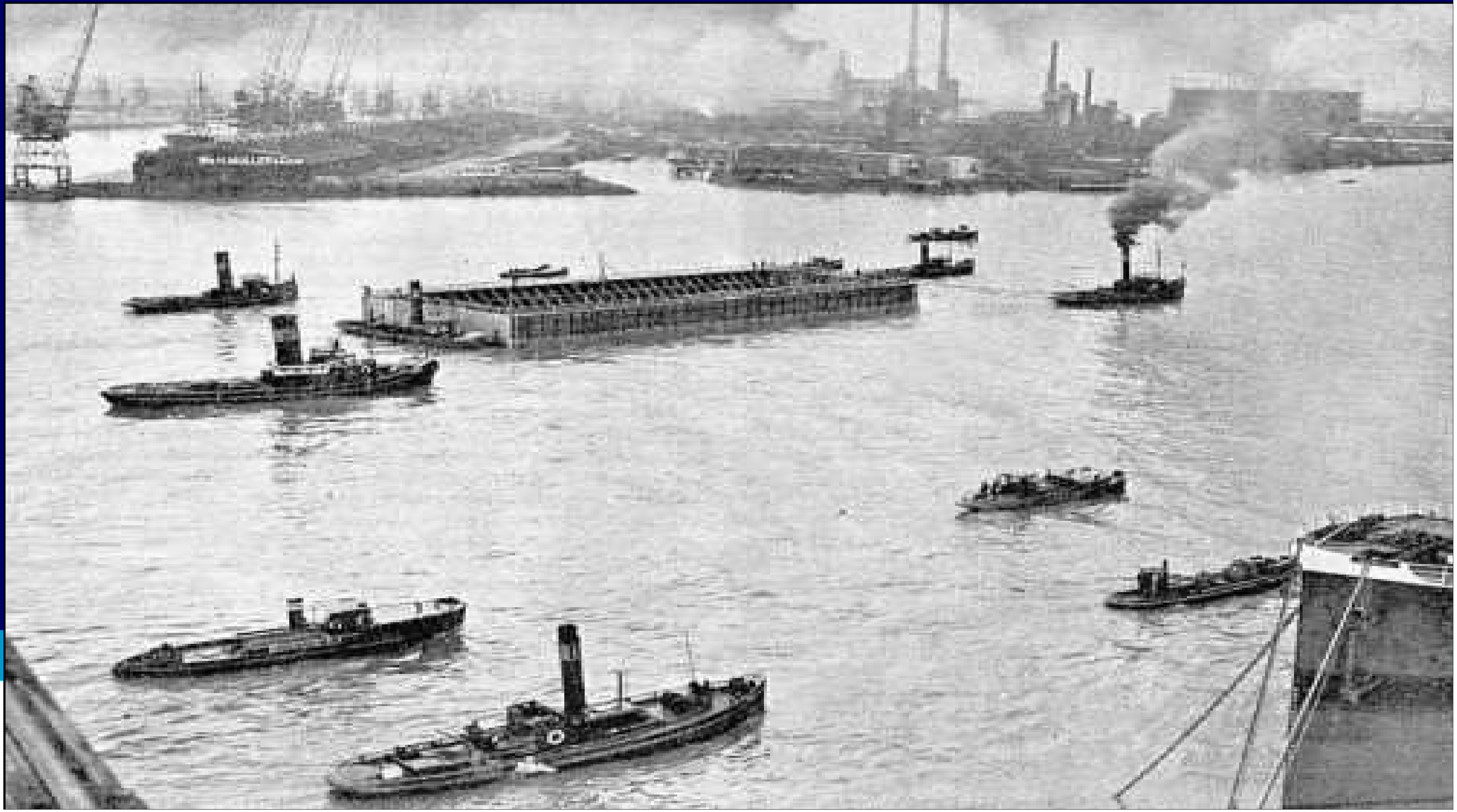
20 February 2009

Department of Underground Space Technology

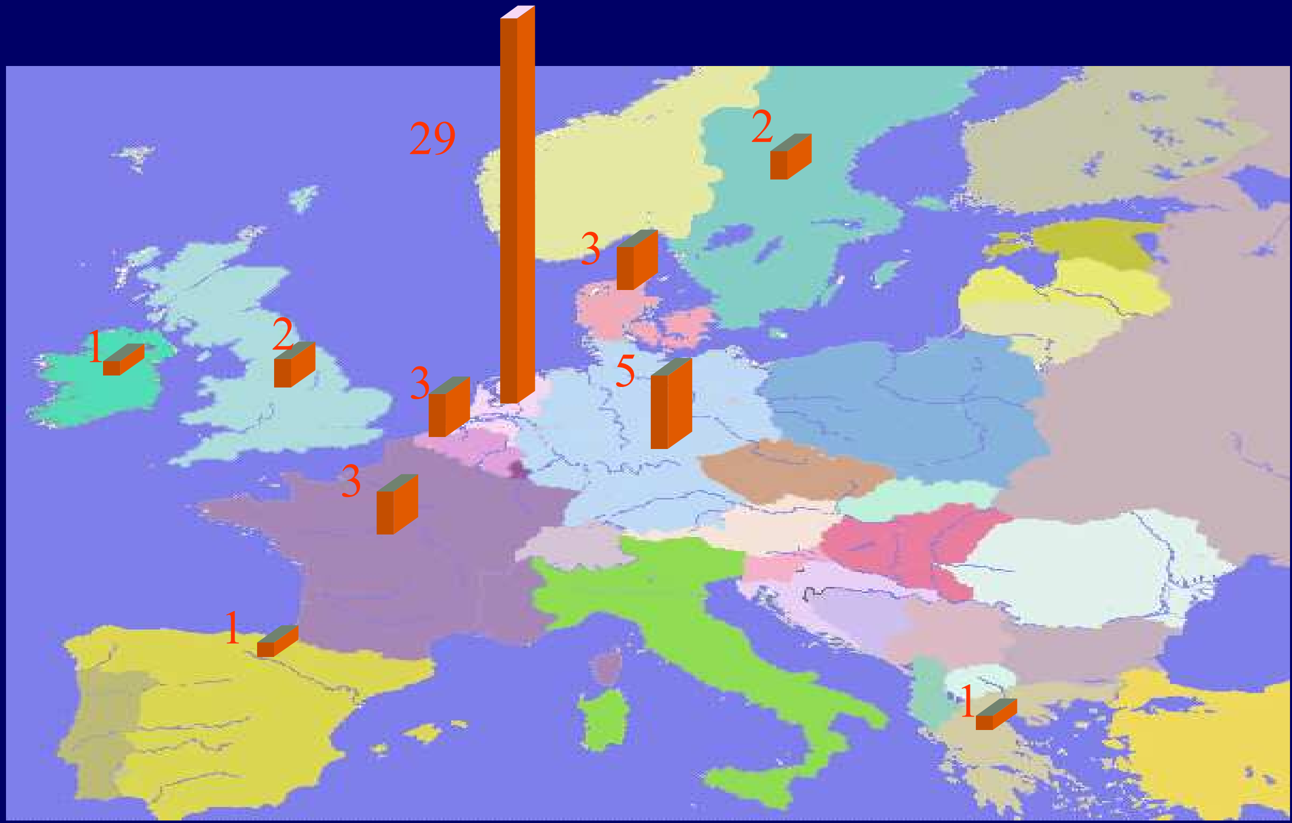
Delft University of Technology

Immersed tunnels

First immersed tunnel in the Netherlands;
the Maas tunnel, 1942



IMMERSED TUNNELS IN EUROPE



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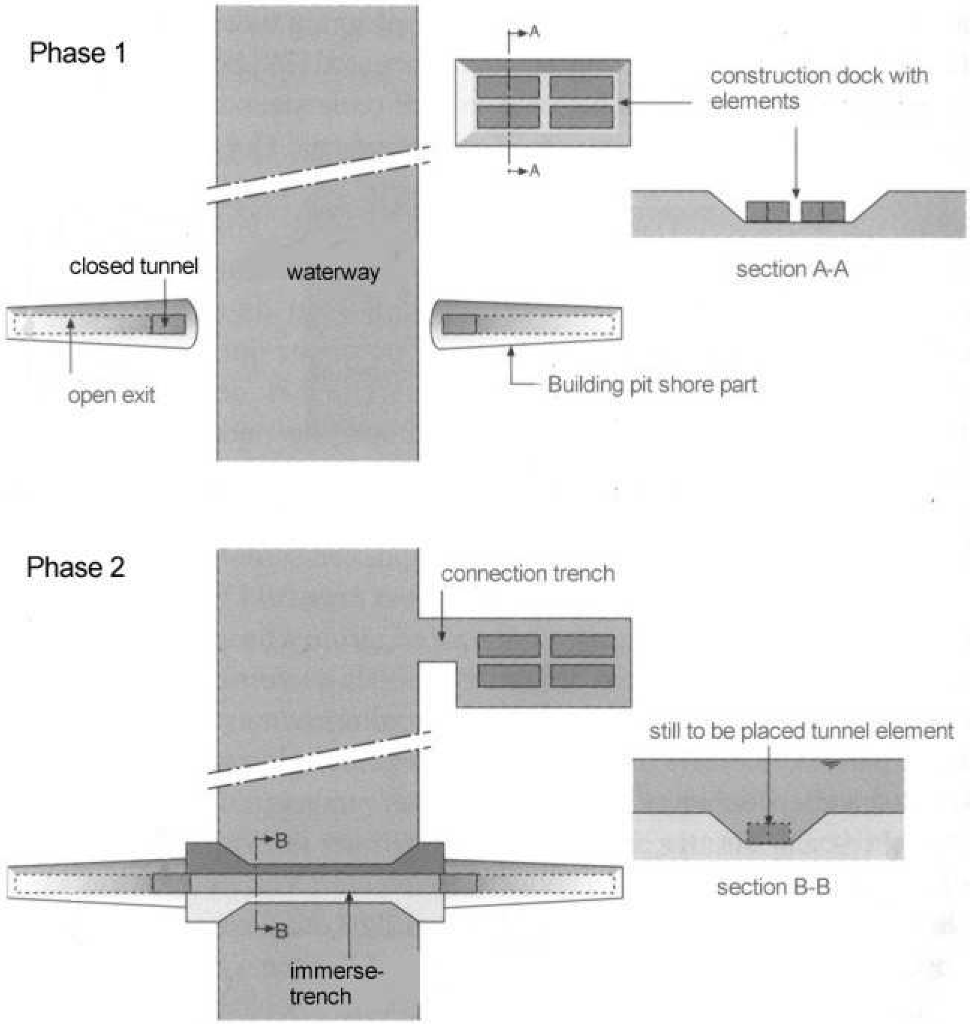
Examples immersed tunnels in the Netherlands

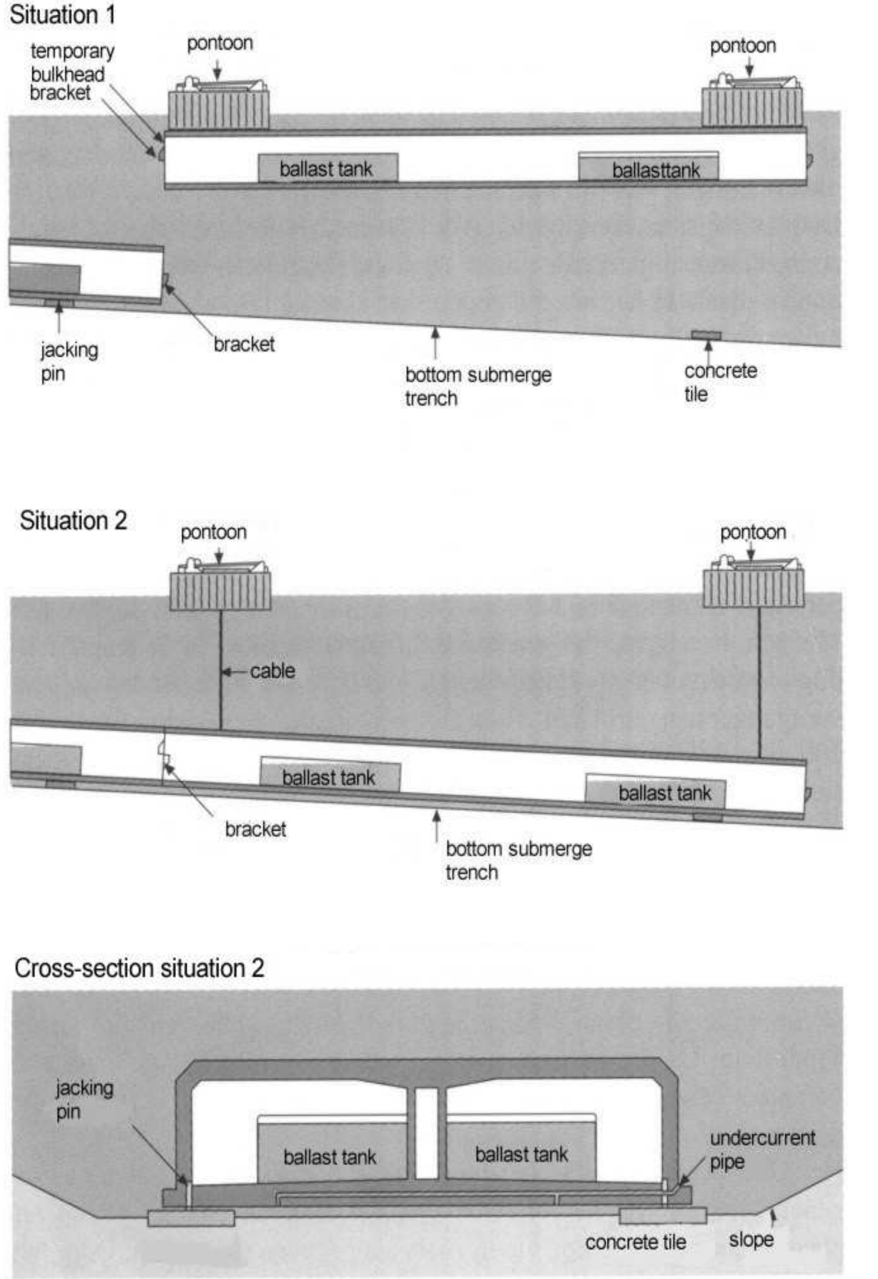
Calland, Piet Hein and 2nd Benelux tunnel

Construction proces immersed tunnel

- Construction dock
- Tunnel elements (with temp. watertights bulkheads)
- Constructing the ramps with the transition structure
- Dredging the immersing trench
- Immersing
- Closure of the joints
- Founding and covering

Principle immersing





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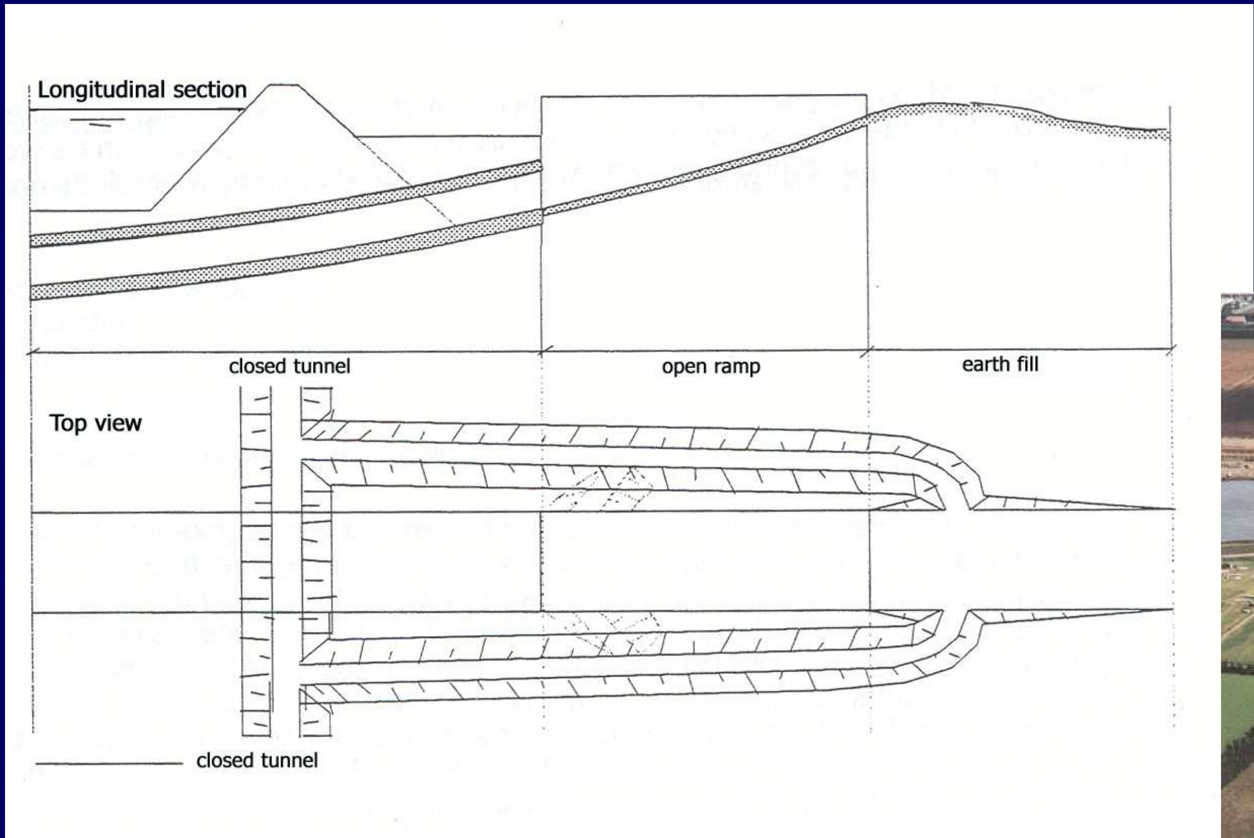
Sectie Ondergronds Bouwen, TU Delft
Construction dock

