Use of Underground Space

Lecture 1: **Overview**

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Use of underground space in the Netherlands

The growing interest for the use of underground space, despite of the unfavourable circumstances in the Netherlands, is the result of:

- The environmental **complexity** and the growing numbers of infrastructural and environmental planning problems
- The continuing demand for better **quality** of environment, nature and liveability
- Economical growth

Use of Underground Space

Use of underground space contains:

- Planning of underground space
- Realization of underground works
- Utilization of underground facilities

Reasons for the use of underground space

Reasons to go underground can be:

- Taking away/ reducing nuisance and thereby improving liveability
- Reducing/ eliminating the security risks and damage to the environment
- Complex infrastructural/ environmental planning problems, especially in areas where space is limited
- Strategic consideration

Amsterdam Centraal Station

Amsterdam Centraal Station

Motivation for going underground	A	B	C
Underground construction as last and only alterna	x	x	
Larger functionality	x	x	
Protection from "outside"	x	x	
Energy saving		x	
Durability and maintainance		x	
Larger building density		x	x
Better accessability/ less limitations	x		x
Multiple/ efficient use of space		x	x
Combination with other facilities	x	x	
"Ugly" objects underground		x	x
Decreasing hindrance for the surroundings		x	x
Decreasing hindrance for the environment			
Maintainance of valuable functions			x
Increasing external safety			x
Economy and transport		x	

A = Users, B = Investors and operators,
C = Nearby inhabitants and workers, D = Society

Different points of view and therefore different reasons for going underground.

Primary functions in general (1)

Living:
- Urban living
- Suburban living

Working:
- Service industries
- Industrial production and public utilities
- Retail trade and small-scale production
- Research and education

Leisure:
- Sports and recreation
- Culture
- Hotel and catering industry

Primary functions in general (2)

Transport:

- Personal transport
- Transportation of goods
- Transport without vehicles (digital information, electricity, bulk goods, chemicals, liquids, gas etc.)

Functions to put underground

Underground location is a good alternative for the following functions:

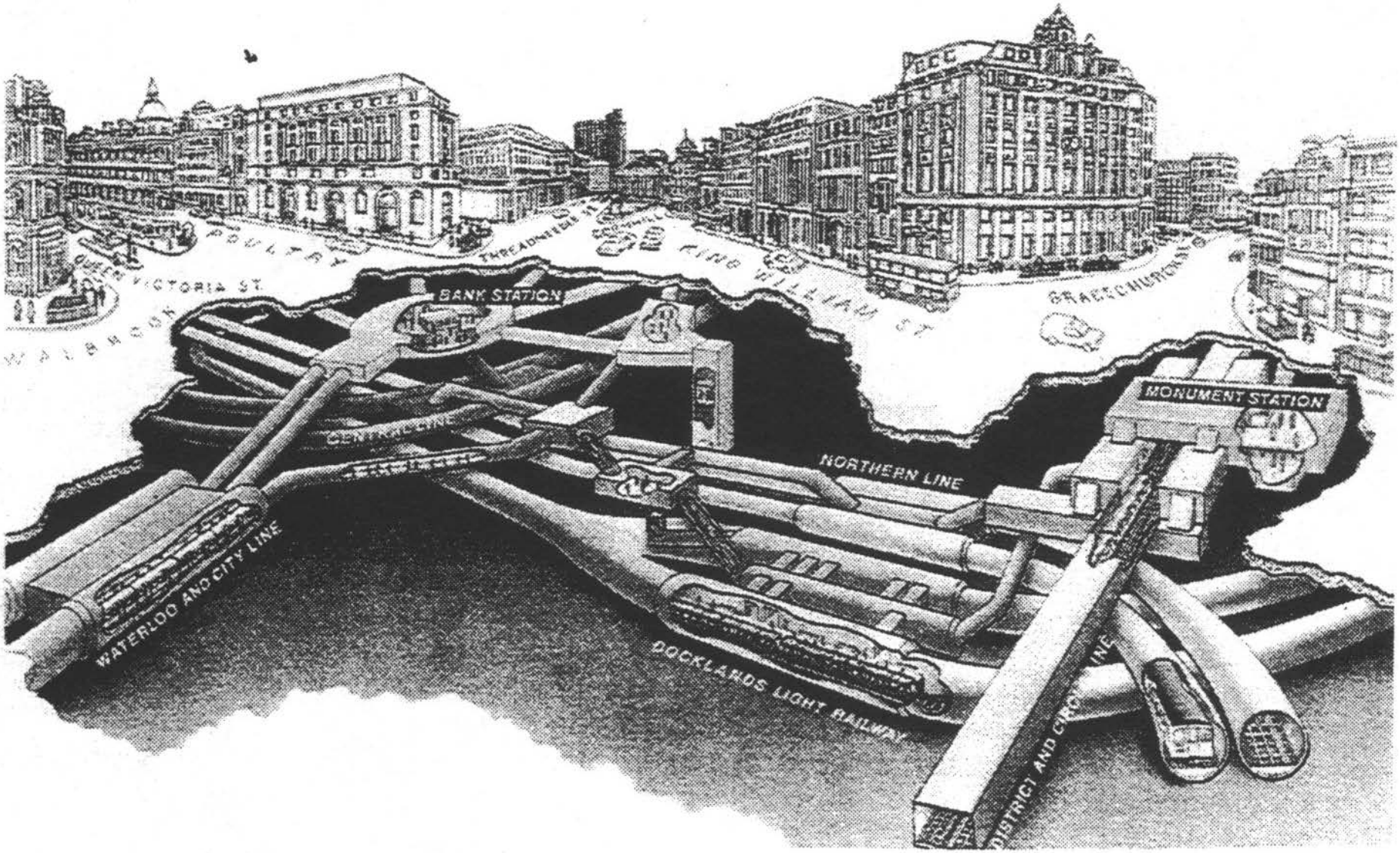
- Storage
- Transportation of goods
- Junctions of infrastructural facilities

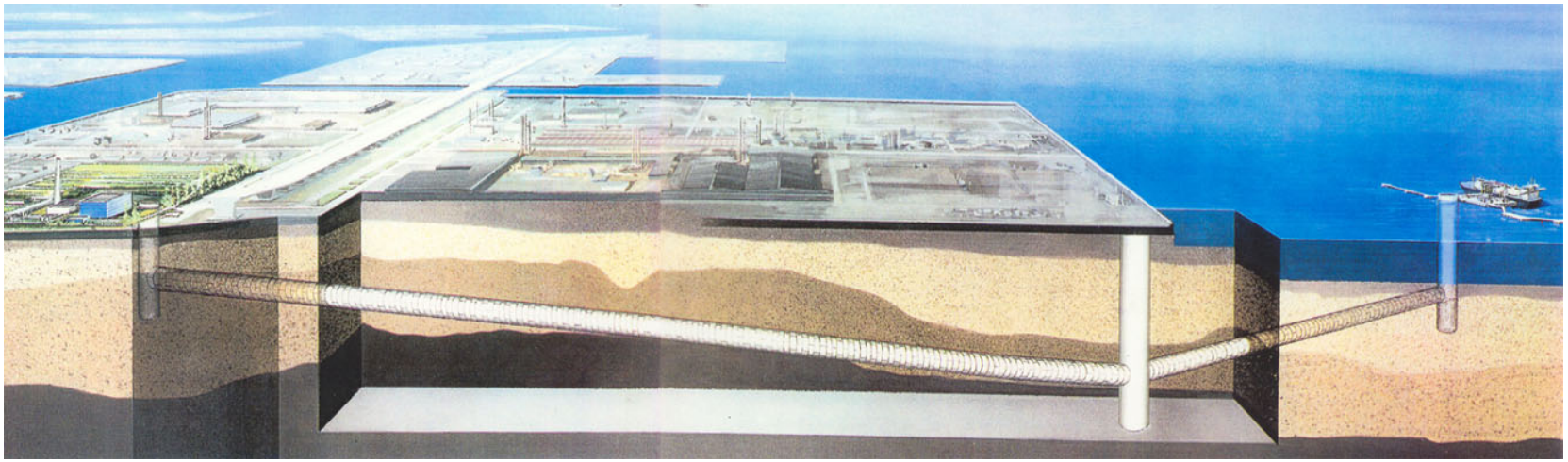
Note: **Living, working and leisure are functions that are, without special provisions, less suitable for underground applications.**

Functions to put underground

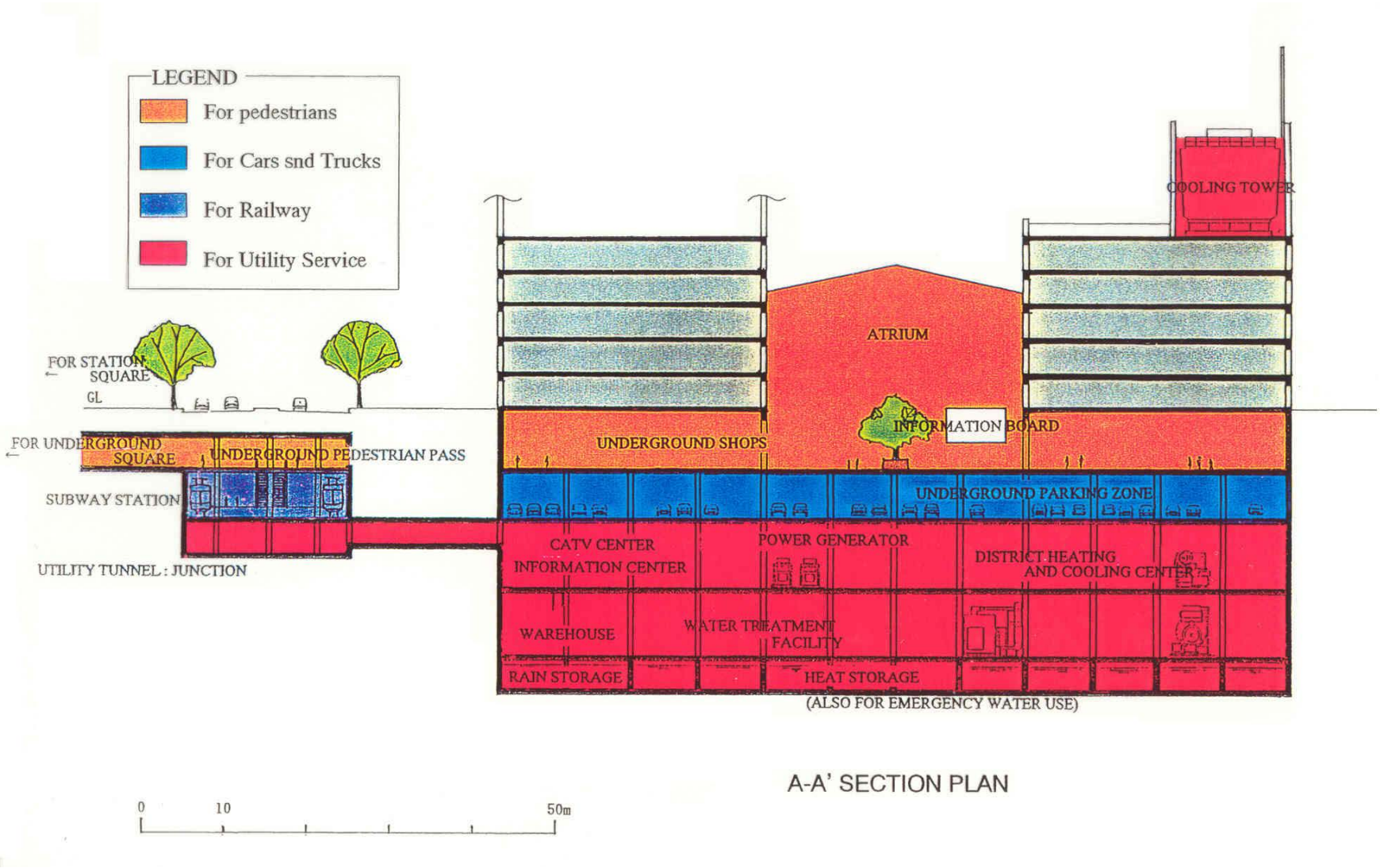
Different types of underground structures by function (5):

