Durability of Sheet Pile Structures

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Corrosion of steel. Basics

- Iron present in oxidized state on earth

- Steel making

$$\underset{\text{iron ore}}{Fe_2O_3} + \underset{\text{coke}}{C} \xrightarrow[\text{Temp.}]{\text{High}} Fe + CO_2 \uparrow$$

- Corrosion of steel (natural phenomenon)

$$Fe \xrightarrow{H_2O} \overset{\text{rust}}{Fe_2O_3}$$

Uniform corrosion

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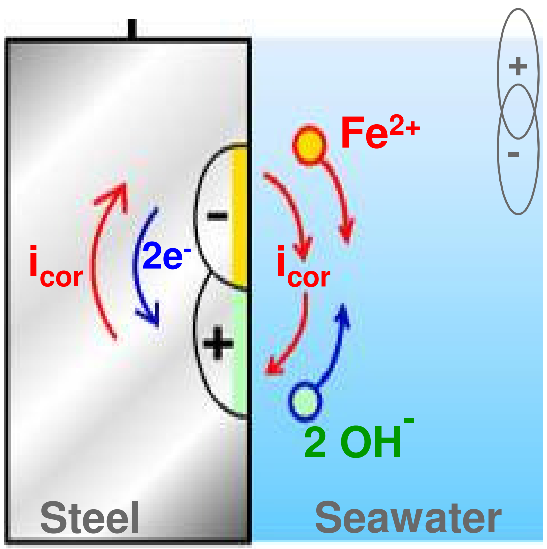
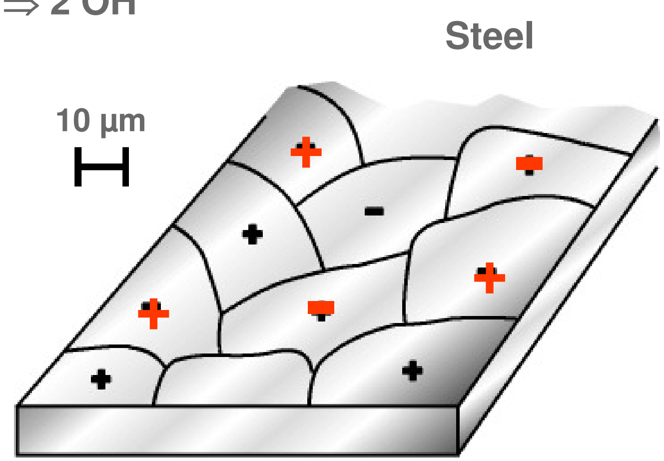
- Homogeneous thickness loss over the steel surface
- Result from random variations of anodic/cathodic area on a microscopic scale
  - steel heterogeneities (grain orientations, composition,...)
  - environmental microscopic fluctuations (dissolved oxygen, solution conductivity,....)



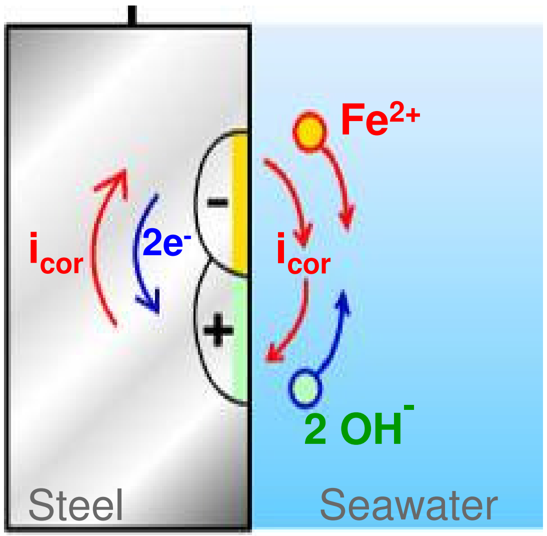
Cathodic area $2e^- + H_2O + ½\ O_2 \Rightarrow 2\ OH^-$