Water barrier



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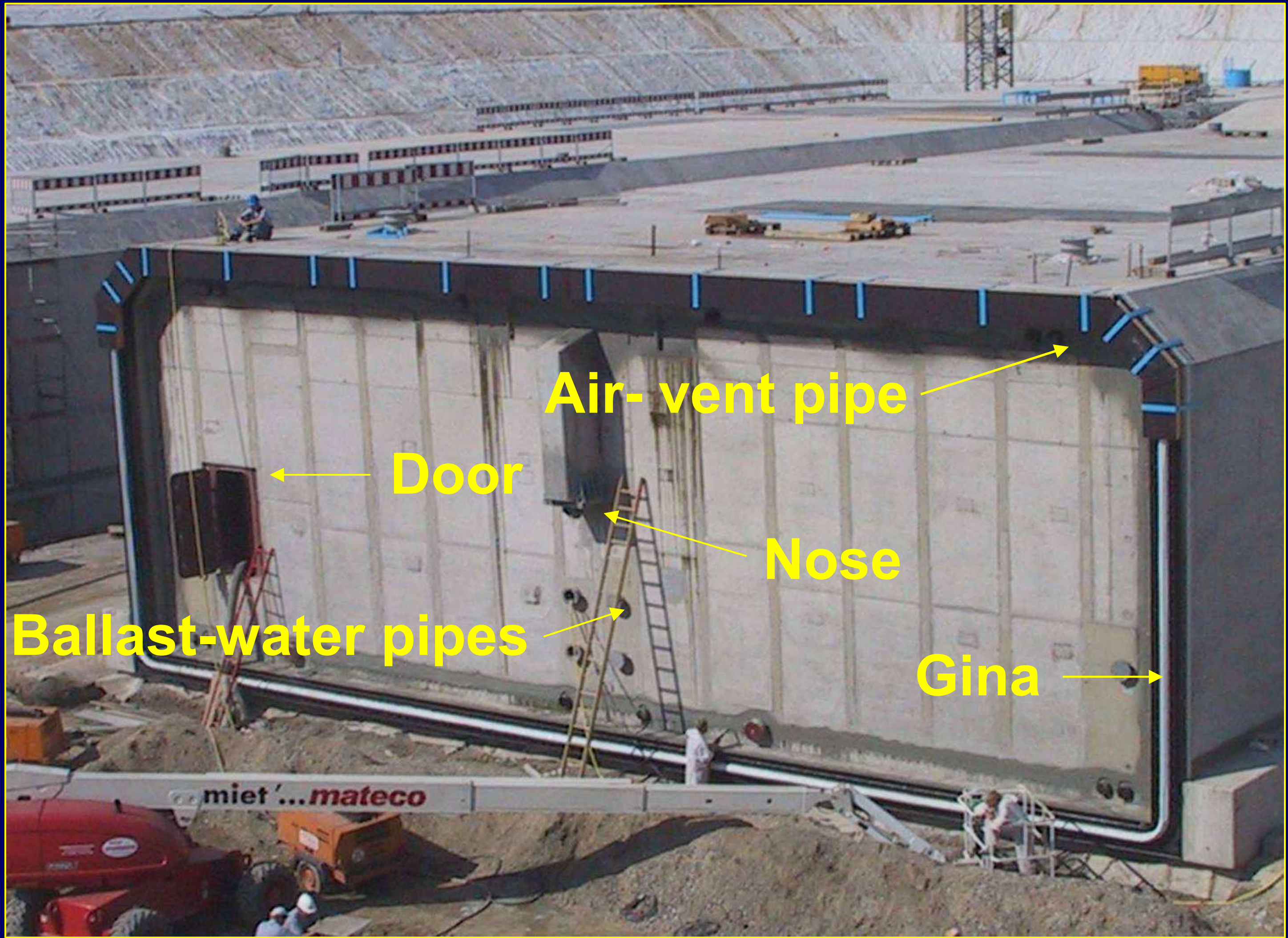
Transition structure

BULKHEAD – OUTSIDE VIEW



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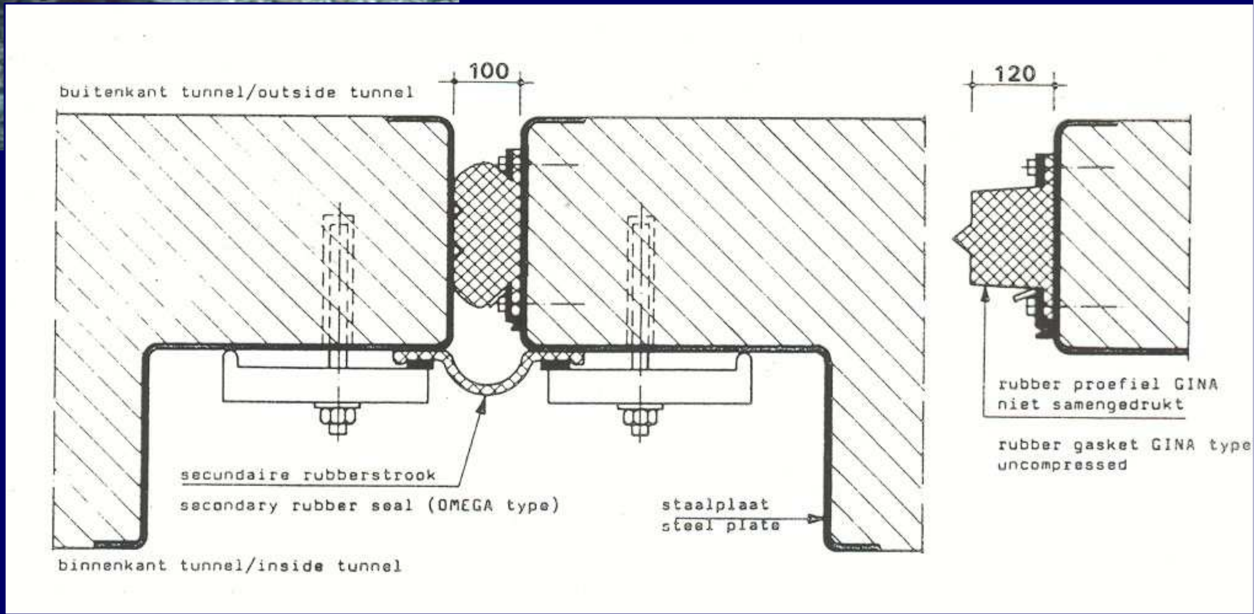
Gina gasket



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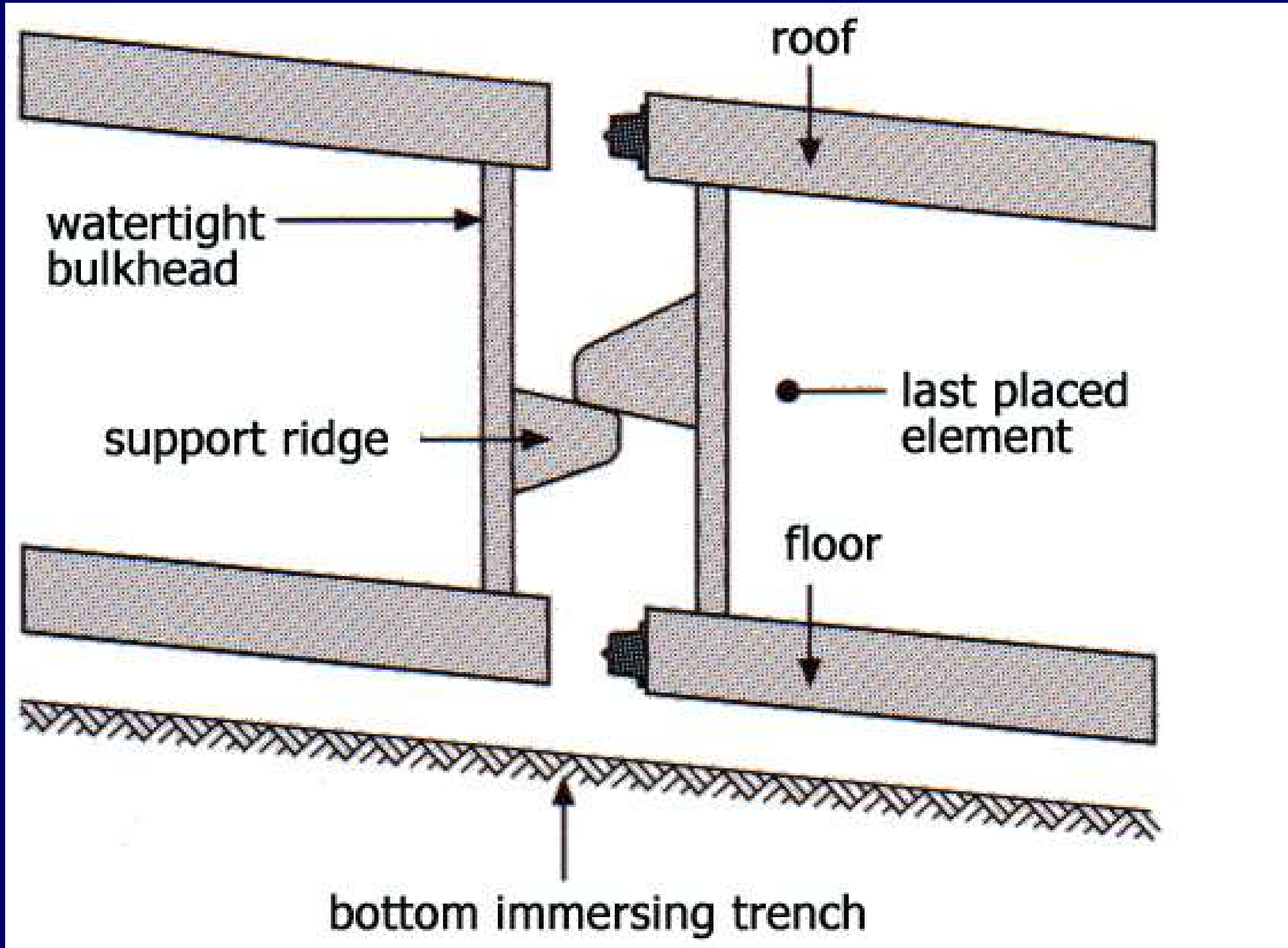
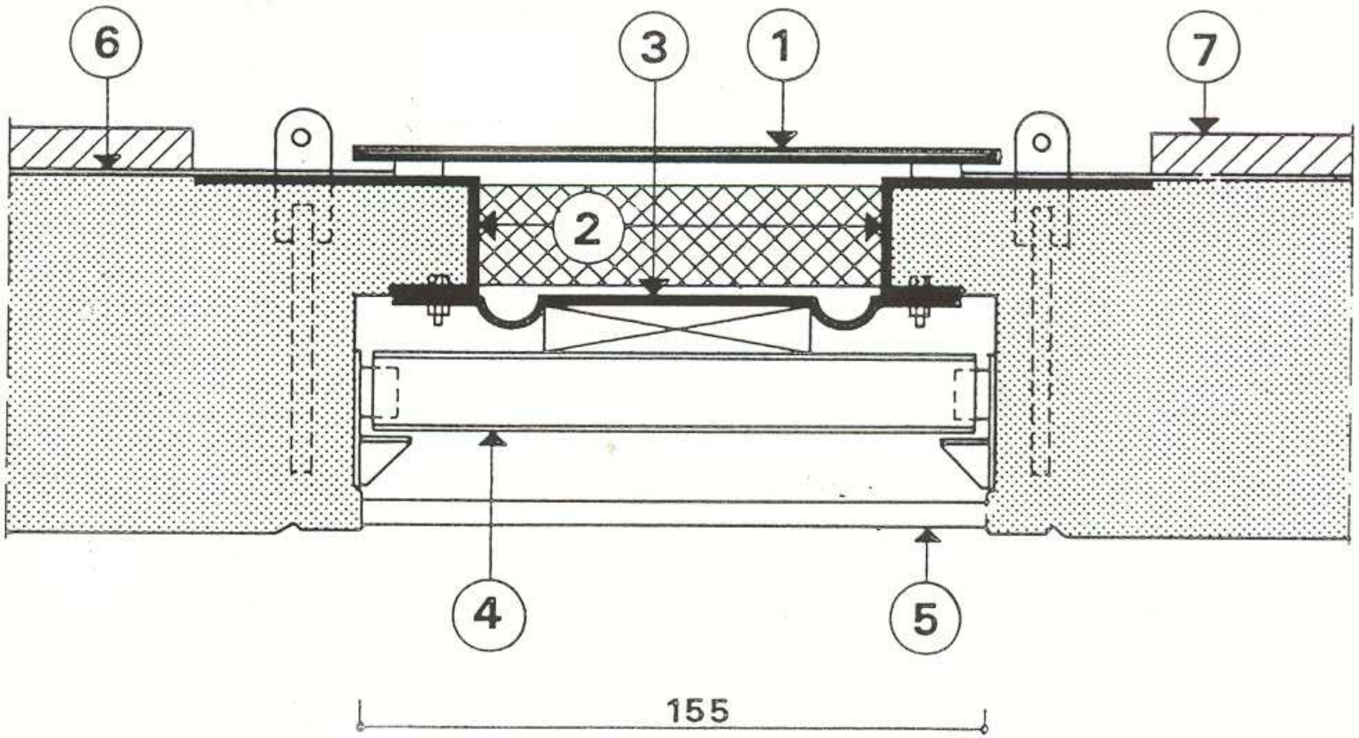
Coupling of the elements

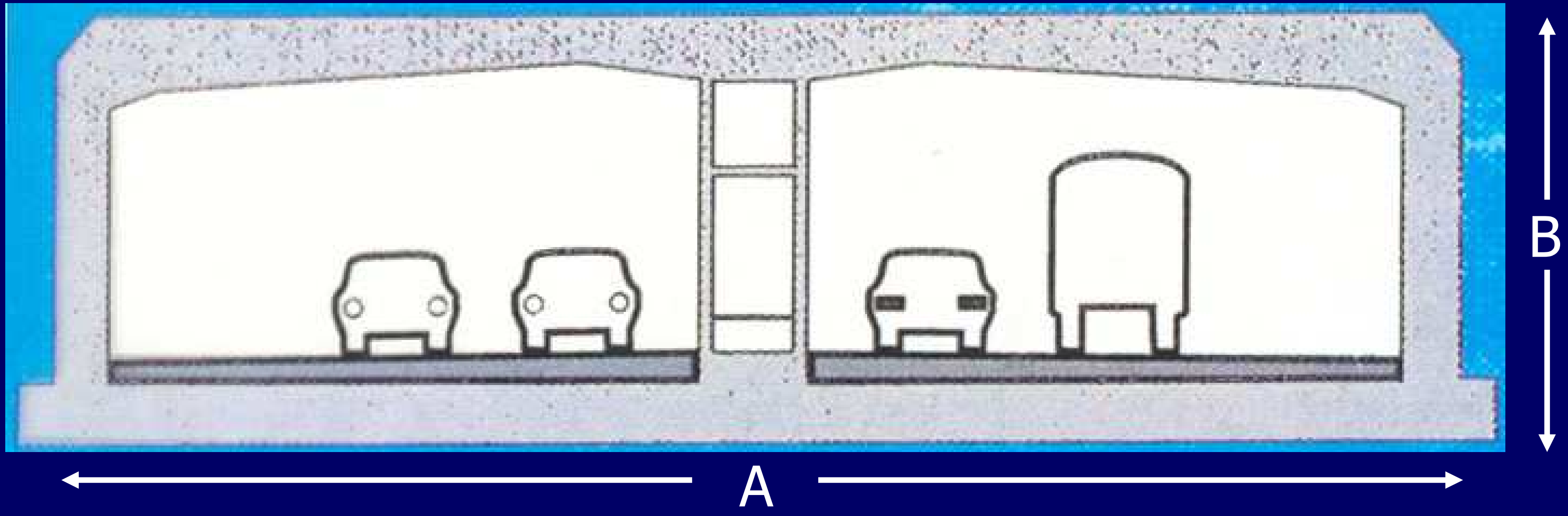


Closure joint

Detail final joint in the wall
1 = primary sealing, 2 = folded steel sheets, 3 = permanent sealing (rubber), 4 = steel support, 5 = fireproof cover, 6 = watertight cover, 7 = concrete protection



