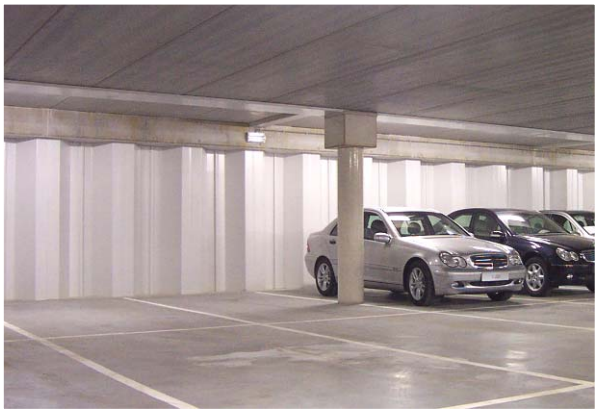
L’uso dell’acciaio nelle applicazioni geotecniche
Quadro normativo di riferimento
Esempi di calcolo secondo le NTC 2008

ArcelorMittal



Programma

15:00 – 15:30	Introduction and product range *ing. Dan Kohnen - ArcelorMittal*
15:30 – 16:00	Installation and watertightness *ing. Cécile Prüm - ArcelorMittal*
16:00 – 17:00	Applications *ing. Cécile Prüm - ArcelorMittal*
17:00 – 17:20	Pausa caffè
17:20 – 18:30	Design of steel sheet piles *ing. Simone Ciabattoni – Piacentini Ingegneri srl*
18:30 – 19:00	Standards, delivery conditions, litterature and conclusion *ing. Cécile Prüm - ArcelorMittal*

ArcelorMittal

Introduction

Origin of ArcelorMittal

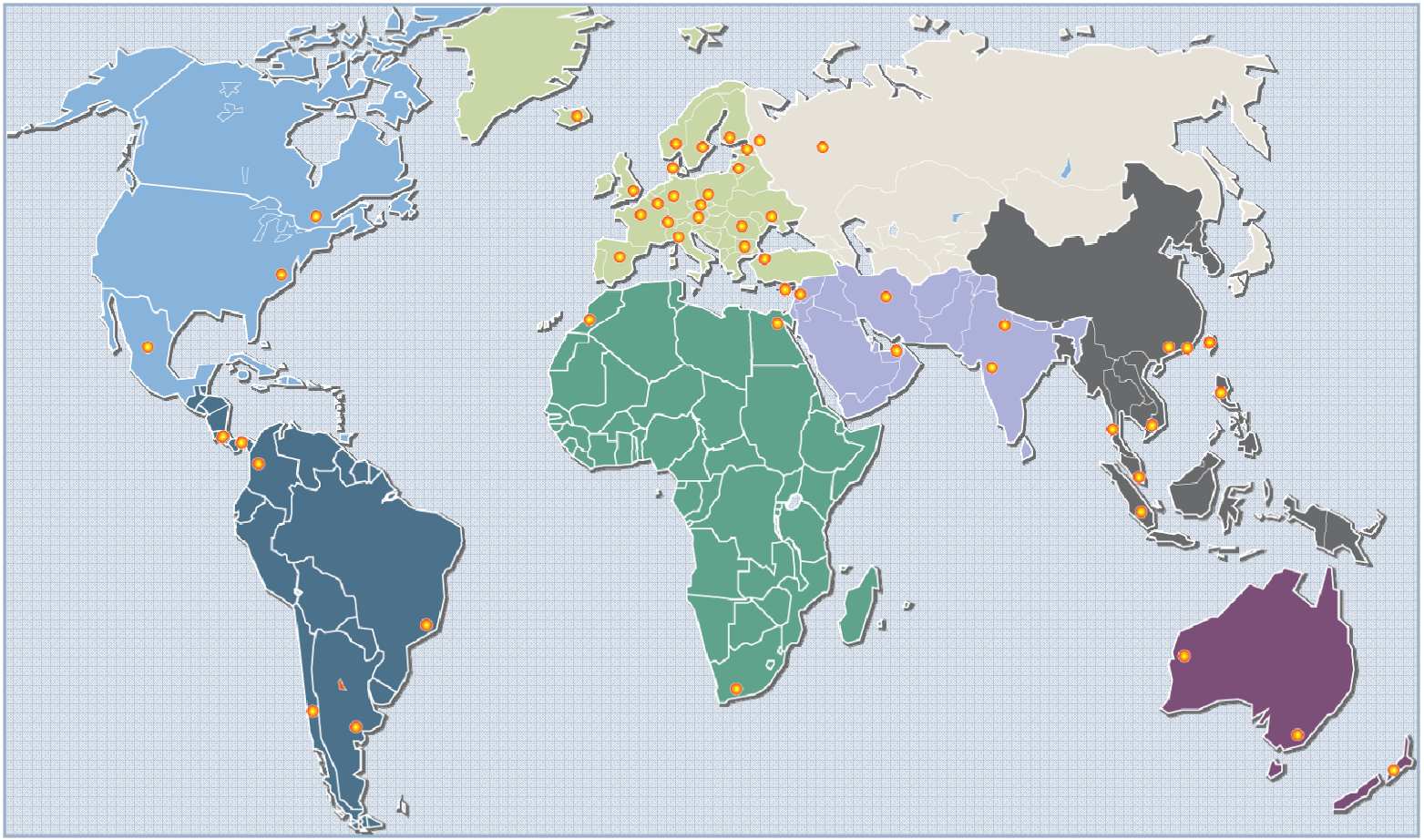
arcelor

+

Mittal Steel

ArcelorMittal

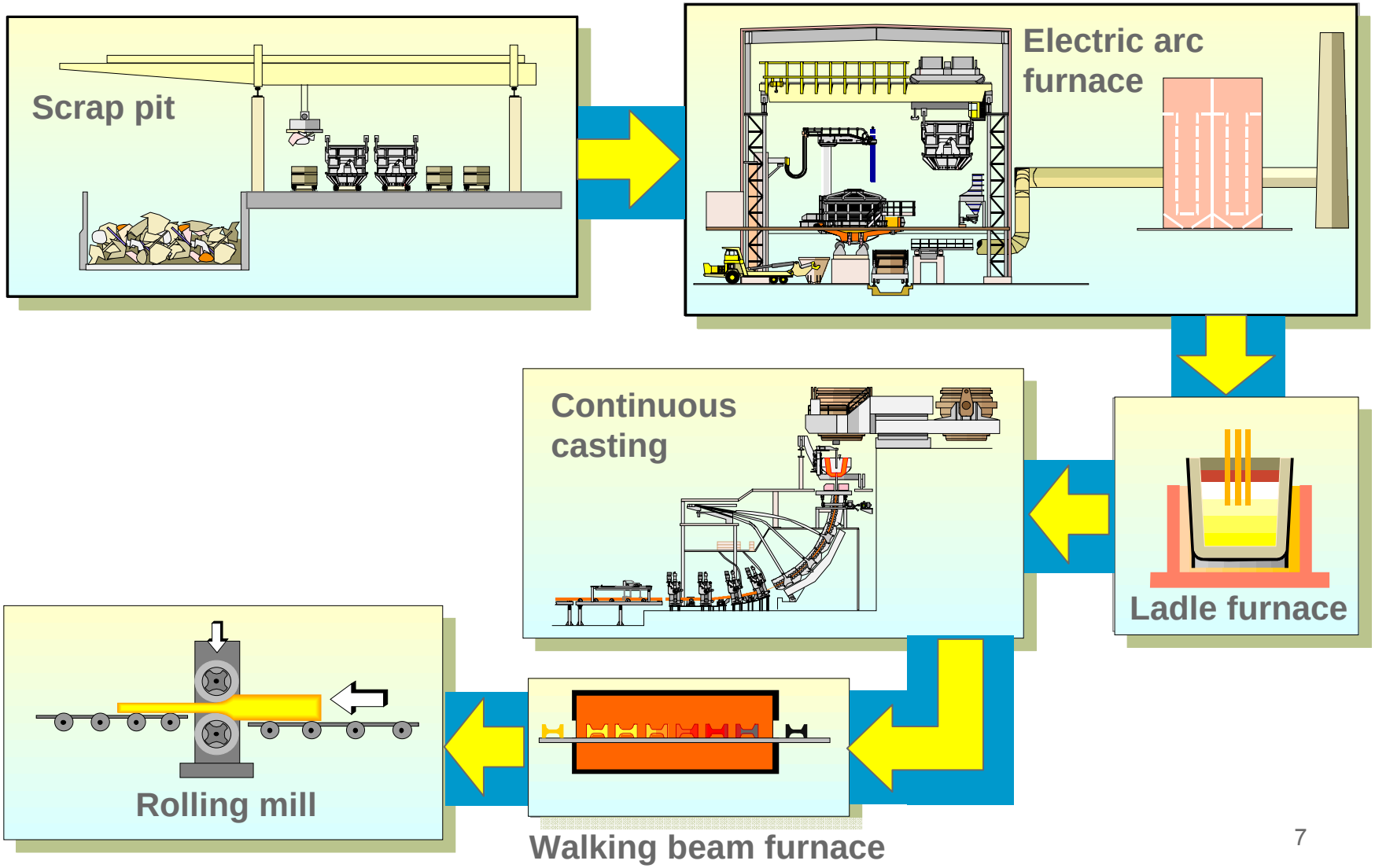
Sales offices and production sites outside Europe