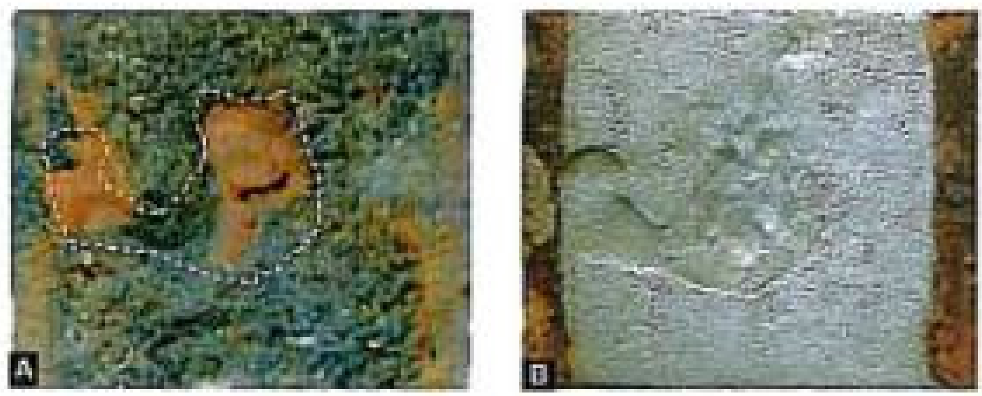
Anodic area $Fe \Rightarrow Fe^{2+} + 2e^-$



Localized corrosion of carbon steel

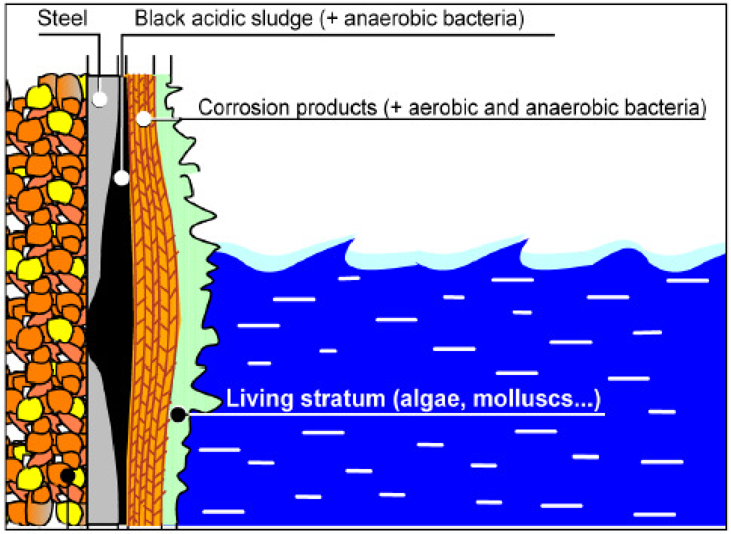
- Pitting corrosion
  - Variations of microscopic parameters, modification steel interface
  - Steel, environment,….





Accelerated Low Water Corrosion (ALWC)

- Aggressive form of corrosion
  - Associated to Microbiologically Influenced Corrosion (MIC)
  - Low Water level (LAT) in Tidal waters
  - Higher corrosion rates than normally observed in Low Water zone



=> Corrosion rates of more than 1 mm per year

Fundamentals of corrosion

- **Basic requirement:**
  - Electrolyte - i.e. conductive solution: fresh water, sea water, moisture film
  - Electrodes - i.e. metallic pieces
  - Species to be reduced: $2H^+ + 2e^- \rightarrow H_2$

    $\frac{1}{2} O_2$ (dissolved) $+ H_2O + 2e^- \rightarrow 2\ OH^-$

  Species to be oxidised: $Fe \rightarrow Fe^{2+} + 2e^-$

  $Zn \rightarrow Zn^{2+} + 2e^-$

- **Thermodynamics:**
  Corrosion possible IF $\underbrace{[E_{cathode} - E_{anode}]}_{\text{Function of pH, } O_2\text{, nature of metal, T°}} > 0$