Cross section



- F upwards = $A * B * \rho_w$
- F downwards :
  - Concrete
  - Reinforcement
  - Ballast concrete

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Design aspects immersed tunnel alignment

- Cross section
  - Horizontal and vertical clearance (dredged trench)
  - Force equilibrium

- Longitudinal section
  - Ramps
  - Joints
  - Transition structure
  - Horizontal and vertical curve radius
  - Cover
  - Maximum slopes
  - Water barrier

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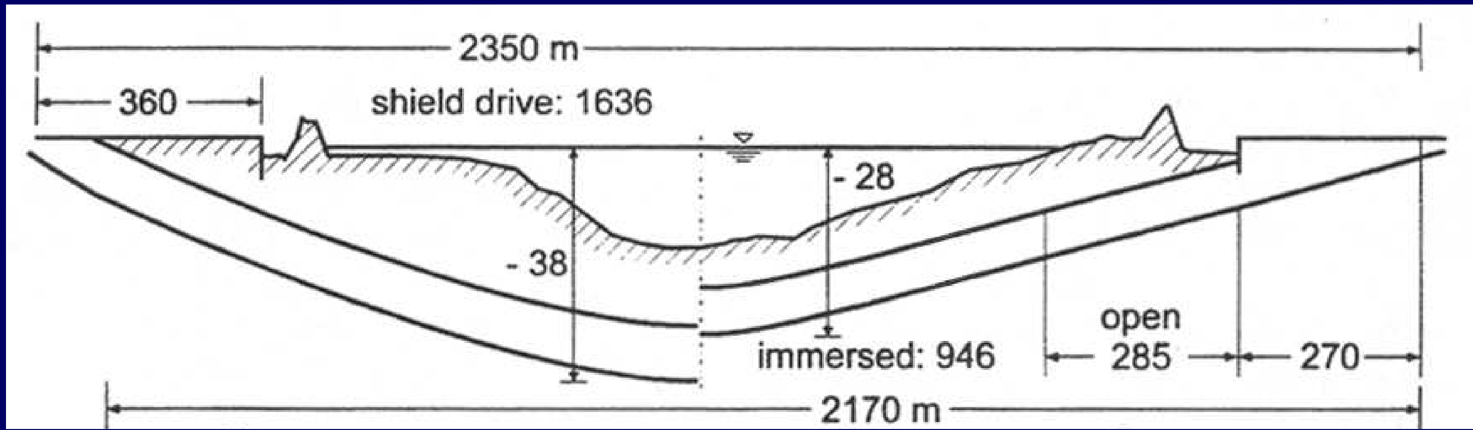
Design aspects Load cases >>>>>4780

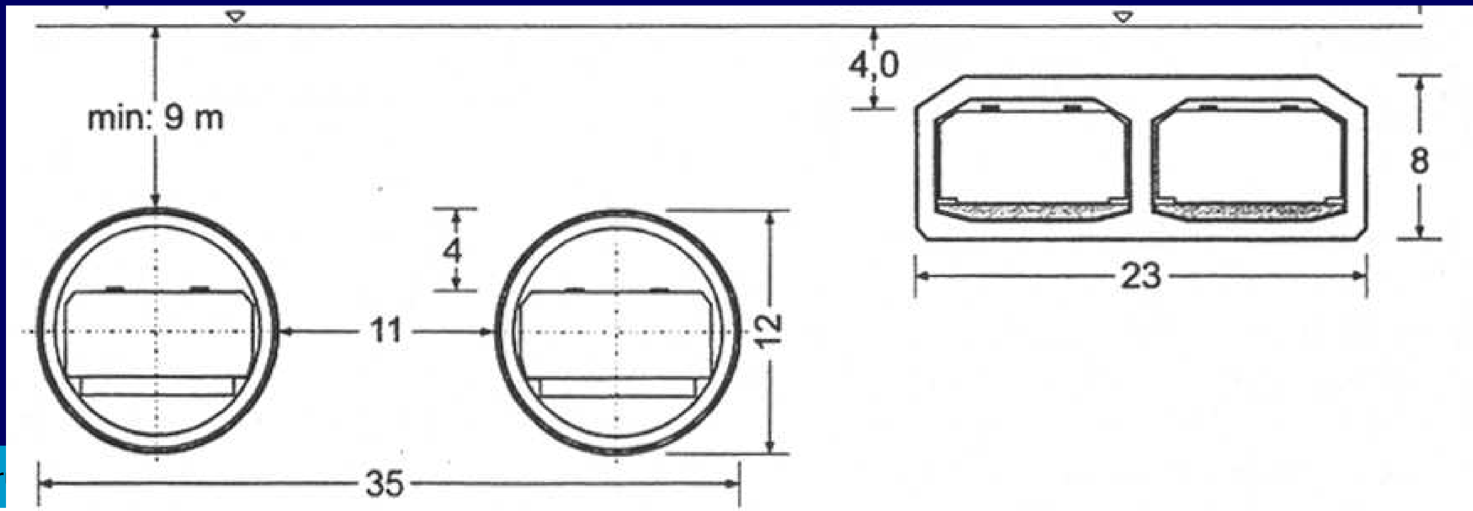
- Permanent loads
  - dead weight, water, earth pressure
- Variable loads
  - mobile loads due to transport, temperature
- Accidental loads
  - earthquake
  - explosion / fire
  - collision
  - falling and dragging anchors
  - stranding ships

Comparison bored/immersed tunnel

- Here we see the entrance of
  - Bored tunnel: The Botlek railway tunnel of the Betuwe route.
  - Immersed tunnel: The Botlektunnel Highway A15

Comparison bored/immersed tunnel





When to choose an immersed tunnel
(with cut and cover ramps)

- Primarily
  - Crossing of rivers/canals

- Advantages compared with a bored tunnel
  - Shallower
  - Shorter ramps
- Disadvantage compared with a bored tunnel
  - Hindrance during construction caused by
    - Dredging,
    - Transport of elements, Immersing
  - Construction of the ramps are adjacent to immersed tunnel
  - Construction Dock

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When to choose a bored tunnel
(with launch and reception shaft)

- Primarily
  - Rivers Canals and any vulnerable object
    - Historic city centre (Amsterdam)
    - Residential areas (den Hague)
    - Infrastructure (also C&P)

- Disadvantage compared with an immersed tunnel
  - Deeper launching and reception shaft of TBM. Longer
- Advantages
  - Little hindrance during construction
  - Shafts can be located on optimal location.

Land Tunnels

- Cut and cover
  - Sheet piles or diaphragm walls
  - Excavation with struts or anchoring
  - Impermeable layer or dewatering or underwater concrete
  - Construction of the tunnel In situ or prefab.
- Top Down method
- Pneumatic caissons

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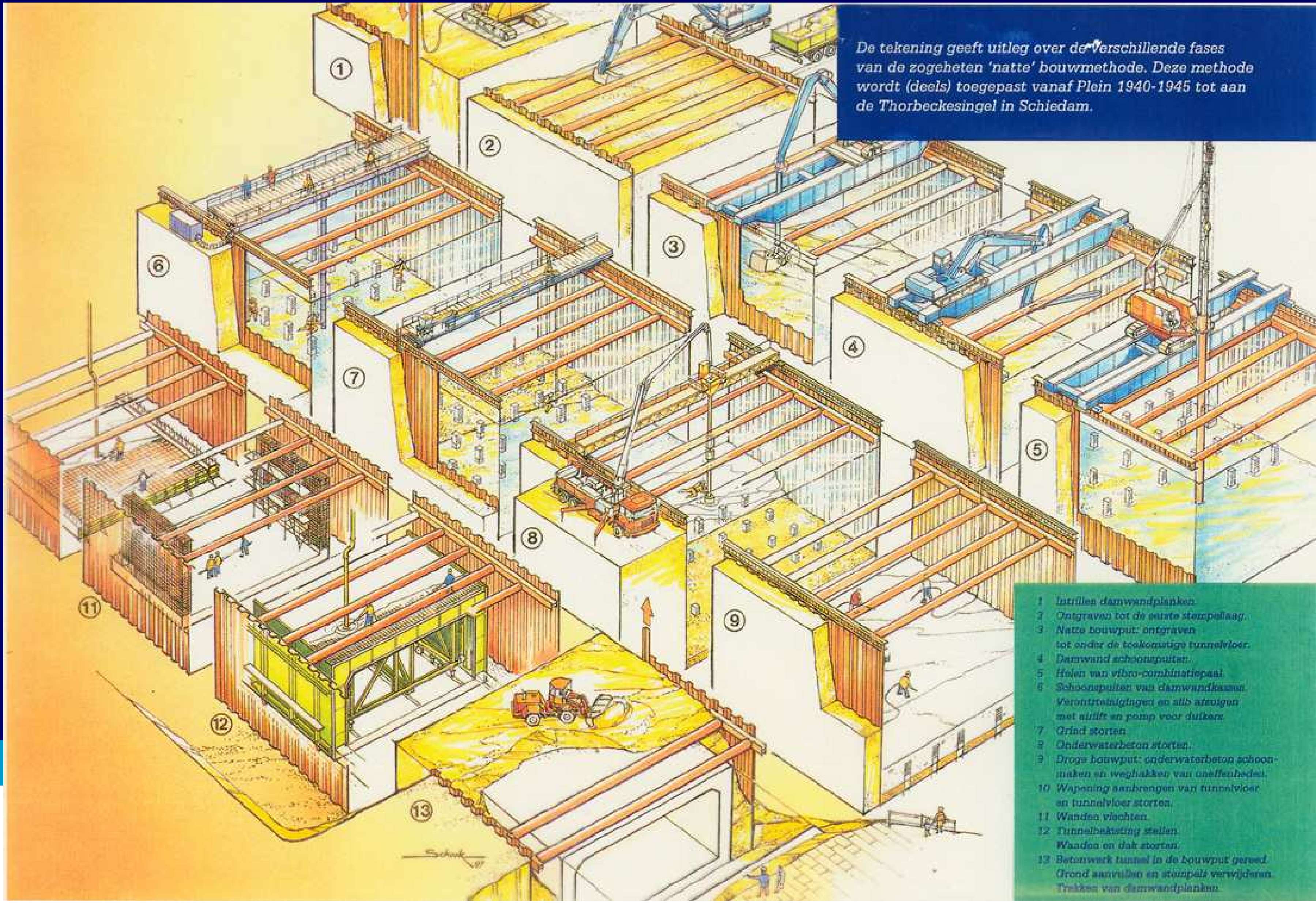
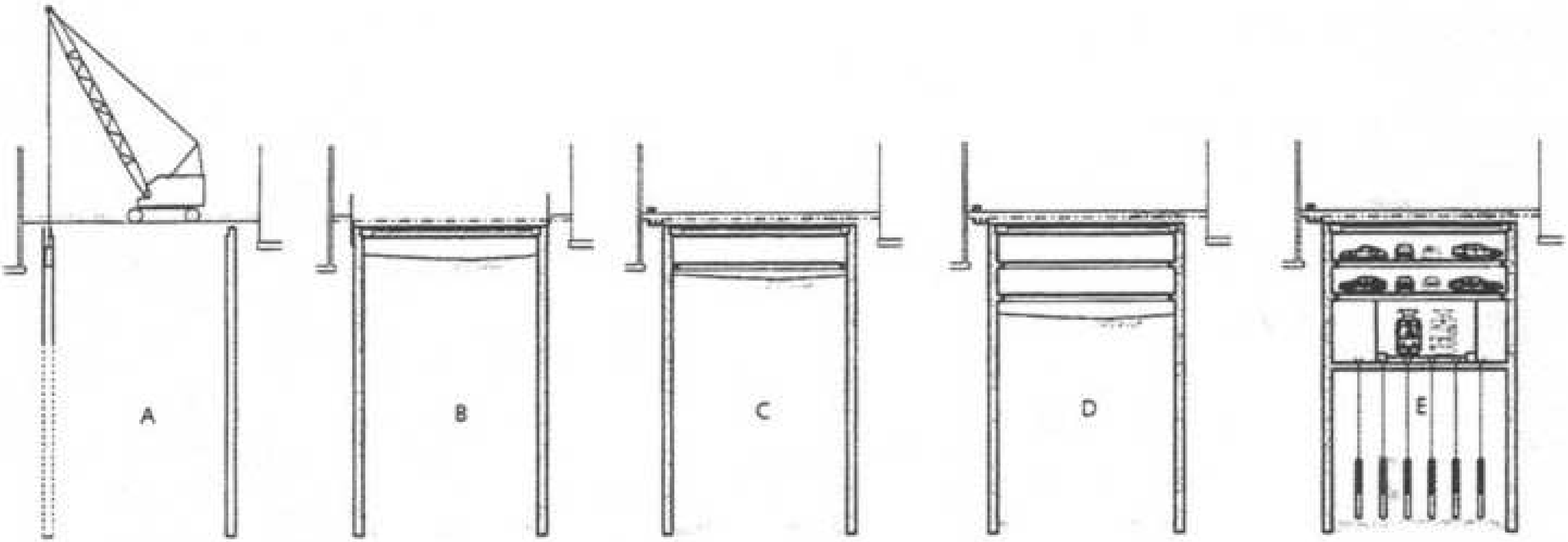
Examples land tunnels in the Netherlands

HSL-zuid,
Betuweroute tunnel
Zevenaar and
tunnel Giessen

Open building pit



Cut and Cover Top down methode



Building from ground level:

A constructing diaphragm walls
B excavating and building roof structure

Building below the roof:

C excavating and building floor -1
D excavating and building floor -2
E excavating and building floor -3

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Cut and Cover / Top Down method