Production HRSSP: mills

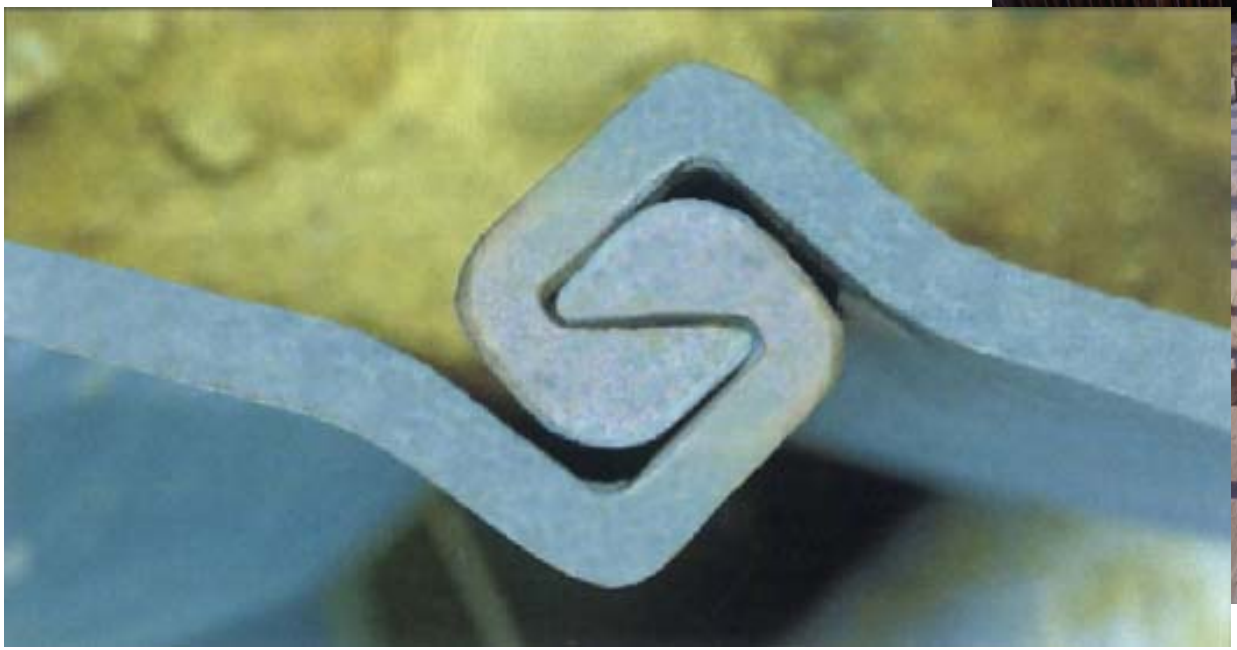
HR SSP	
Belval	(LU)
Differdange	(LU)
Rodange	(LU)
Dabrowa	(PL)
Capacity	900 kt

Manufacturing of steel sheet piles (EAF)



ArcelorMittal - Steel sheet piling

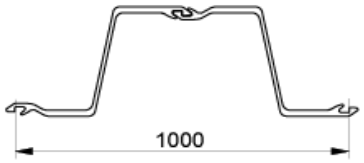
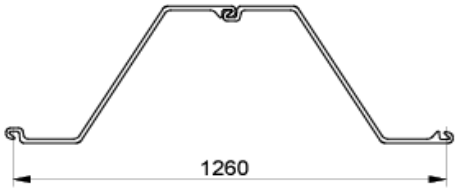
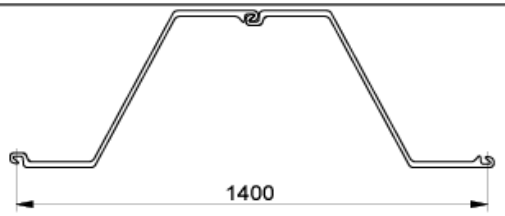
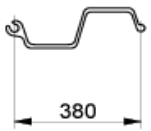
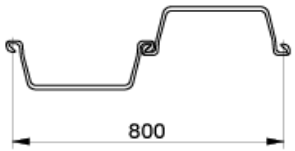
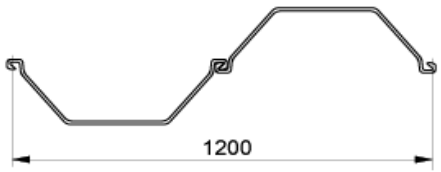
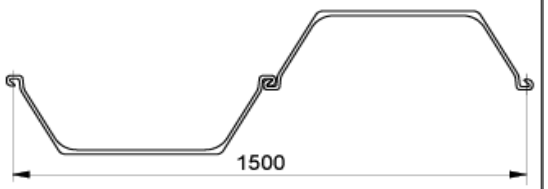
Row of interlocking vertical pile elements that form a continuous wall retaining soil and / or water



Steel sheet piling: historical overview

STEEL SHEET PILING 100 YEARS MADE IN LUXEMBOURG

- First rolled steel sheet pile in USA: Lackawana type, 1908
- Since 1911, **ArcelorMittal** has improved sheet pile sections

Type	RANSOME 1911	BZ 1933	AZ 1990	AZ - 700 2004
Z				
Type	**TERRE-ROUGE 1912**	**LARSSEN 1914**	**PU 1988**	**AU 2000**
U				

Ecology and steel sheet piles

ArcelorMittal's mills are certified

ISO 9001, ISO 14001, OHSAS 18001

- Esch-Belval since December 2002 (ISO 14 001)
- Differdange since November 2003 (ISO 14 001)

ArcelorMittal

Product range:

- straight web (flat sheet piles)
- bending resistant sheet piles (U, Z, HZ,…)
- bearing piles (HP)

Hot rolled steel sheet piles (2011)

