L’uso dell’acciaio nelle applicazioni geotecniche
Quadro normativo di riferimento
Esempi di calcolo secondo le NTC 2008

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1. Installation of steel sheet piles
2. Watertightness
3. Applications

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Installation of steel sheet piles

Installation of steel sheet piles

Equipment:

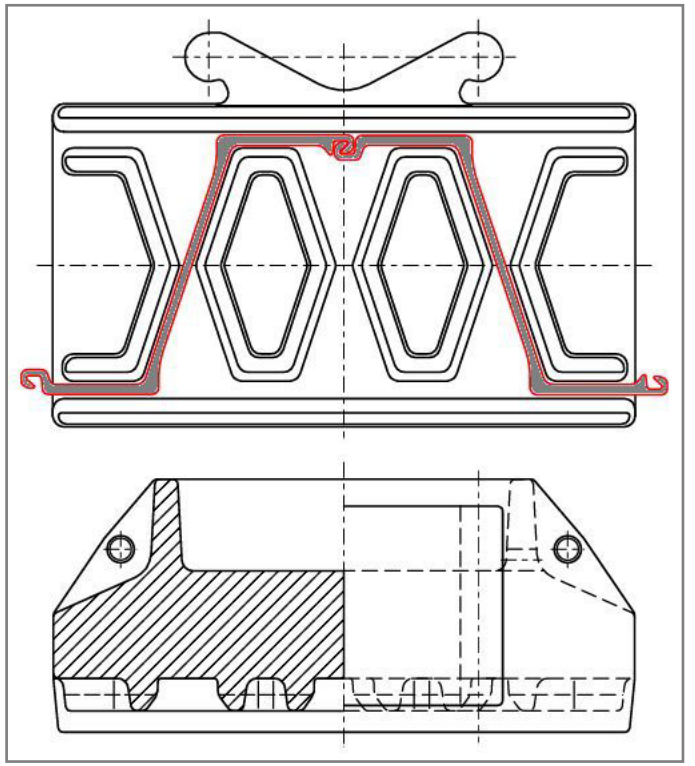
- diesel hammer
- impact hammer (hydraulic, free fall)
- vibrohammer
- hydraulic press

Accessories:

- leader, template, driving cap
- driving assistance:
  - water-jetting
  - pre-drilling
  - blasting

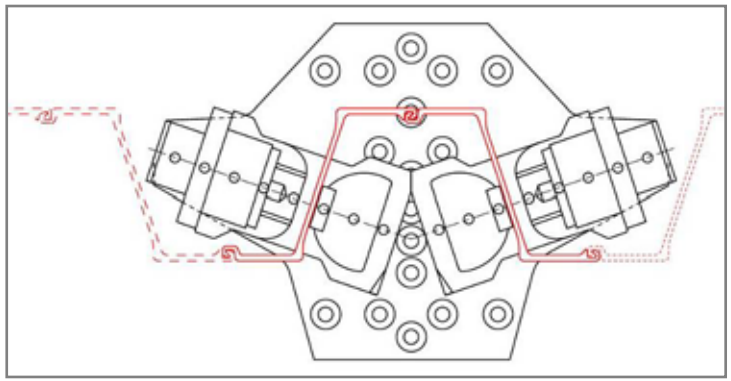
Installation: impact hammer

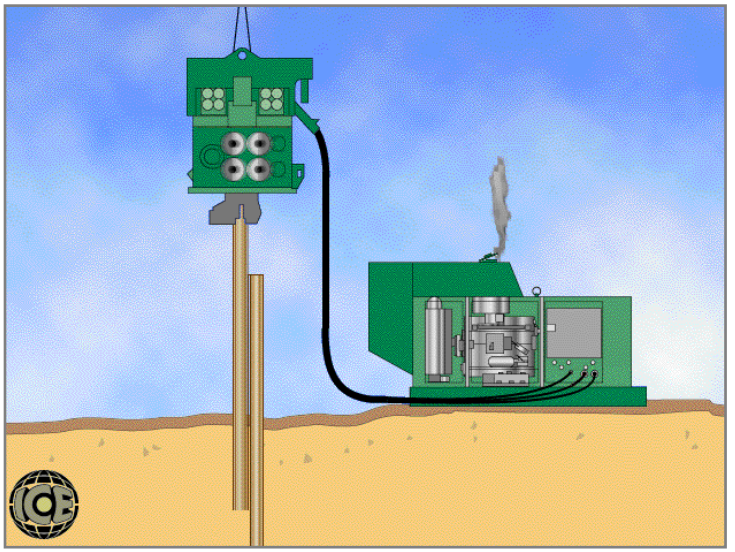
- drive in pairs (stiffness)
- avoid eccentricity
- distribute impact energy uniformly over ssp
- driving cap with diesel hammer
- large plate with hydraulic hammer



Driving cap for diesel hammer

Installation: vibrohammer

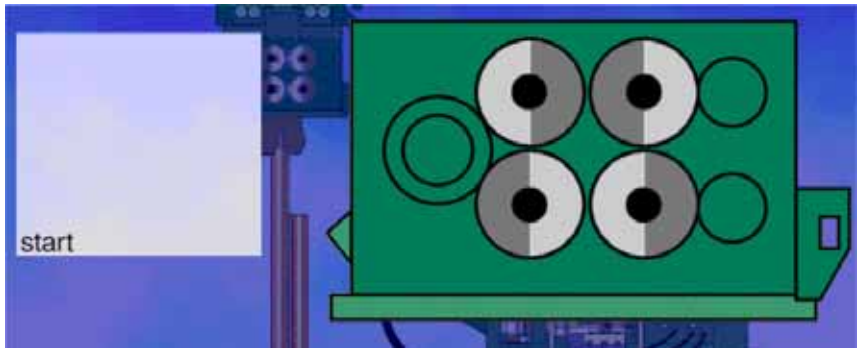




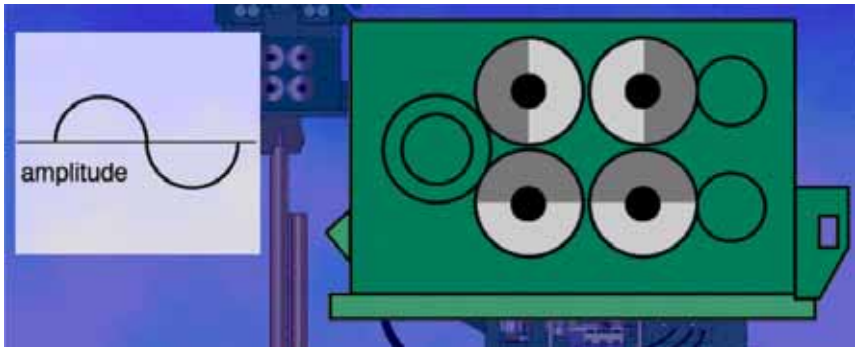
- drive in pairs (stiffness)
- avoid eccentricity
  ⇒ use 2 clamps
- guide the ssp in adequately (leader, template,…)
- mainly used in granular soils / soft cohesive soils

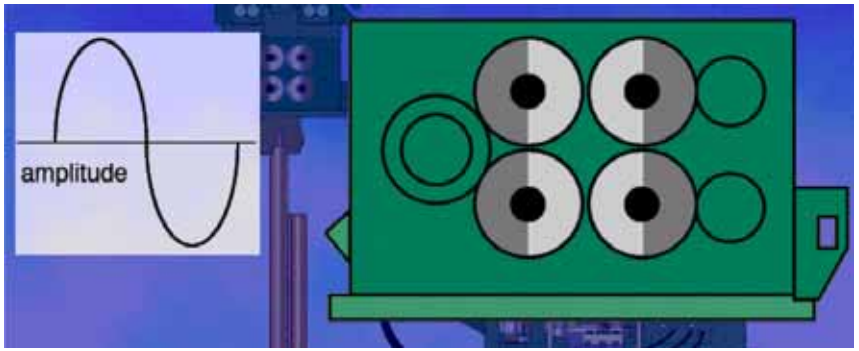
Installation: Resonance-free vibrohammer

Weights in opposed position
→ no amplitude during start up phase
→ no vibrations during start up phase

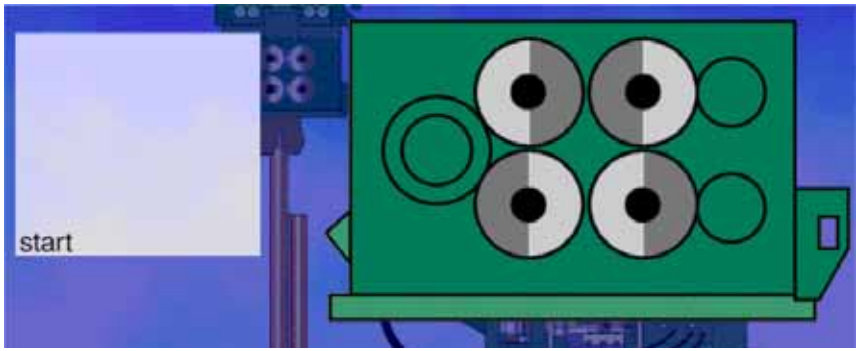


Weights turned once working frequency is reached → amplitude and vibrations applied to sheet pile



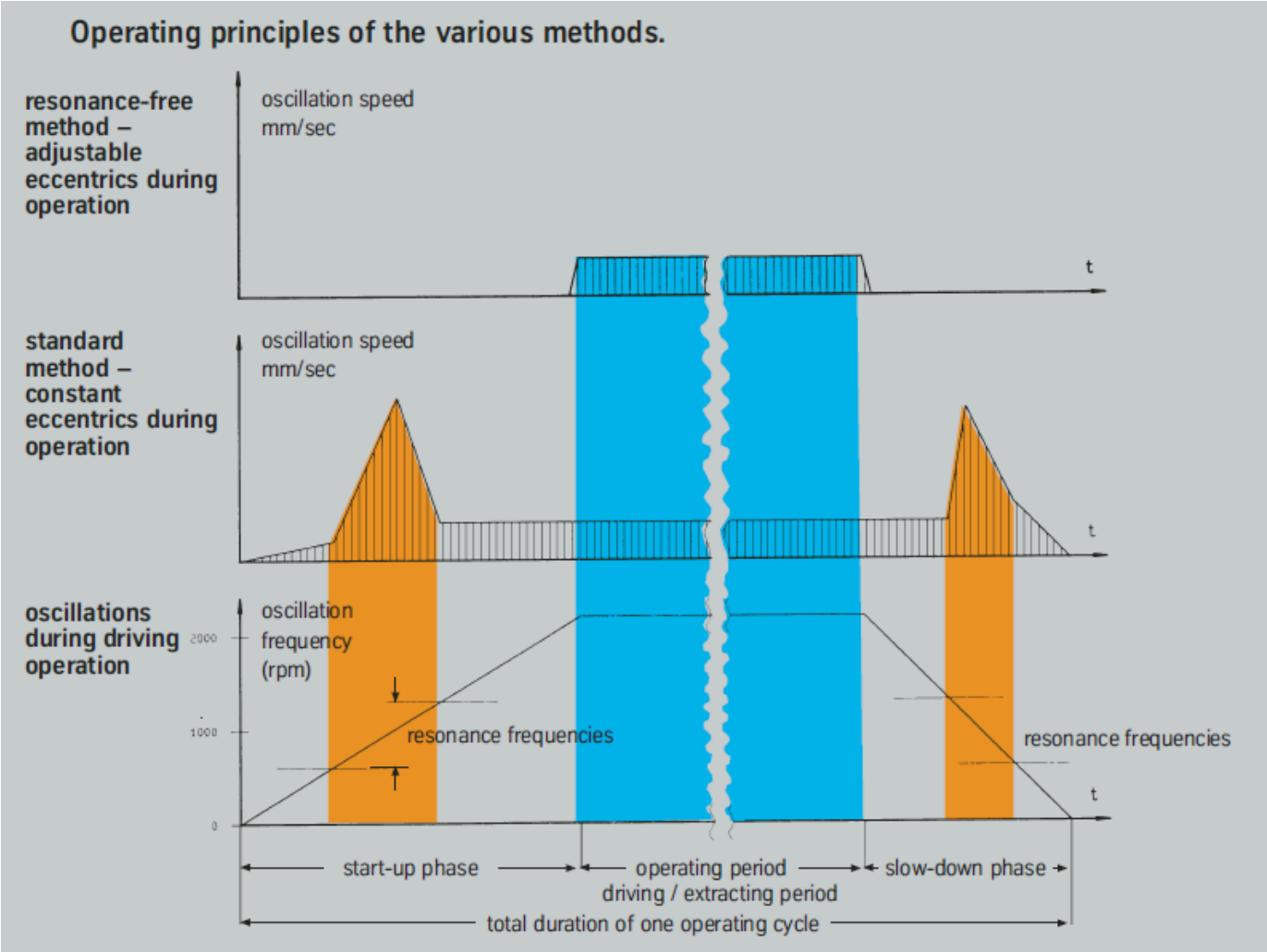


Weights giving maximum amplitude



Weights in opposed position
→ no amplitude during stop phase
→ no vibrations during stop phase