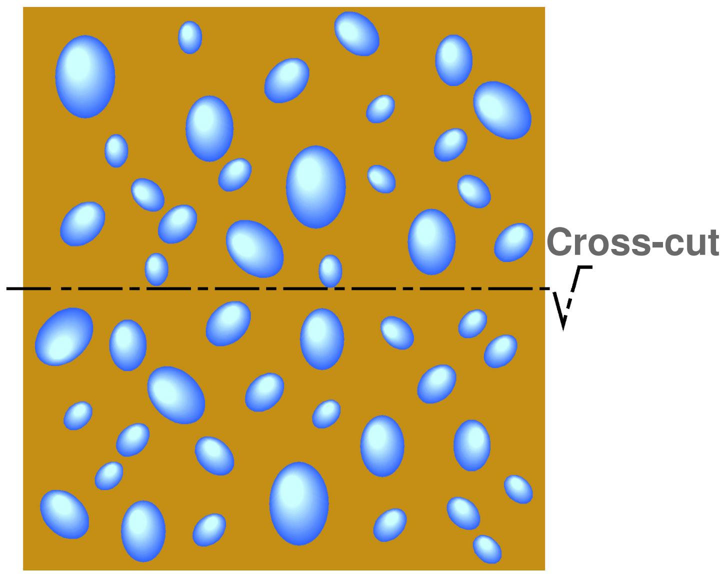
- **Kinetics:**

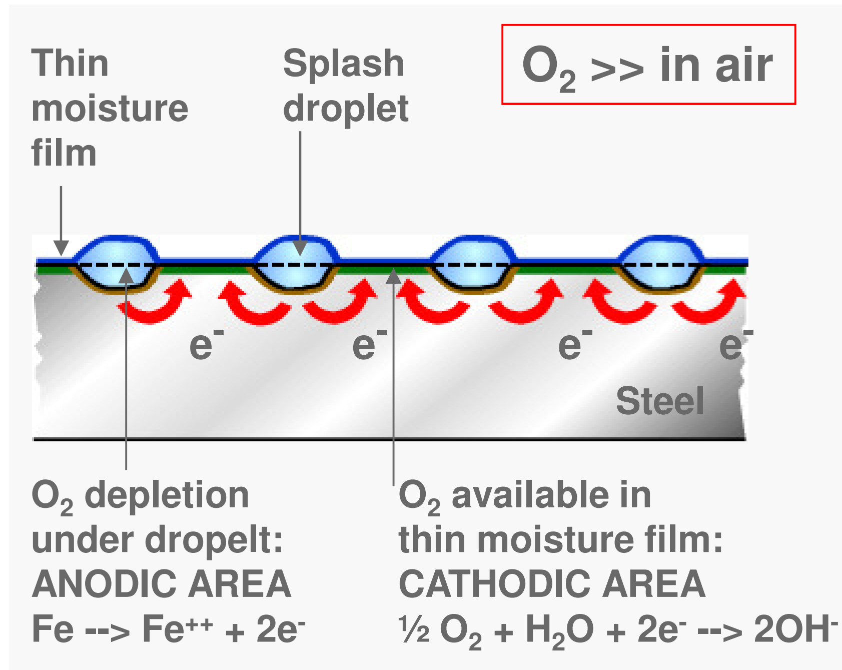
  Corrosion rate function of Electrolyte conductivity

  H^+ / O_2 availability (T° , agitation)