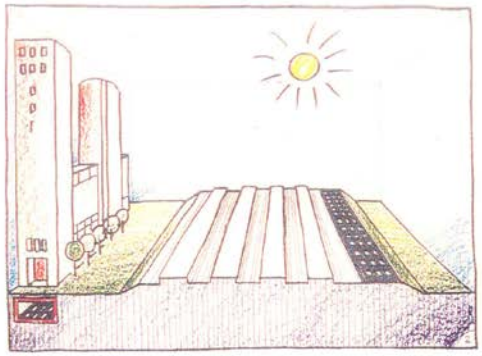
- Large infrastructure: road and rail
- Small infrastructure: sewerage, water, electricity, gas, data
- Storage: oil, gas or archives
- Public spaces: shopping mall, parking
- Dedicated systems (OLS)

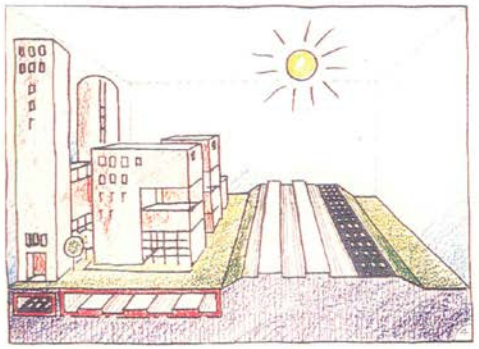

BANK STATION
MONUMENT STATION
NORTHERN LINE
WATERLOO AND CITY LINE
DOCKLANDS LIGHT RAILWAY

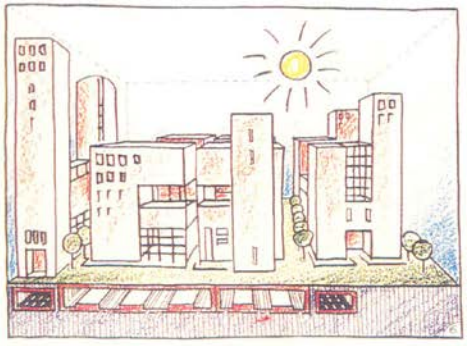



Yung-An LNG receiving terminal, Taiwan


LEGEND
For pedestrians
For Cars snd Trucks
For Railway
For Utility Service
COOLING TOWER
ATRIUM
FOR STATION SQUARE
GL
INFORMATION BOARD
FOR UNDERGROUND SQUARE
UNDERGROUND PEDESTRIAN PASS
UNDERGROUND SHOPS
SUBWAY STATION
UNDERGROUND PARKING ZONE
CATV CENTER
INFORMATION CENTER
POWER GENERATOR
DISTRICT HEATING AND COOLING CENTER
UTILITY TUNNEL : JUNCTION
WAREHOUSE
WATER TREATMENT FACILITY
RAIN STORAGE
HEAT STORAGE
(ALSO FOR EMERGENCY WATER USE)
A-A' SECTION PLAN
0
10
50m





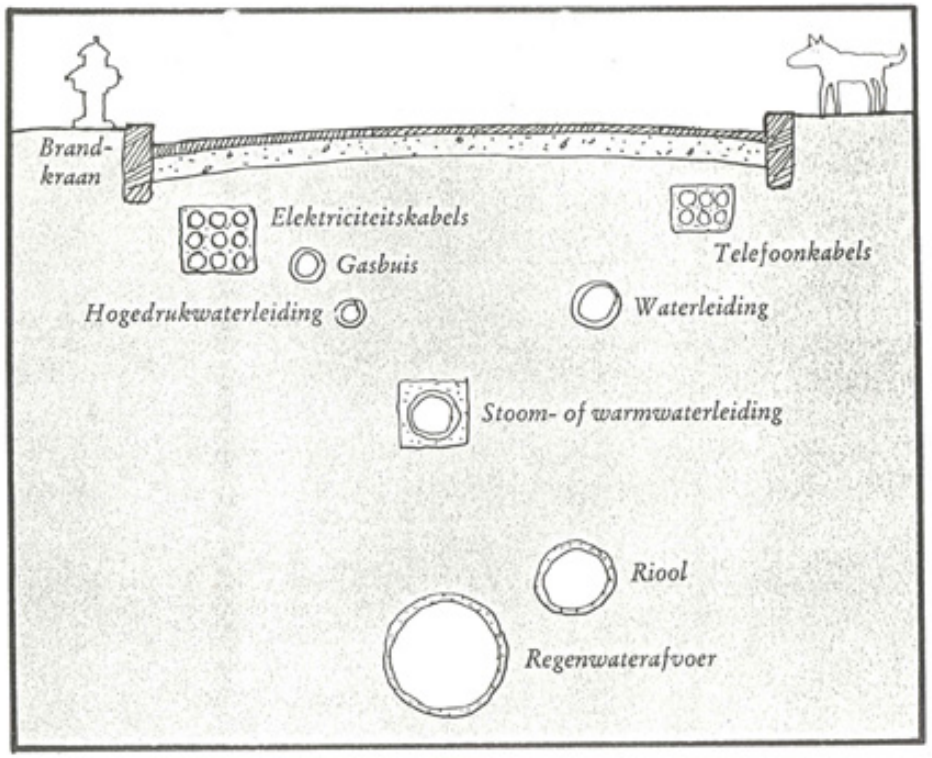


Conditions for underground construction

Whether the underground is going to be used for different functions is determined by:

- Geological/ geo-technical/ geo-hydraulic conditions
- Availability of space on ground level
- Specific advantages which underground works could offer
- Cost level versus alternatives (ground prices)
- Developing phase of relevant industrial/ potential users
- Possible adverse effects by using the underground (fire safety, social safety, perception aspects)

Obstacles in the underground (1)



IDEALE AANLEG VAN VOORZIENINGEN

Obstacles in the underground(2)