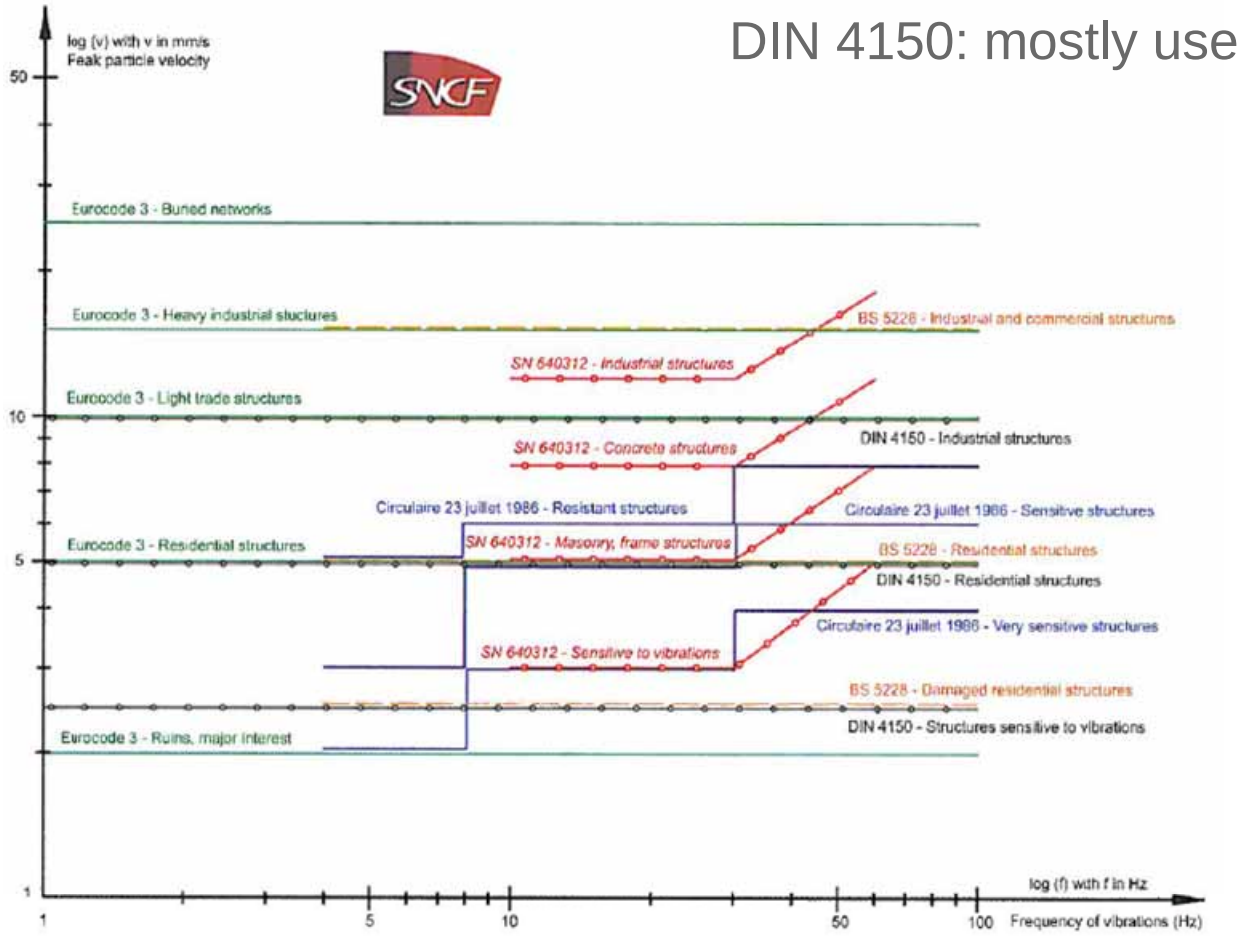
Installation: Resonance-free vibrohammer



Installation: Peak particle velocity limitations avoiding damage to buildings

- Differentiate continuous and non continuous vibrations

DIN 4150: mostly used

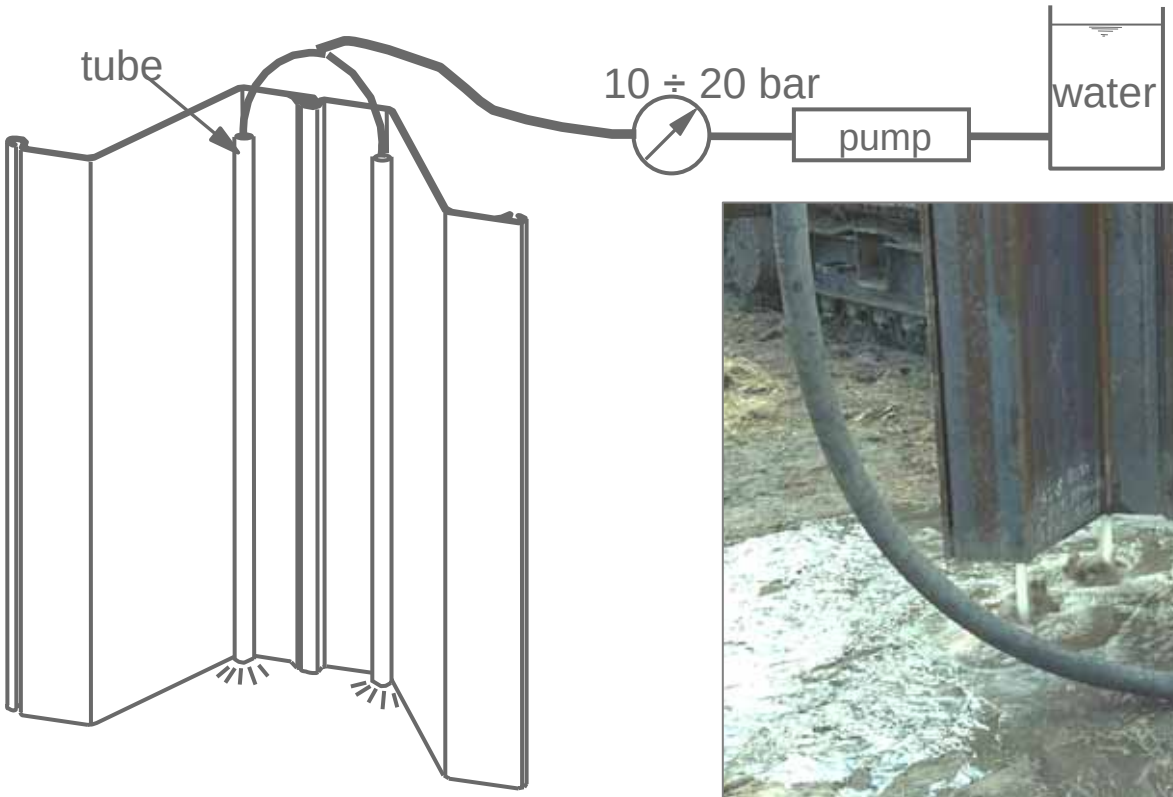


Installation: hydraulic press

- drives single / double piles
- ‘crawls’ over the driven sheets
- soft soils, water-jetting & pre-drilling capability

- drives 4 single piles
- soft soils, predrilling capability

Driving assistance: water-jetting



- reduces resistance at toe of the sheet pile
- water lubricates the surface of the sheet (friction ↓)

Pre-drilling

Installation of combined walls HZ/AZ

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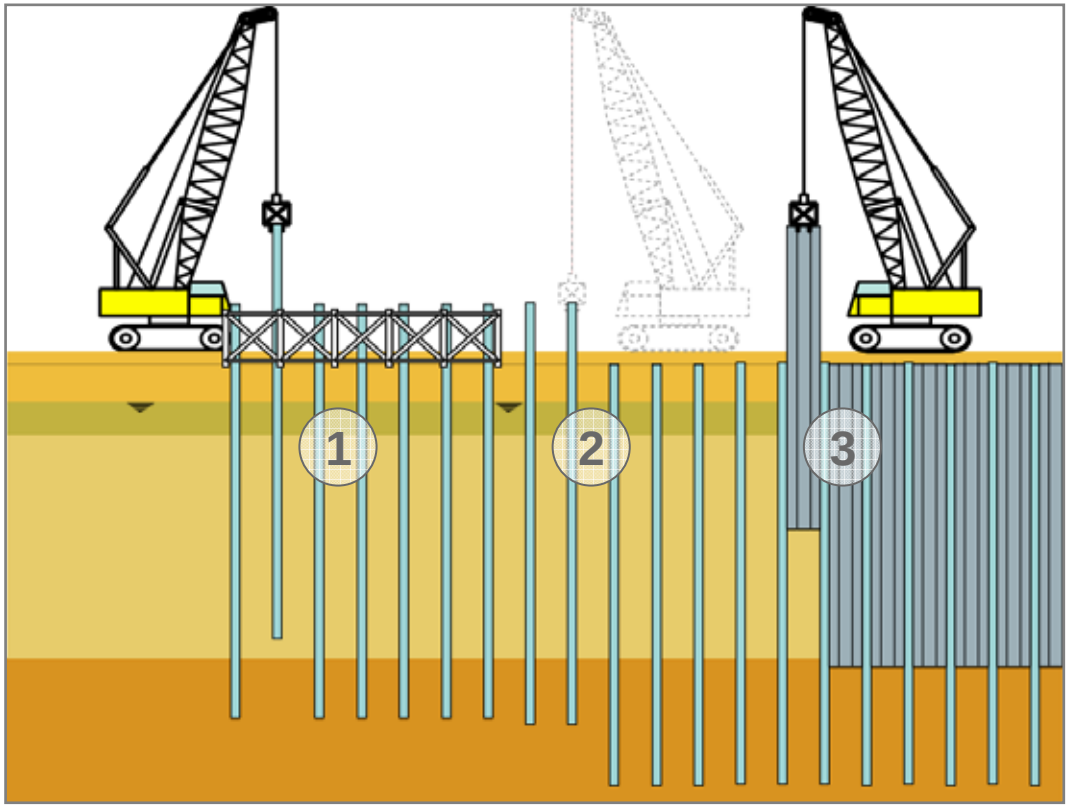
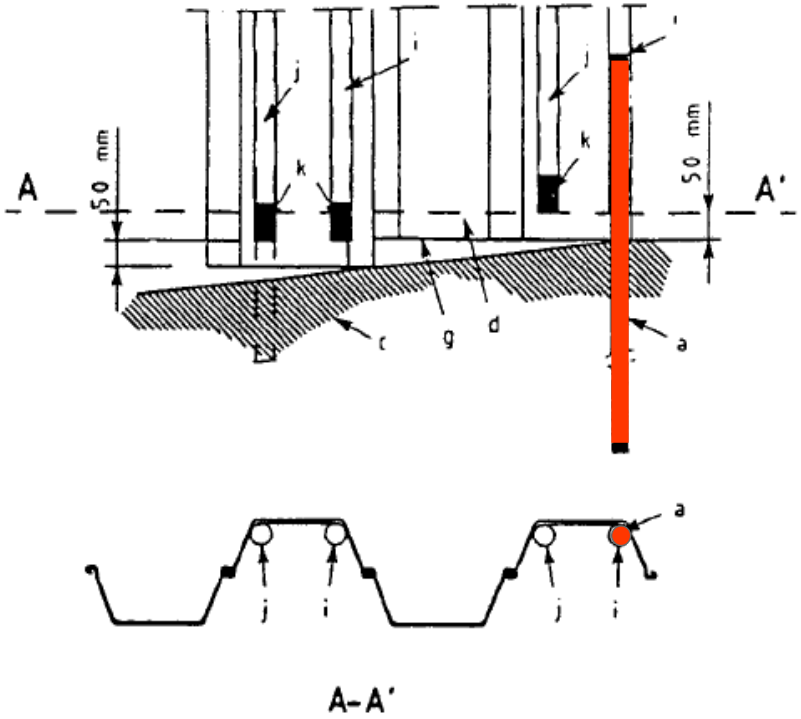
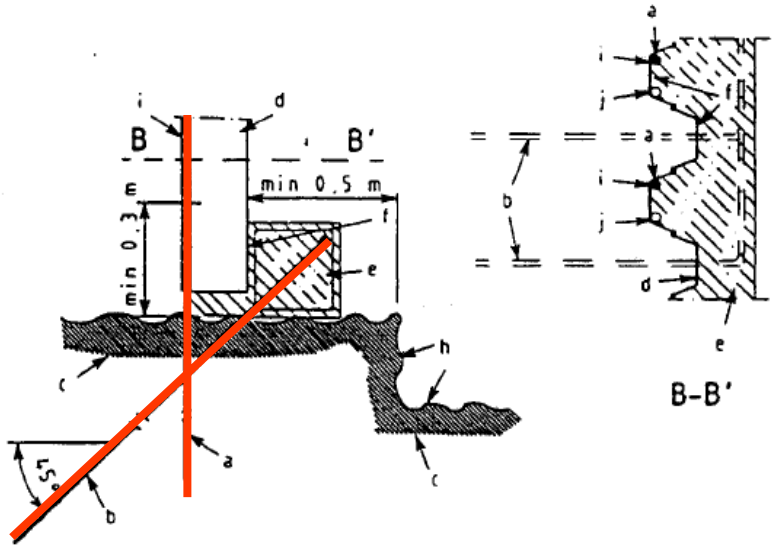
Driving Sequence