- Tram tunnel The Hague

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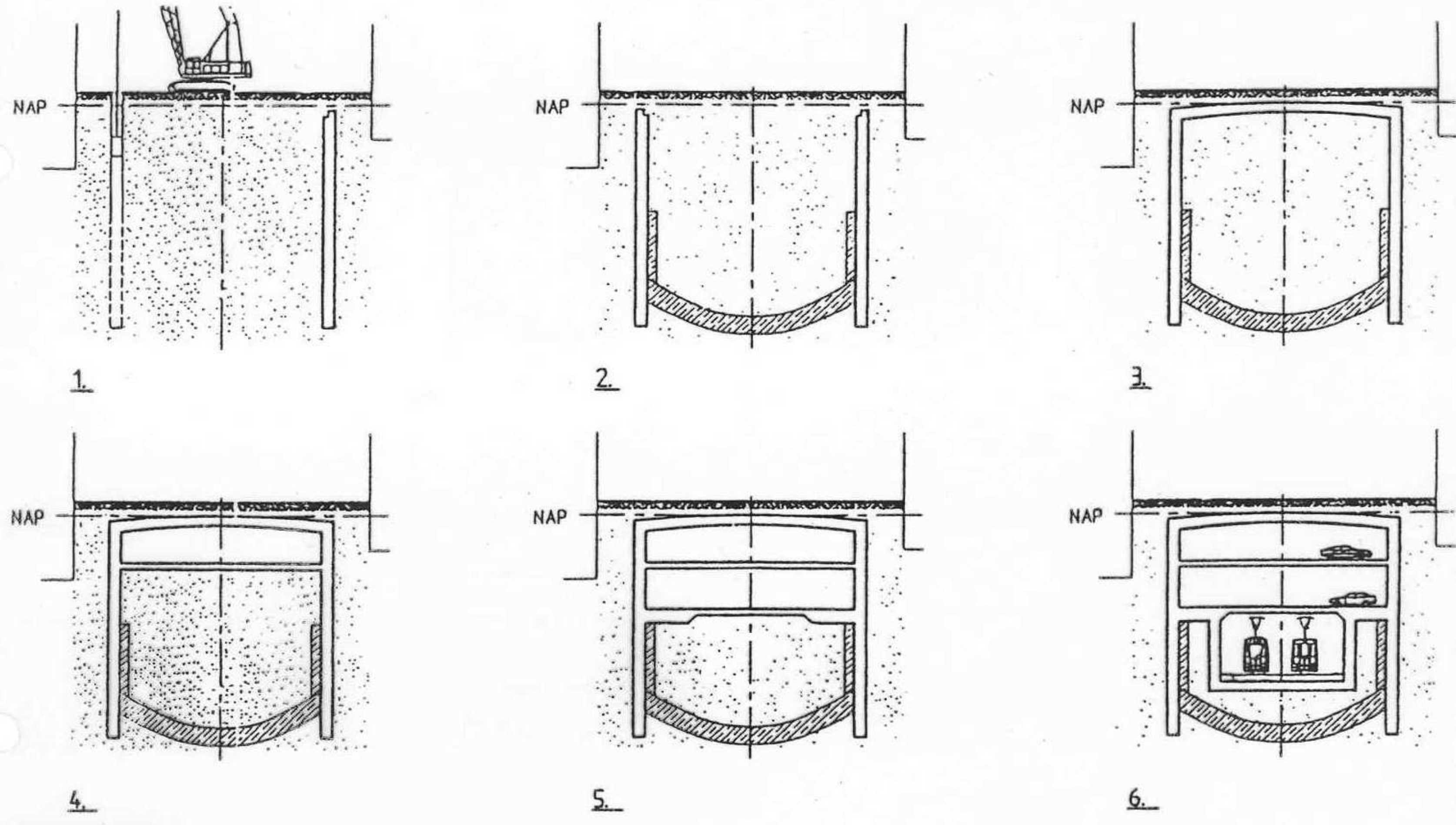
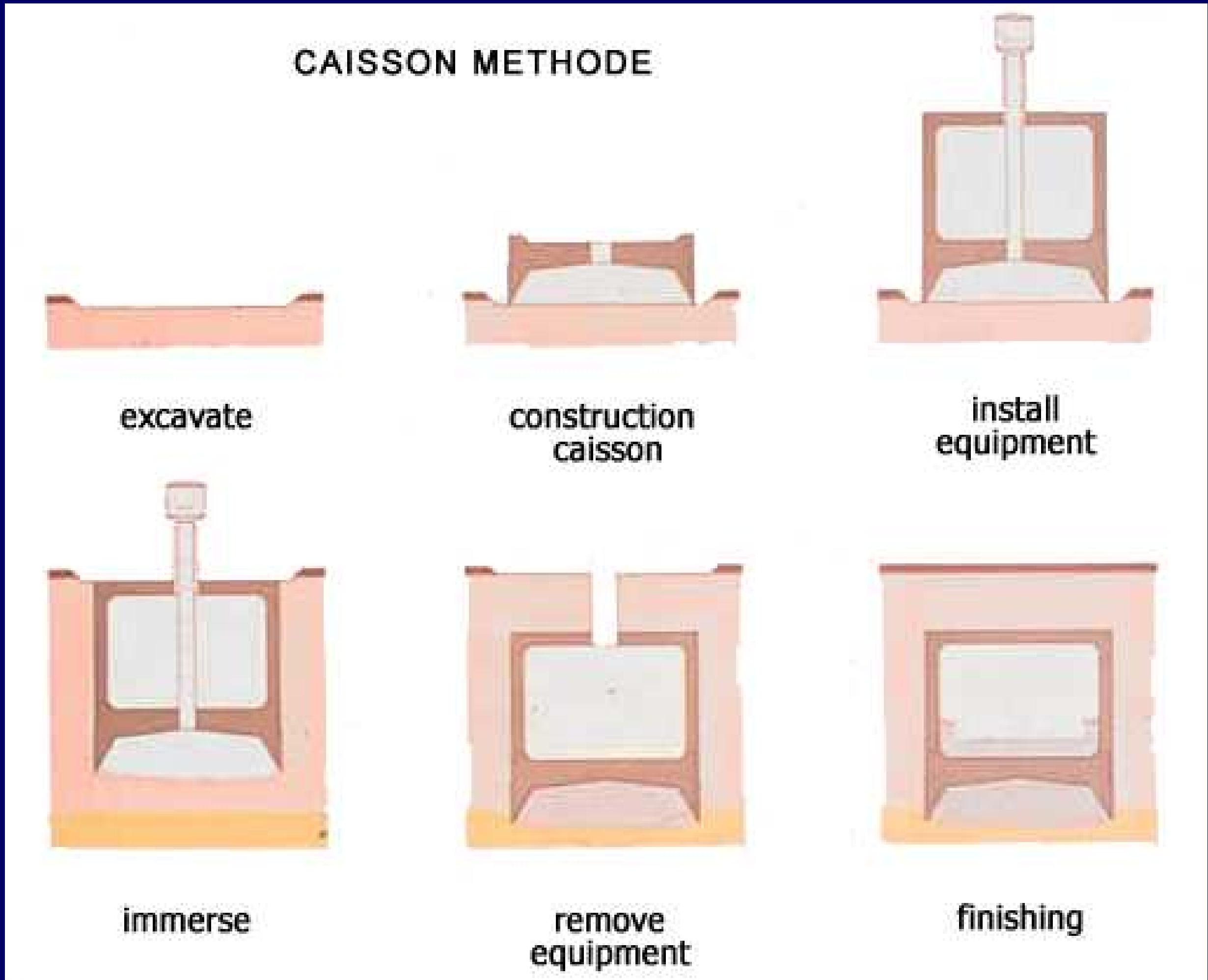
Cut and Cover Grout arch; Tramtunnel top down method>>> lecture 9



Principle pneumatic caisson method



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Caisson method

- East line Metro Amsterdam

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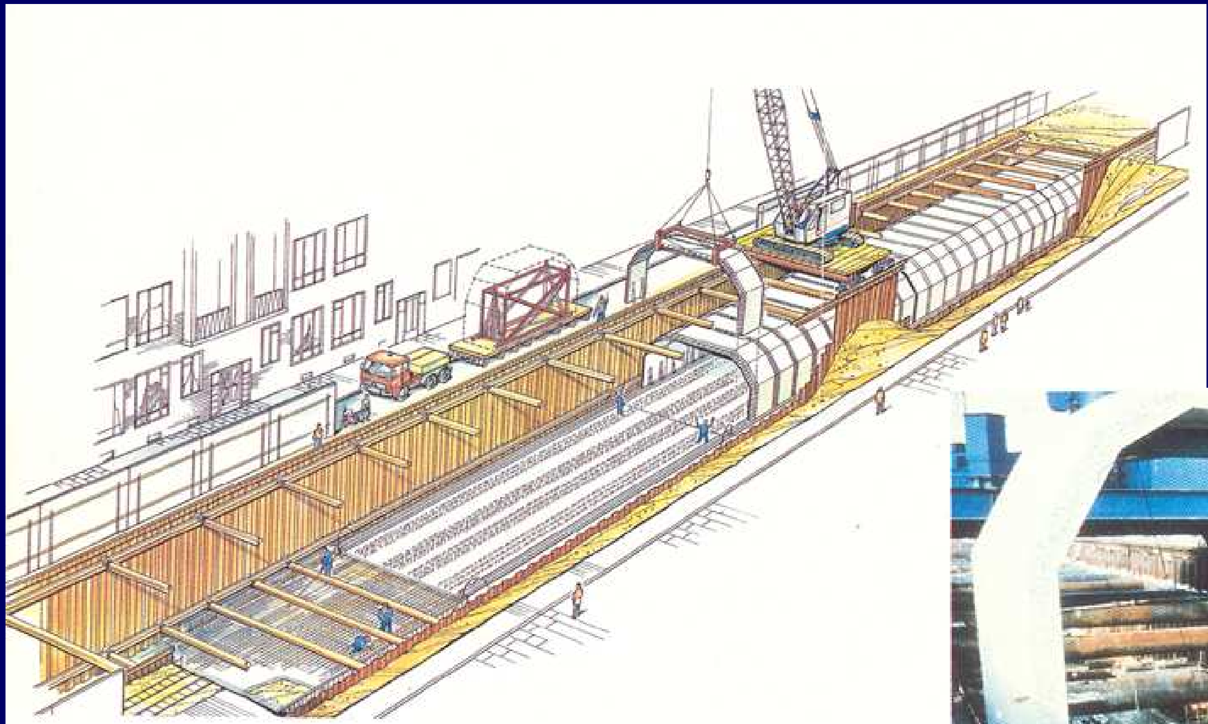
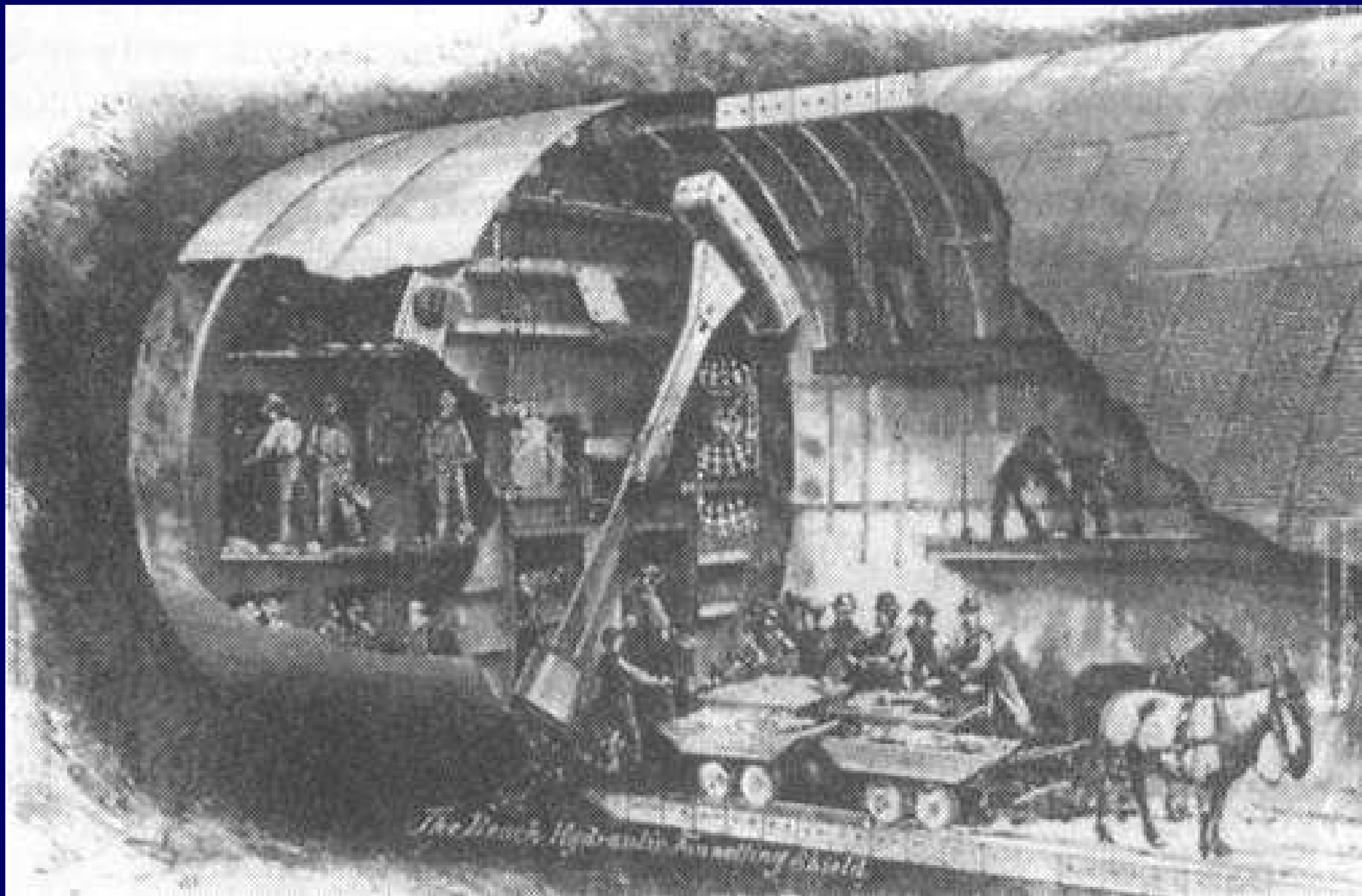
Prefab shell tunnel



- Metro Rotterdam

Bored Tunnels Introduction



Tunnel-construction under the St. Clair River more than 100 years ago.

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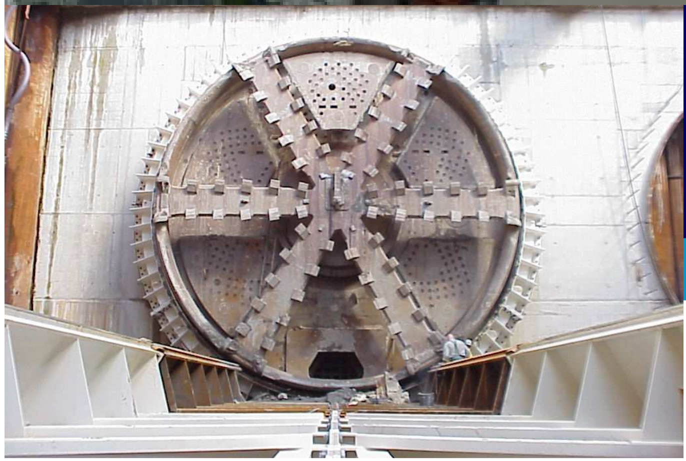
Bored Tunnels in the Netherlands

Hubertustunnel the Sophia tunnel and the Botlekrail tunnel



Constructing a tunnel with a TBM

Functions of a TBM:

- Controlled excavation of the ground.
- Support the ground/rock. (The shield)
- Construct the tunnel
- Facilitate the logistics (Transport of soil & tunnel elements & power, etc.).

Constructing a tunnel with a TBM

Pipejacking versus Tunnelling

Pipejacking	Tunnelling
Shield and tunnel pushed	Shield pushes against tunnel
- D = 0,8m to ca. 3m	- D > 3m
- Limited length	- Unlimited lengths
- Lining = pipe	- Lining = segmented ring
- No sharp curves!	- Sharp curves!
	- 2 additional processes

Pipejacking >>> lecture 12

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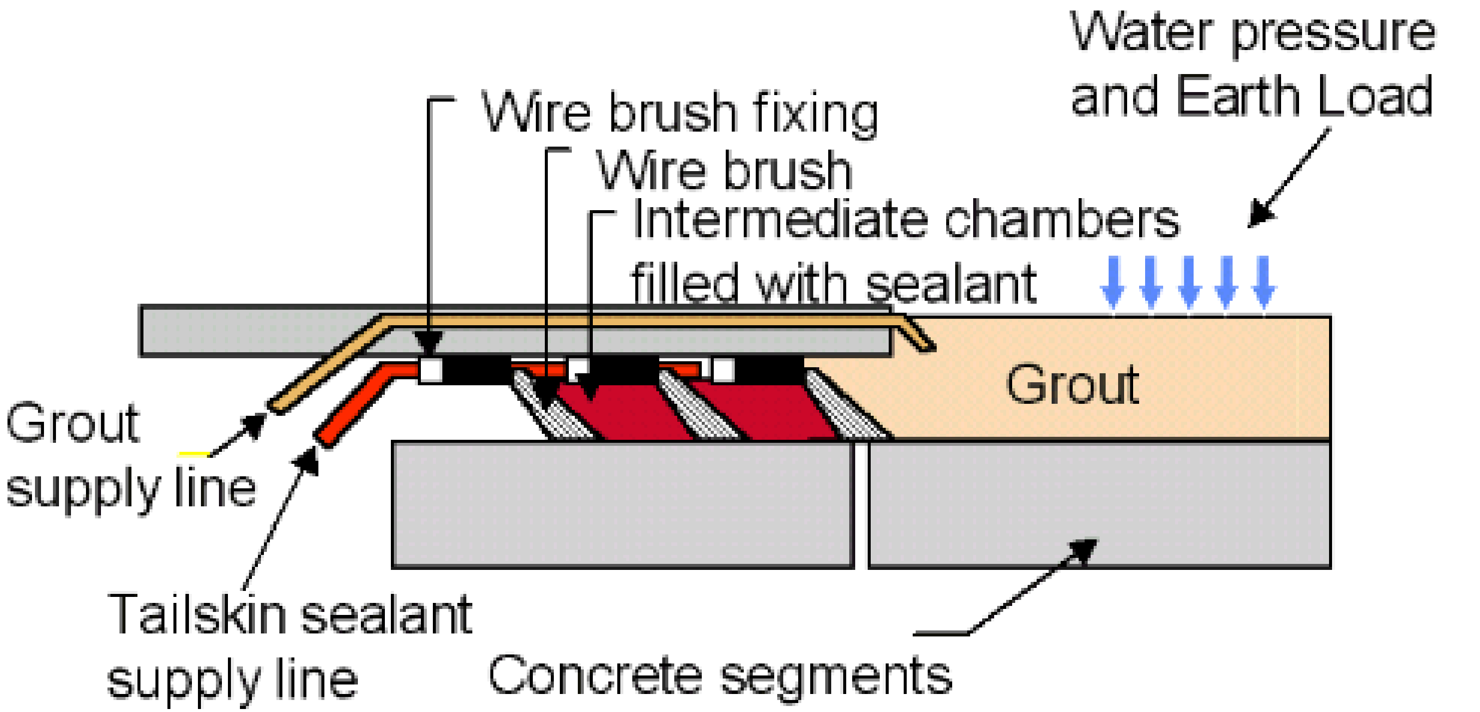
Tunnelling