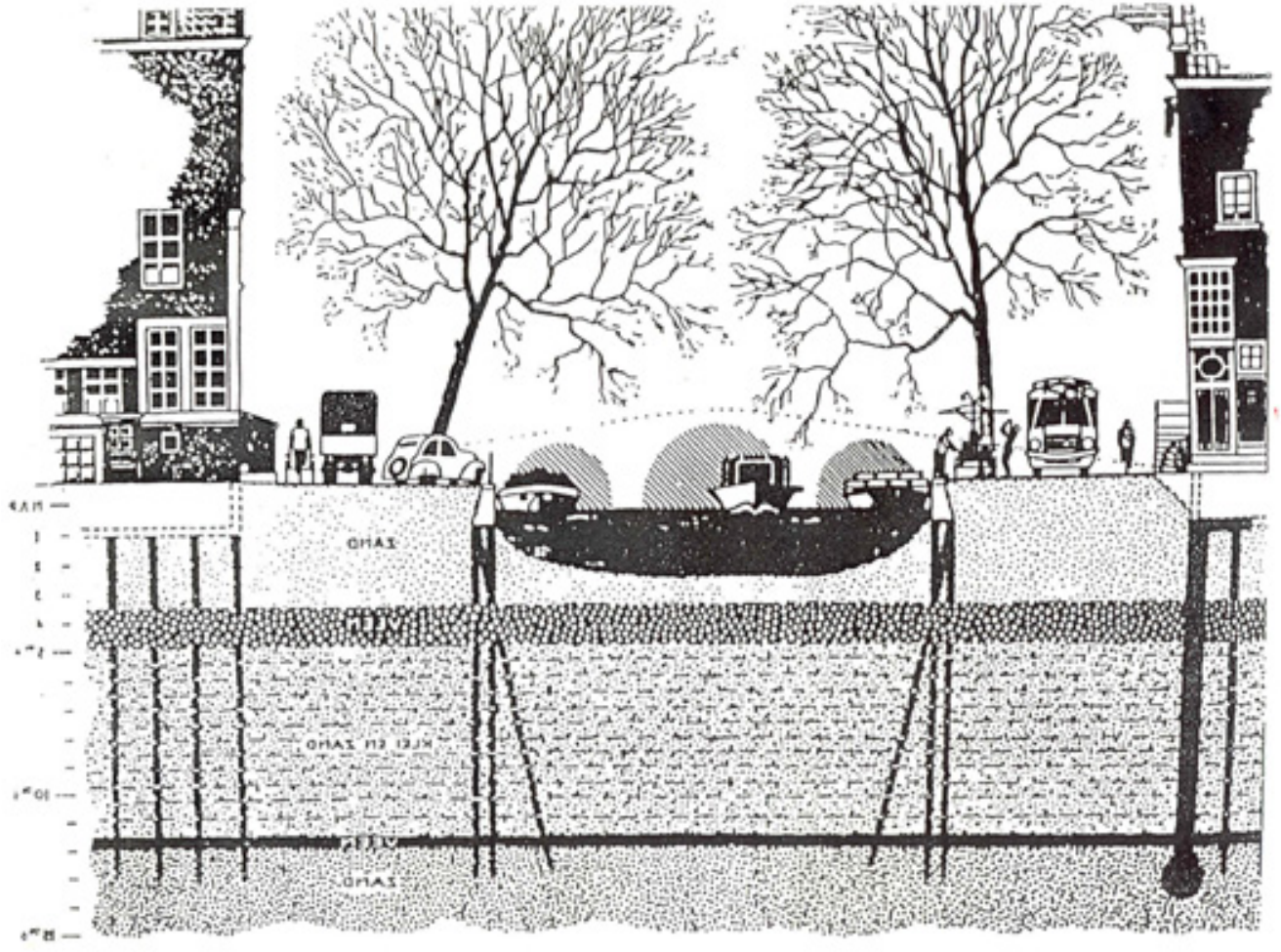
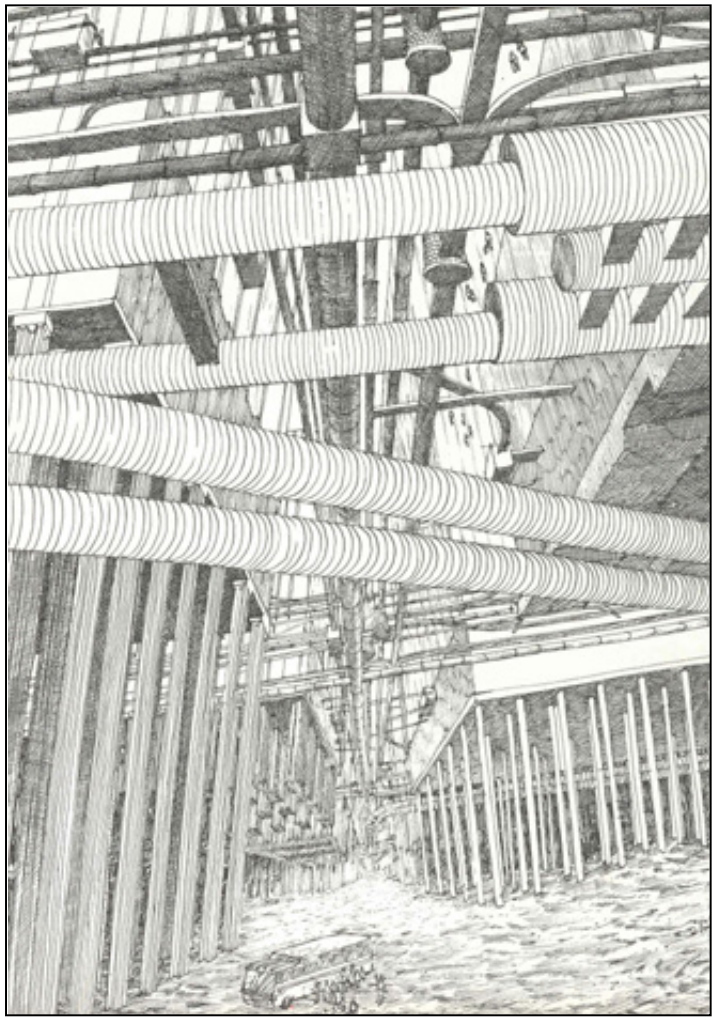
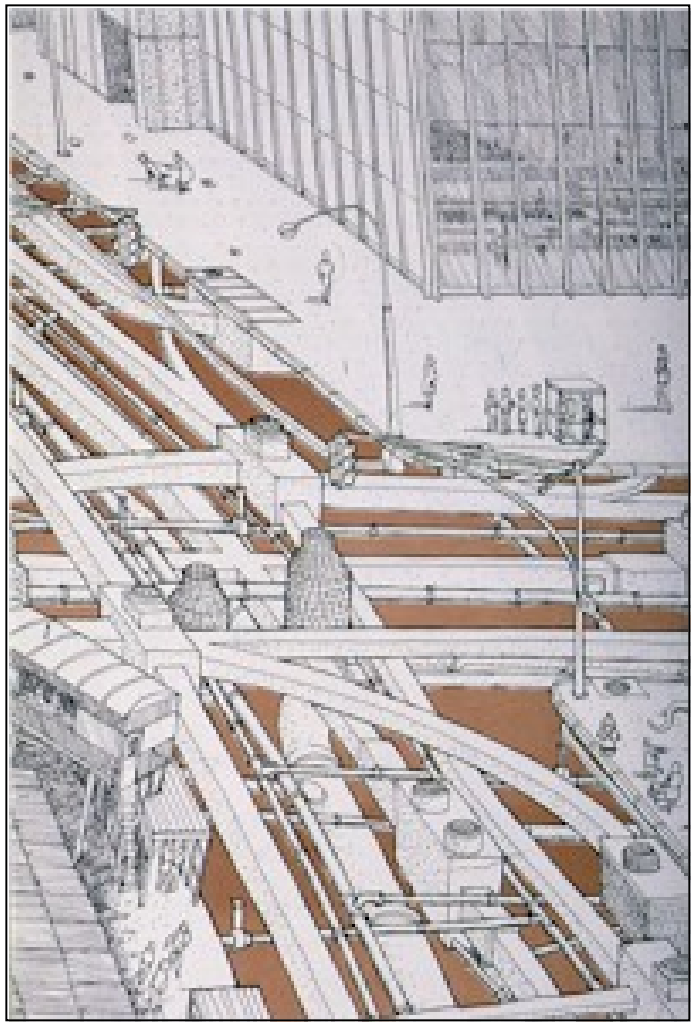
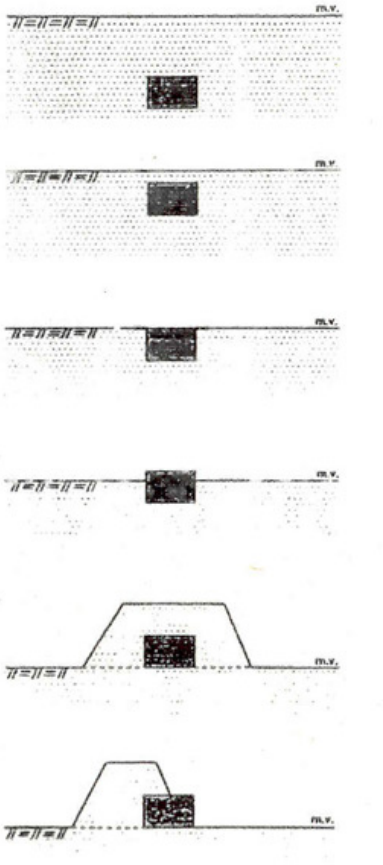


Image of the underground



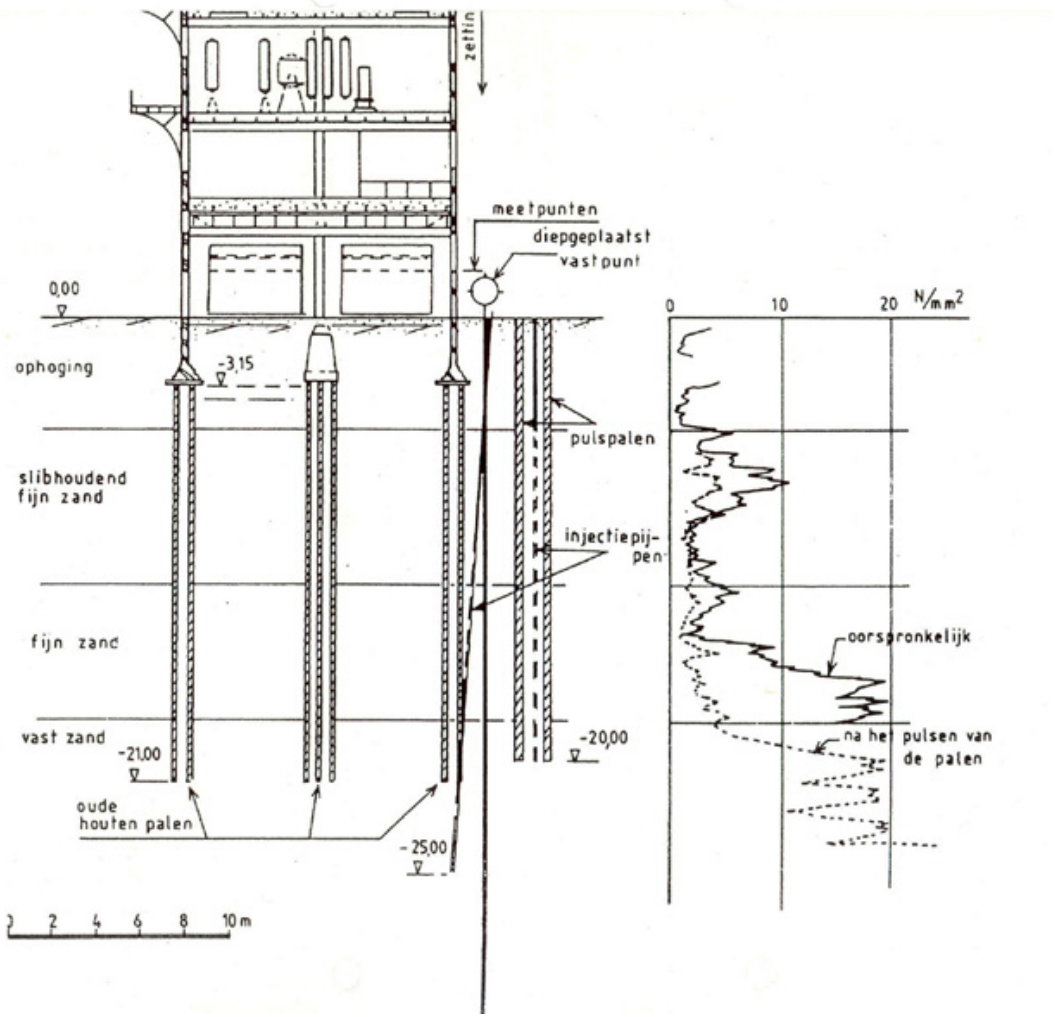


Different depth of underground constructions



- Deep-down the surface
- Close to surface, shallow construction
- At the surface
- Partly below surface
- Covered
- Partly covered