Uniform corrosion of steel sheet-piling in water and soils

- **Splash zone**





Differential aeration micro-cells
wet / dry cycles alternating at high rate

⇨ High attack: 0,075 mm/year on average in sea water

Uniform corrosion of steel sheet-piling in water and soils

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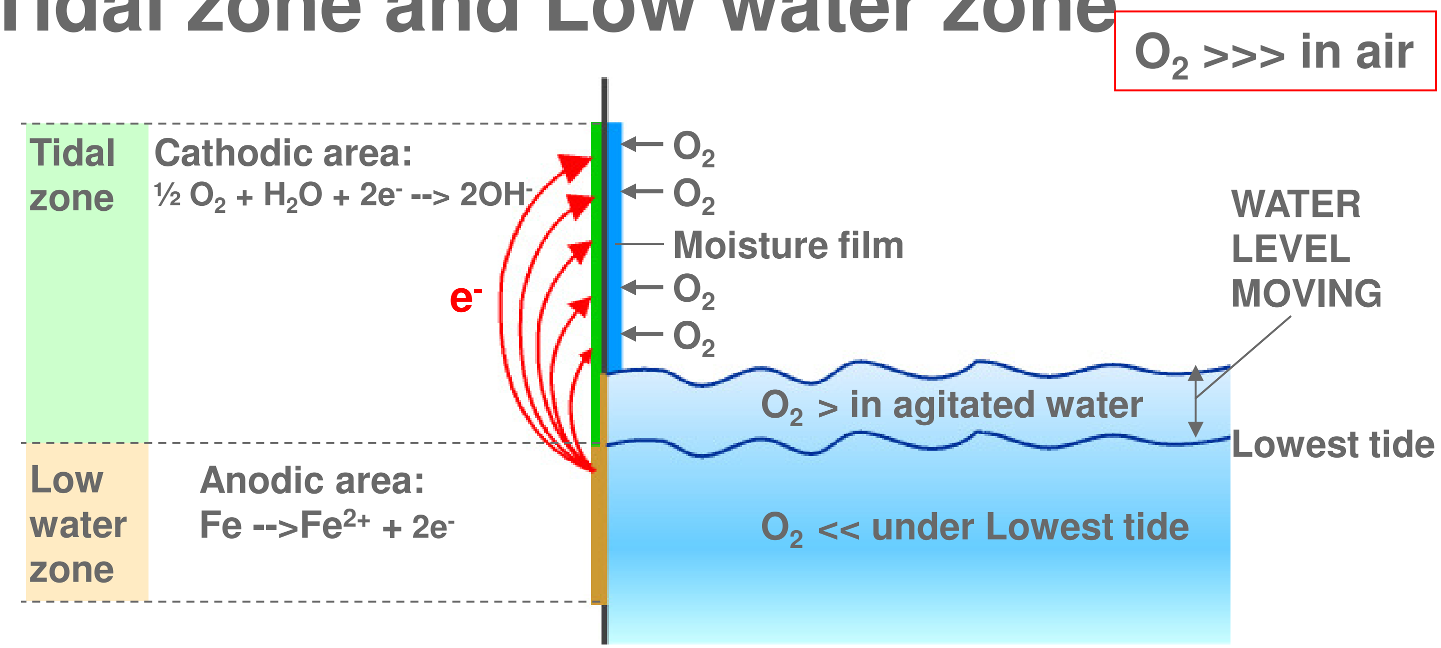
- **Tidal zone and Low water zone**



- Differential aeration macro-cells
- Surface of cathodic area >> Surface of anodic area

  Balance of charge transfer

  Example: 3 m^2 x [½ O_2 + H_2O + $2e^-$ --> $2OH^-$] <---> 1 m^2 x [Fe --> Fe^{2+} + $2e^-$] x **3**