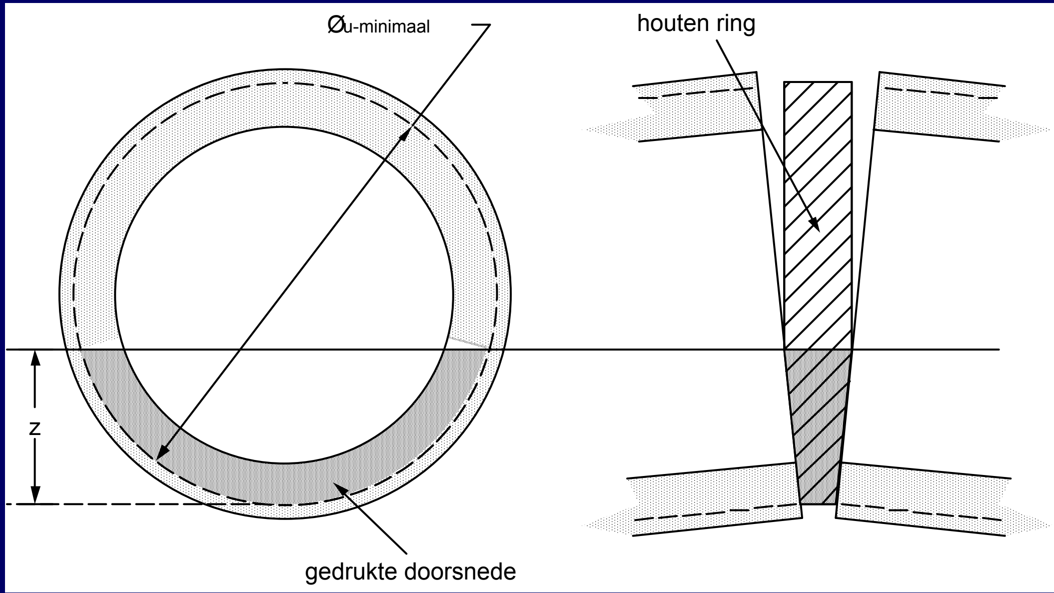
2 additional processes:

- Ring erection in the shield
- Shield tail injection (mortar injection)

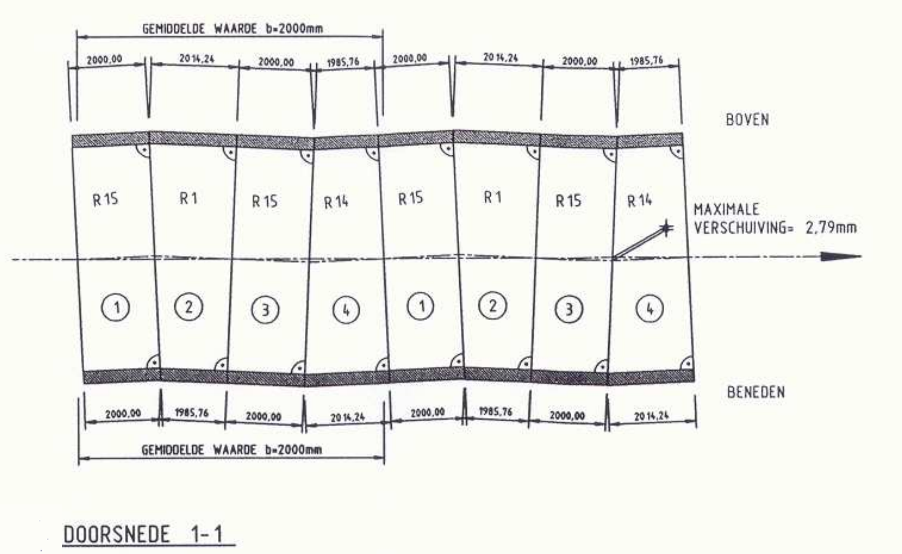
Tail-sealing-mechanisms

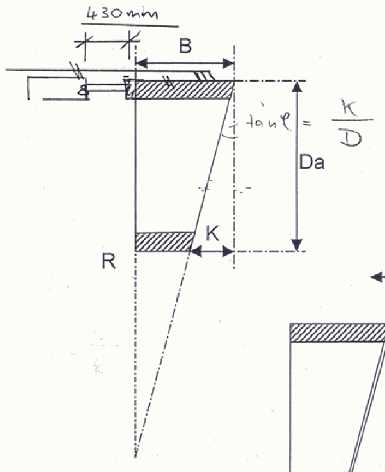


Curves in pipe-jacking

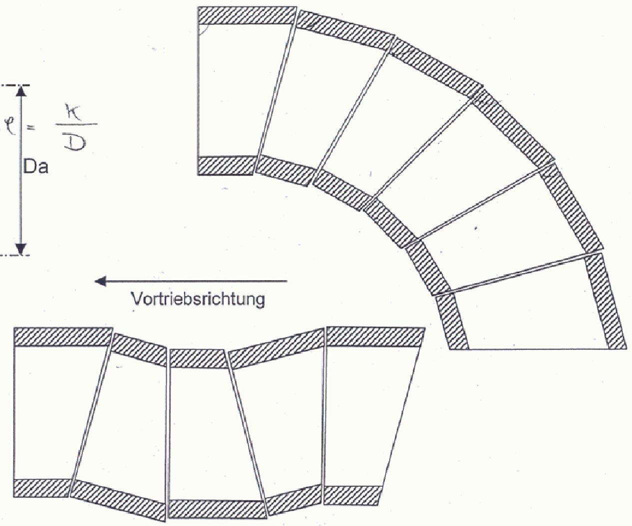


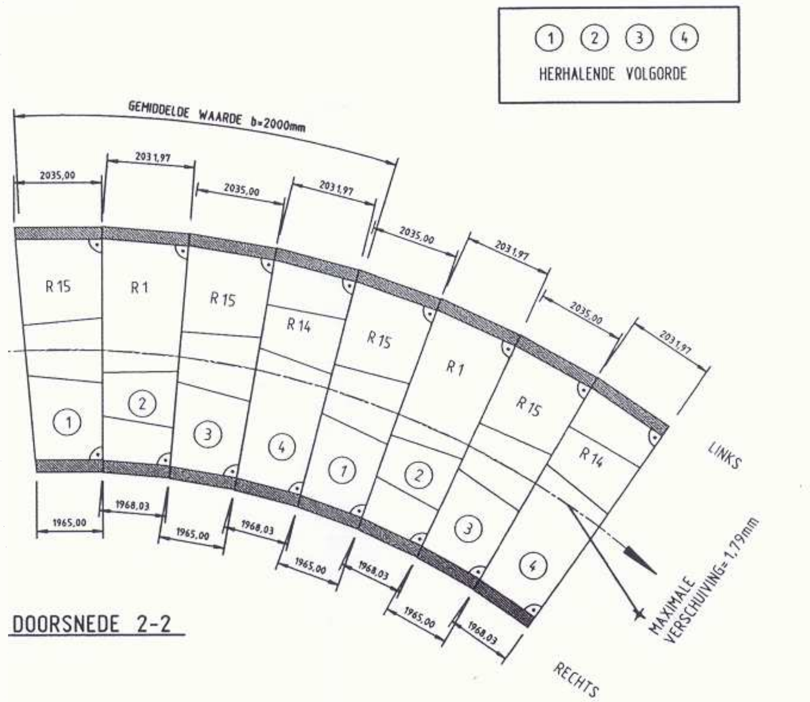
Curves in Tunnelling





$$K = (Da \cdot B) / R$$





$$\tan \varphi = \frac{B}{R} = \frac{K}{D}$$

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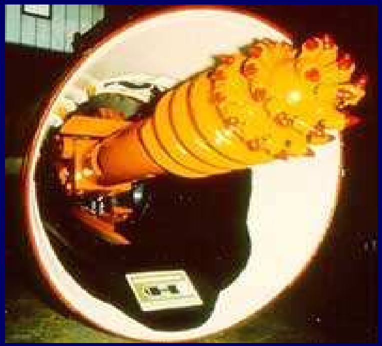
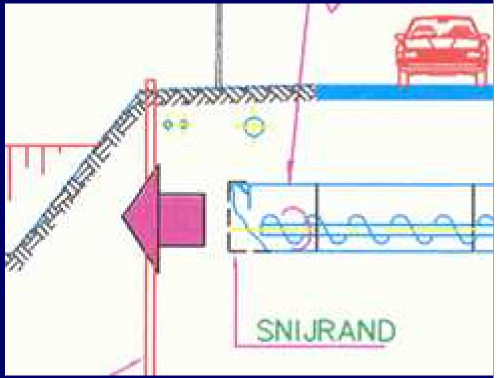
Different shield types depending on the Geology and other boundary conditions

- Open Face (atmospheric pressure)
  - In Rock; hard rock TBM (with grippers)
  - In Soil conditions limited
    - only small diameter and above ground water

>>> lecture 12



Thix-shield



Auger boring

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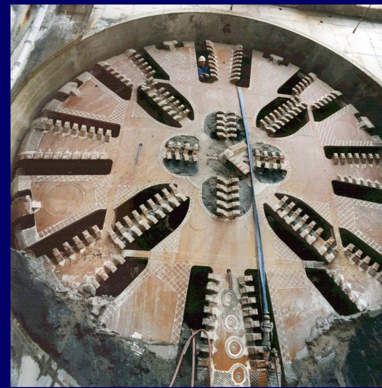
Different shield types depending on the Geology and other boundary conditions

- Closed Face (support pressure)
  - In soft soil conditions and in mixed geology
  - Depending on soil conditions different types of support medium
    - Support with bore fluid (bentonite)
      - Slurry shield
      - Hydro shield
    - Support with excavated soil
      - Earth pressure balance shield (EPB-shield)
    - Support with Air (only special occasions)



EPB-shield

Hydro-shield

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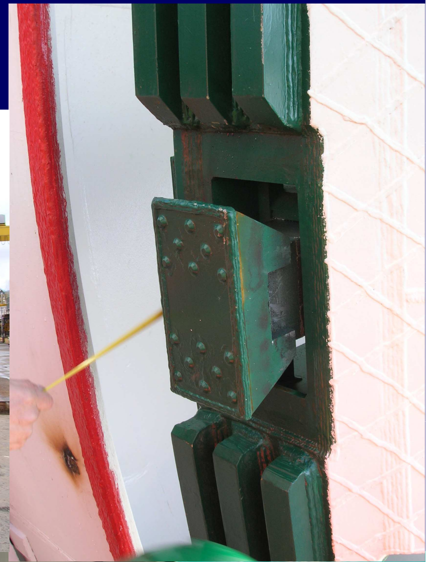
TBM: cutting elements and obstacles

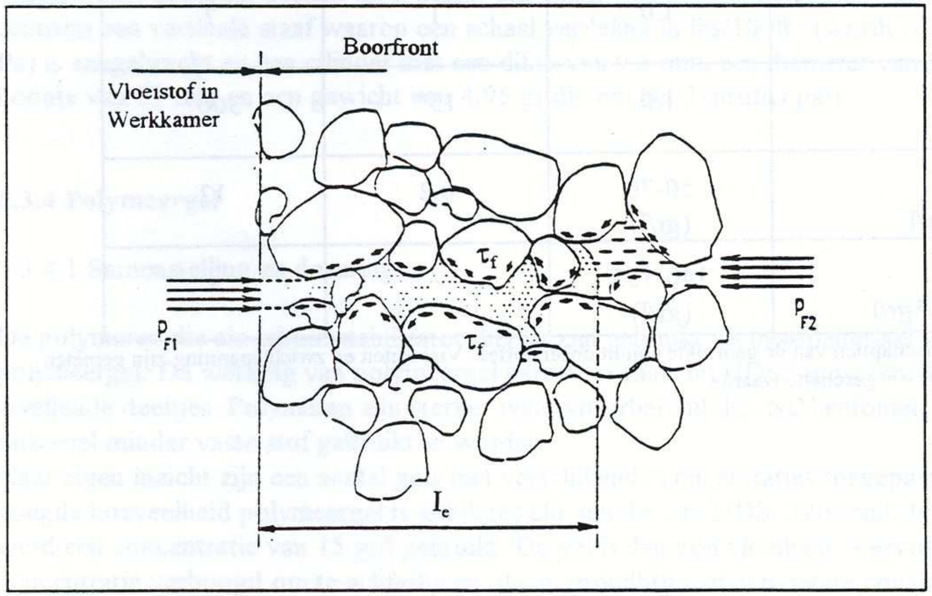


Selection criteria for type of TBM:

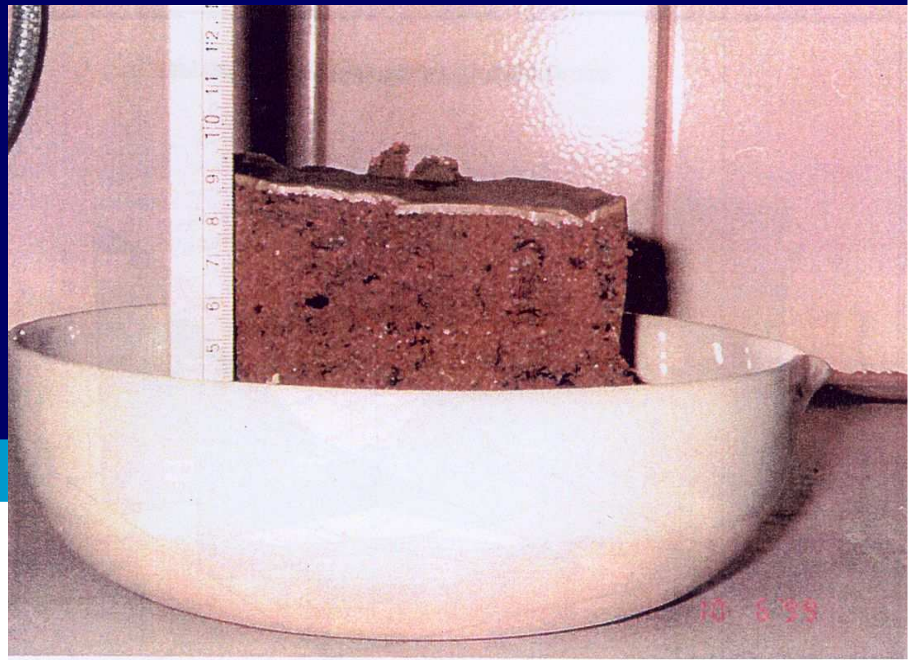
- Geological profile of the project.
- Groundwater pressures (support pressure is normative).
- Depth, horizontal- and vertical alignment of the tunnel.
- Surrounding area (settlements, ground-deformations).
- Logistic / available space.

Slurry shield principle of support pressure

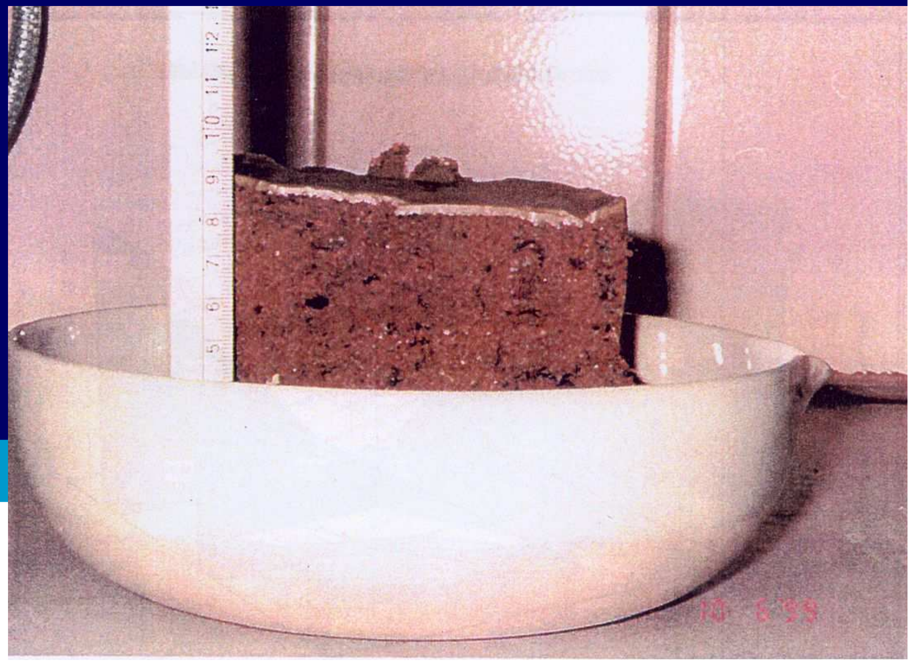
- **Bentonite =Bore fluid** **(is the support medium)**
- **Functions of the bore fluid**
  - **Maintaining support pressure**
    - **Building a membrane and/or**
    - **Creating an invasion zone (plug the pores)**
  - **Transport of the soil particles to the Separation plant**



Figuur: 6.6 Indringdiepte van vloeistoffen, Jancsecz (1994), figuur 14.