Influence of drilling

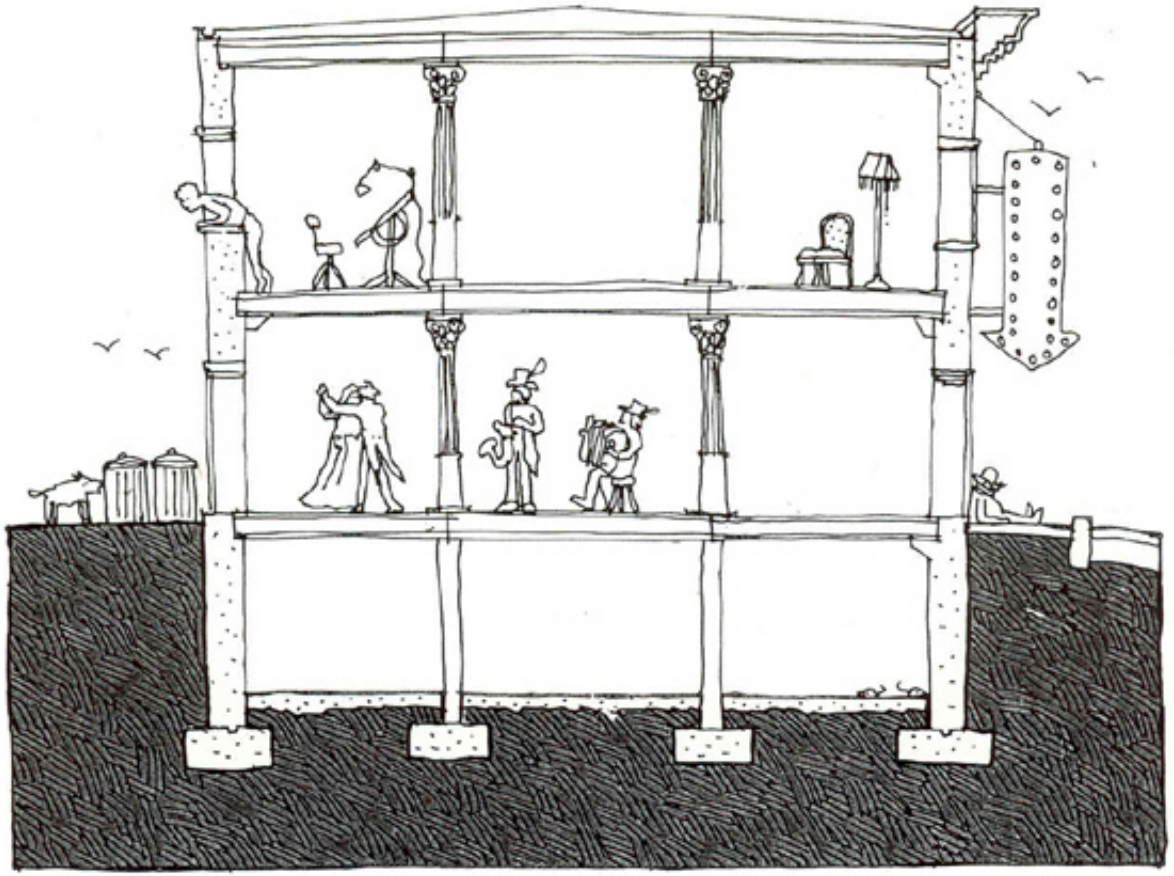


Study field: development of basements

- Basement structures are a well developed part of the study field, with sophisticated designs to save money. The cost level is the limiting factor for applying basement structures, but because of the increasing complexity of the circumstances or the scarcity of space aboveground, the techniques are more often applied.

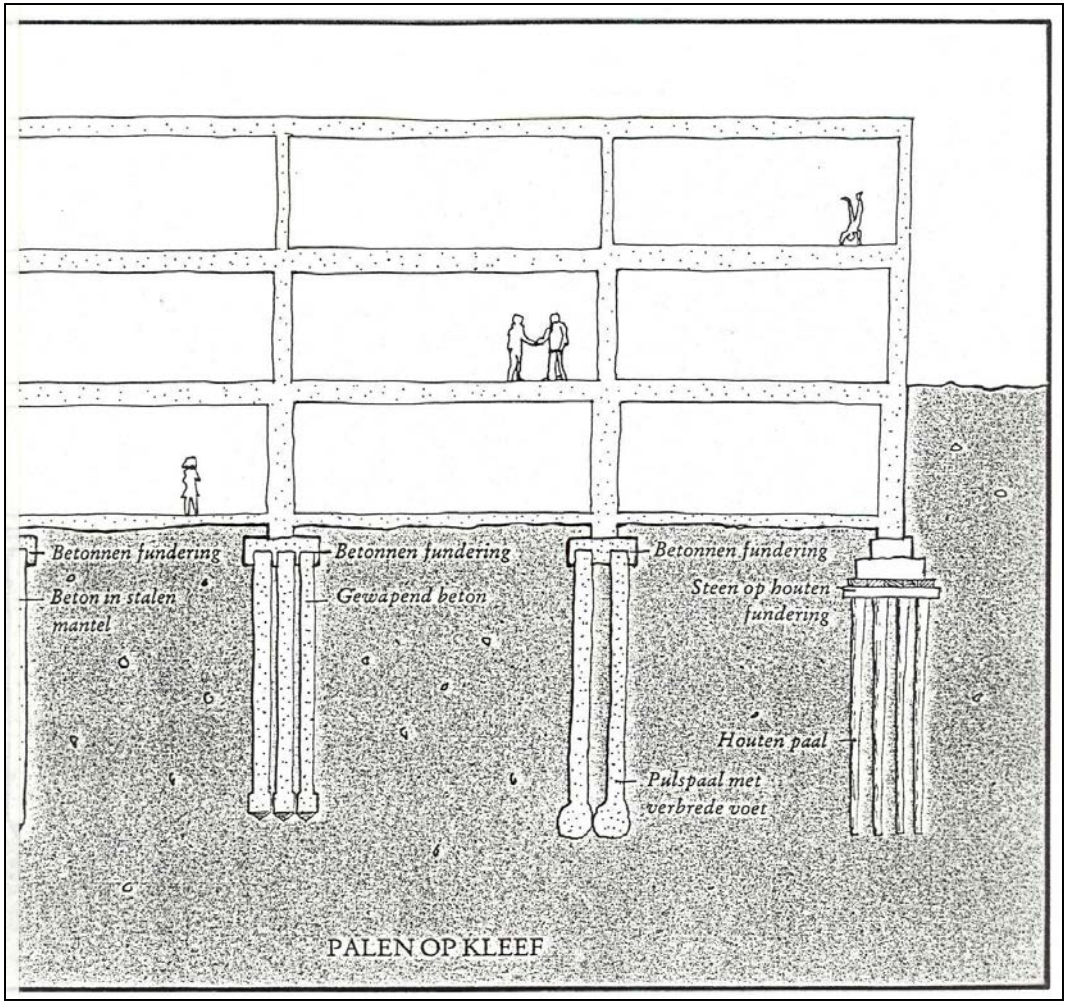
- Points of attention are:
  - the quality control
  - verifiability of the temporary and permanent construction elements

Shallow foundation



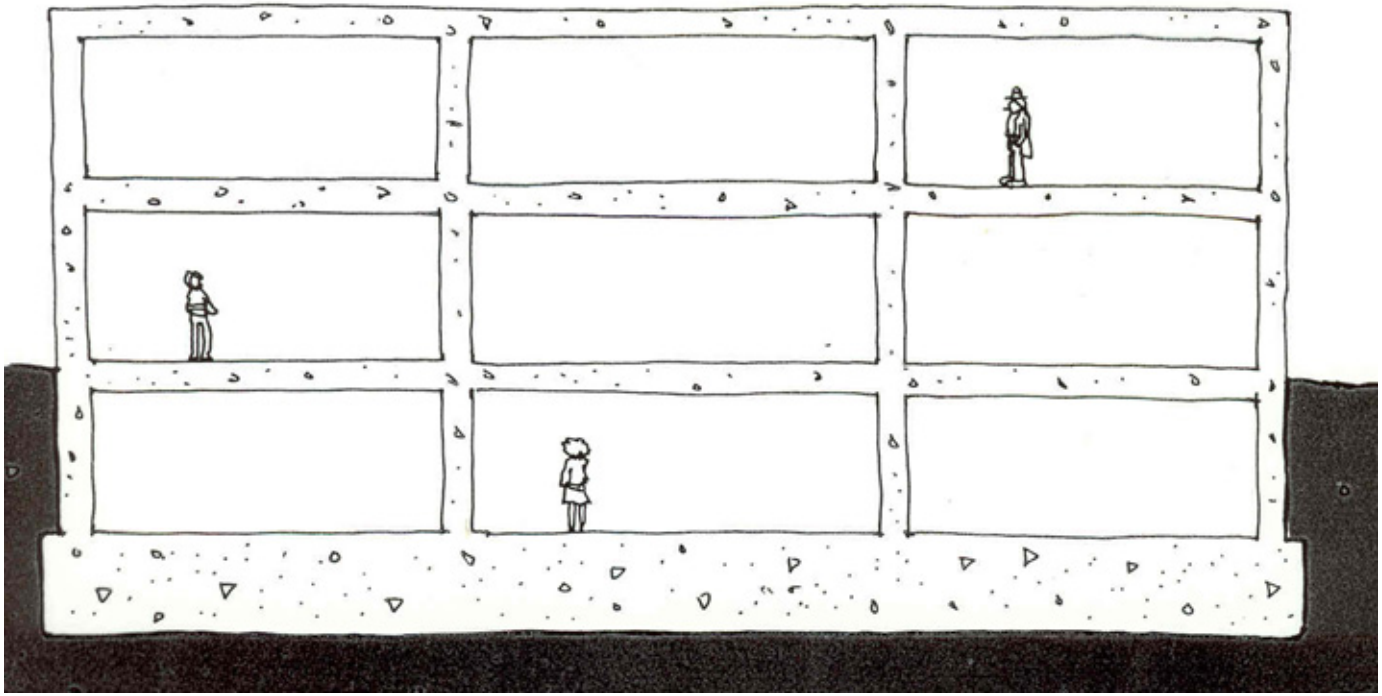
Pile foundation

- Shaft friction
- Bearing capacity of pile point



Floating foundation

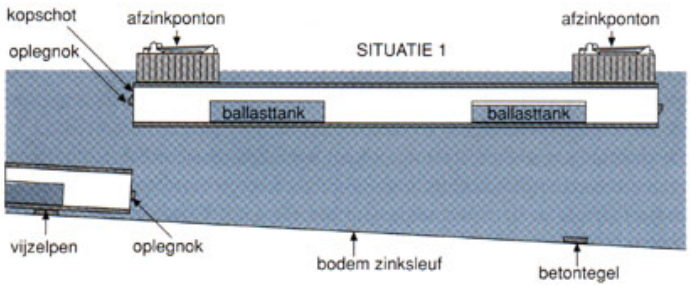
- Equally divided

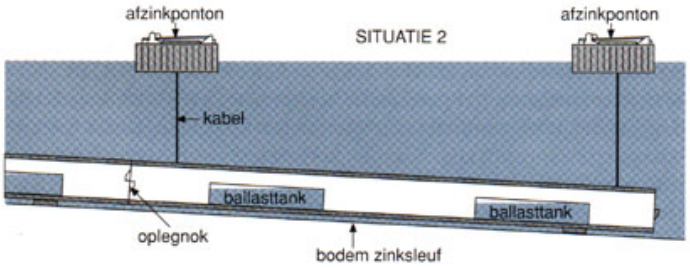


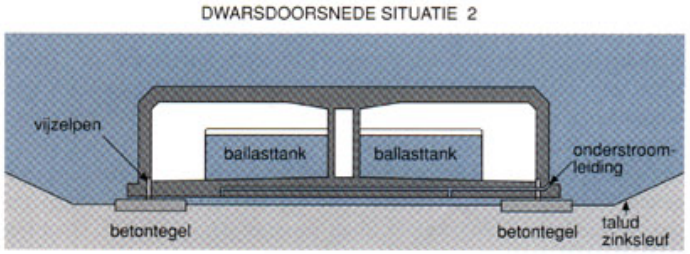
Tunnels: general

- Land tunnel
- Immersed tunnels
- Bored tunnel (EPB or Slurry shield)
- Innovative methods
  - U-polder
  - V-polder
  - TOMAS
  - Membrane