⇨ High attack in LW zone: 0,075 mm/year on average in sea water

Low attack in tidal zone: 0,035 mm/year on average in sea water

Uniform corrosion of steel sheet-piling in water and soils

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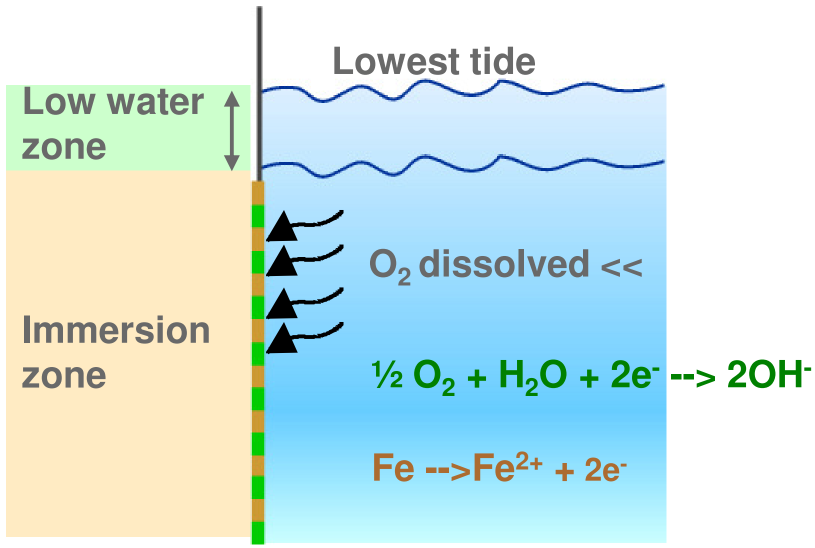
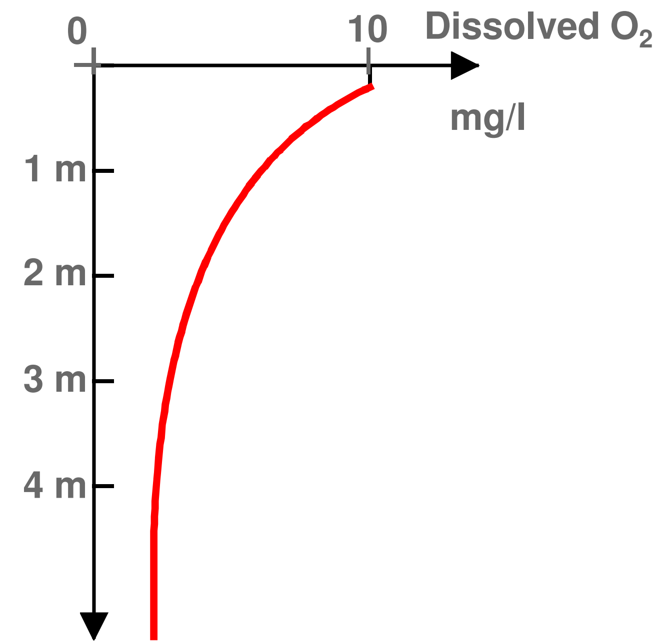
• Immersion zone

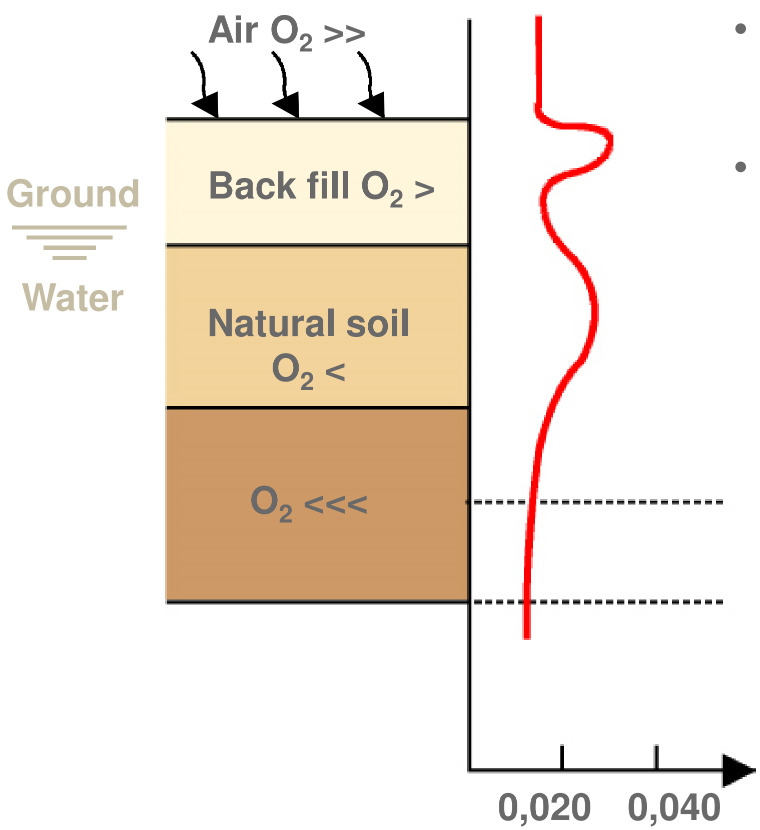




- Corrosion controlled by O_2 availability
- O_2 diffusion on large scale from surface
- O_2 diffusion close to interface through fouling, deposits and corrosion products
- Low attack: 0,035 mm/year on average in sea water