ArcelorMittal

W_x up to 5.000, resp. 46.500 cm^3/m

Z type

AZ 13-700R
AZ 17 / 18 / 19
AZ 25 / 26 / 28
AZ 46 / 48 / 50
AZ 13-770
AZ 18-700
AZ 26-700
AZ 38-700N

U type

AU 14 / 16 / 17
AU 18 / 20 / 21
AU 23 / 25 / 26
PU 8R
PU 10R
PU 14R
PU 12
PU 18
PU 22
PU 28
PU 32
GU 7N&S
GU 13-500
GU 16-400

HZ / AZ

HZ 775
HZ 975

HZ 880M
HZ 1080M
HZ 1180M

Flat-type

AS 500 - 9.5 / 11.0 / 12.0 / 12.5 / 12.7

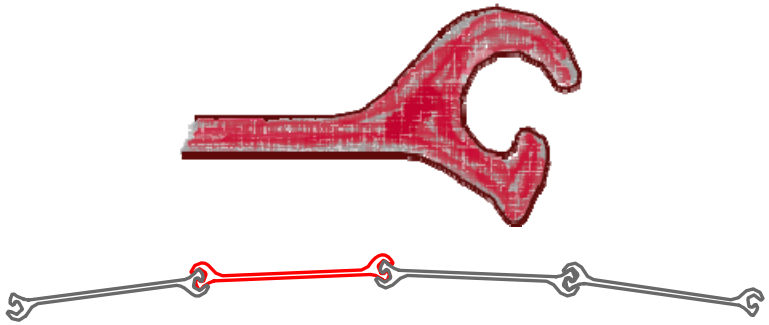
Flat steel sheet piles

Large cofferdam with **circular cells** resting on bedrock

Seo-Hae Grand Bridge, South Korea

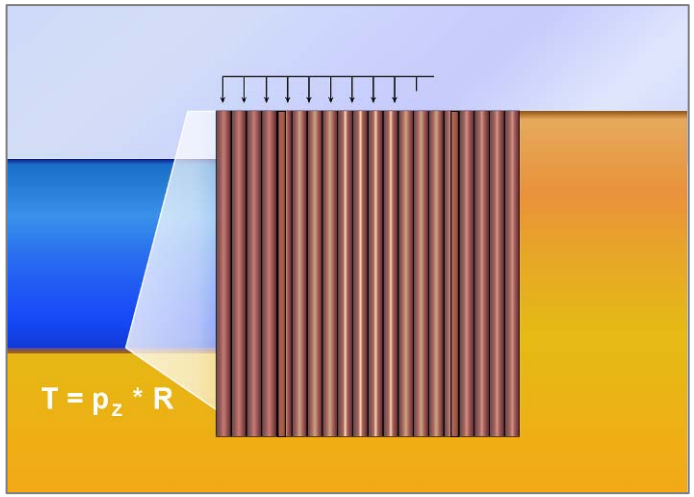
Flat steel sheet piles

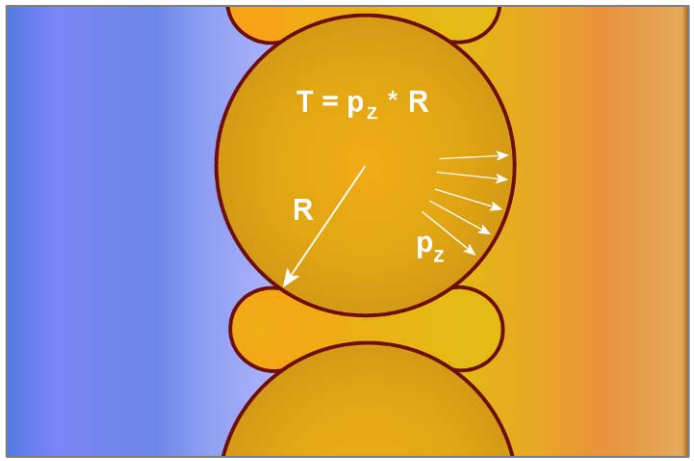
Resisting by **interlock tension**



Straight web AS

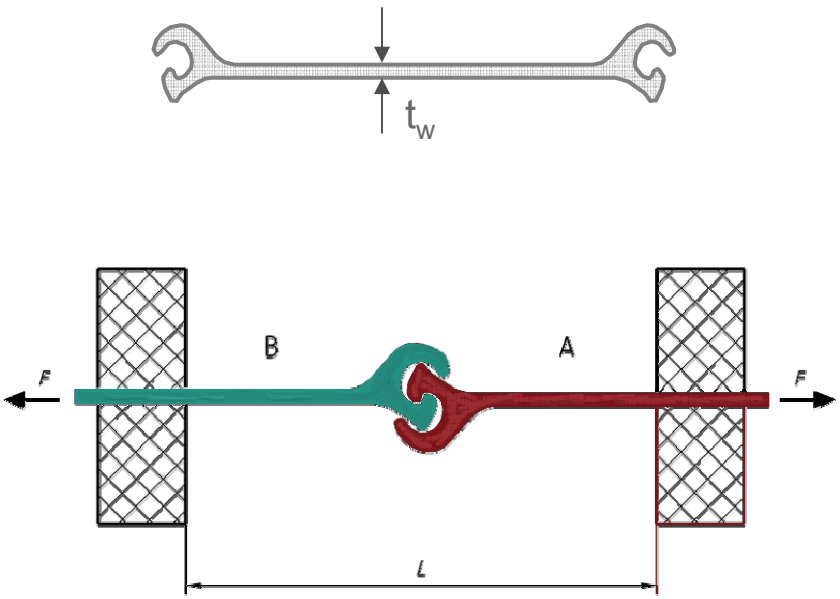
- gravity structure
- deep wharfs / quays / breakwaters / cofferdams
- structures founded on bedrock
- no anchors





Flat steel sheet piles AS 500

Width = 500 mm (nominal)



300 mm ≤ L ≤ 500 mm

testing: **EN10248-1**

Thickness web t_w [mm]	**Interlock strength** (tension) [kN/m]	f_{yk} min. yield strength [MPa]
9.5	3 000	355
11.0	3 500	355
12.0	5 000	355
12.5	**5 500**	355
12.7	**5 500**	355

Tug-boat quay, Paraíso, Panama Canal (2004)