Immersed tunnels (concrete)



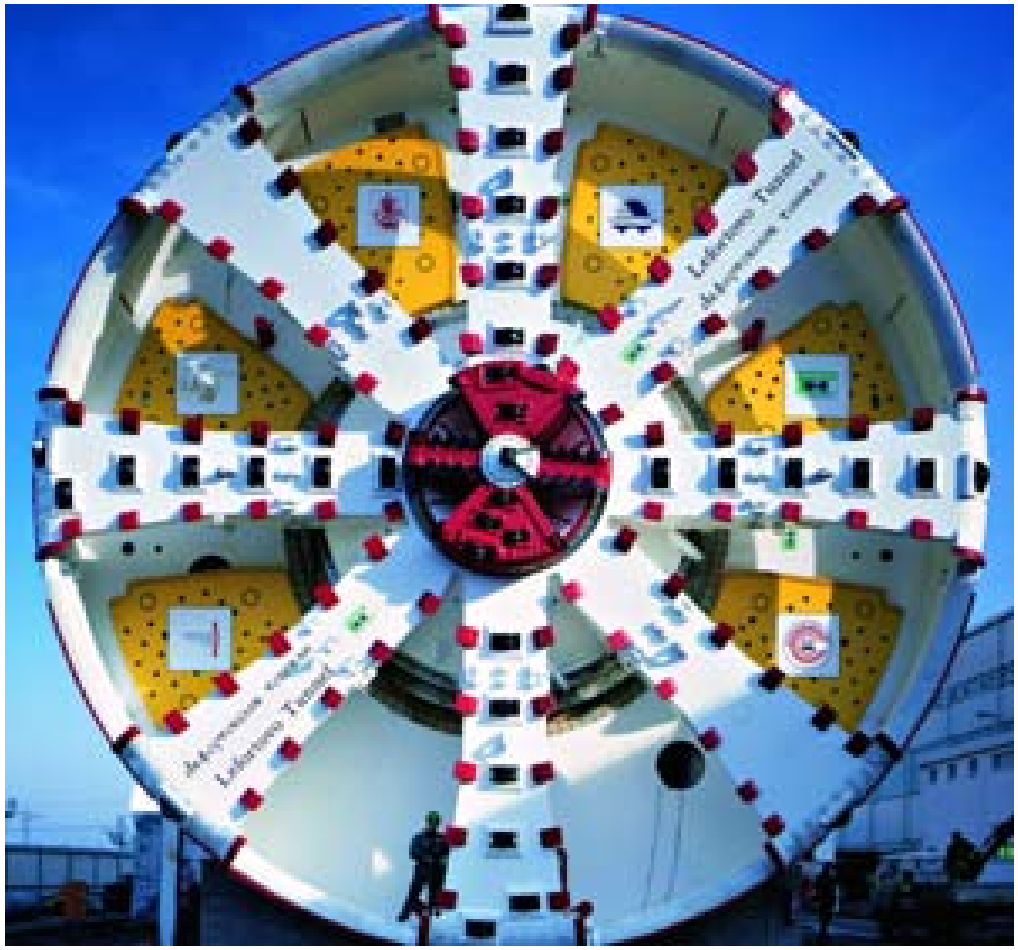




Steel Immersed tunnels (Japan)