AZ infill sheets installed after driving of king piles HZ

Very hard soils: alternative solutions
Rock dowels

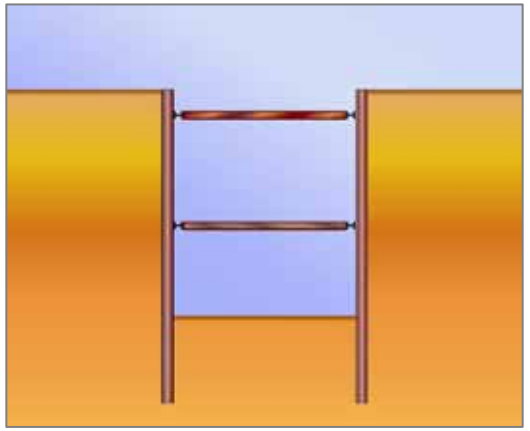




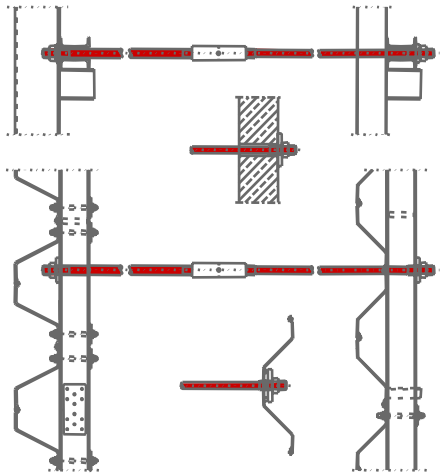
Very hard soils: alternative solutions
Circular cells

Anchors / struts

- excavation with more than 4-5 m height: anchors / struts most probably required
- prefer systems easy to install (driving tolerances)
- avoid / limit introduction of bending stresses due to settlements (hinged systems)

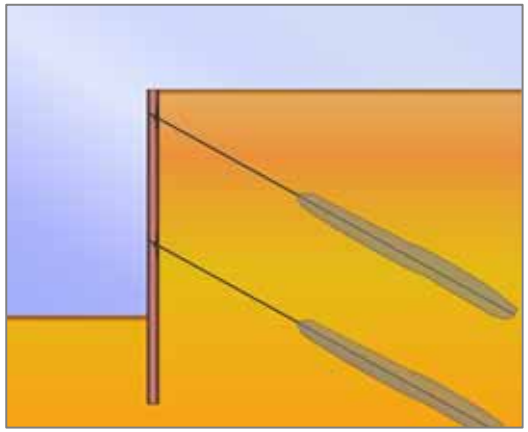


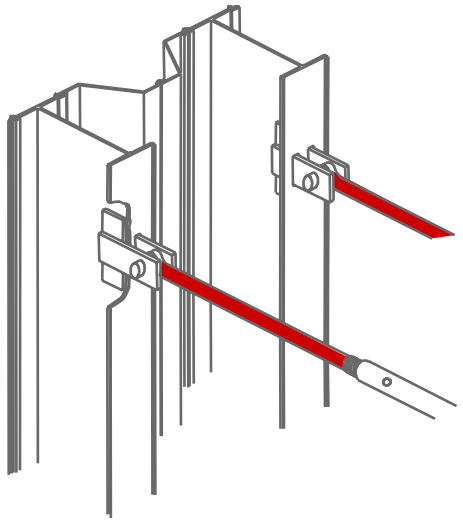
struts



tierods

tension piles / grouted anchors





Anchors

Raked steel piles
working in tension

Tie-rods / walers

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Watertightness

Impervious steel sheet pile walls

For higher watertight wall requirements:

- bituminous filler **Beltan** (p ≤ 1 bar)
- environmental friendly **Arcoseal**, mix of wax and mineral oil
- waterswelling filler **Roxan®** (p ≤ 2 bar), applied with special template
- weld the interlocks

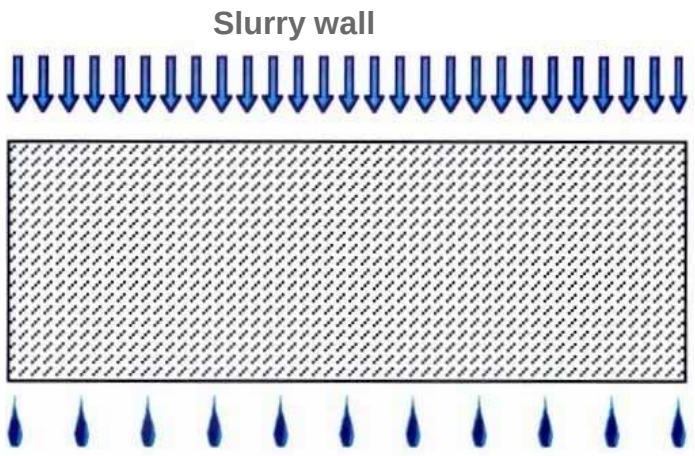
Applications:

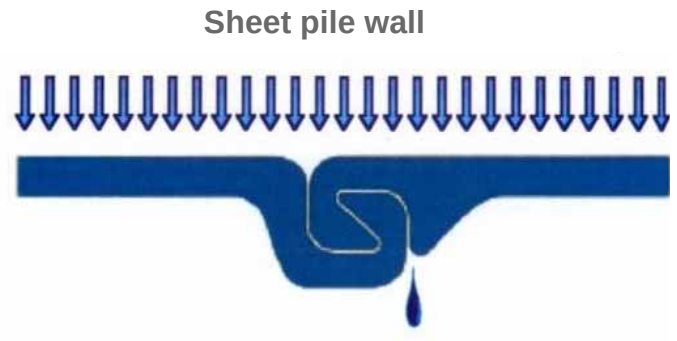
- cofferdam (high water pressure)
- cut-off wall in contaminated sites
- underground car parks

Watertightness of a sheet pile wall

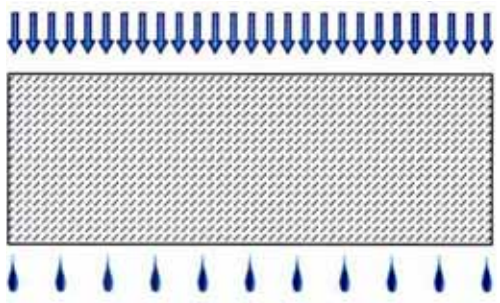
- Research Project in collaboration Delft Geotechnics (Deltares):
  - Development of a coherent theoretical model for the hydraulic permeability of a sheet pile wall (≠ Darcy's law)
  - Development of a testing device to determine the permeability of the interlock in situ and in laboratory

  → Method included in a standard (EN 12063)





Discharge relation of sheet piles and porous media



$$\frac{K}{d} = \frac{\rho}{b}$$

K : permeability coefficient of the porous media [m/s]
d : thickness of the porous media wall [m]
ρ : inverse joint resistance of the sheet pile [m/s]
b : width of the sheet pile [m]

Current ArcelorMittal sealing systems for sheet piles

- Inverse Joint Resistance values determined following in-situ tests in collaboration with Geodelft (Deltares)

Interlock sealing system	**Inverse joint resistance ρ (m/s)**
Welding	0 → Underground car parks
Roxan	3×10^{-10} → Cut-off walls in contaminated sites
Beltan et **Arcoseal**	6×10^{-8} → Cofferdam (high water pressure)
Without sealing system	$>10^{-7}$




ρ (ms) ↓, watertightness level↑

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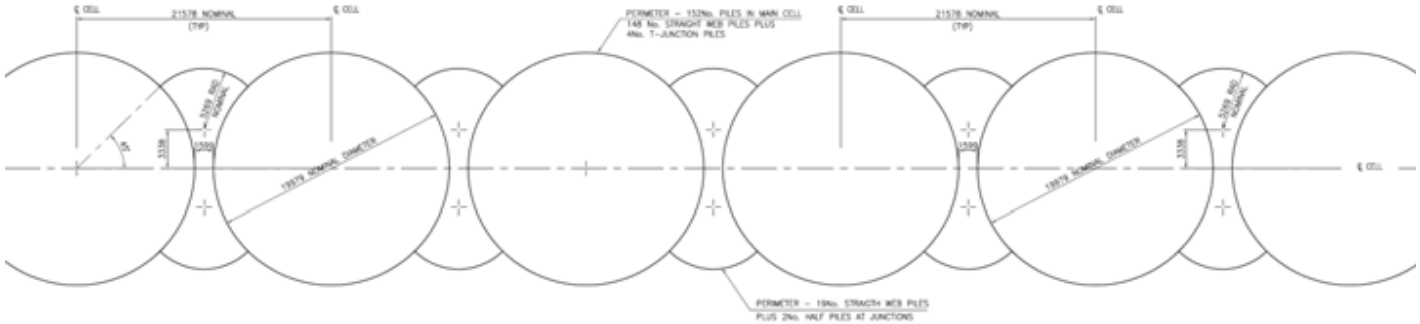
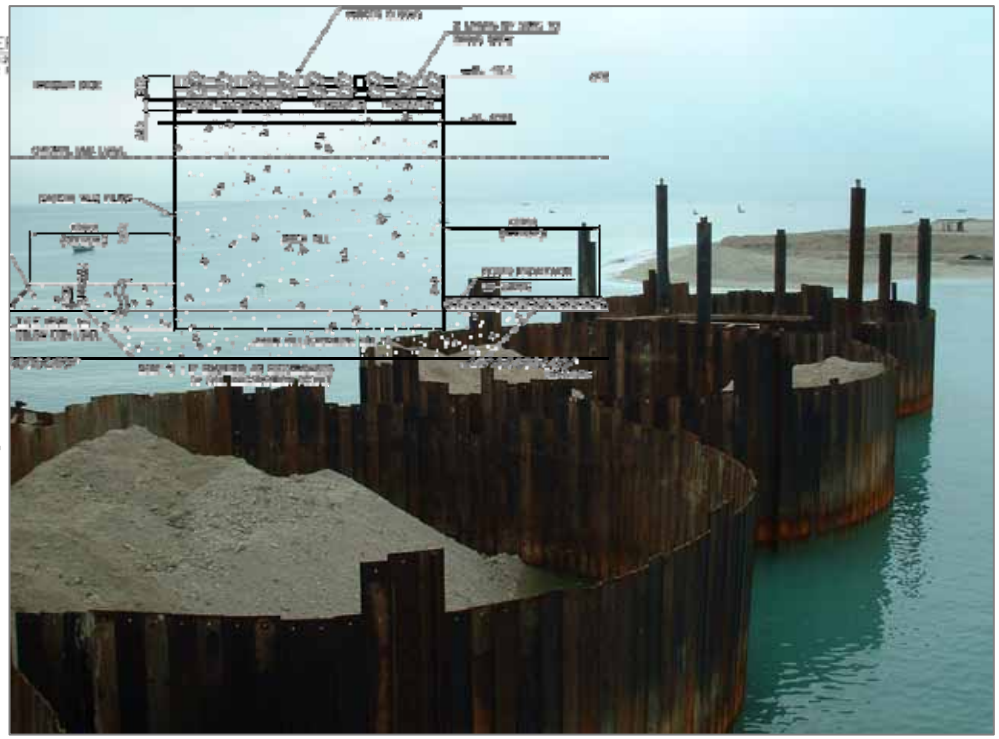
Applications

Applications



- Temporary cofferdams
- River embankments & Flood protection
- Land reclamation & Port and Harbour construction
- Cut-off walls & Waste Disposal
- Road works & Underground Car Parks
- Foundations