Slurry shield principle of support pressure

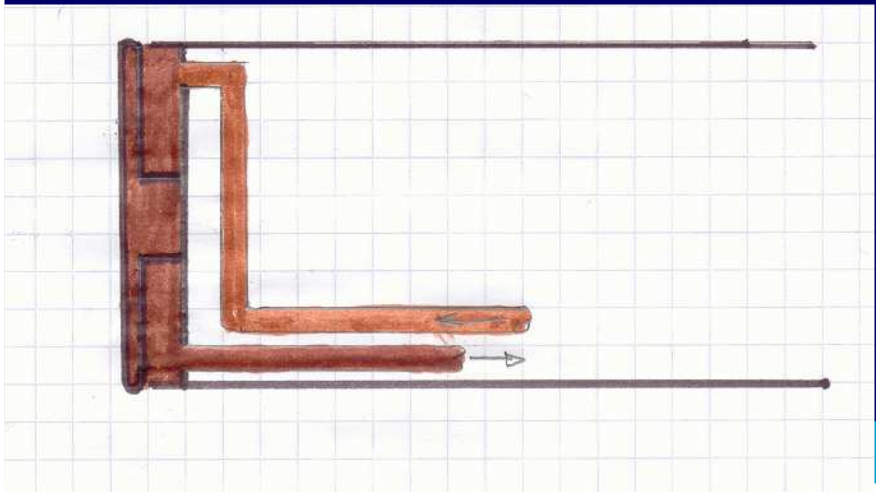


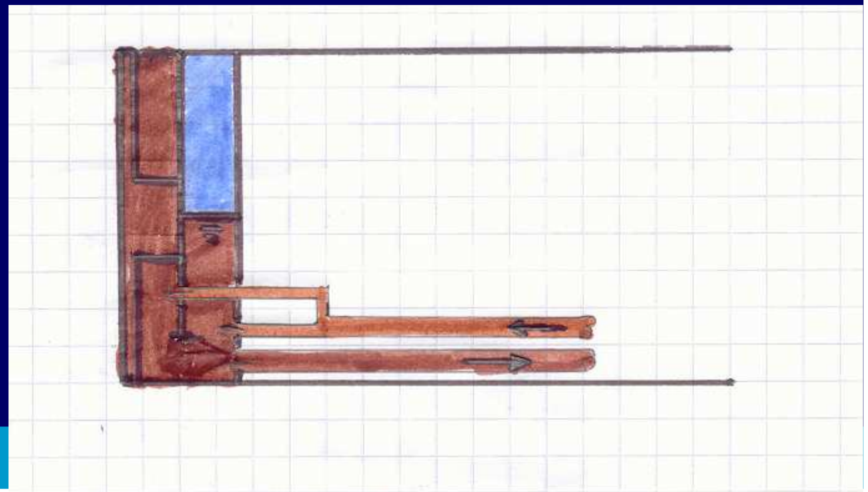
Slurry shield versus Hydro shield

Slurry shield Versus Hydro shield

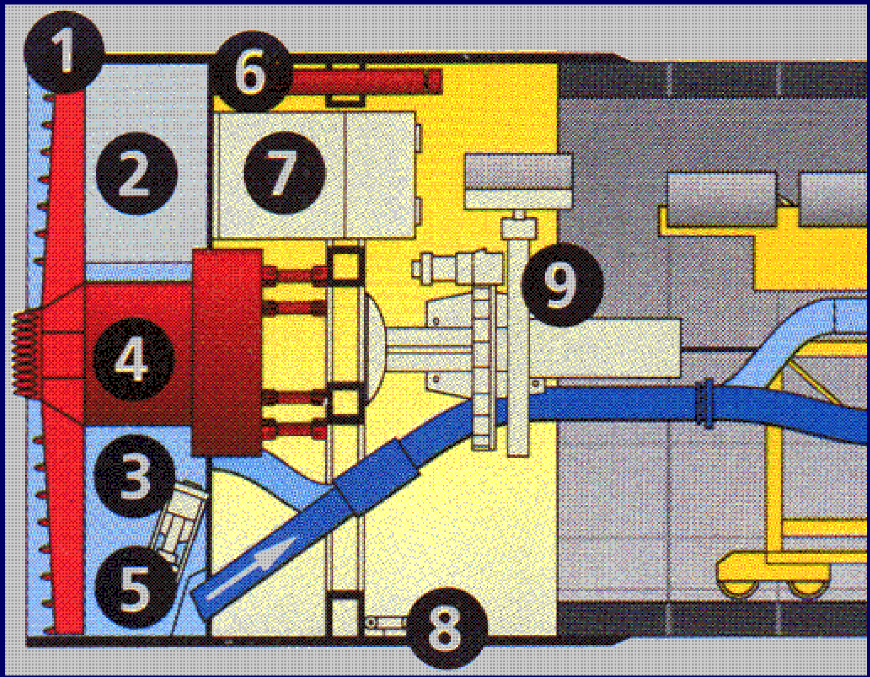
- Vulnerable for errors pumps
- More simple TBM
- Japan and pipe jacking

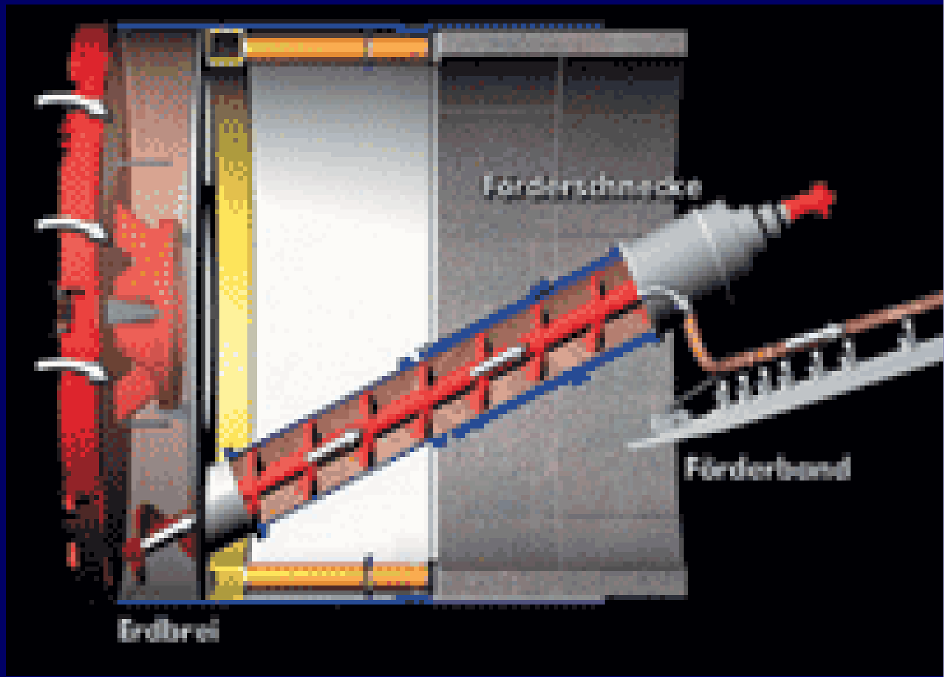
- Air bubble levels out
- Accurate support pressure
- Europe



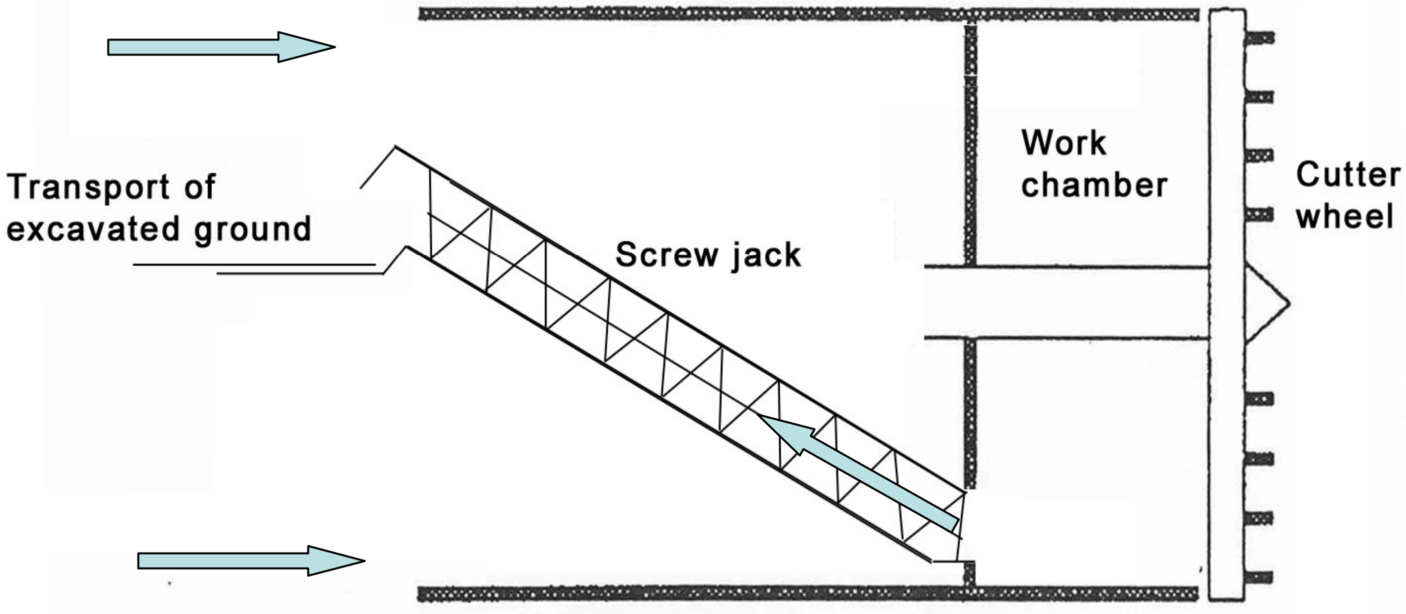


Principles of slurry shield and EPB

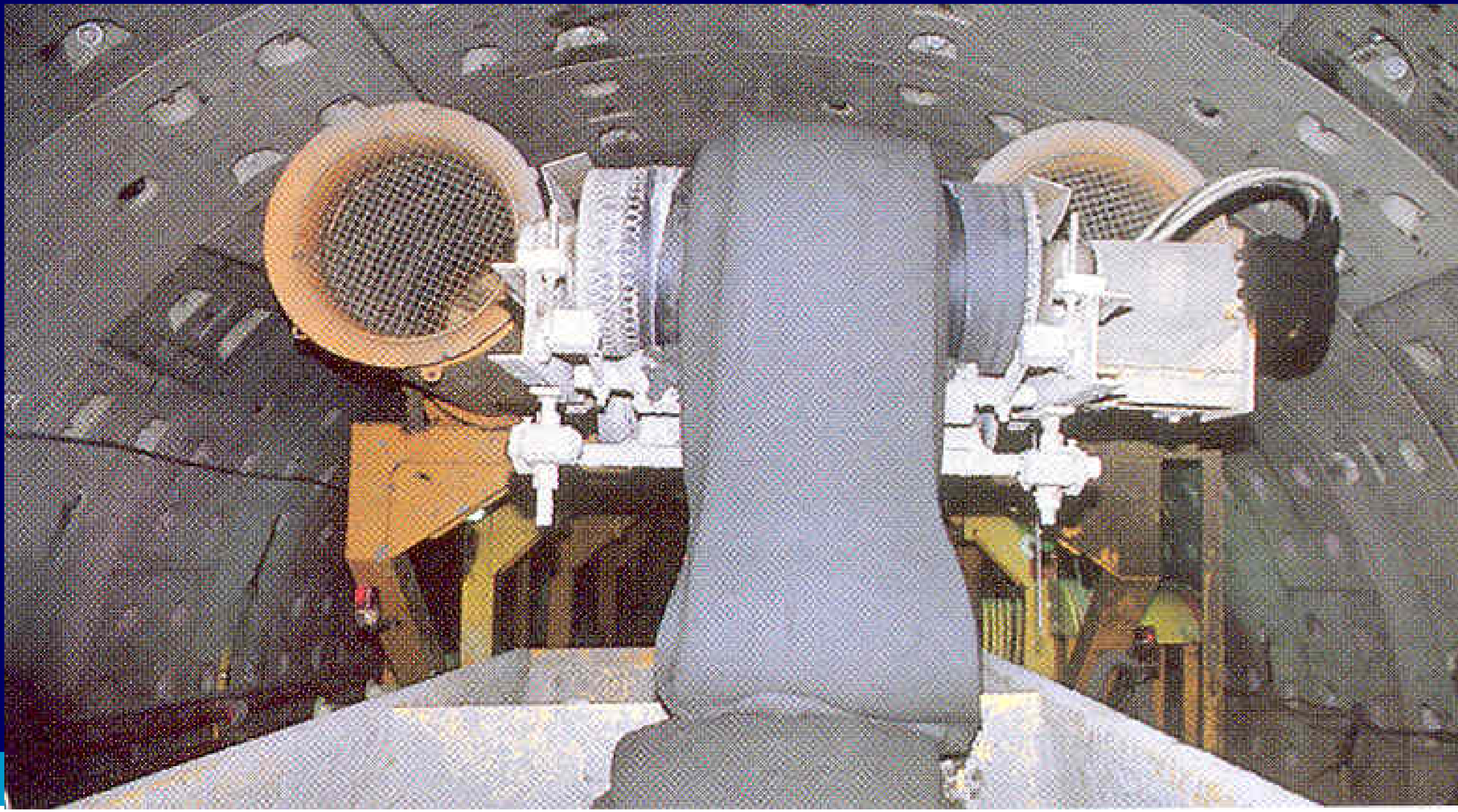




EPB shield


Transport of
excavated ground
Screw jack
Work
chamber
Cutter
wheel

Earth Pressure Balance (Elastic soil mixture from excavation face)



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Slurry

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Separation plant (cost factor)

Separation plant Groene Hart, 2500m3/hr supplied by MS in 1998

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Slurry versus EPB

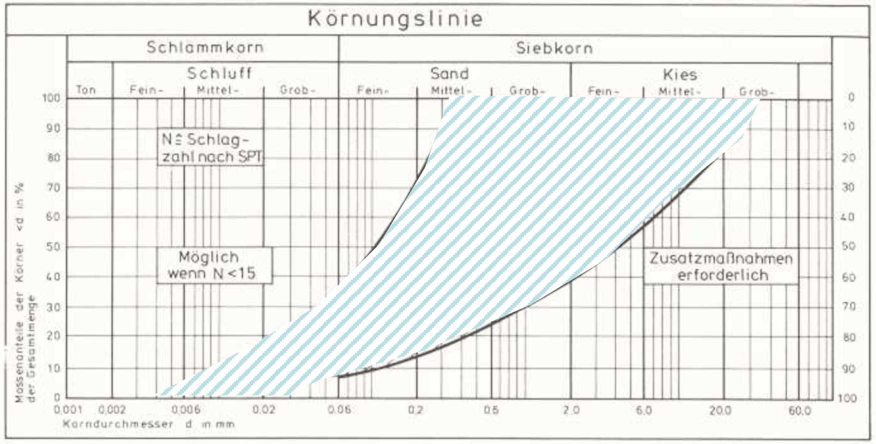


Bild 10-5
Einsatzbereich des Slurry-Shields in Abhängigkeit von der Bodenart [207]