AS 500-12.0

20 circular cells

ϕ = 15.0 m, L = 18.5 – 20.0 m

$\approx$ 3000 t

Types of steel sheet piles

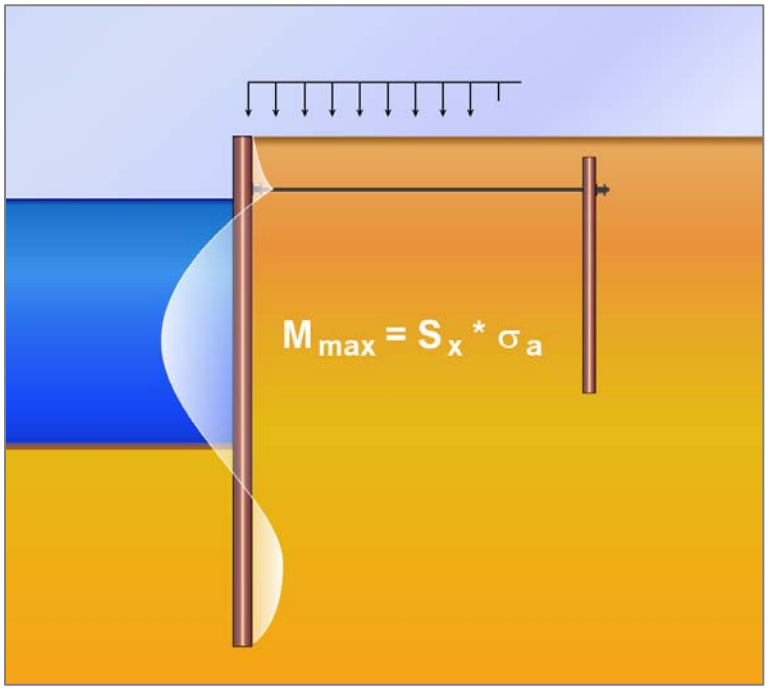
ArcelorMittal

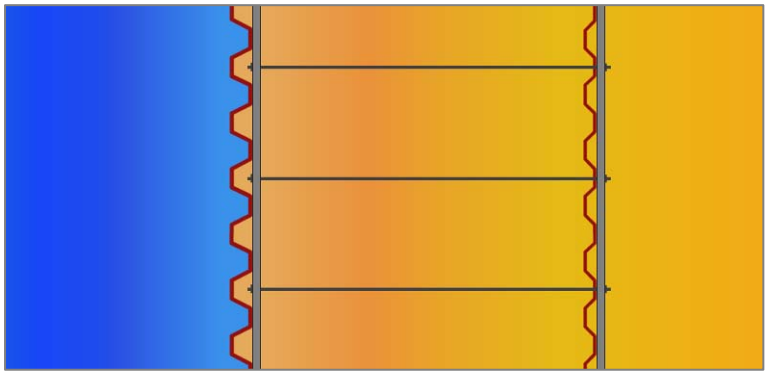
Bending resistant

U - section

Z - section

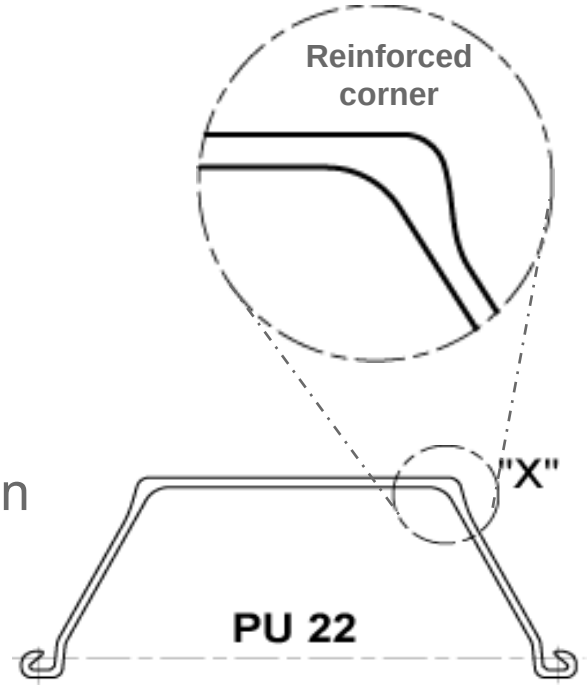
Combi-wall HZM / AZ

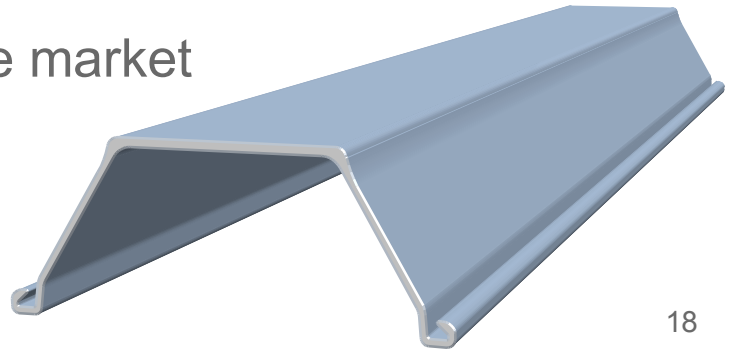




The new PU 18, PU 22 & PU 28

- optimized shape (**reinforced shoulders**) for use in hard and difficult driving conditions
- designed for **multiple re-use** (rental business)
- in situ driving tests prove excellent installation performance
- complementary to the wider AU piles
  ⇒ cover complete range of the U-pile market





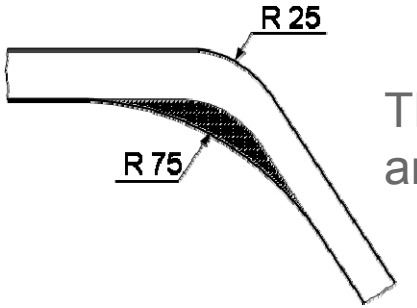
Hot rolled U-sections: AU (2000)

AU 14
AU 16
AU 17

AU 18
AU 20
AU 21

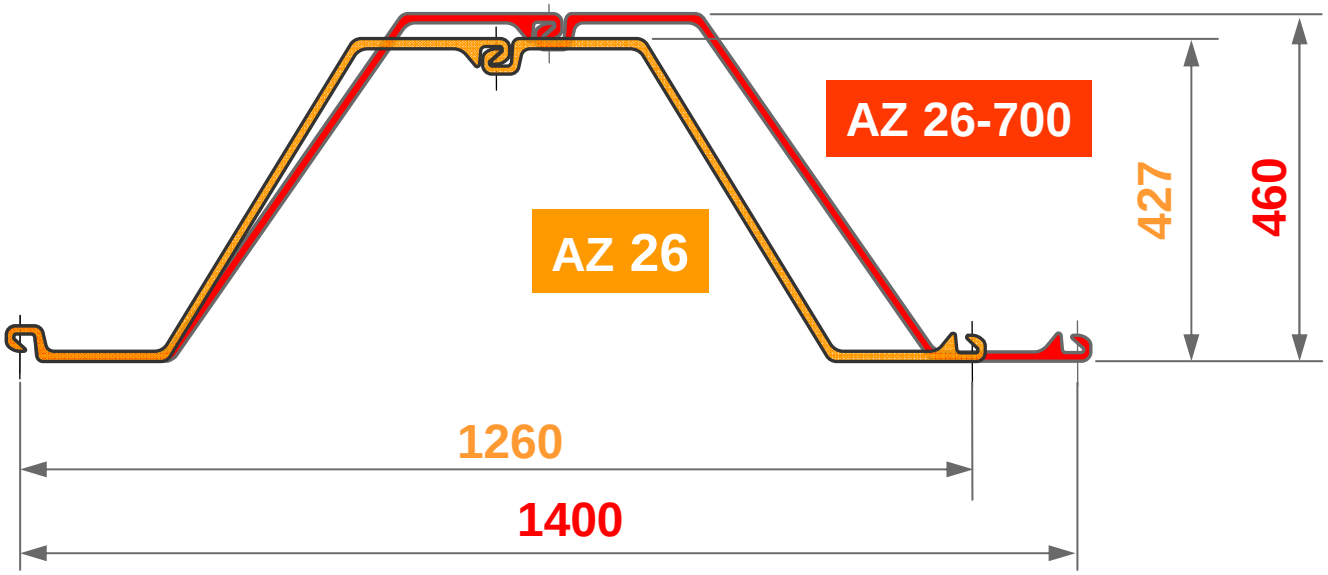
AU 23
AU 25
AU 26

Width	**750**	(mm)
Elastic section modulus	1410 - **2580**	(cm^3/m)
Moment of inertia	28710 – 58140	(cm^4/m)