Uniform corrosion of steel sheet-piling in water and soils

• Corrosion in soils



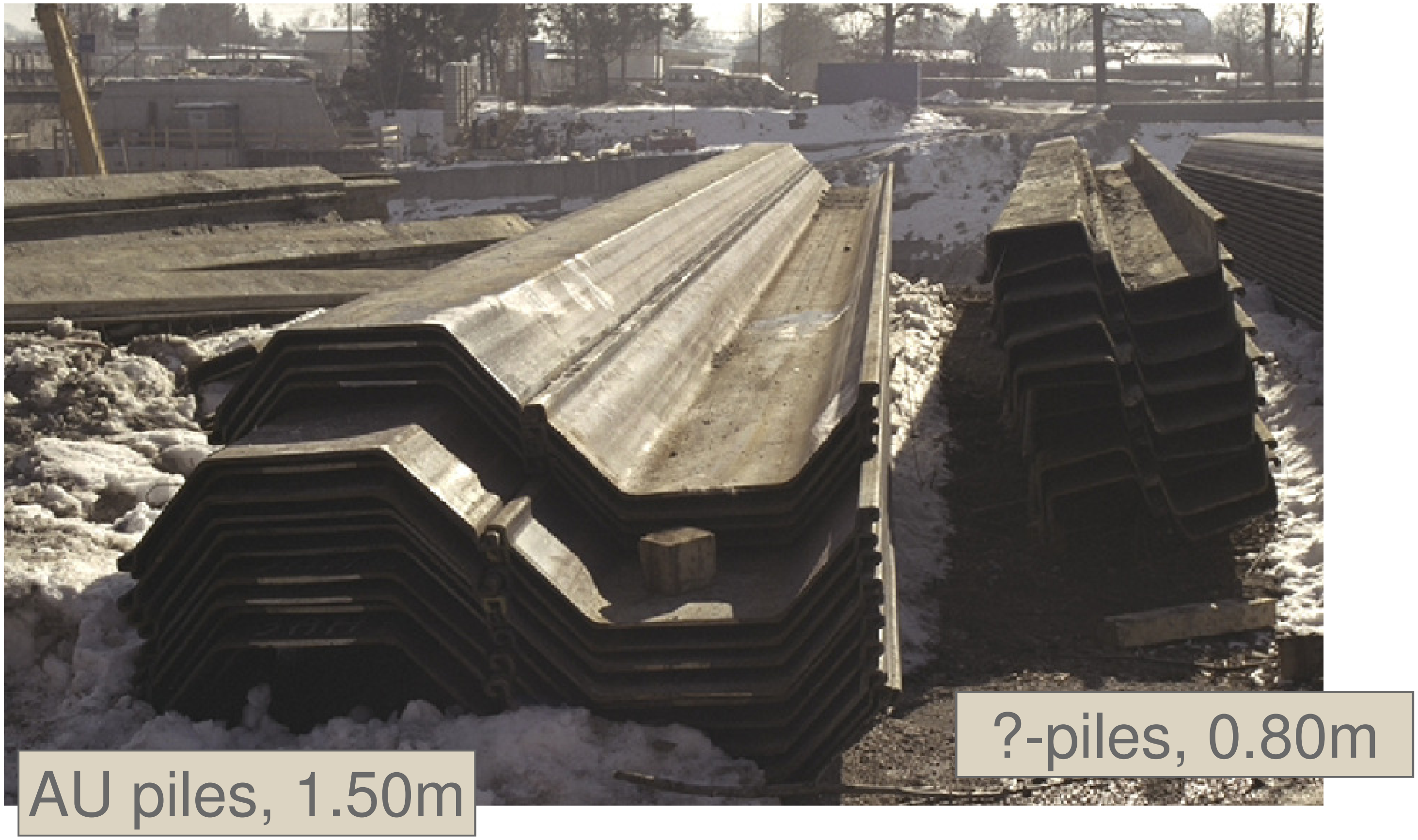
- Low uniform corrosion generally speaking: 0,010 - 0,020 mm/year on average
- Risk of localized corrosion:
  - Various soil layers with variable porosity e.g. backfilled materials
    ⇒differential aeration cell
  - Soluble salts (Cl^-, $SO4^{--}$) and ground water
    ⇒conductivity
  - Nature of soil
    ⇒pH << or pH >>