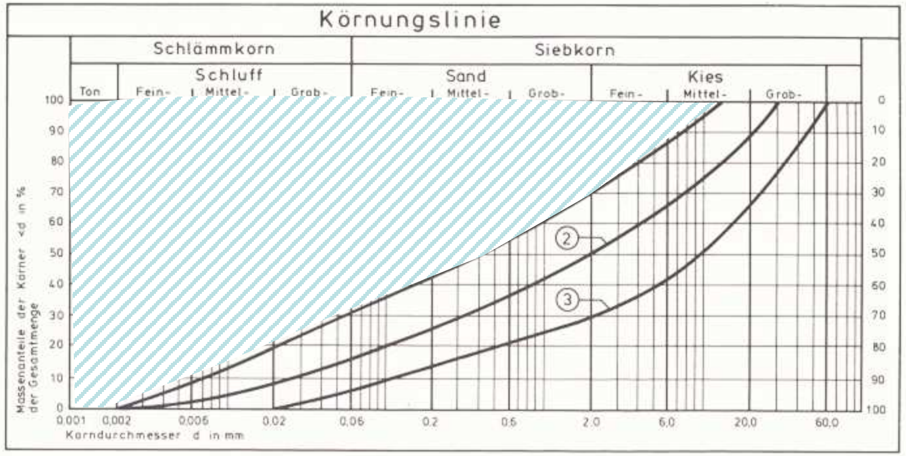
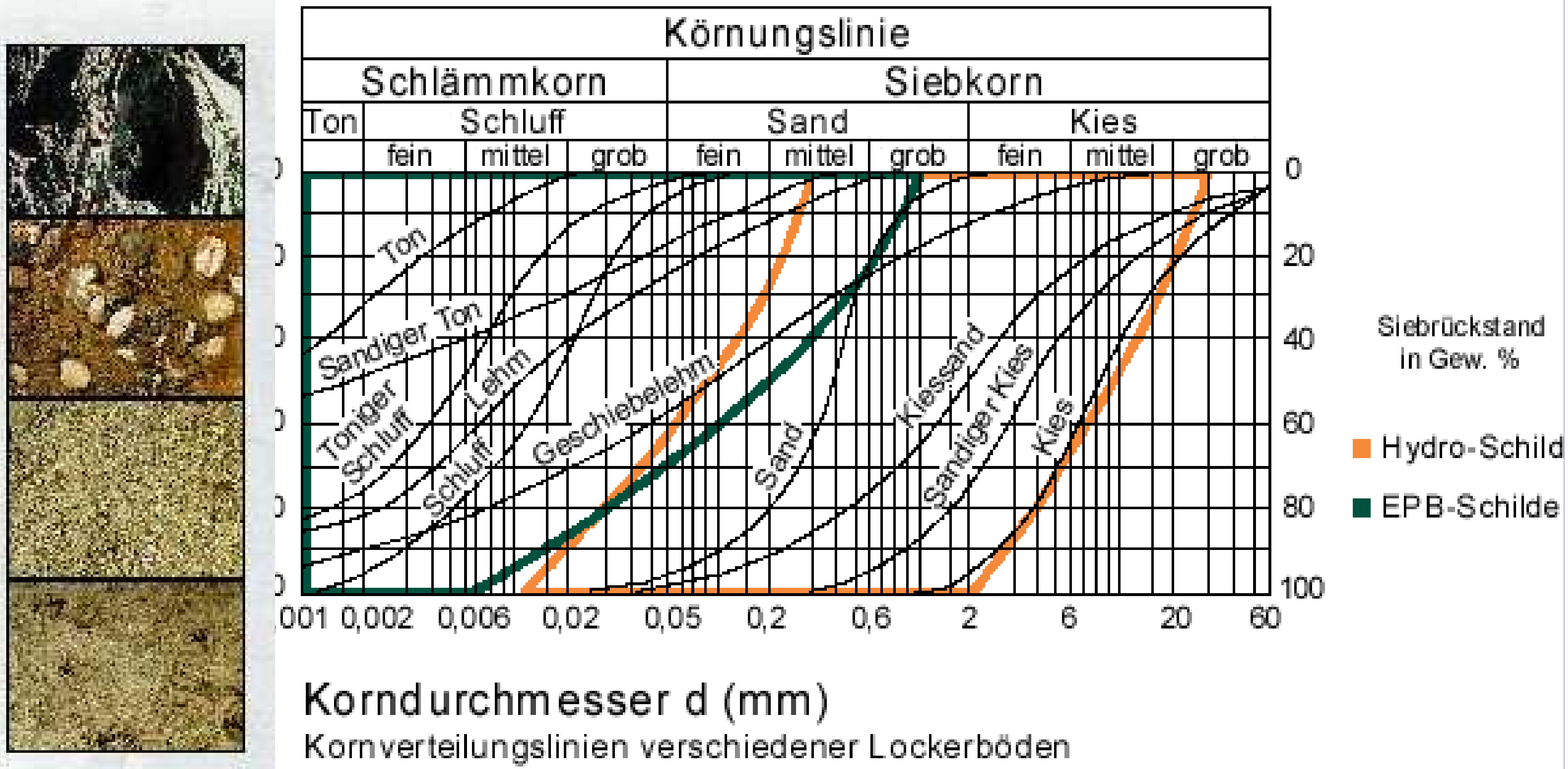


Bild 11-5
Einsatzbereich der Erddruckschilde in Abhängigkeit von der Kornverteilung des Bodens

Slurry-shield	versus	EPB-shield
non cohesive	versus	cohesive

EPB versus Slurry



Support pressure EPB- versus Slurry

Safety against excavation face collapse:

$P = 1{,}5 * \sigma'_h + 1{,}05 * \sigma_w$ (all levels of cross section top and bottom)
The bottom is normative

Safety against blow out:

$P_{max} = \sigma'_v \ / \ 1{,}1$ (for all levels)
the top is normative

>>> CT 5305 & CT 5330 Foundation Eng. and Underground Construction

>>>>CT 5305 & CT 5330 Foundation Eng. and Underground Construction

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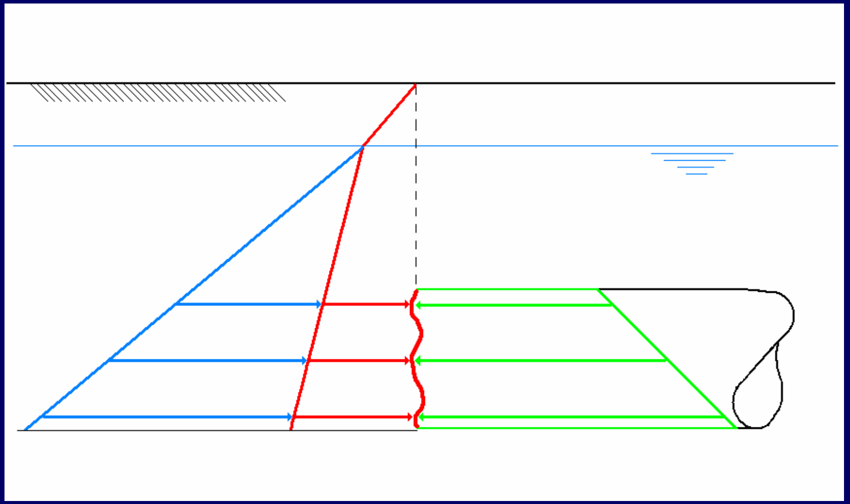
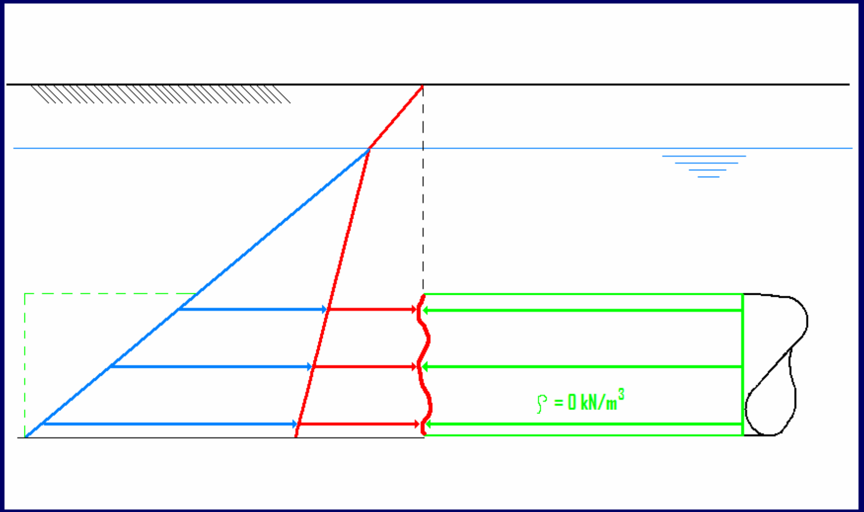
Support pressure EPB- versus Slurry

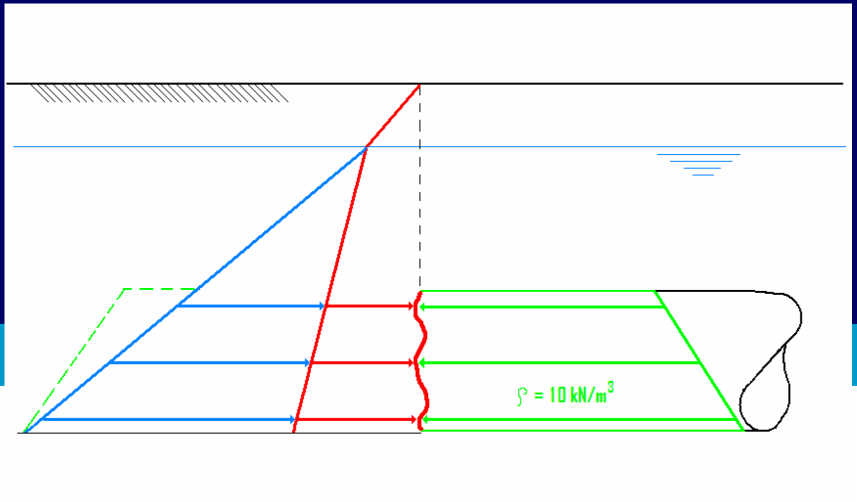
Ideal situation for support pressure



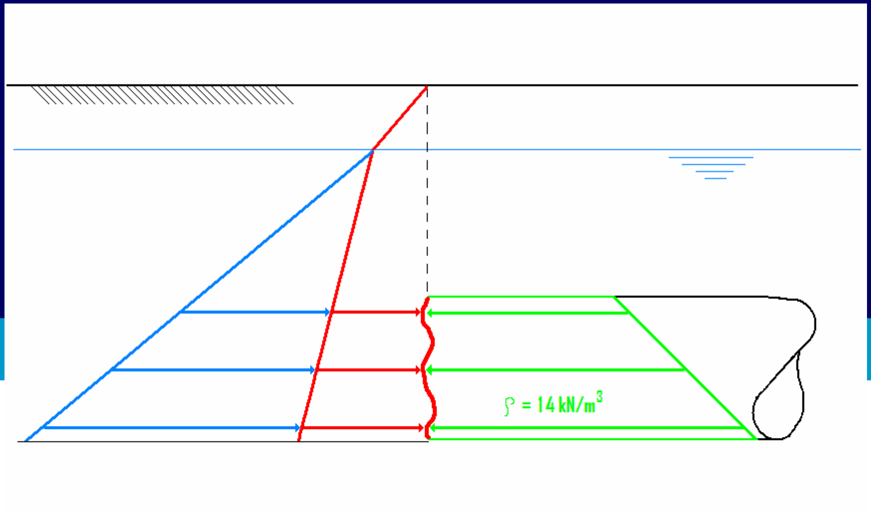
“worst case” air support



Support with bore fluid



Support with earth paste EPB



Summary Slurry versus EPB

Slurry shield	EPB-shield
support with (bentonite) fluid	support with the excavated soil
minimum cover +/- 1 D	minimum cover +/- 0,5 D
in non- cohesive soil	in cohesive soil
extraction with pumps	extraction with screw conveyor and ?
Pressure can be adjusted accurateley	pressurre fluctuations
Separation plant	-
simple TBM	complex TBM (high torque, more wear, conveyors)
overall higher costs	overall lower costs

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Extend the use of EPB in unfavourable geological conditions

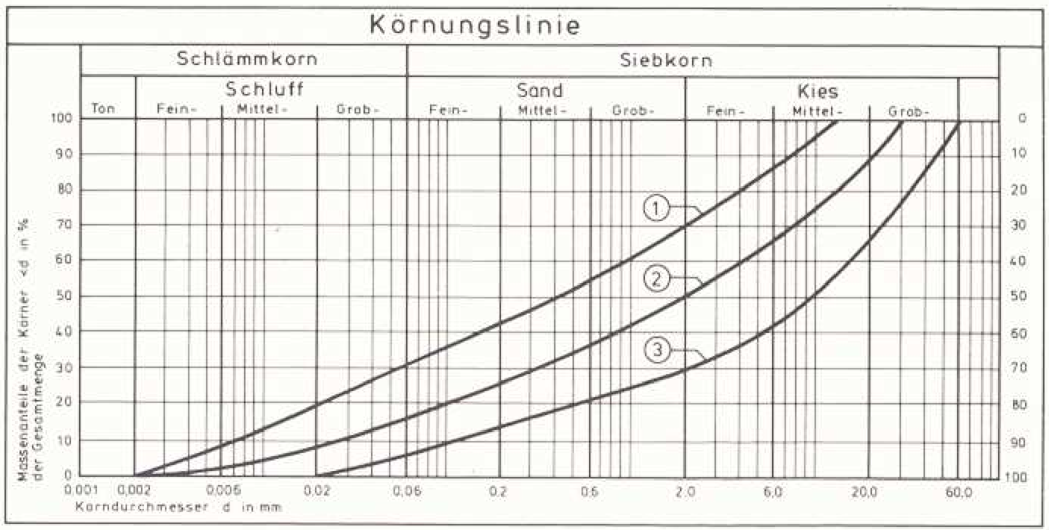
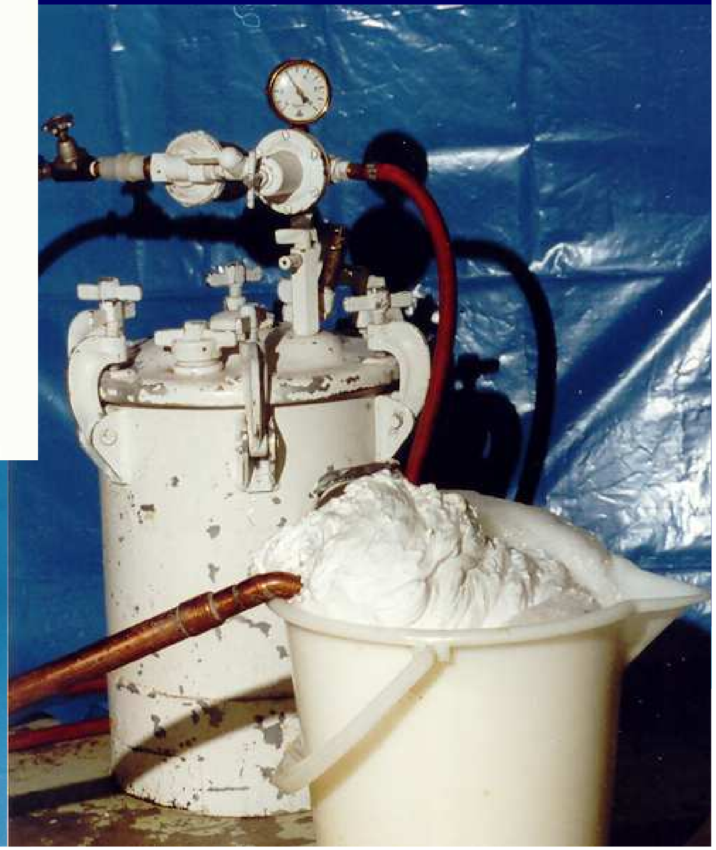
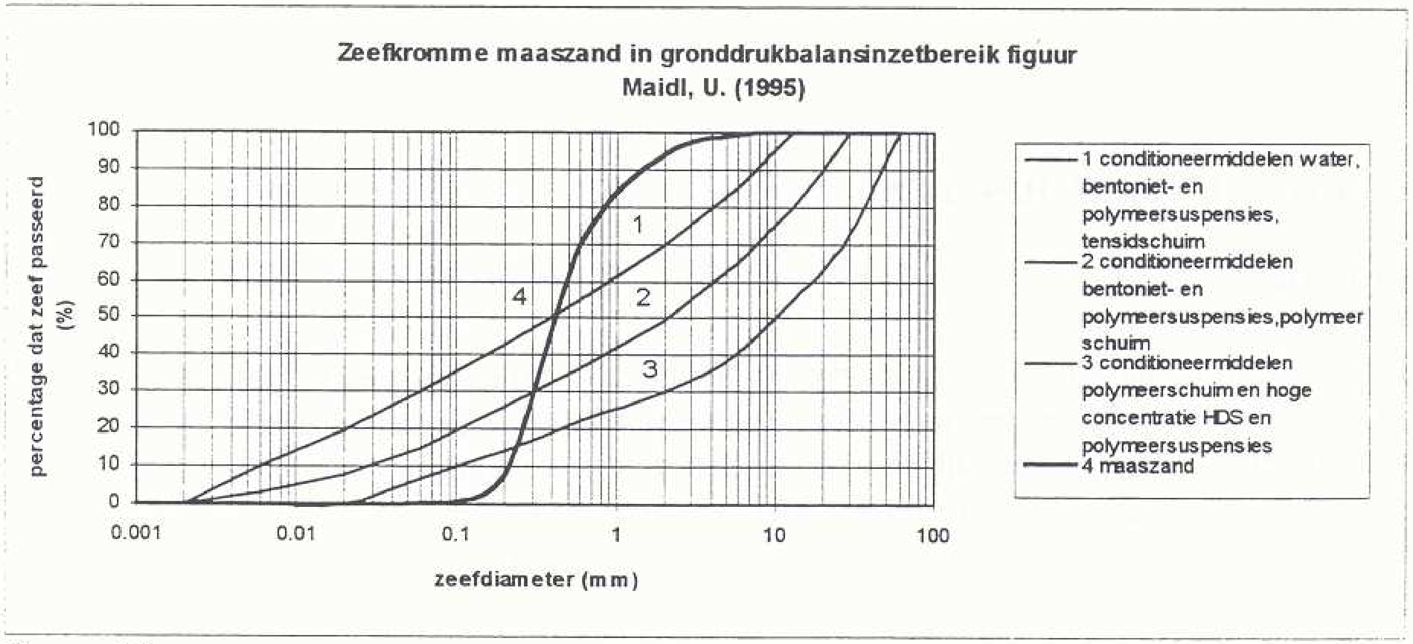