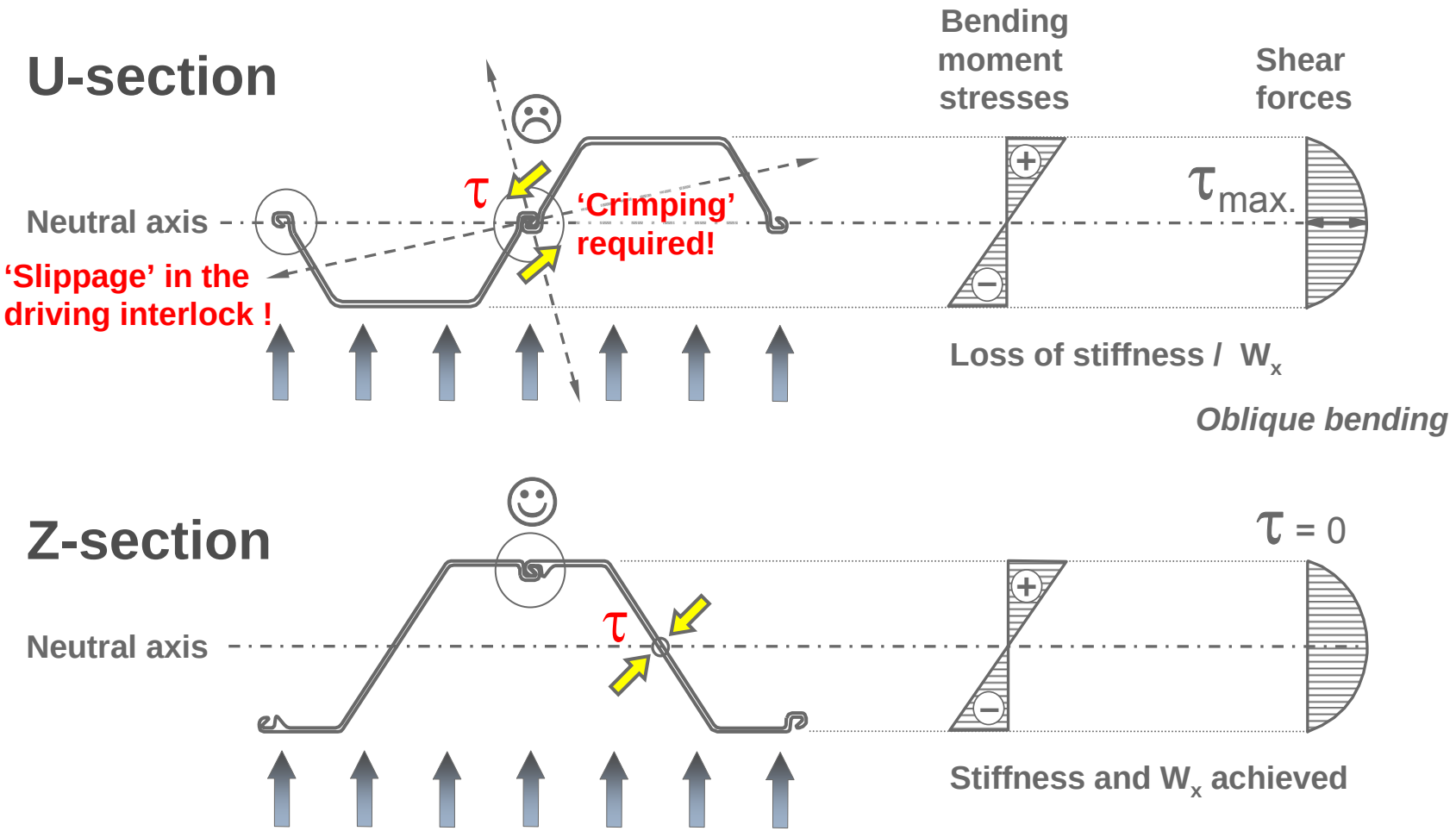
The optimised radii of the AU have been patented and are an exclusivity of ArcelorMittal

AZ 26 | new AZ 26-700 (April 2008)

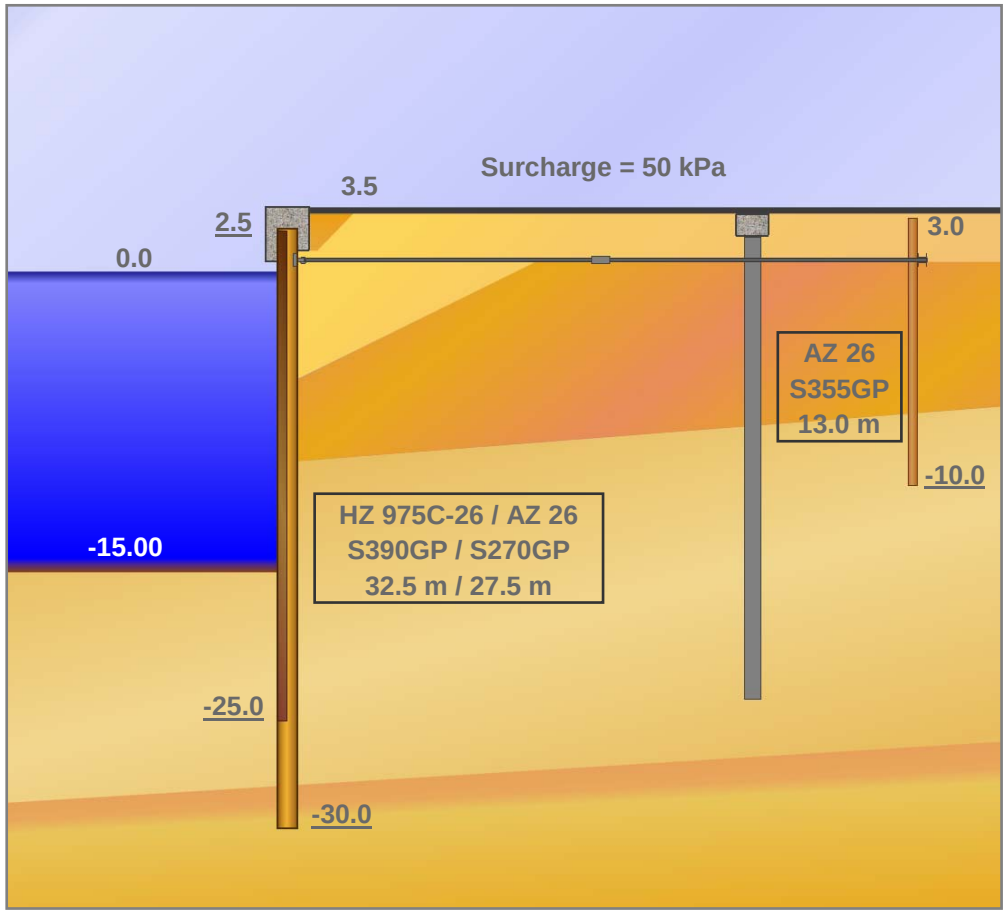


	AZ 26	AZ 26-700	
W_x (cm³/m)	2 600	2 600	
mass (kg/m²)	155.2	**146.9**	⇒ **- 5 %**

Different behaviour of U and Z-piles



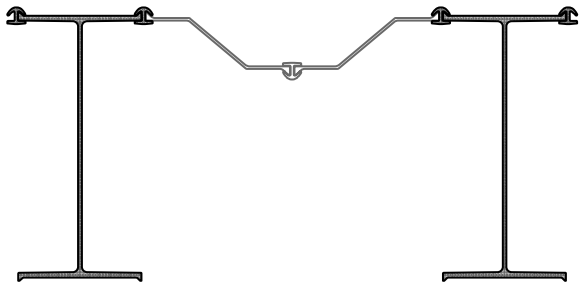
Combined wall: main applications



- waterfront structures with deep dredge level
- high retaining walls and deep cofferdams
- structures with limited deflection requirements (i.e. cantilever walls)