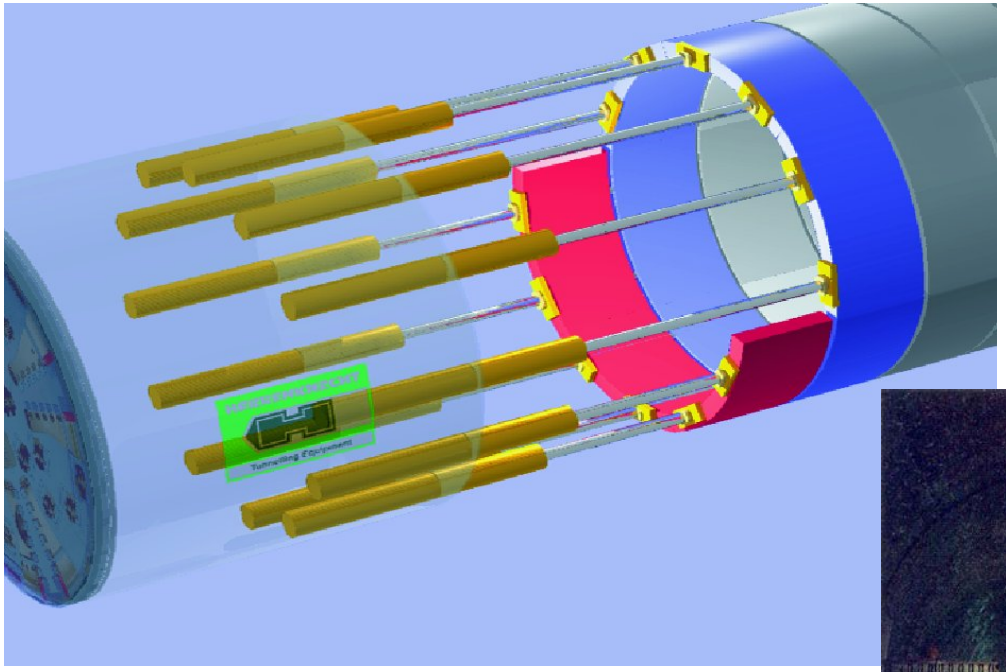
Bored tunnels

- Lining
- Types of Machines:
  - Slurry Shield
  - EPB shield

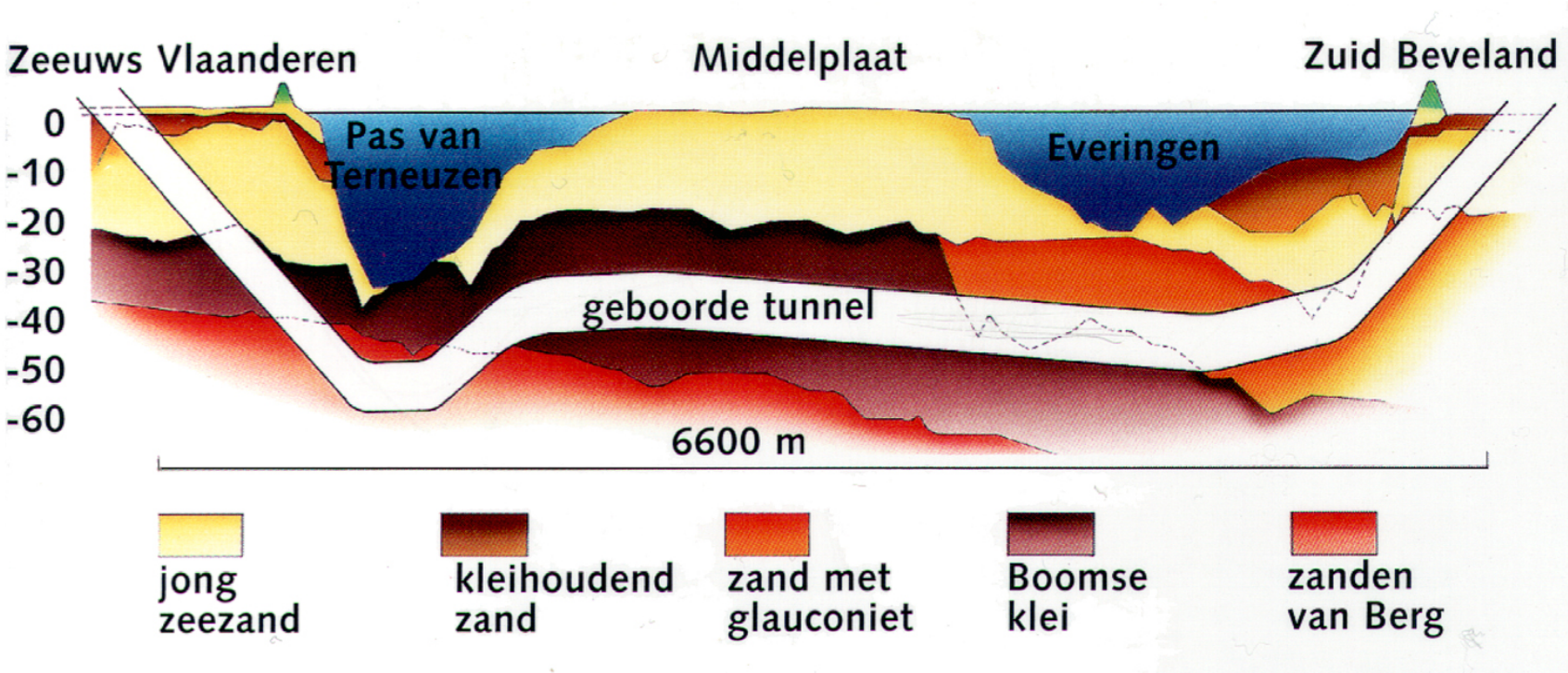


Moskou (d=14,2m) *Photo: Herrenknecht*

Bored tunnels: Lining

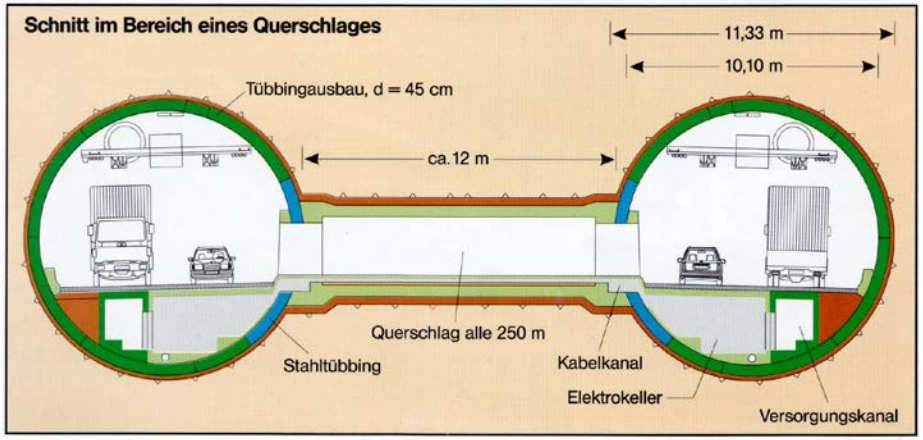


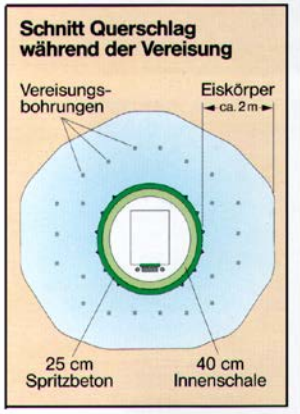
Trace Westerschelde Tunnel



Cross-section Westerschelde Tunnel

Bore head Westerschelde Tunne
D= 11,33 m





Innovative methods

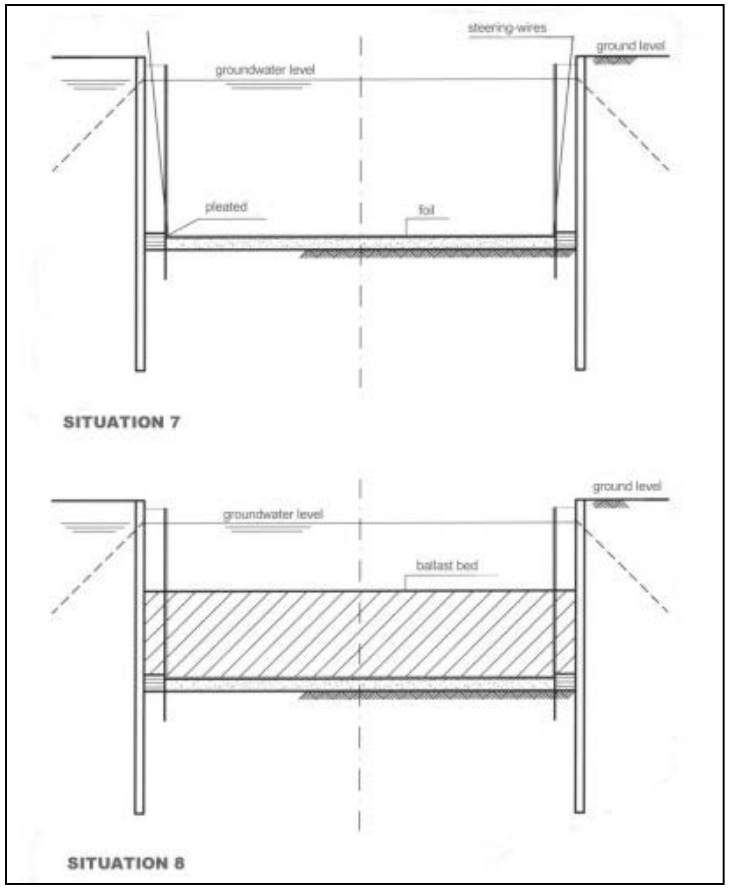
- U-polder
- V-polder
- TOMAS
- Membrane solutions

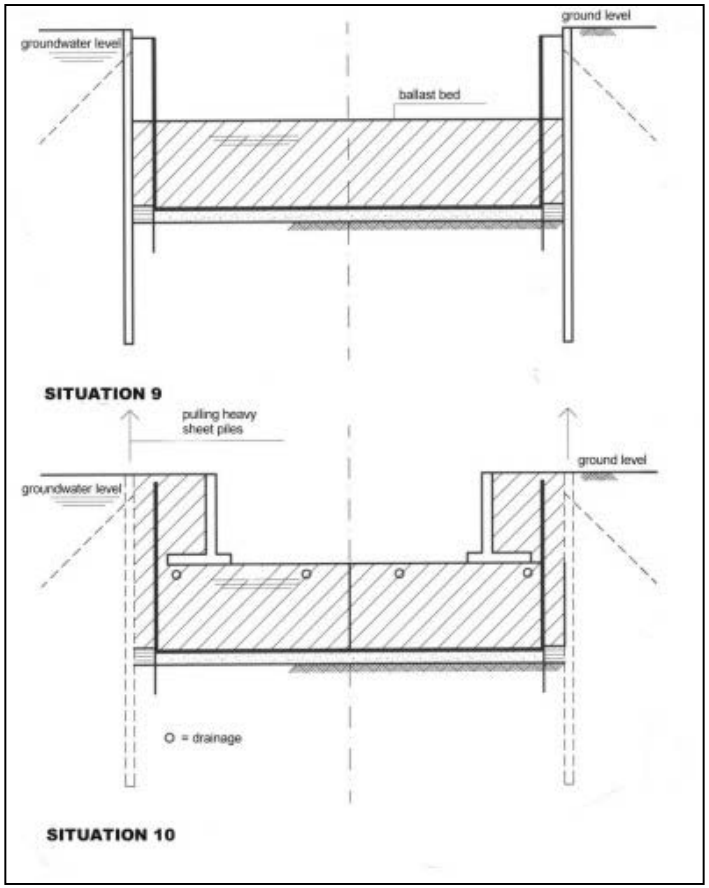
Innovative methods

Points of attention:

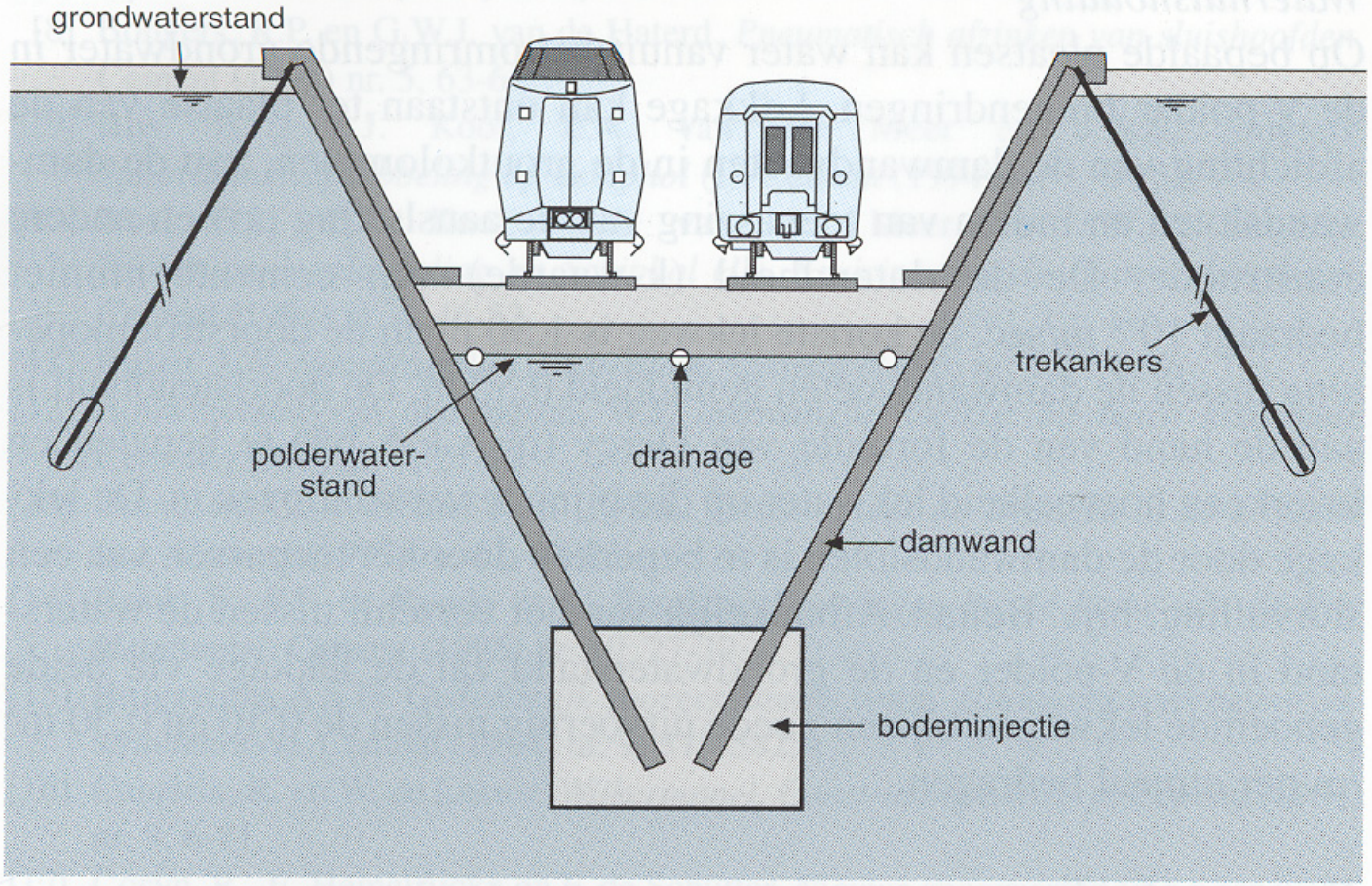
- Quality control
- Verifiability of the temporary and definitive construction parts, which are going to be built.
- The sensitivity of the constructions on the deviation of the circumstances (obstacles)
- The conduct in long-term