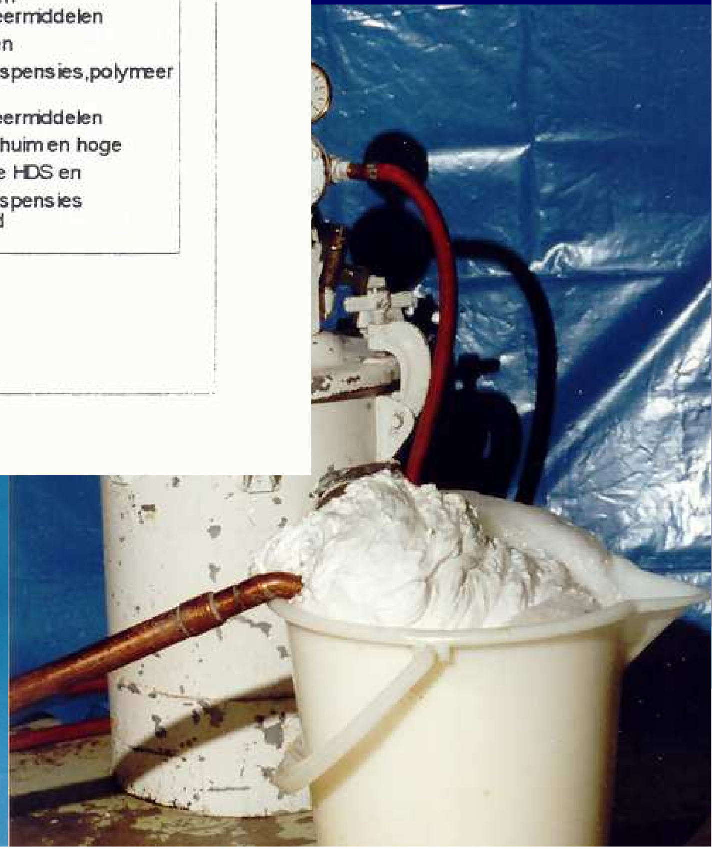
Bild 11-5
Einsatzbereich der Erddruckschilde in Abhängigkeit von der Kornverteilung des Bodens



Extend the use of EPB in unfavourable geological conditions



Figuur: 6.3



Botlek Tunnel EPB in sandy soil

Summary

- Immersed tunnels
- Building techniques for land tunnels.
- Functions of a TBM
- Pipe jacking versus tunneling
- Slurry versus Hydroshield
- Principle of support pressure
- Slurry versus EPB
- Extending the use of an EPB TBM

>>>>chapter 7, 8, 9, 10 of the reader

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CT 3300 in relation to other courses

- CT 3300 Use of underground space.
  - Broad introduction
  - "Inleiding ondergronds bouwen"
- CT 4780 Special Topics
  - New developments on UC
- CT 5305 Bored and immersed tunnels
  - In detail
- CT 5330 Foundation Eng. and Underground Construction
  - Amongst others Bored tunnels in detail
- CT 5740 Trenchless Technology
  - Pipeline construction techniques In detail

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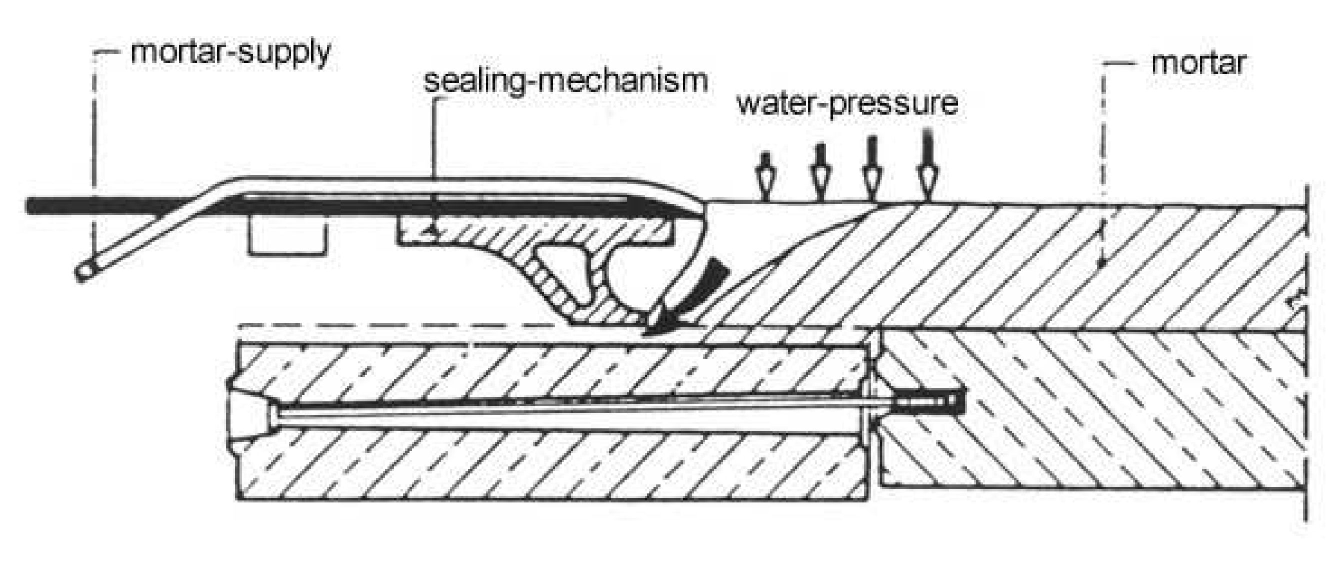
Tail-sealing-mechanisms (S1 seal)

- Rubber tail sealing mechanism



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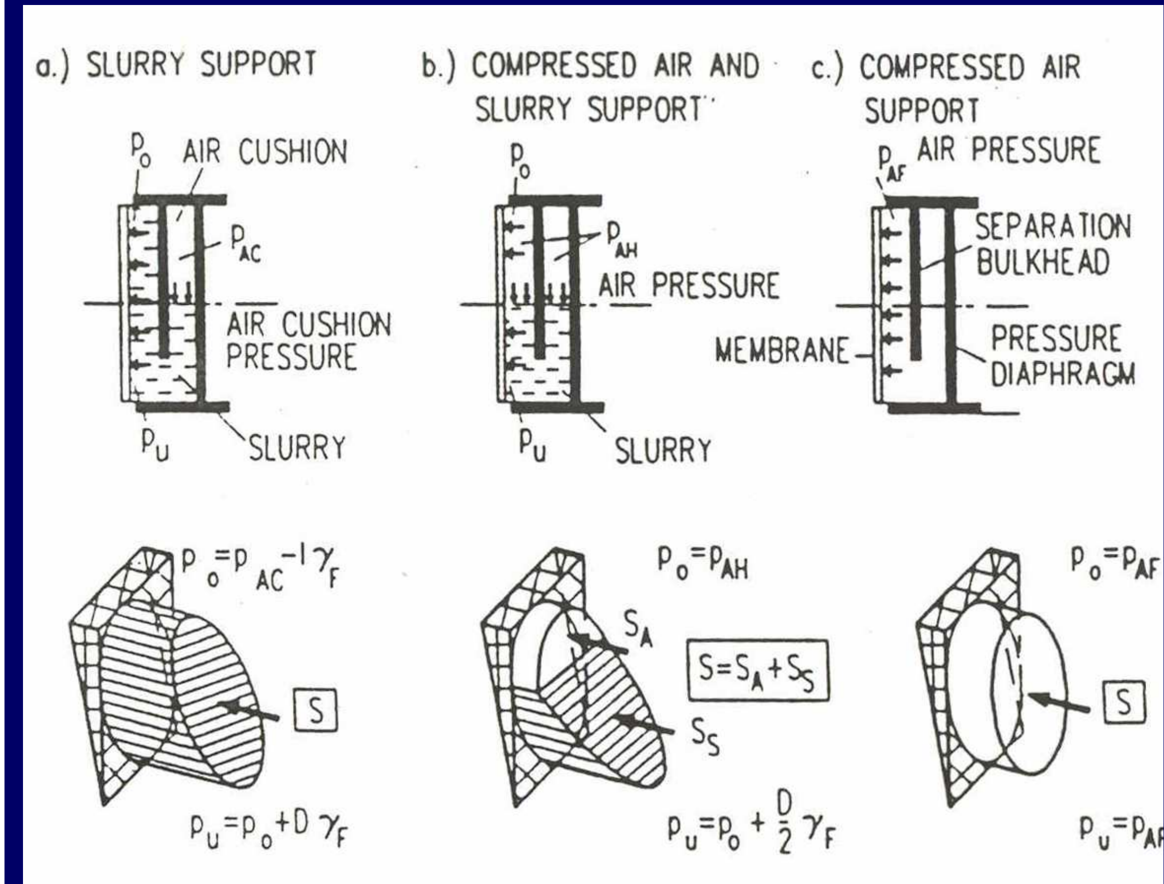
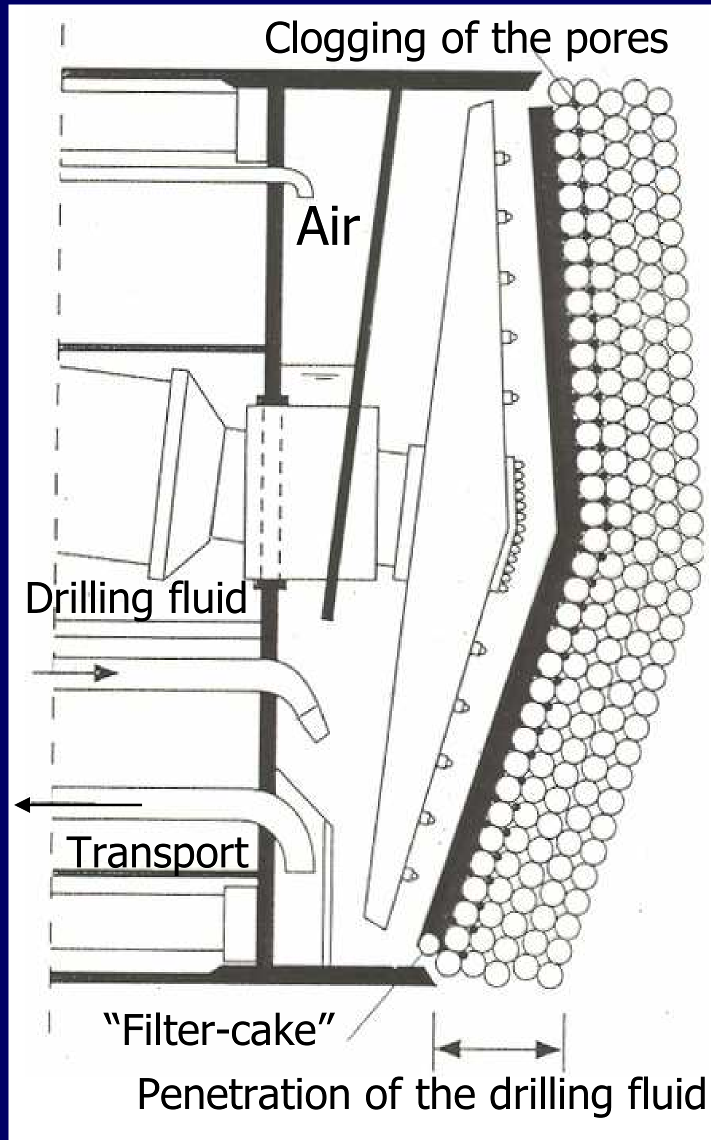
Principle of the drilling fluid





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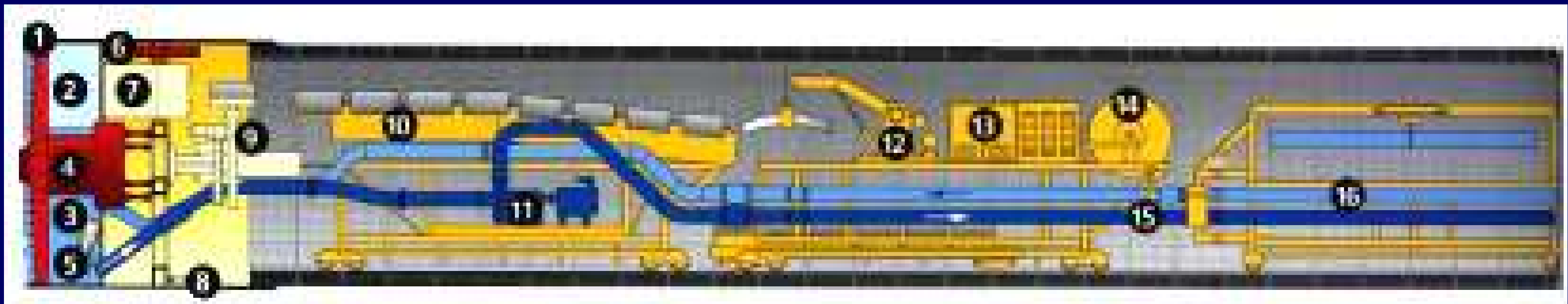
Slurry shield

1 Cutting wheel
2 Air bubble
3 Bentonite suspension
4 Drive unit
5 Stone crusher
6 Push cylinder
7 Air lock
8 Steering cylinder - Shield tail

9 Erector
10 Segment conveyor
11 Slurry pump
12 Segment crane
13 Main electric panel
14 Cable reeling drum
15 Discharge line
16 Feed line



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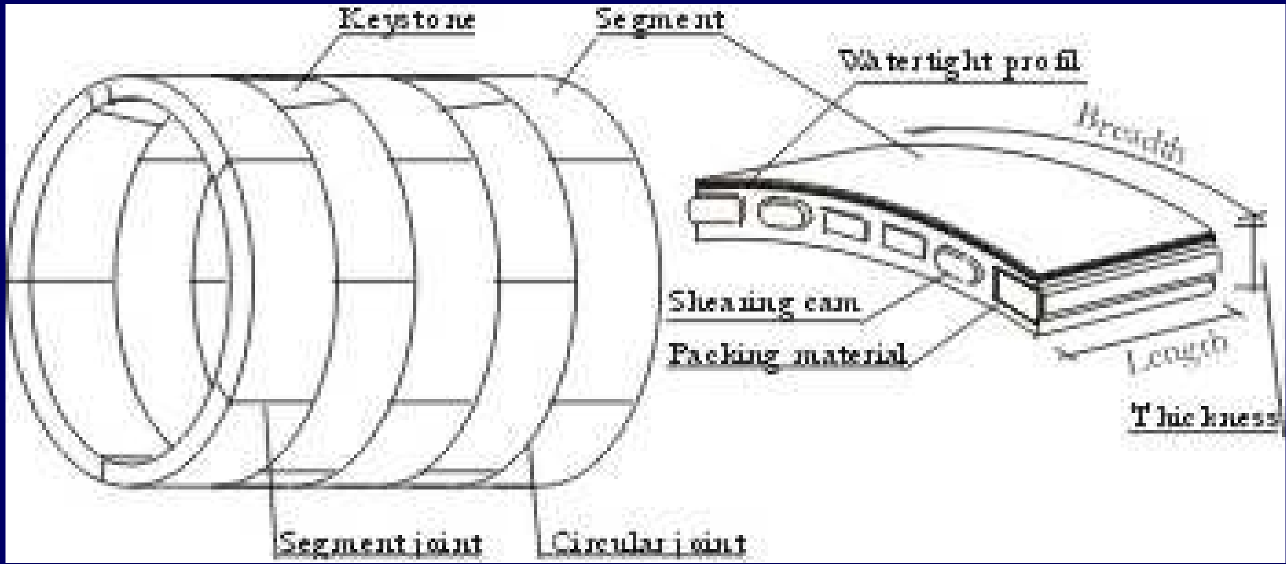
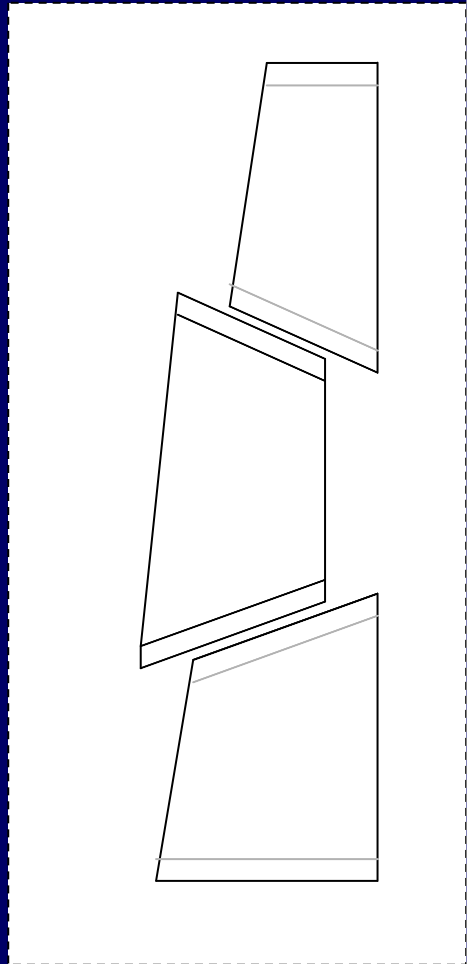
Segments tunnel lining





- Variation of the position of left and right segments change the dirrection of the tunnel
- Keystone closes the arch

Next year,

- boulder clay foto TBM delfzijl.
- Foto groene Hart
- Tunnel lining Engineering

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