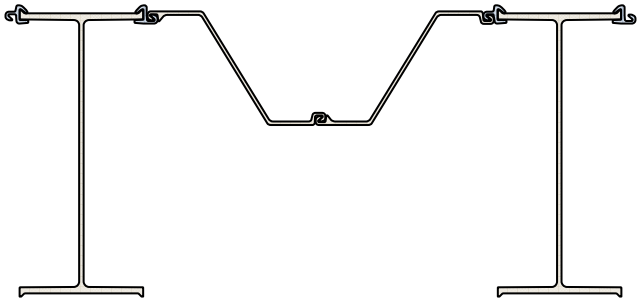
The success story

- 1972: **HZ-ZH** system
  - HZ king piles
  - ZH specific infill sheets
  - RH connectors on HZ or ZH



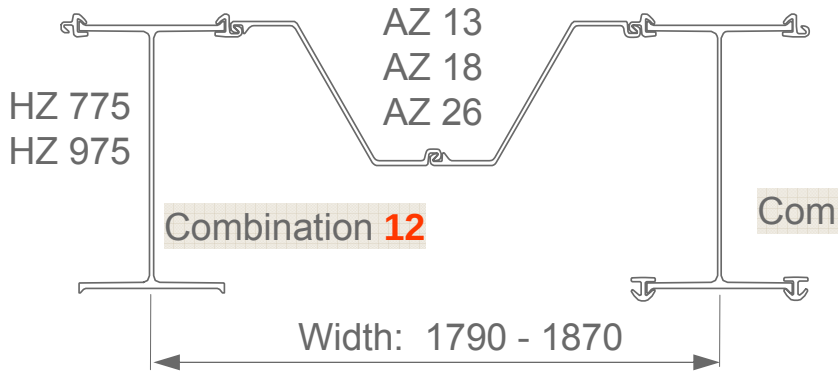
HZ 975 B - 12 – ZH 9.5 -11

- 1990: **HZ-AZ** system
  improvement of the system
  - HZ king piles
  - AZ standard infill sheets
  - RH/RZ connectors on HZ

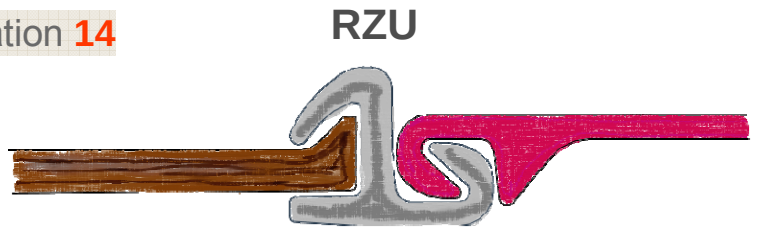


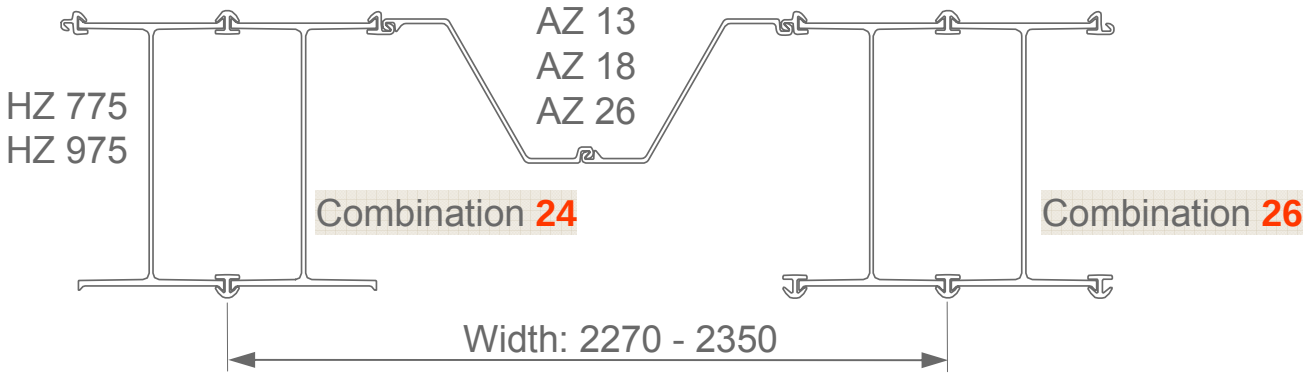
HZ 1050 D - 12 – AZ 26

HZ / AZ Steel Wall System



Combination **14**



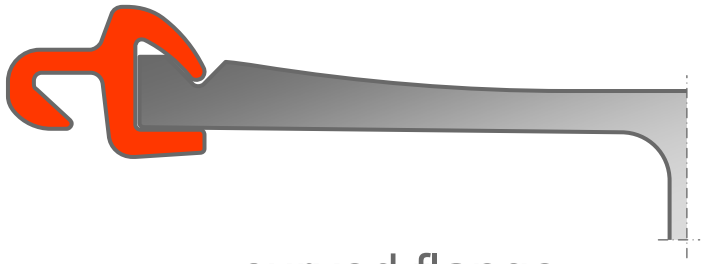


Elastic section modulus	2 875 - **14 940** (cm^3/m)
Moment of inertia	96 800 - 741 840 (cm^4/m)

New HZ-M range (2009)

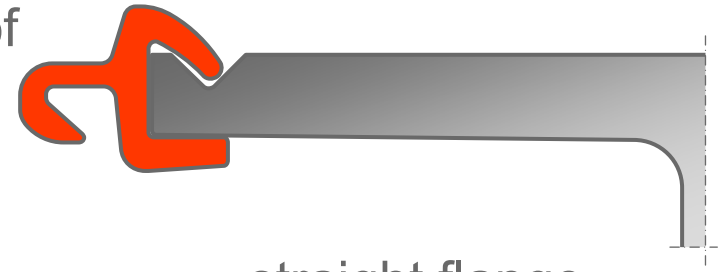
- increase competitiveness of HZ range
- achieve much higher W_X

- $\Rightarrow$ new shapes of flange:
  - **460** mm wide
  - deeper sections (ratio $W_{el,y}$ / weight $\uparrow$)
  $\Rightarrow$ higher productivity of the mill & vast range



curved flange

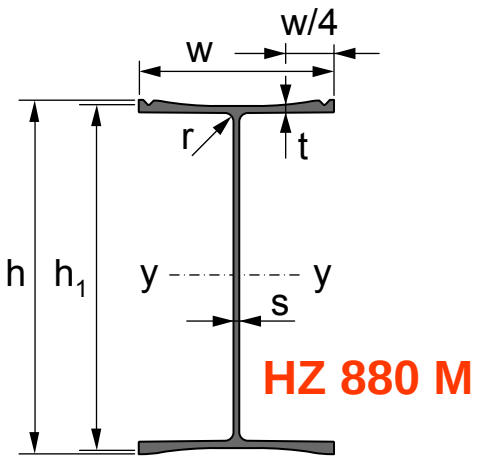
- milling of the groove (enhanced respect of interlock tolerances)
  $\Rightarrow$ develop new milling machine (challenge)



straight flange

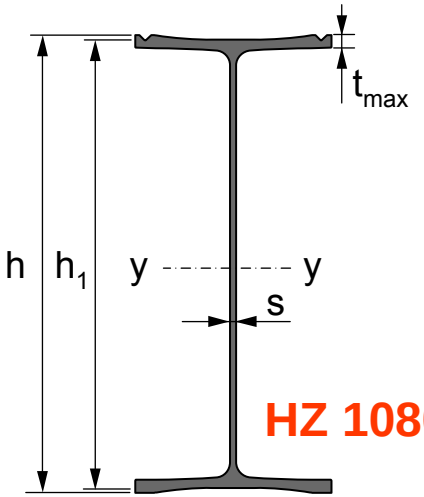
Range of HZM

	Nb of sections	h (mm)	t (mm)	s (mm)	w (mm)
HZ 880 M	A, B, C	831	19 - 23	13 - 15	458 - 460
HZ 1080 M	A, B, C, D	1075	20 - 30	16 - 19	454 - 457
HZ 1180 M	A, B, C, D	1075 - 1087	31 - 37	20 - 22	458 - 460