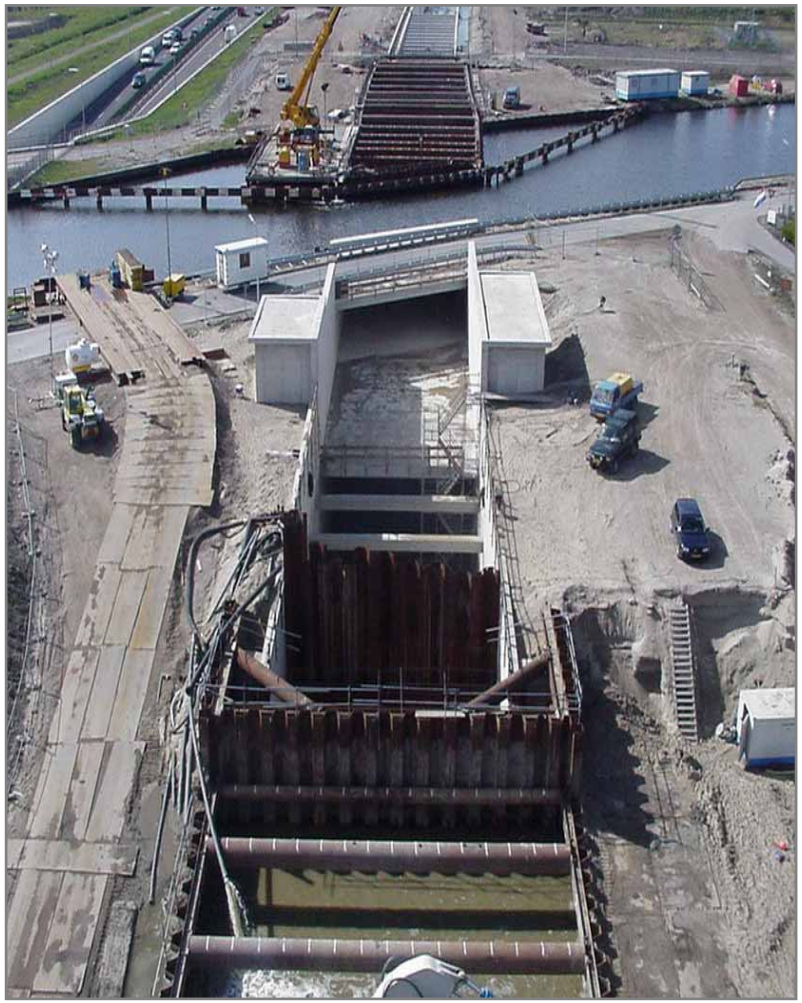


Temporary cofferdams

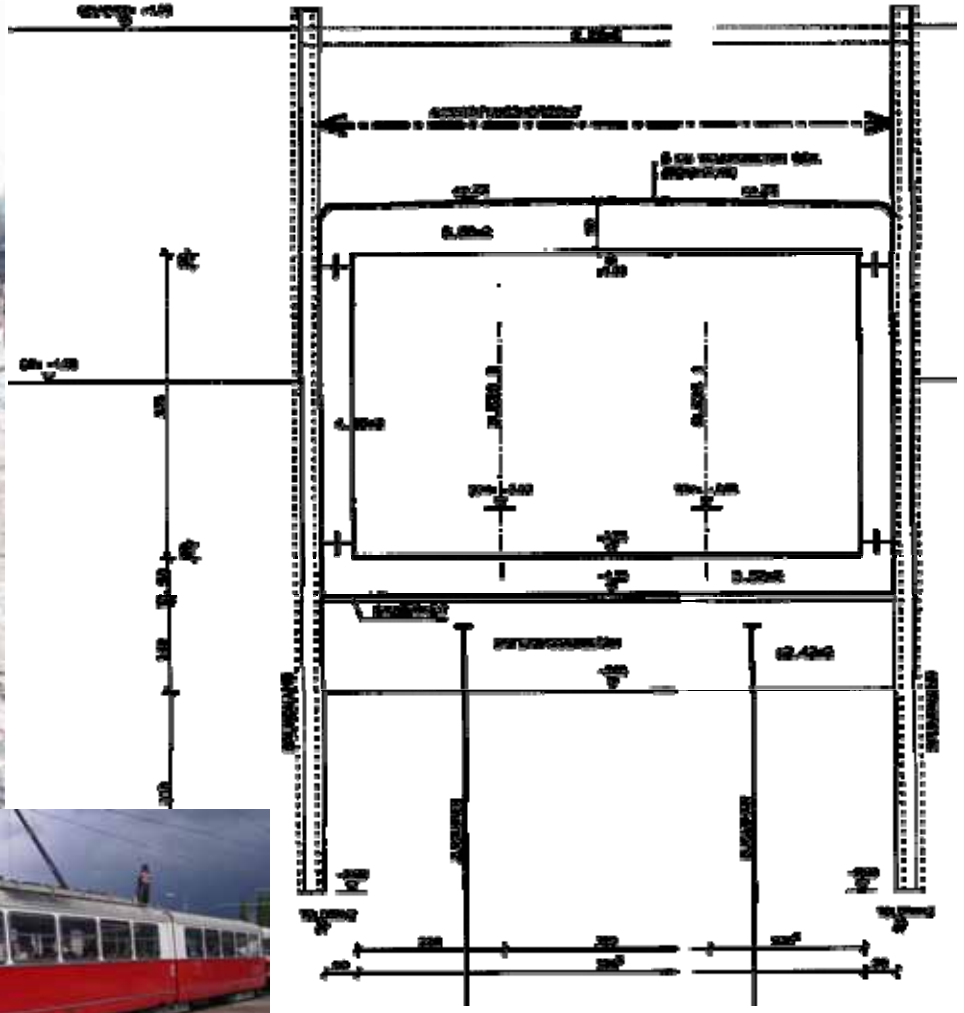
Impervious cofferdam / retaining wall

Spandau Lock, Berlin, Germany

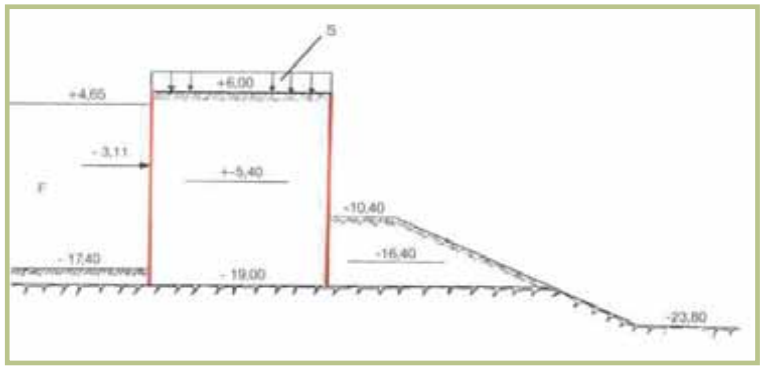
HSL-High Speed Line,The Netherlands



Vienna Metro Extension



Seo-Hae Grand Bridge (Korea)



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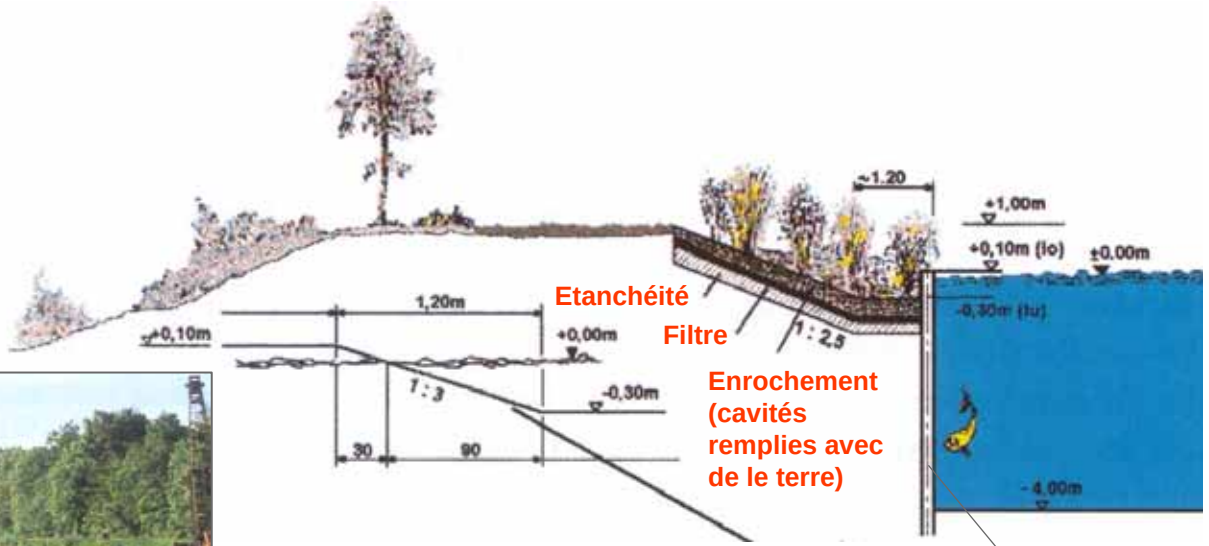
River embankments and Flood protection

Canals & Rivers

Embankments and canal protection

Mittellandkanal (D)



Stonegarden, Bremen (D)

Flood protection walls

St Pierre de Gaubert, France

1400 t AZ 36 sheet piles to protect the city from the floods

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Land reclamation &
Port and Harbour construction

Jurong Island, Singapore

Land reclamation

Marina Pez Vela | Quepos | Costa Rica (2008)

Breakwater

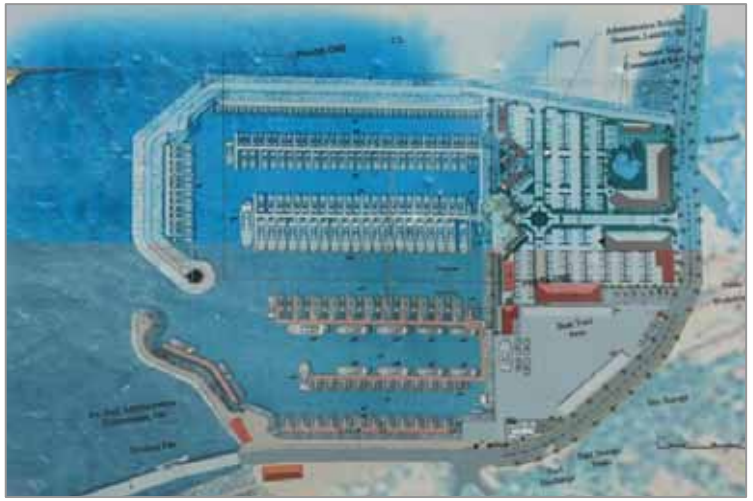
Circular cells, ϕ = 12.2 / 18.6 m, **L = 540 m**

AS 500-11.0 & 12.0

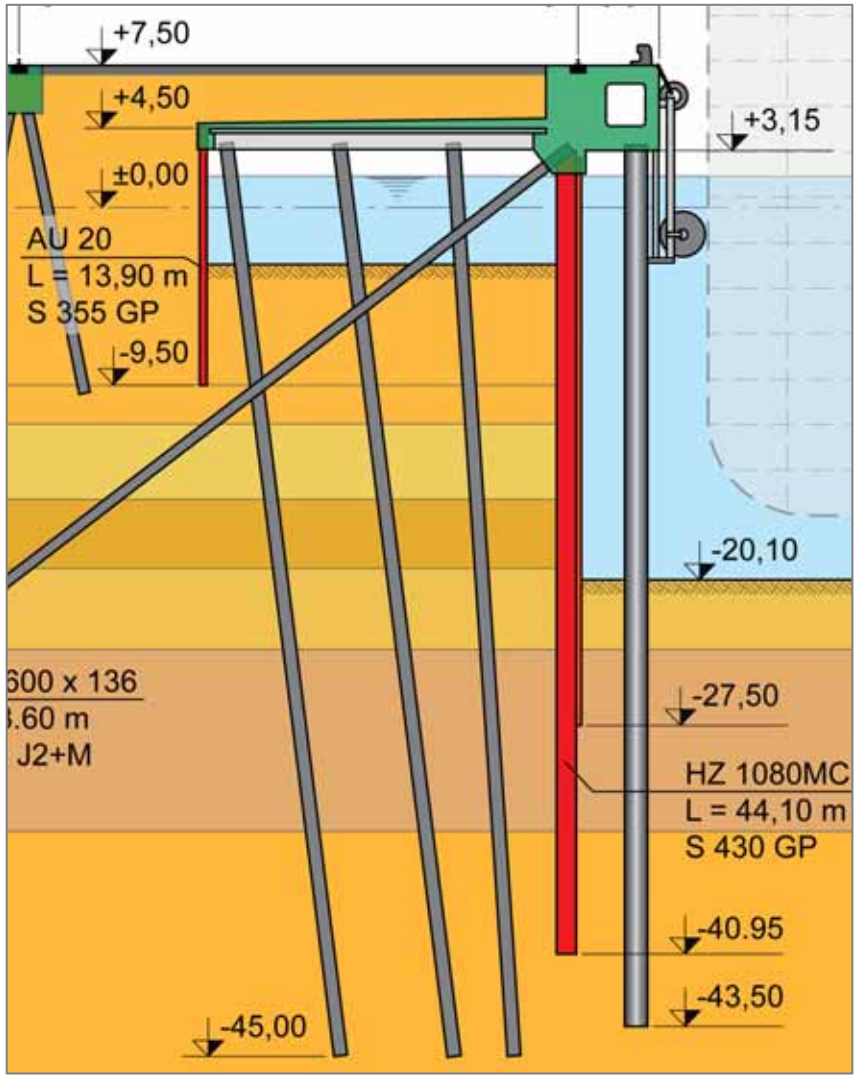
A690, I.S. = 3500 / 5500 kN/m

l = 7.0 ~ 15.0 m

3‘440 t



JadeWeserPort, Wilhelmshaven, D (2008-2009)