Open-trench Constructions

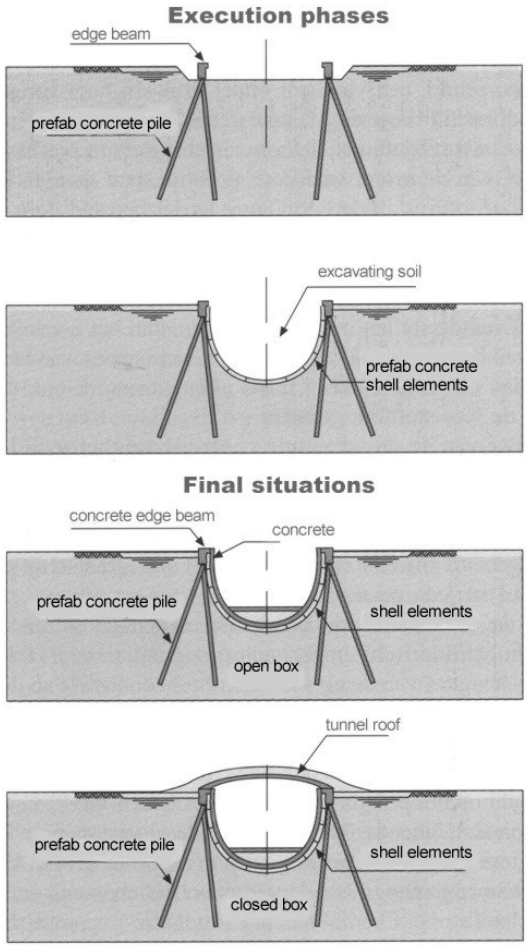


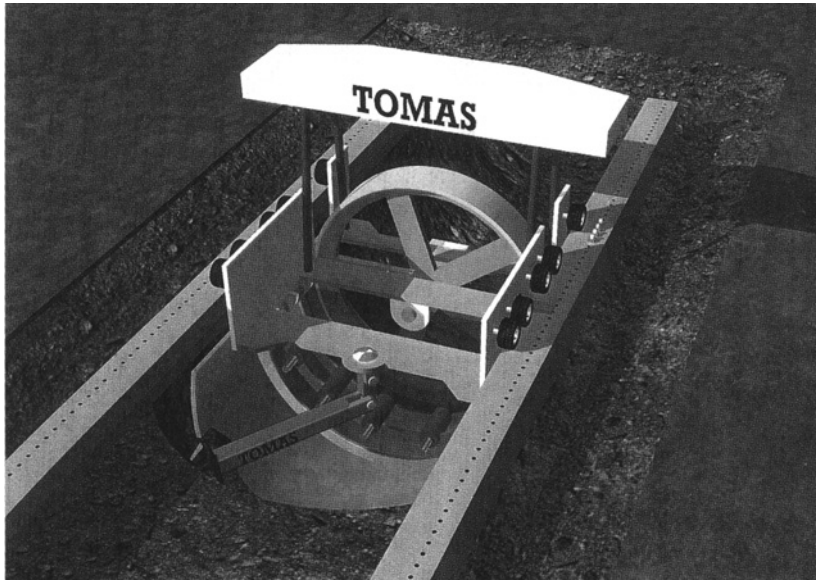


Open-trench Constructions: V-polder

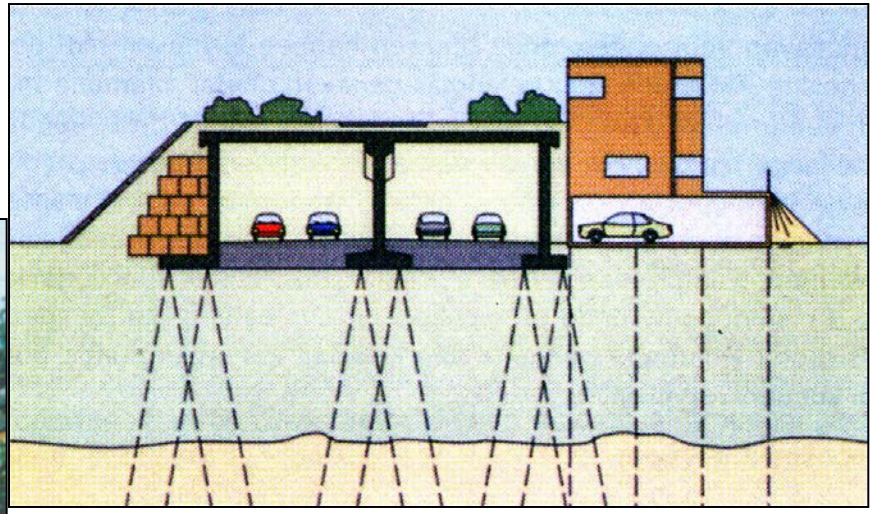


Open-trench Constructions: TOMAS method

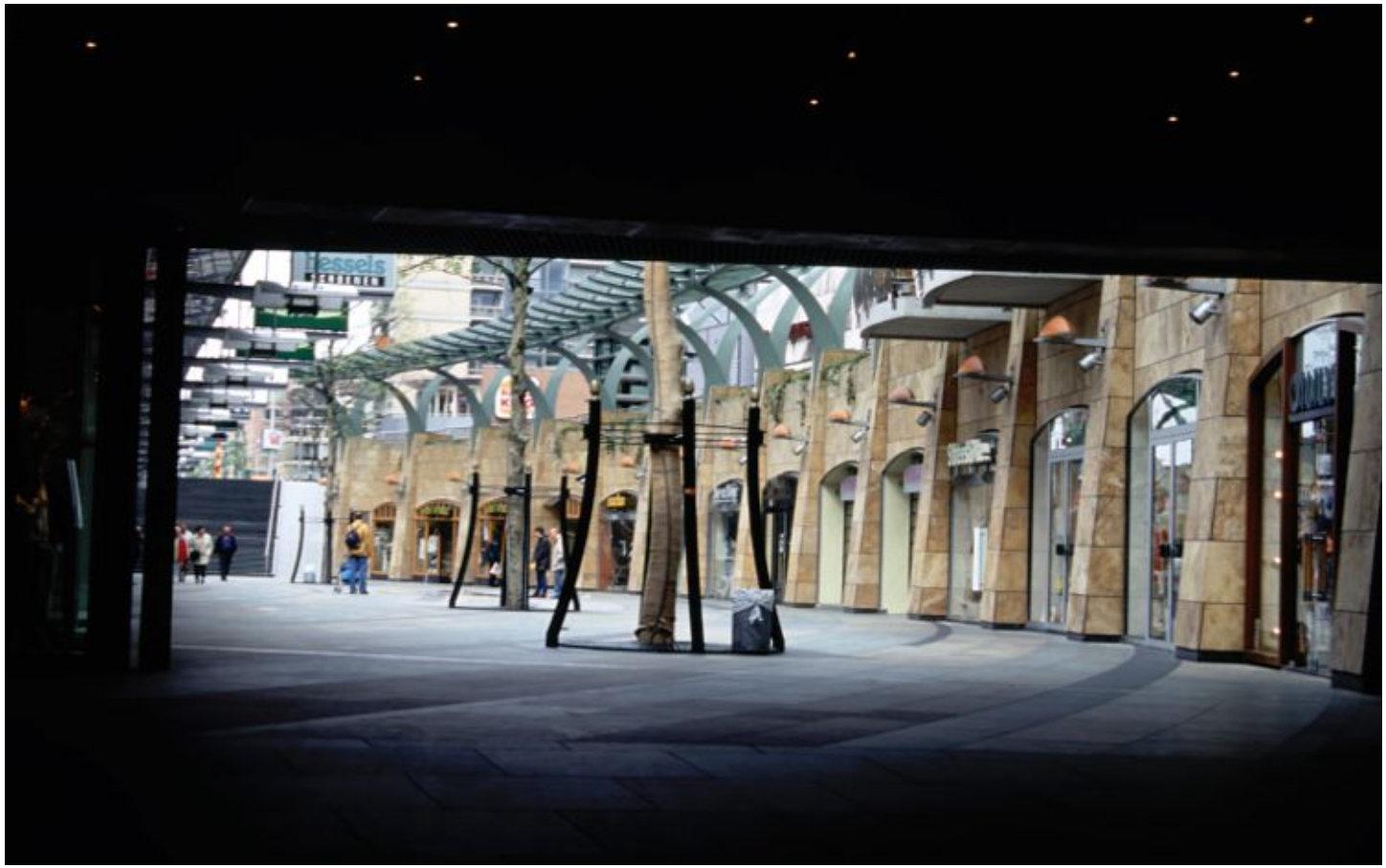




Multiple use of land



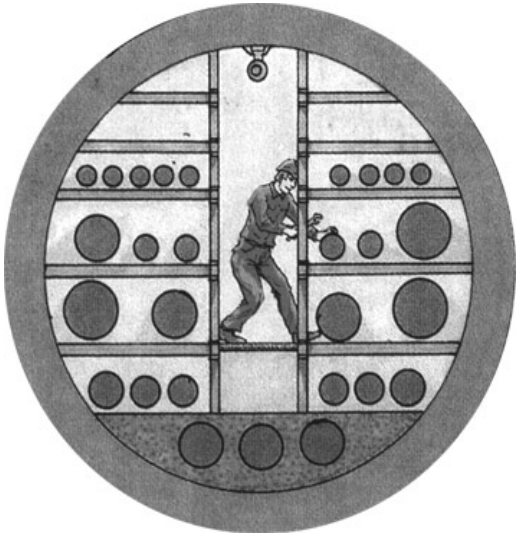
Multiple use (Rotterdam)



Multiple Use (Switzerland)

Trenchless Technology

- CIE5741
- Application for small infrastructure: cables, tubes and pipes
- Small diameter
- Two drilling techniques:
  - Horizontal Directional Drilling
  - Micro-tunnelling
- Renovation of pipelines



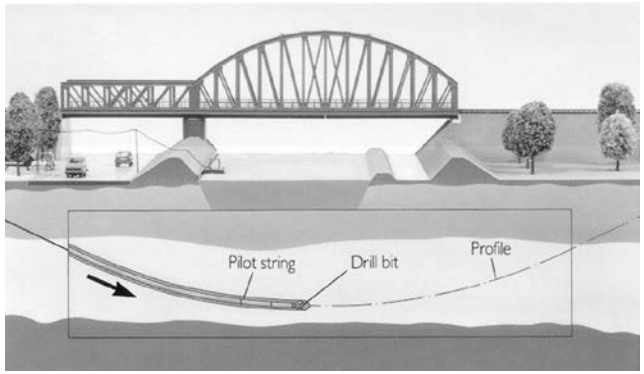
Multiple Use of pipeline

Trenchless Technology: Steps in HDD drilling

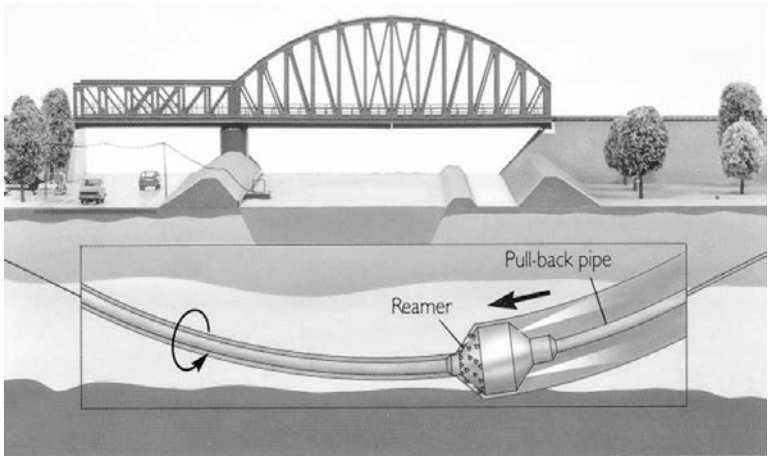
Pilot boring

The boring can be divided in three phases:

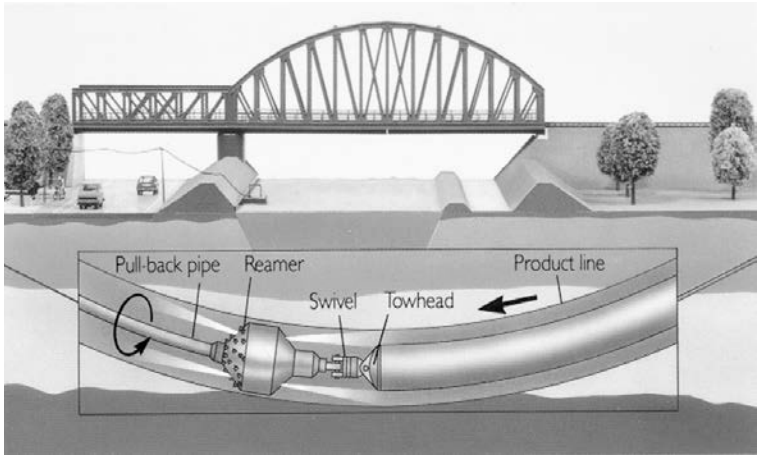
- Pilot drilling
- Pre-reaming
- Pipe positioning (pulling)