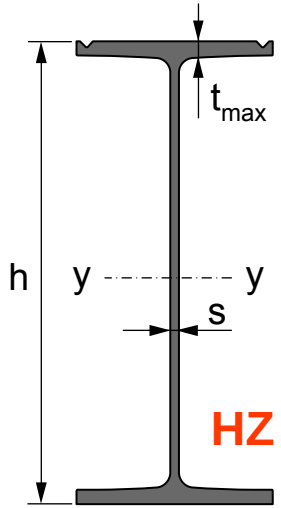
HZ 880 M

t = 19, 21, 23 mm



HZ 1080 M

t = 20, 23, 26, 30 mm

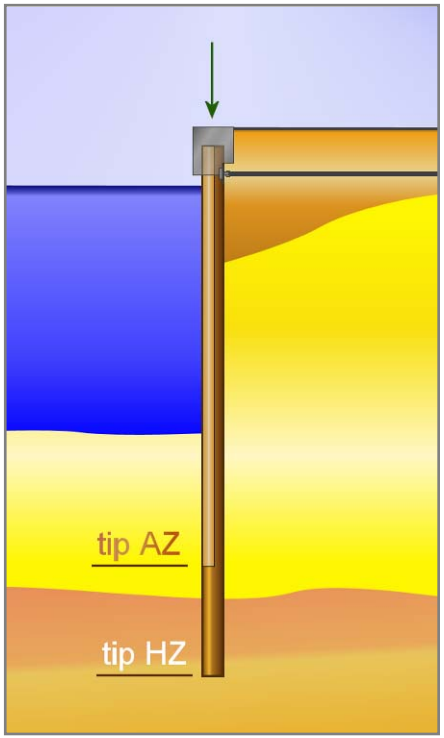


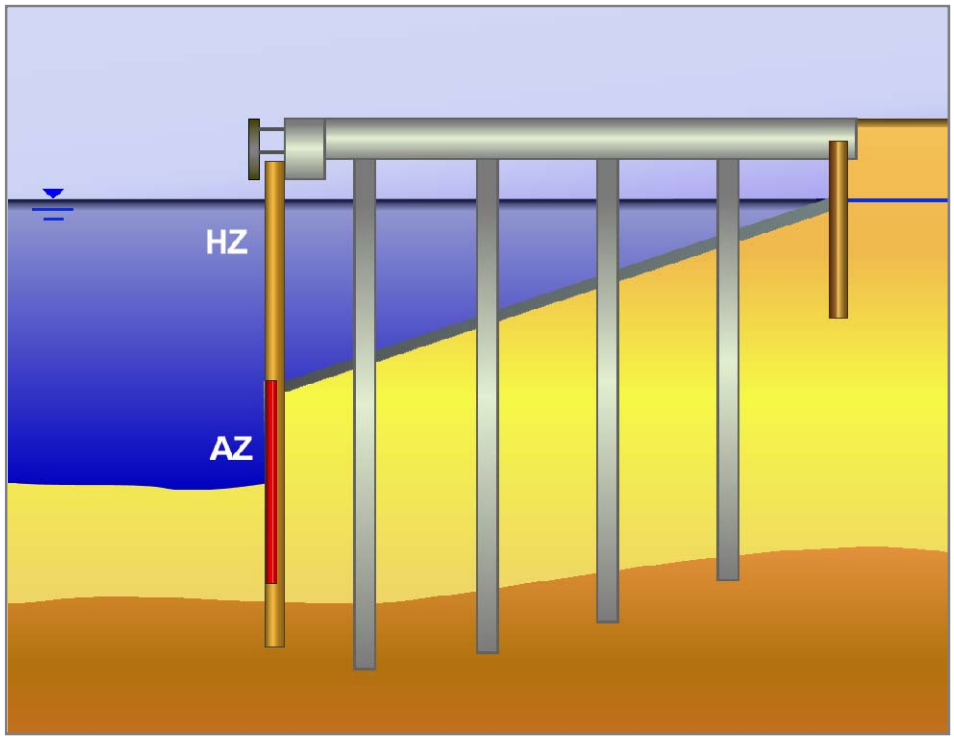
HZ 1180 M

t = 31, 33, 35, 37 mm

Reduced length of infill sheet piles

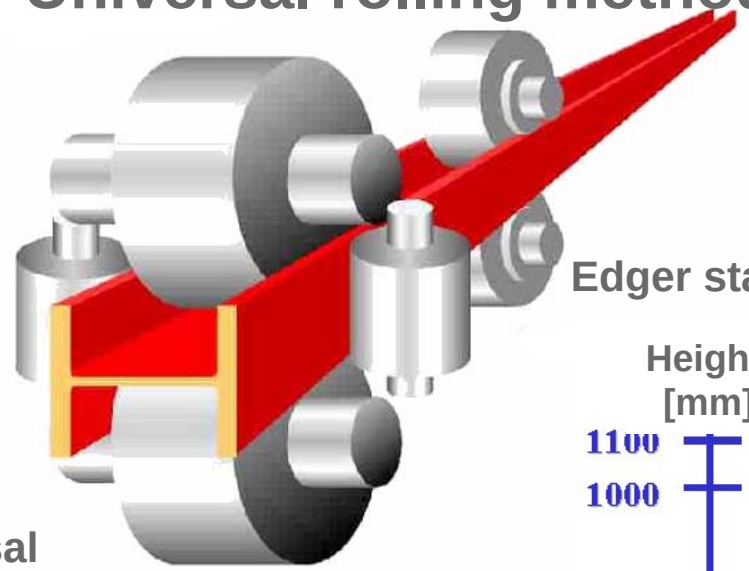
- the **shorter** intermediate piles AZ are designed to guarantee wall continuity
  ⇒ weight savings
- passive **3D effect**: design as continuous wall