1.725 km long quay wall

HZ/AZ & new **HZM/AZ** system

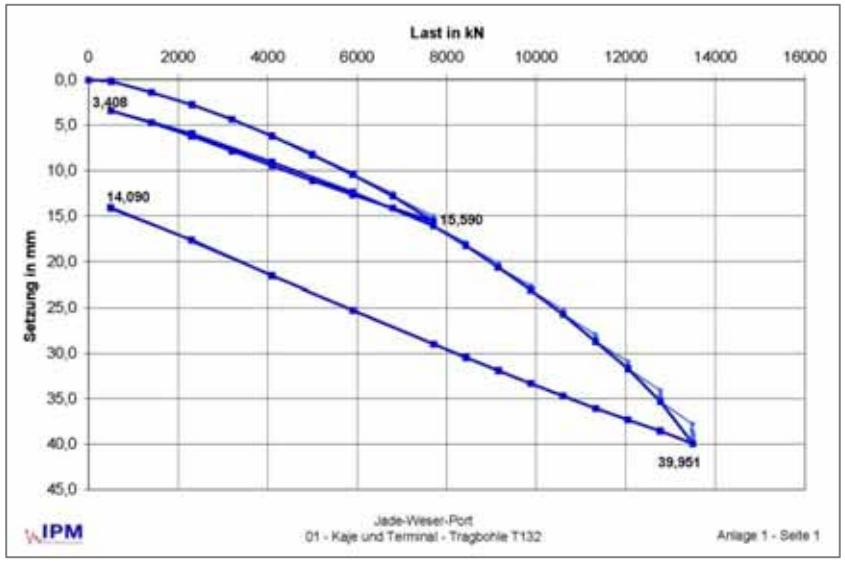
≥ **40 000 t,** length up to **44.0 m**

S 430 GP / S 355 GP

HZM: 17,200 t, HZ: 10,600 t, AZ: 9,000 t HTM: 7,000 t

JadeWeserPort, Wilhelmshaven, D (2008-2009)

Load bearing tests for HZ-M king piles



Load bearing test: compression

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Tension tests for HTM anchor piles

Profil HTM 600/136	nachzuweisende Tragfähigkeit [kN]	nachgewiesene Tragfähigkeit [kN]
S 127	3.302	3.750
S 212	3.302	3.500
S 260	3.179	3.750
S 344	3.149	3.750
S 380	3.438	3.750
S 428	3.661	3.905

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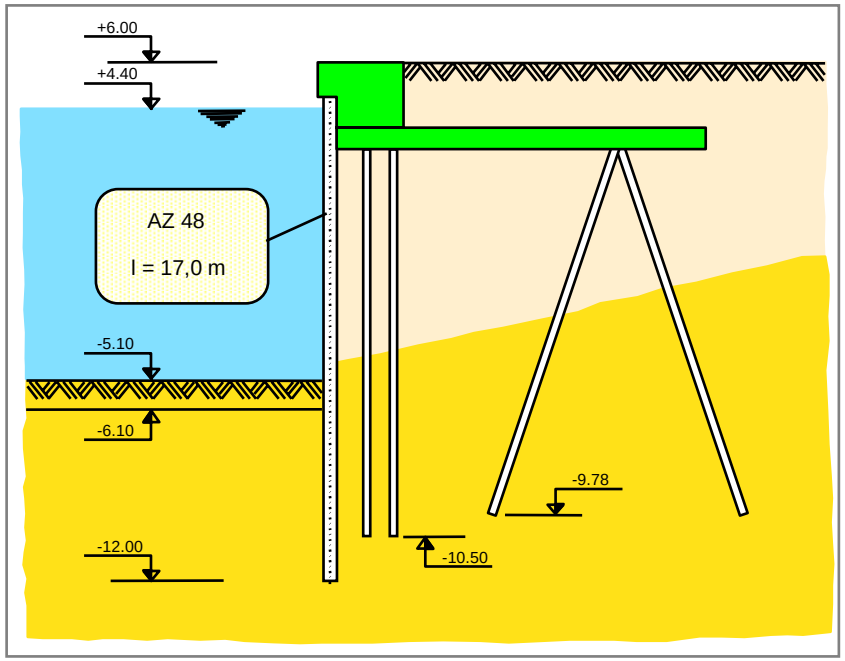
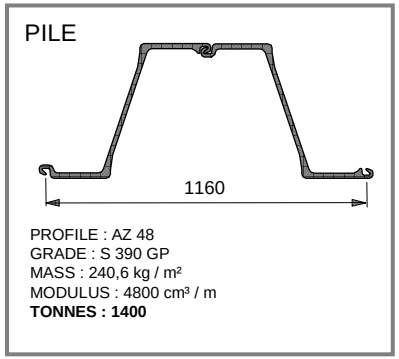
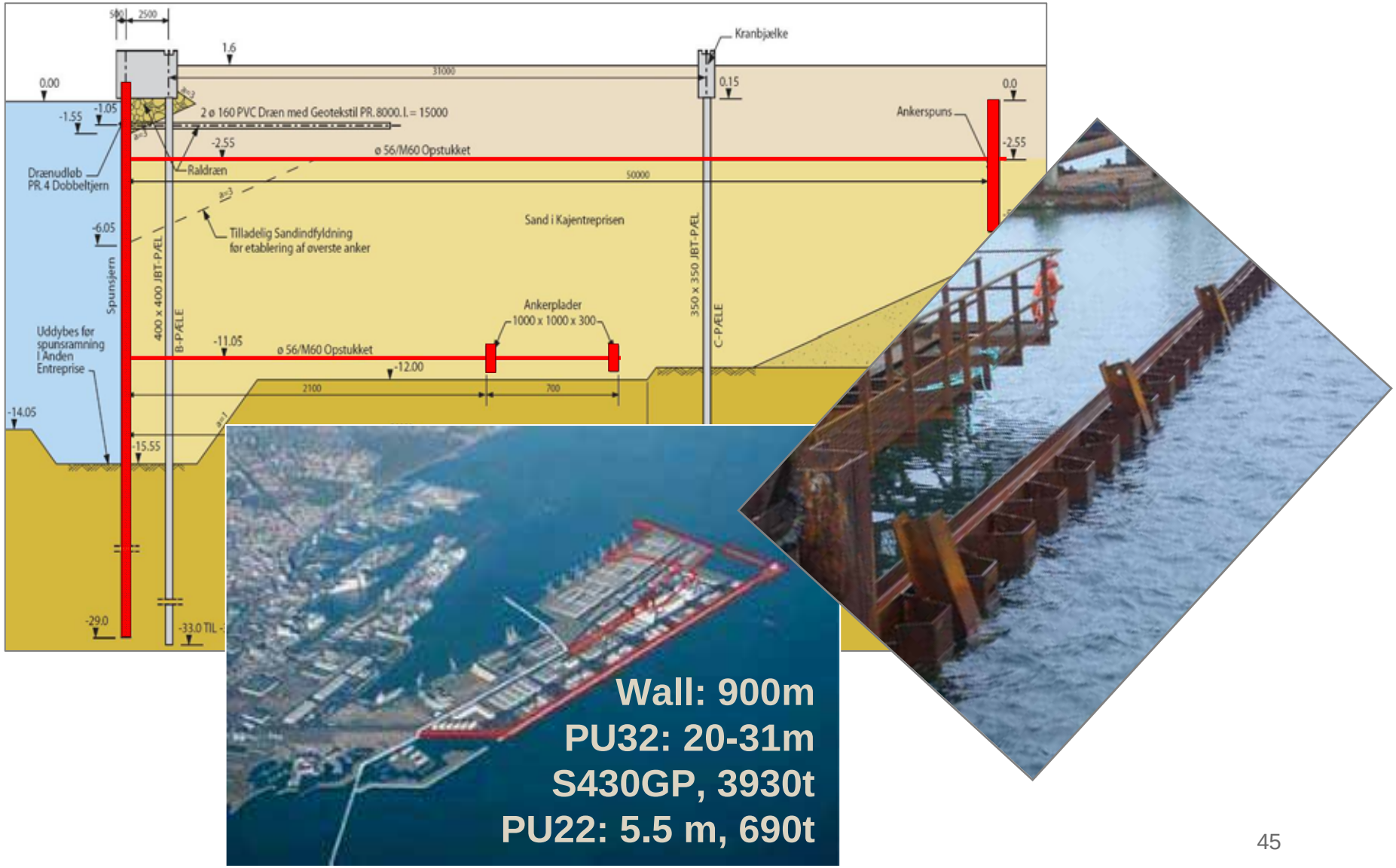
Quaywall Hellegat | Zeekanaal | B

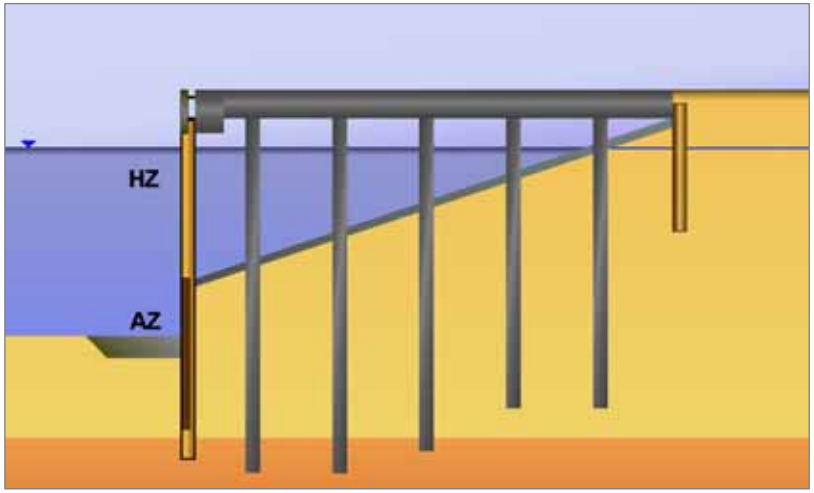




Port of Aarhus | Denmark (2005)

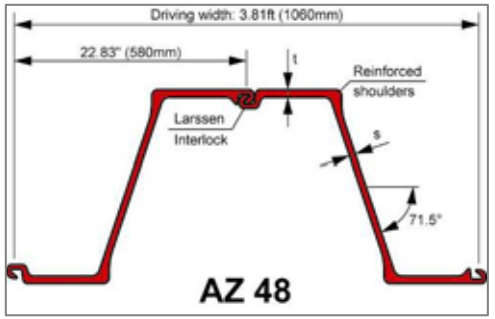


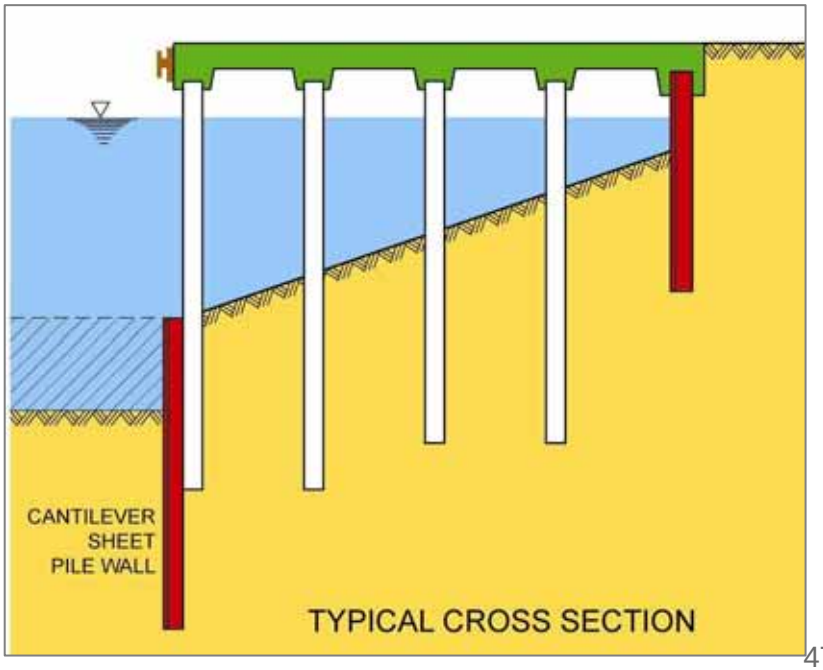
Maersk Terminal | Port Elizabeth | NJ | USA (2002)



HZ 575 B & C-12/AZ18: 1220 mt
HZ: ± 24.4m
AZ: ± 7.6m

Terminal 5 | Port of Seattle | USA





Prostneset | Tromsoe | Norway (2009)