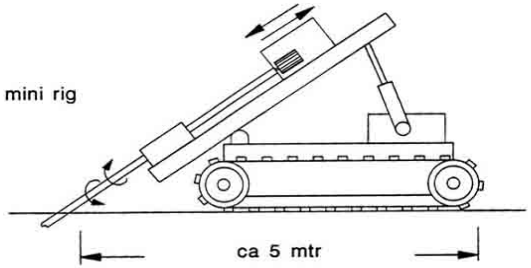
Pre-reaming

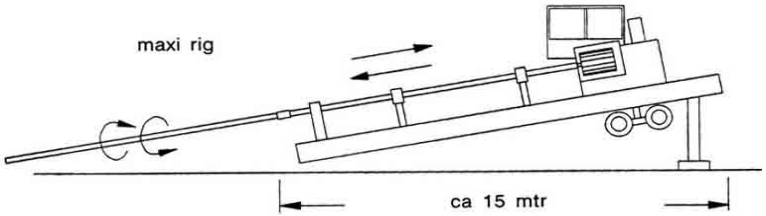


Pipe positioning

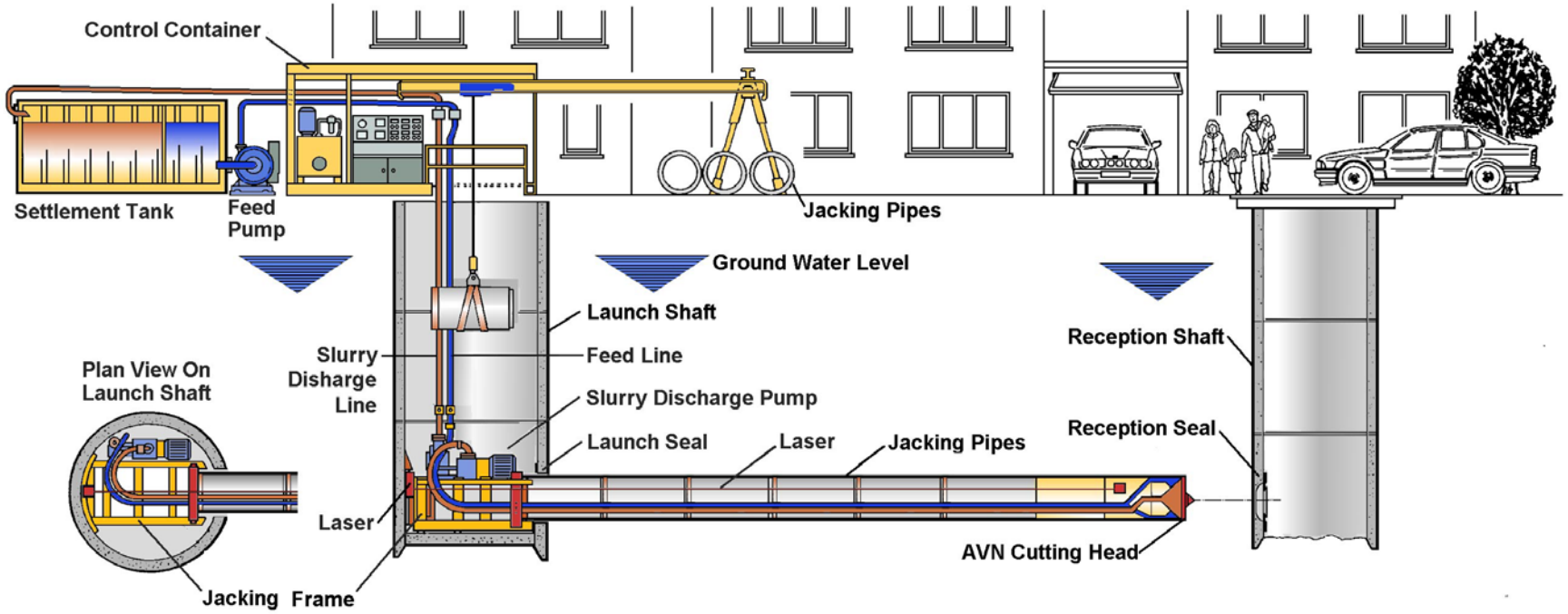


Midi and maxi-rig





Trenchless Technology: Micro-Tunnelling



Trenchless Technology: Micro-tunnelling

Specific points of attention for use of underground space

- Safety
  - Internal safety: safety of the users of the underground construction (personal risk)
  - External safety: safety of people in the neighbourhood of the construction (group risk)
  - Social safety: do the people feel comfortable underground? (light, open view)
- Management
- Risks

Internal Safety

Safety measures:

- Physical measures if a calamity occurs:

fire escape routes, fire extinguisher, one way traffic, fire resistant covering etc.

- Process measures to minimize a calamity:

use of underground construction, adapt measures if the use changes, appointing responsibilities etc.

External Safety

Safety measures are taken to minimize the consequences of a possible calamity for the surrounding buildings close to the underground construction.

Social safety: Perception

Metro Rotterdam

Wilhelminaplein

Stadhuis

Social safety: Perception

Metro Oriente (EXPO), Lissabon (Calatrava)

Metrostation Eendrachtsplein Rotterdam

Safety Chain

Pro-action:	To avoid structural causes of unsafety.
Prevention:	To prevent a calamity to occur.
Preparation:	If a calamity occurs, the necessary equipment and measures are present.
Repression:	Providing help when a calamity occurs.
Maintenance:	To get everything as soon as possible in the ‘normal’ condition, so the needed safety level is reached again.

Risks

Permanent risks because of the use of the underground construction.

This is important for the choice whether the construction will be built underground or not (transport hazardous materials)

Risks occurring during the whole process:

Designers must be aware of the risks involved using a certain construction method. To repair underground construction is extremely expensive and difficult. It's important to now in advance, the possible measures to be taken if an accident happens.

Risks

Risks occurring during the whole process:

- Risks on which the construction is designed for and can be controlled by safety measures
- Risks on which the construction is designed for, but because of failure of the safety measures, causes inadmissible consequences.
- Risks on which the construction isn’t designed for.
- Risks of which the danger wasn’t realized.

Risks

- Legal risks
- Organizational risks
- Technical risks
- Spatial risks
- Financial risks
- Social risks
- Political risks

Management

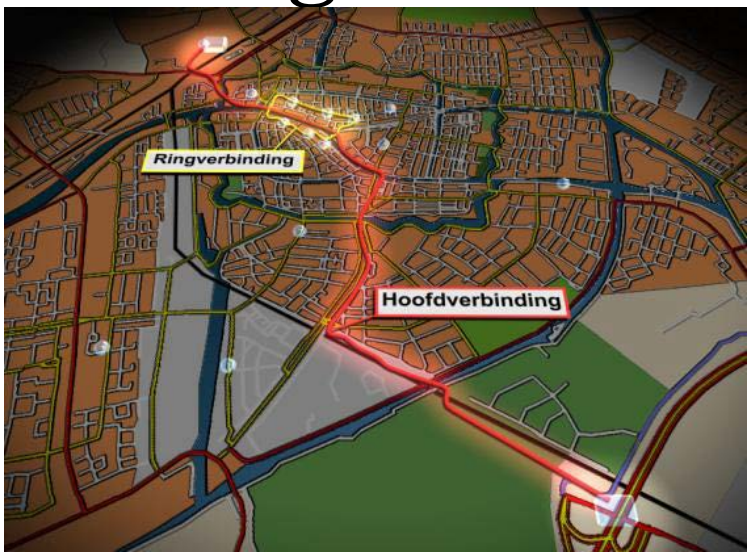
Integral approach is needed:

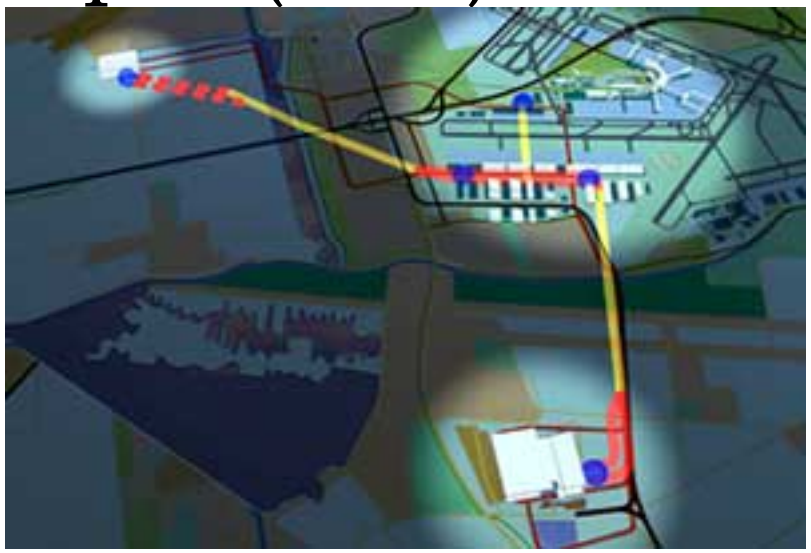
- The purpose of an underground construction is hard to change or to expand, so long term vision is needed
- The underground construction must be integrated in the above ground space.
- To implement the safety chain in the beginning of the project.
- Better communication between different stakeholders.
- More transparent responsibilities.
- Division of risks: what's the risks that is left and who is responsible for it.

Legal aspects

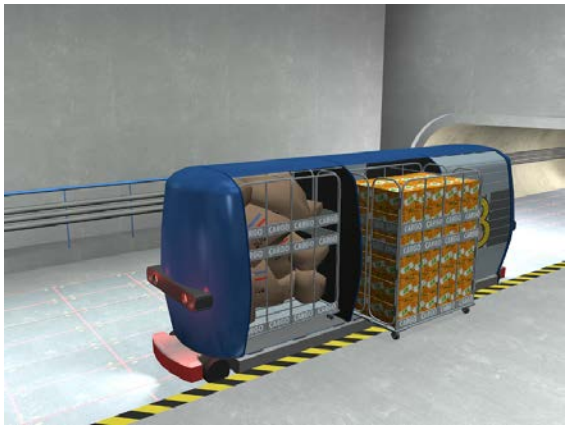
- There's no specific law in which the conditions and demands are listed for underground constructions. This causes difficulties in the decision and designing process.
- A lot of indistinctness and uncertainties about ownerships, liability, environmental laws and the like will frighten lots of investors, governments to apply underground structures.
- Zoning plan

Underground transport(OLS)





Possible underground logistic system Amsterdam/Hoofddorp- Schiphol



Underground transport(OLS)

Transport OLS to platform