Production of HP bearing piles

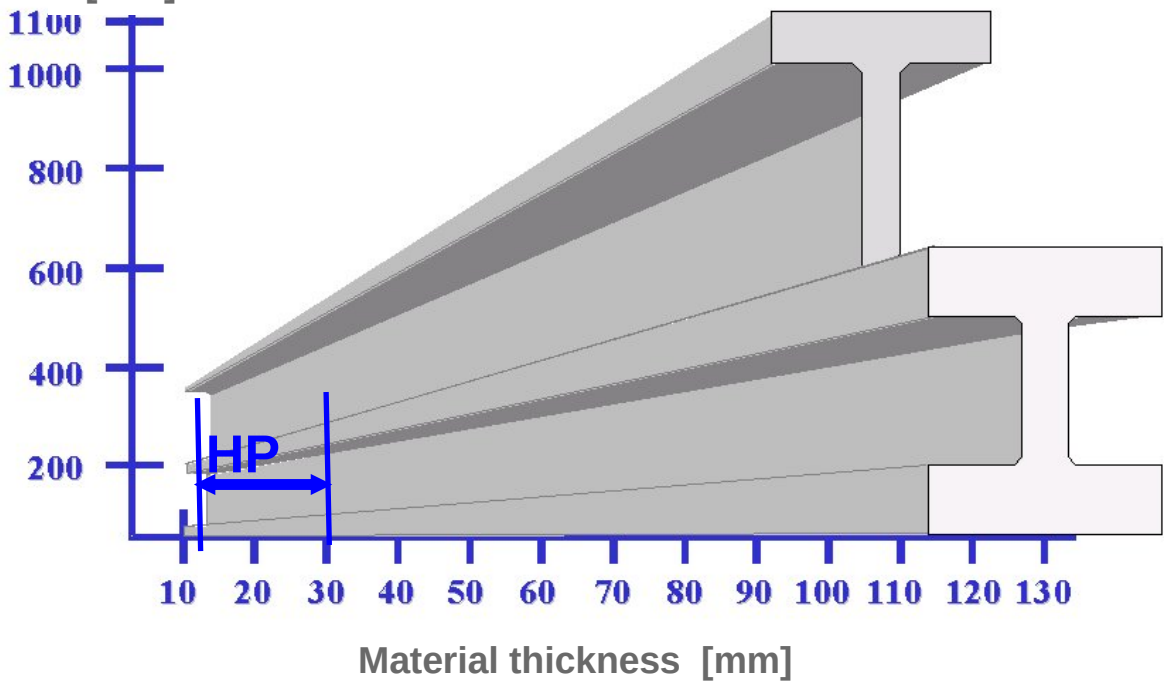
Universal rolling method



Universal stand

Edger stand

Product range Differdange mill



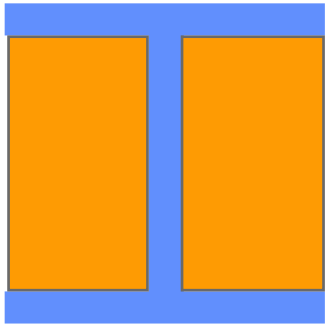
Assessment of pile capacity by design

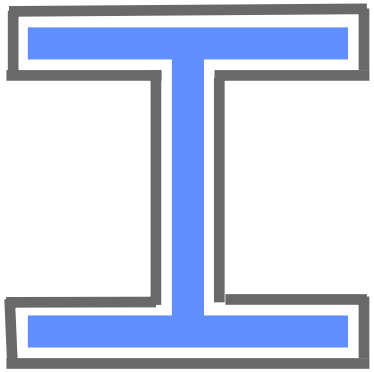
$$Q_u = Q_b + Q_s$$

Base area A_b

Perimetre A_s

Compression resistance





Friction resistance (compression or tension)

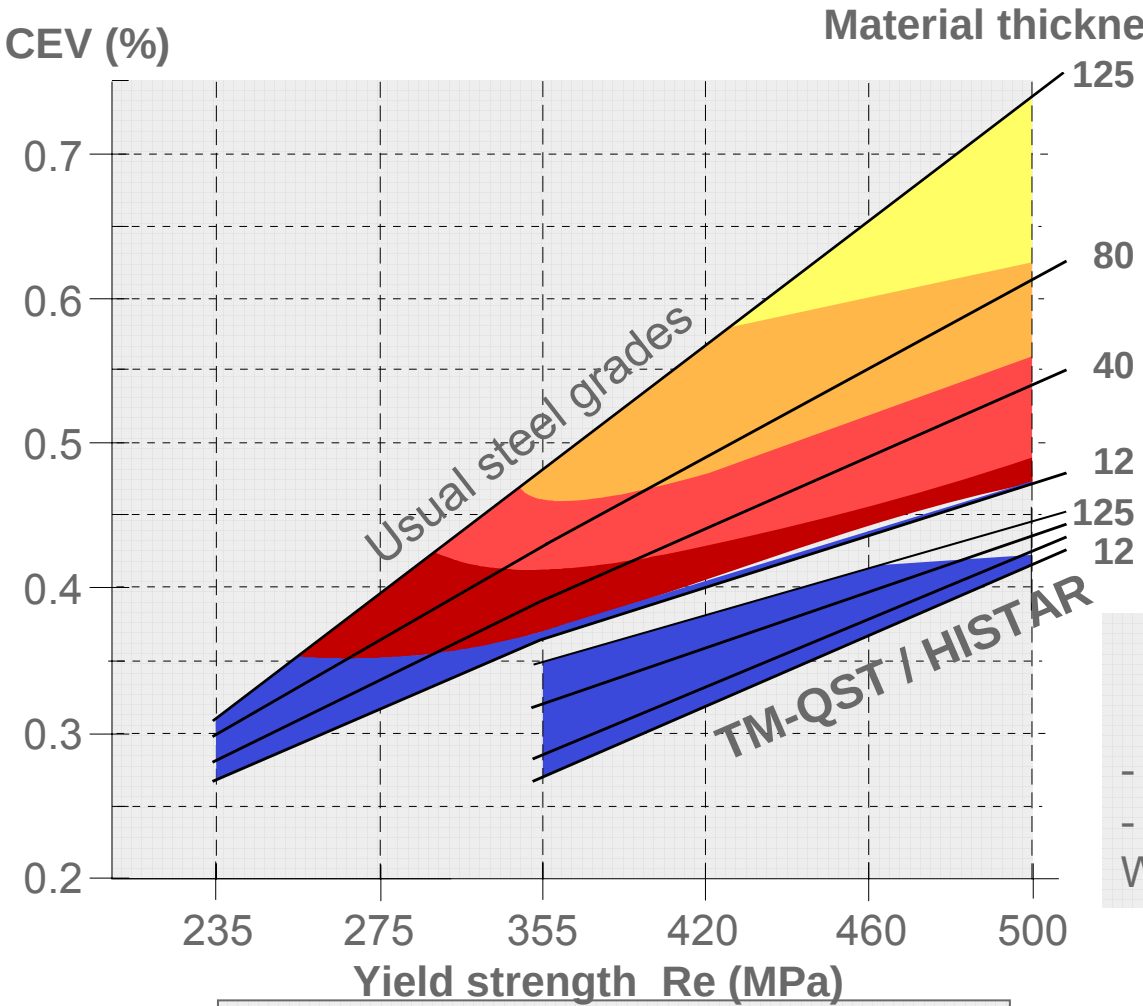
A_b =  A_s =

Soil reduction factors:

granular	ß $_b$ = 1,00	ß $_s$ = 0,67
cohesive	ß $_b$ = 1,00	ß $_s$ = 1,00

Production of HP bearing piles

Weldability and preheat temperatures (EN 1011-2)



Preheat-temperature (°C)

200
150
100
50
0

No preheating for HISTAR steels if:

- Re < 460 MPa: $H_2 \leq 10$ ml/100g
- Re ≥ 460 MPa: $H_2 \leq 5$ ml/100g

Welding energy: E ≥ 10 kJ/cm

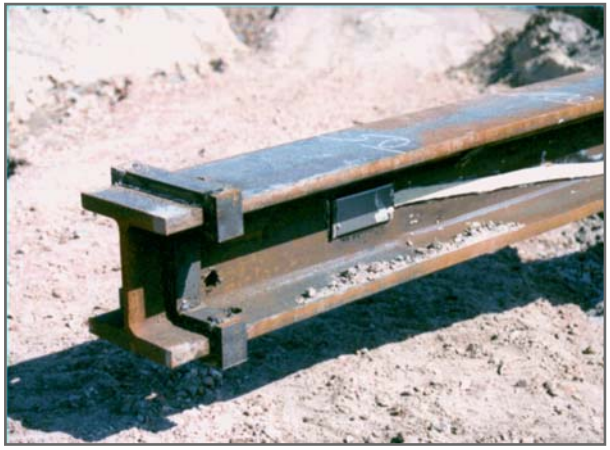
$$CE\ (\%) = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15}$$

Types of HP piles
Bare HP piles

Bare HP piles installed with a hydraulic impact hammer

Fruitkai – Ghent (B)

Types of HP piles
Injected HP piles



Toes of HP-injection piles

Types of HP piles
Enlarged HP piles

Compression piles
Maasvlakte – Rotterdam (NL)

Tension piles
Bremen (D)