Quay wall with circular cells

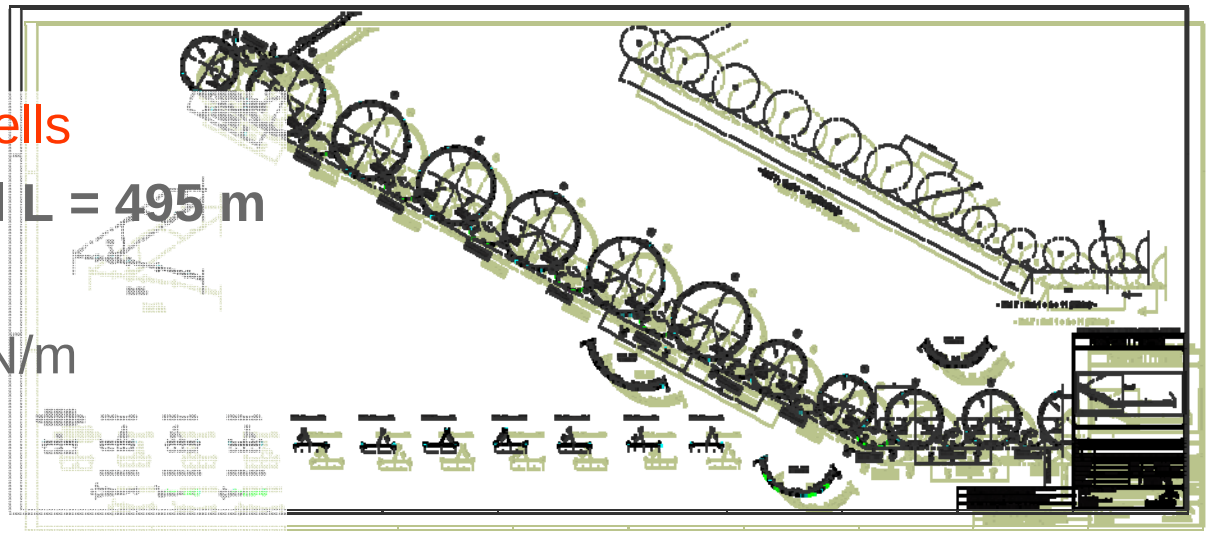
ϕ = 14.0 m / 19.2 m, total **L = 495 m**

AS 500-12.0

S 355 GP, I.S. = 5000 kN/m

l = 8.6 m ~ 15.0 m

3 100 t



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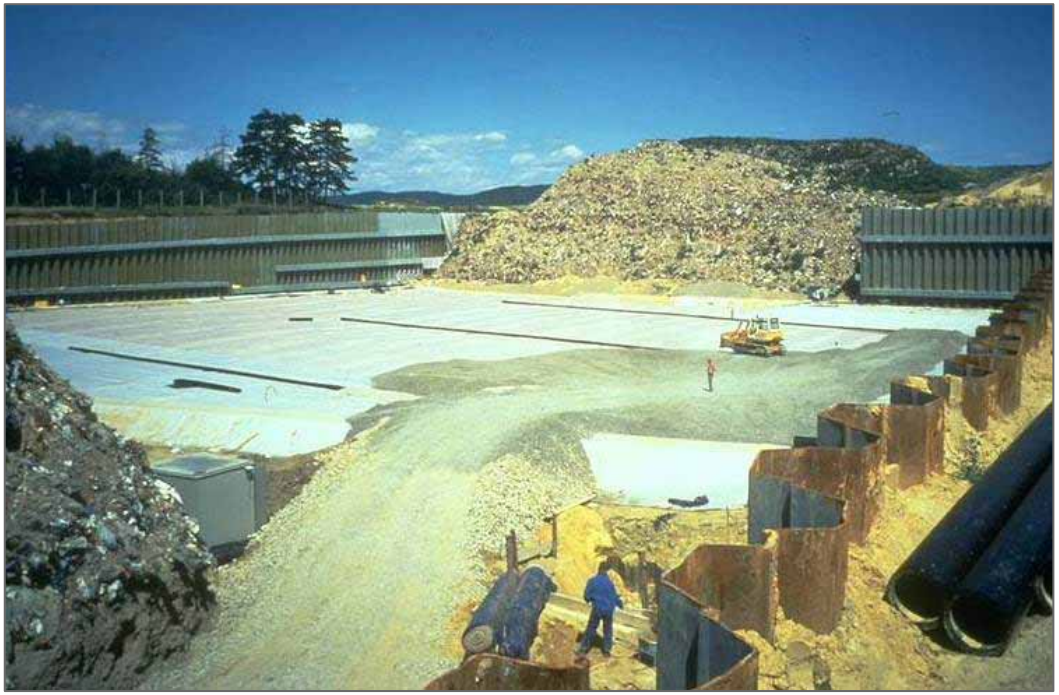
Cut off walls & Waste Disposal

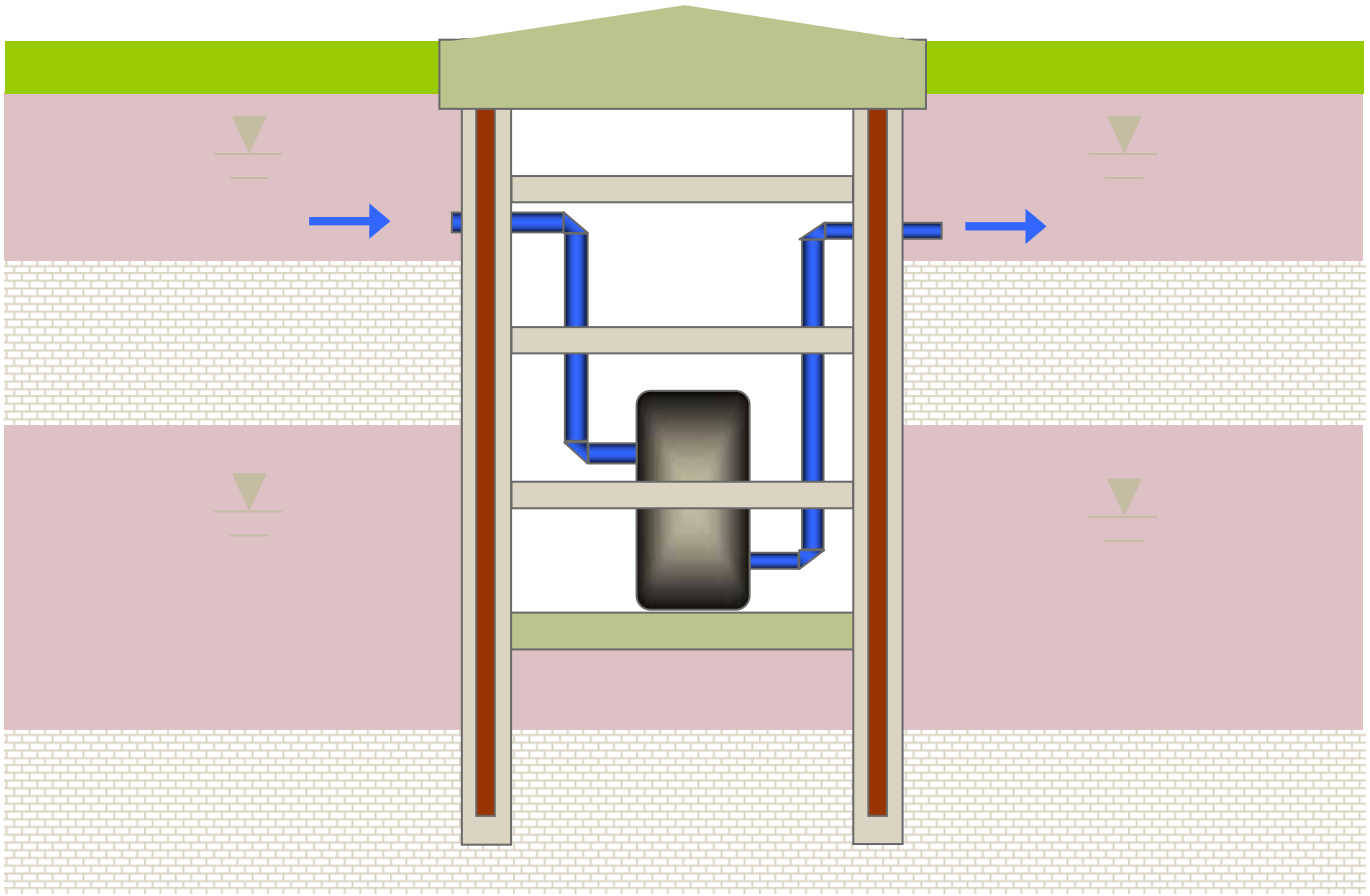
Kralingen (NL)

Porto Marghera

Waste disposal



Funnel and gate



Funnel and gate

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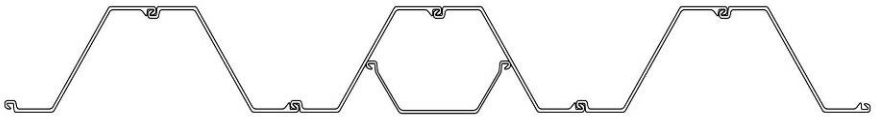
Road works & Underground Car Parks

Road works: Underpasses & Tunnels

Vicenza (It)



Frisange (L)

Warsaw: Load bearing test

Congonhas Airport (Brazil)

AU 14, S430GP


Woerden (NL)

Siemens, La Haye (NL)

Markthal Rotterdam (NL)

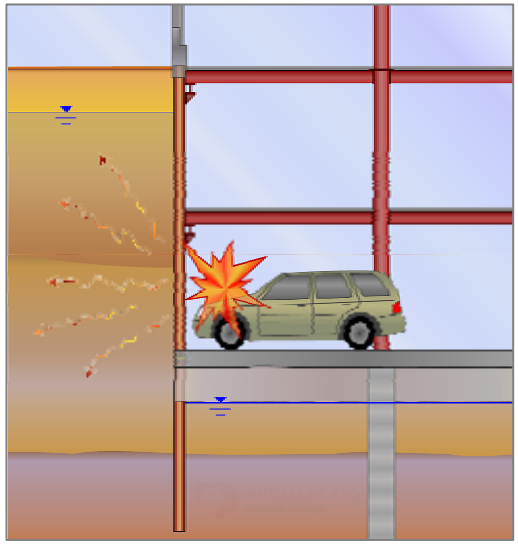
Underground car park

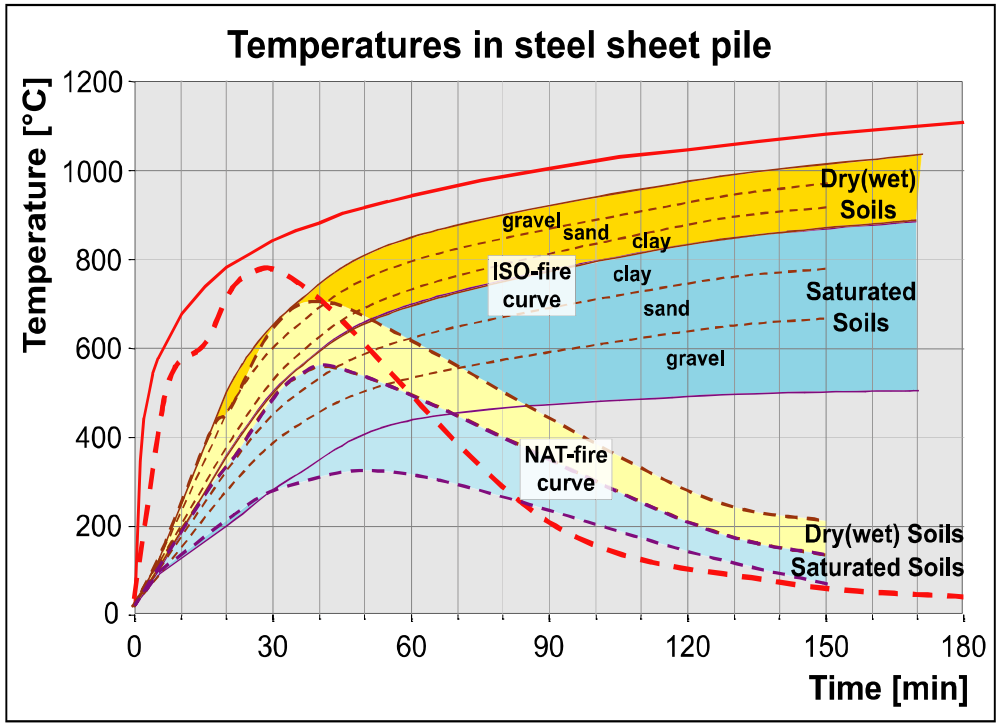
Netherlands

UK

Belgium

Fire resistance: design for UGCP

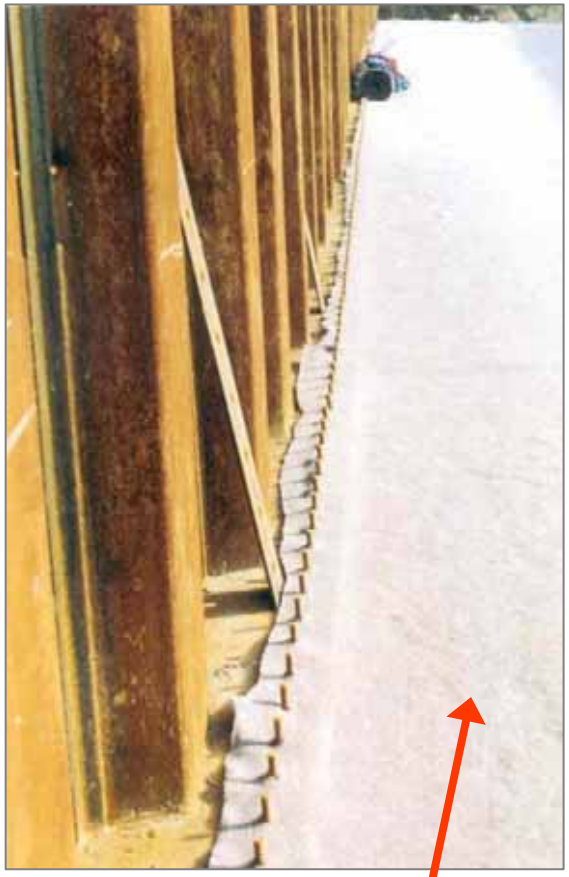




Behaviour of ssp in a 'natural' fire / ISO fire developed in collaboration with University of Liege, Belgium (⇒ software **Safir**).

Bottom slab-sheet pile connection

Studs



Sealed Floor

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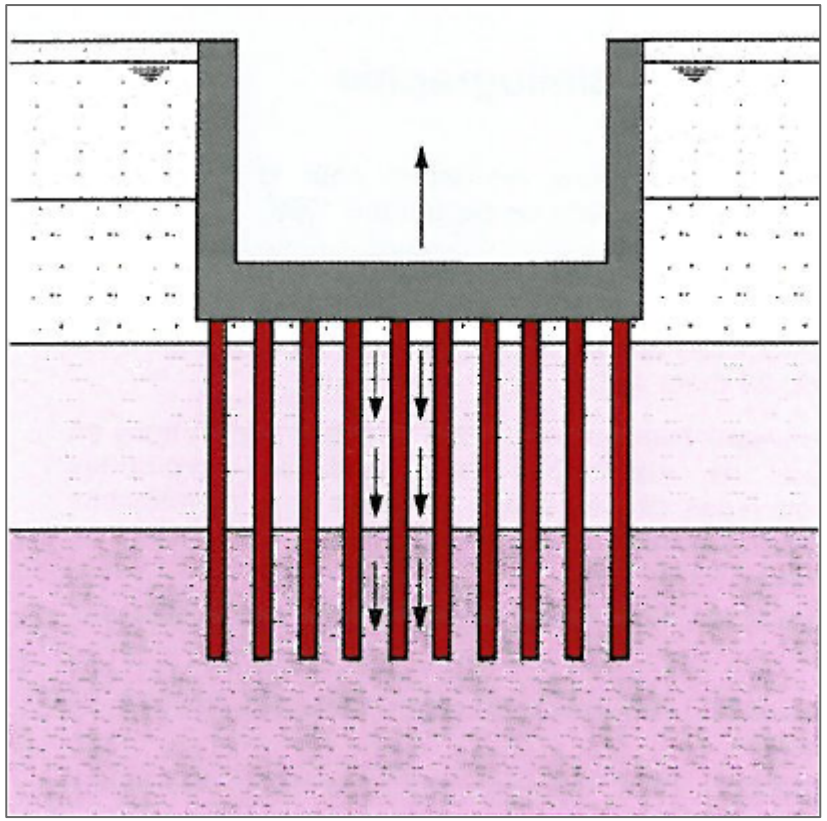
Foundations

Steel sheet piles for bridge foundations

Saalach-Kraftwerk Rott (Ö)

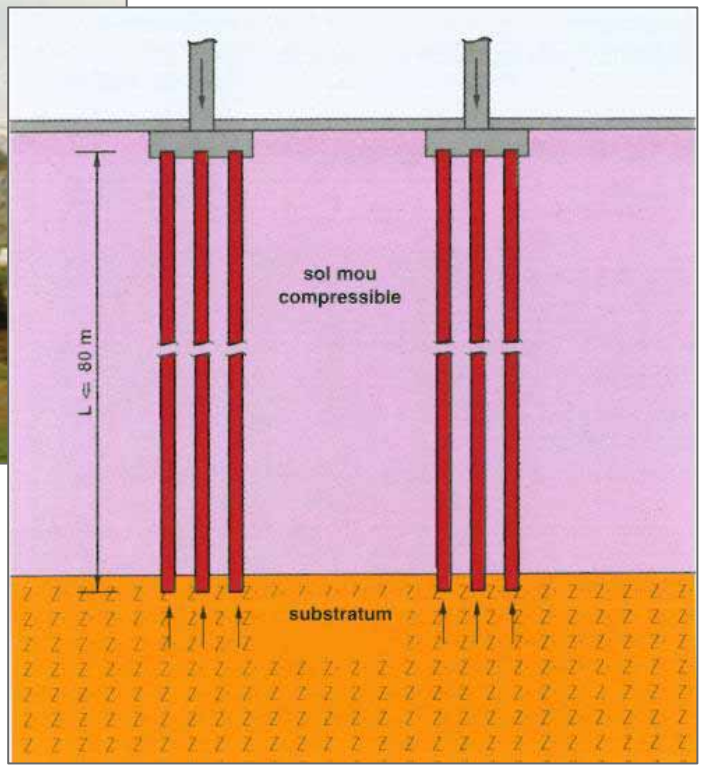
HP Pile Foundations

Waste water treatment plant
Lübeck (D)



HP Pile Foundations

A29 highway
Viaduct of Merville (F)



HP bearing pile applications

Injected piles for bridge pier foundations Viaduct at José (B)

HP bearing pile for bridge foundations

Injected piles for bridge pier foundations
Viaduct at José (B)

Assessment of pile capacity by design

The assessment of pile capacity by design can be performed based on geotechnical tests:

- Impact probe (light, heavy, SPT)
- Pressiometre (PMT) cf french fascicule 62
- Cone penetration test (CPT)
- Dynamic penetrometre
- Laboratory tests

1. Standards
2. Literature
3. Environmental Product Declaration
4. Conclusions

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Standards

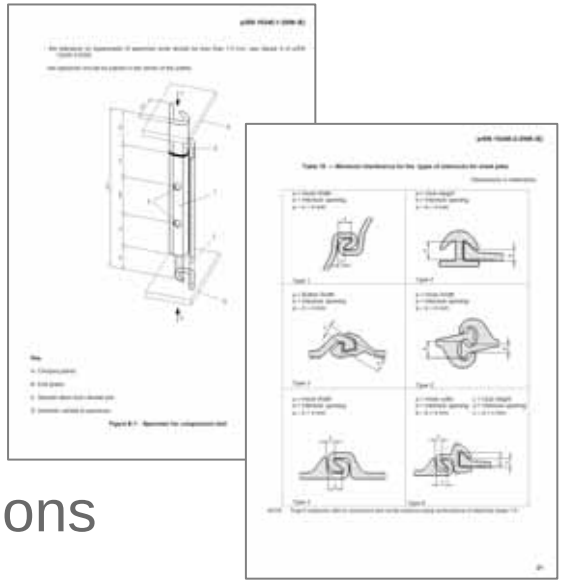
European standards

Design:

- **Eurocode 3** - Design of steel structures – **Part 5**: Piling.
  - Final version in Feb. 2007, release in 2008.
    New design concept for steel structures: semi-probabilistic approach. Steel sheet piles and bearing piles.

- **EN1997**: Geotechnical design (Part 1 & 2)
  - Design methods, assumptions, testing methods and geotechnical investigations are handled in this standard.
    Release in 2008.

European standards



Product: sheet piles

- **EN 10248**: Hot rolled steel sheet piling
  - Part 1: Technical delivery conditions.
  - Part 2: Tolerances on shape and dimensions

Contains sheet pile characteristics (properties of steels, chemical composition) and tolerances (length, mass, …).

Steel grades of HRSSP

EN 10248		ASTM		
	f_{yk} [MPa]		f_{yk} [ksi]	f_{yk} [MPa]
S 240 GP	240			
S 270 GP	270	A 328	39	270
S 320 GP	320			
S 355 GP	**355**	**A 572 Gr. 50**	**50**	**345**
S 390 GP	390	A 572 Gr. 55	55	380
S 430 GP	430	A 572 Gr. 60	60	415
*S 460 AP**	*460*	*A 572 Gr. 65*	*65*	*450*

- ASTM **A 690**: high strength steel for use in **marine environments**
- **Decreto Ministeriale**

European standards

Product: HP piles

- **EN 10025**: Hot rolled products of structural steels
  - Part 1: General technical delivery conditions
  - Part 2: Technical delivery conditions for non-alloy structural steels
  - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain steel

- **EN 10034**: Structural steel I and H sections – Tolerances on shape and dimensions

Steel grades of HP Piles

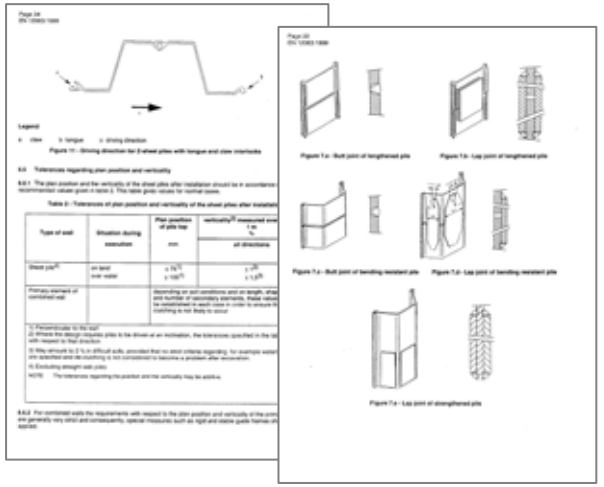
EN 10025			HISTAR	
	f_{yk} [MPa] t ≤ 16 mm	f_{yk} [MPa] t > 16 mm t ≤ 40 mm		f_{yk} [MPa]
S 235	235	225		
S 355	355	345	HI 355	355
S 460	460	440	HI 460	460
			HI 500	**500**

- **HISTAR** can be supplied for almost all sections
- **HI 500** only on request

European standards

Execution of Special geotechnical Works:

- **EN 12063**: Sheet-pile walls.
  - Covers fabrication, welding, installation tolerances, special solutions, handling & storage, .
- **EN 12699:** Displacement piles



Coatings:

- **EN ISO 12944:**
  - Guidance on coatings and their applications, etc

European standards

Other standards:

- **EN 10204**: Metallic products – Types of inspection documents
  - Describes the different inspections at the mill that can be agreed. Different types, different costs.
    Generally: inspection certificate 2.2 or 3.1
- **EN 287:** Approval testing of welders
- **EN 288:** Specification and approval of welding procedures for metallic materials
  - Welding of steel, quality control of welding, etc
- etc…

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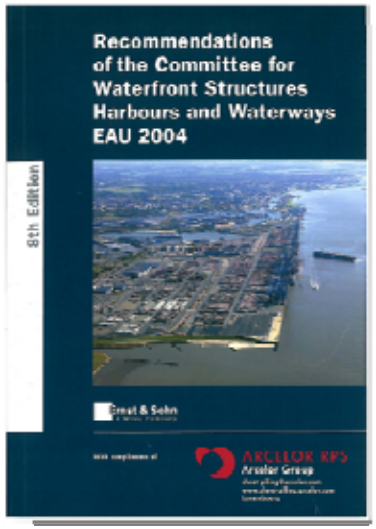
Literature

Reference books / publications

- **EAU 1990 / 1996 / 2004**: Recommendations of the Committee for Waterfront Structures Harbours and Waterways.
  Available in D, E

- EAB 2004: Empfehlungen des Arbeitskreises Baugruben.
  Available in DE & GB

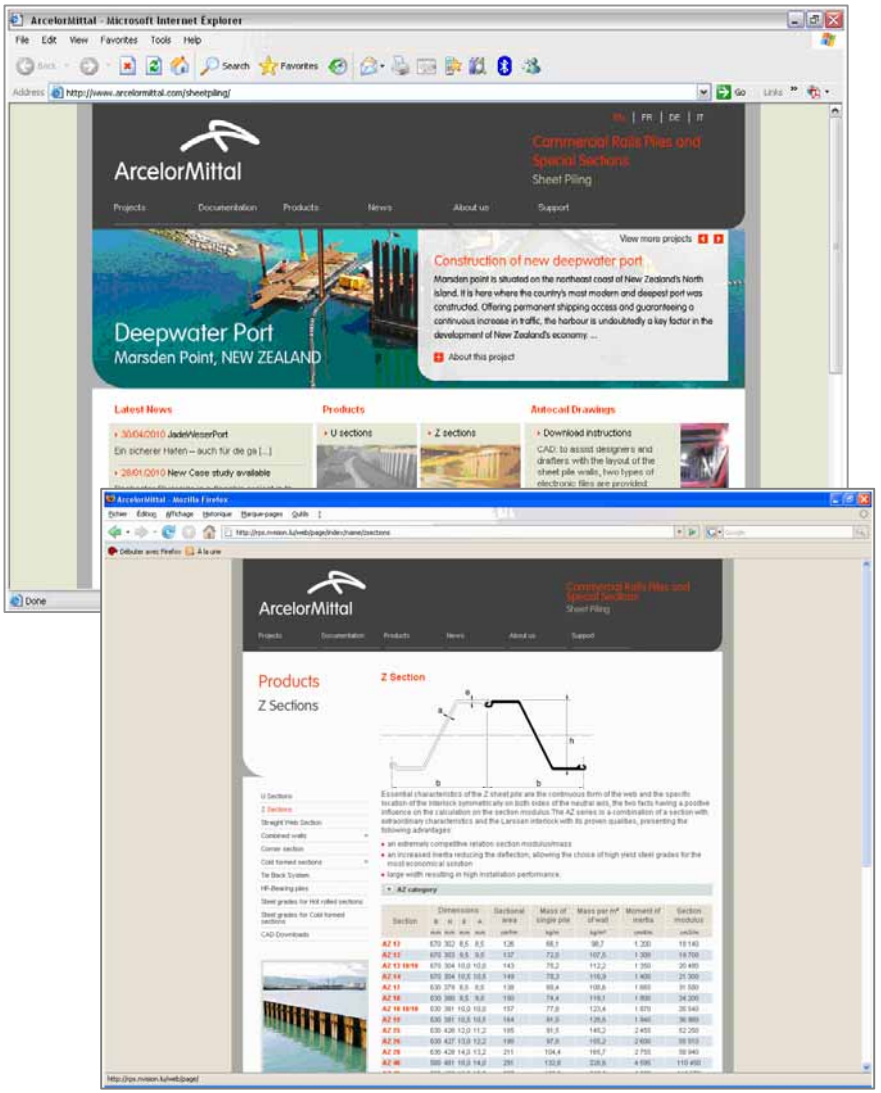
- CUR166: Damwandconstructies.
  Only in Dutch



Websites

- Lots of information (up-to-date):
  www.arcelormittal.com/palancole

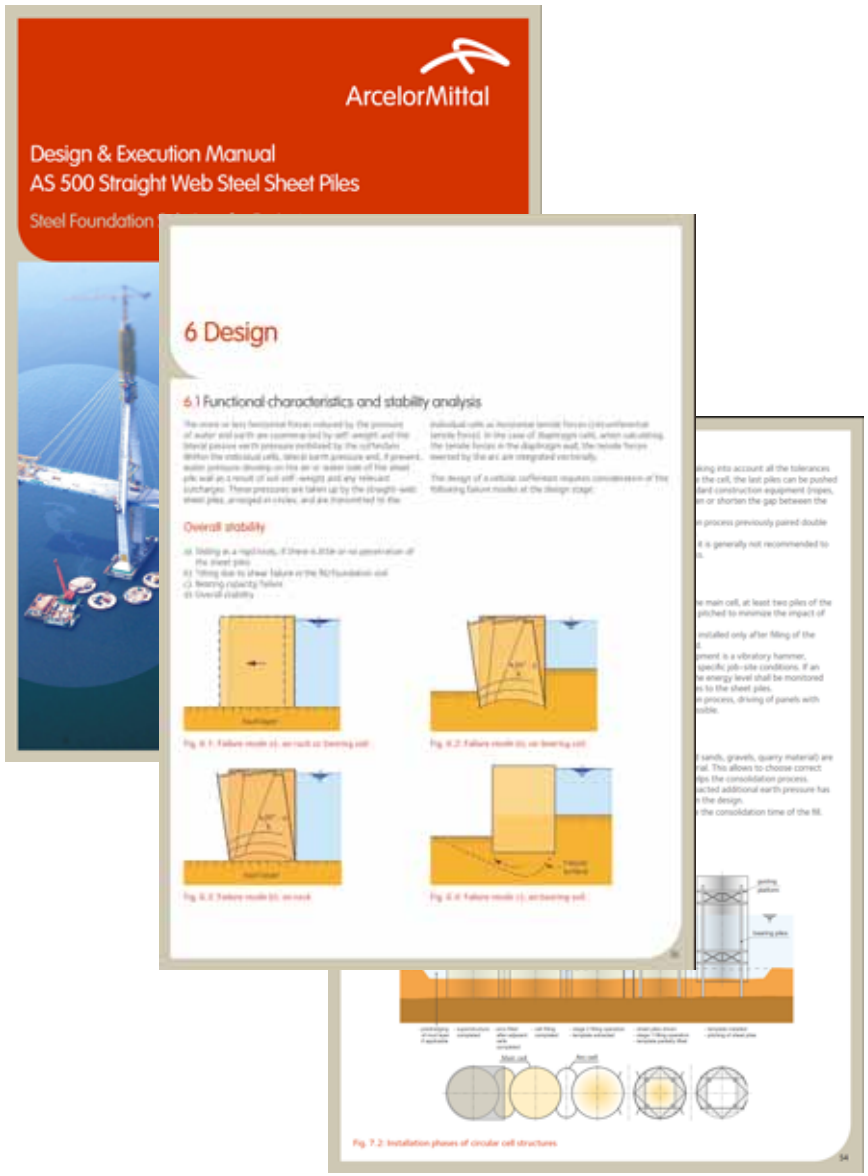
- **AutoCad files,** software (Prosheet, Durability,…) & main catalogues and brochures available for download



Available literature from ArcelorMittal

- Most relevant are:
  - **General catalogue** & HZM/AZ catalogue
  - **Installation** of steel sheet piles
  - **Piling Handbook**
  - **AS 500 straight web steel sheet piles**
  - **Special Finishing Brochure**
- Case studies:
  - **Harbour construction** (2007)
  - rail & motorways,
  - underground car parks (2008)
  - etc…

AS 500 brochure



- unique & comprehensive **design and installation manual** dedicated to straight web steel sheet piles AS500
- no such equivalent document, up-to-date available worldwide
- handles design aspects based on EuroCodes
- describes installation procedure
- contains 3 design examples

Free software / design support

- ‘Prosheet’: design of cantilever walls / one anchor level
- ‘Durability’: verification of steel stresses for standard HRSSP, based on design results and loss of steel (tables in EN1993-5)
- ‘HZ / AZ Stresses’: verification of steel stresses in the HZ/AZ system, may help choosing a combination

Free download from AMCRPS’ website.

No guarantee is given that they work correctly.

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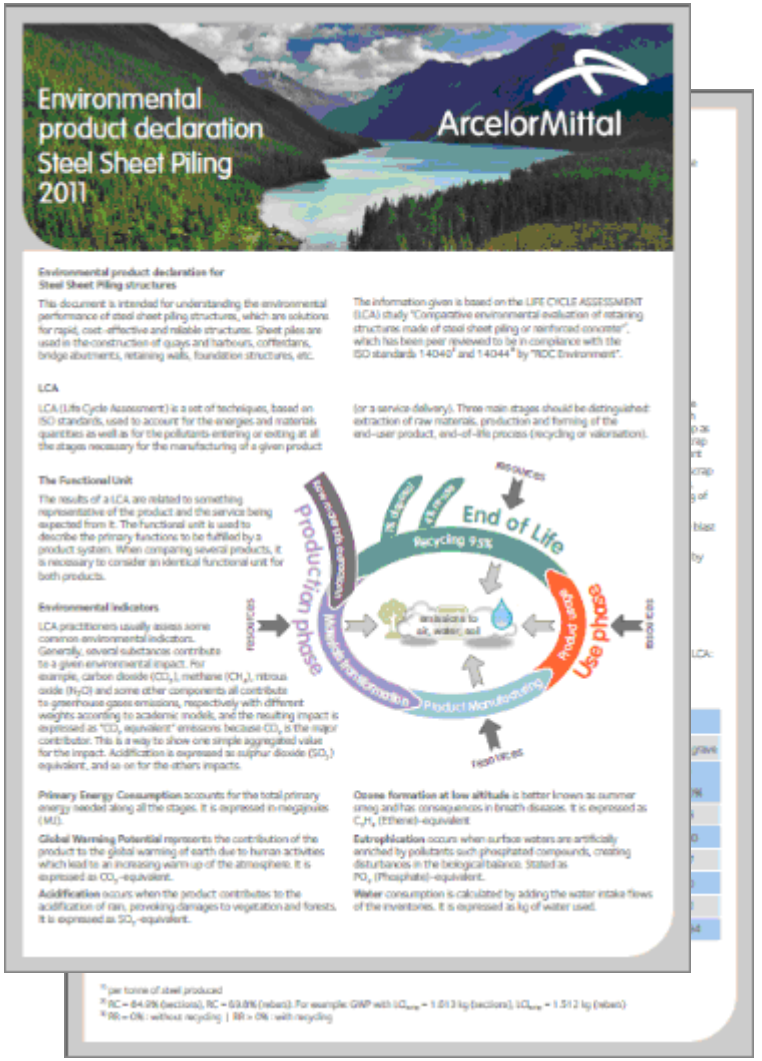
Environmental Product Declaration (EPD)

Environmental Product Declaration for steel sheet piling

- environmental impact: major criterion for material selection by authorities
- reliable and understandable data have to be provided for the complete sheet piling solution: sheet piles, wailing, anchors, installation, transport
- LCA (Life Cycle Assessment) allows to compare the environmental performances of products / structures
  cf ISO 14040 & 14044
- Deliverables:
  - certified LCA report ✓
  - Environmental Product Declaration ✓



Conclusions

Summary

Solutions for **temporary** and **permanent** structures:

- prefabricated product with high **quality control**
- fast execution
- design life of 50 years (and above)
- rehabilitation / dismantlement is possible
- steel sheet piles are a **recycled product** & easy to recycle
- **technical & commercial support** from ArcelorMittal:
  - preliminary designs
  - shop-drawings, special piles, fabrication, coatings
  - driving recommendations (method, equipment)
  - technical assistance at job-site (if required)

For technical questions please write to
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or phone to +352 53 13 29 71
For commercial questions please write to
giancarlo.scianatico@arcelormittal.com
or phone to 347 67 61 447

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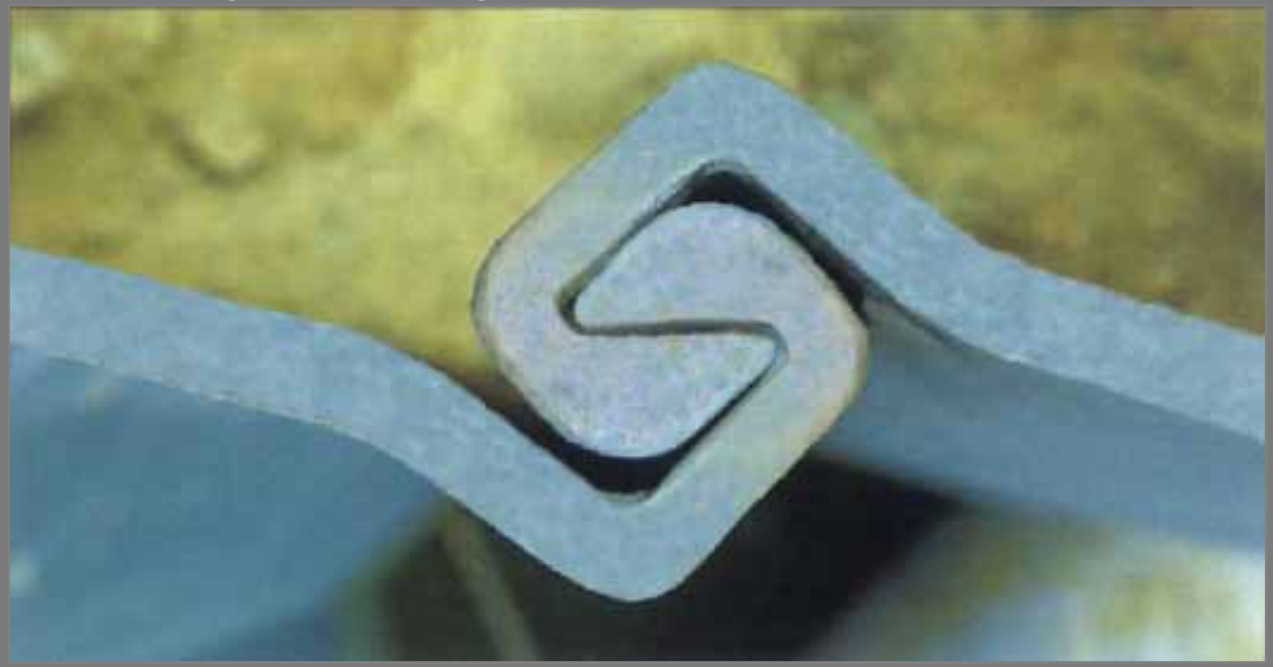
Thank you for your attention ...



... and let us stay connected!