    Peat

Splash zone corrosion – Example
Guaymas Marina – Baja California - Mexico

- Severe climatic conditions (heat / high salinity / strong winds)
- AZ26, 5 years exposure without protection
- Corrosion product 15-20 thicker than actual corrosion loss
- Thickness measurements confirmed that corrosion was in normal range

Corrosion in soil - Example



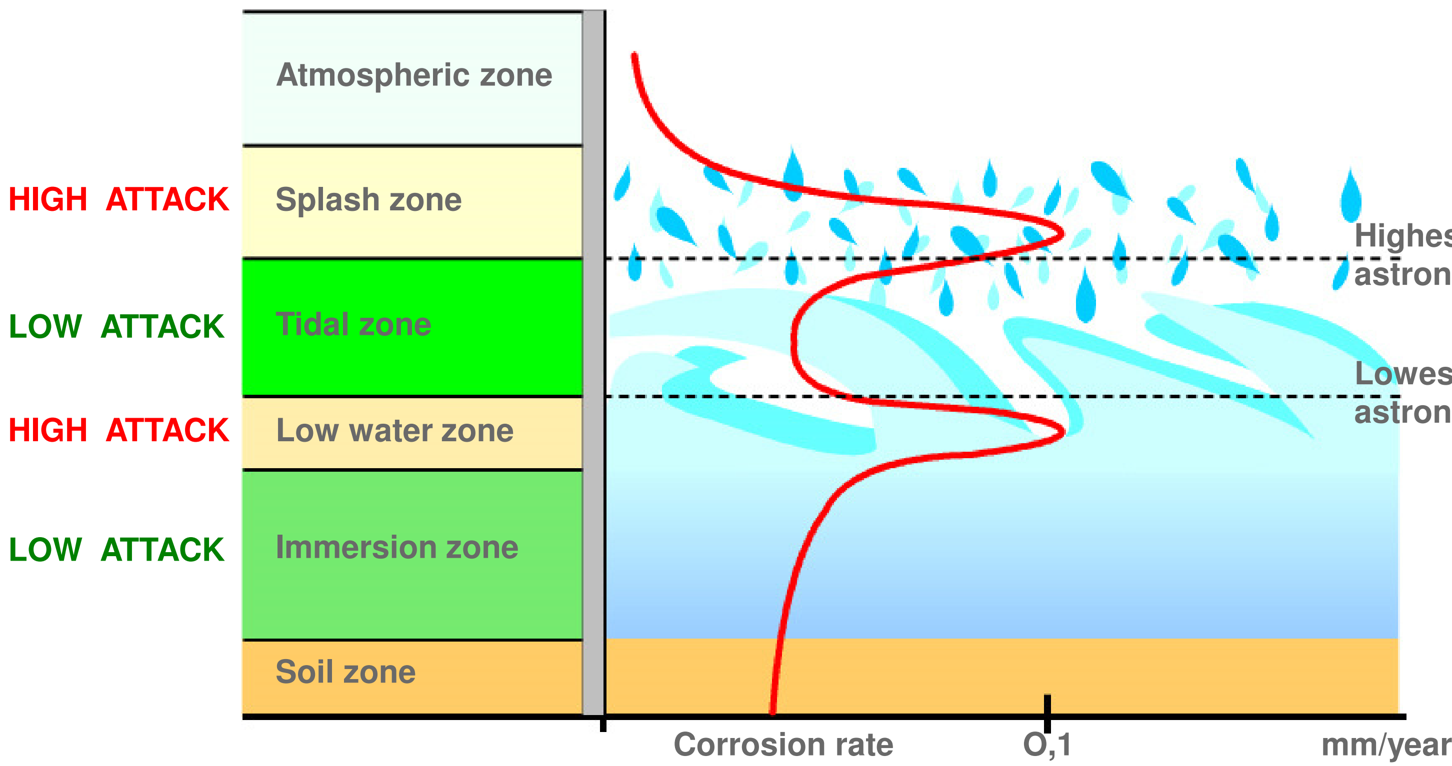
- pulled out 400 mm wide double piles after 40 years in good condition

Corrosion behaviour of the interlock

- low corrosion inside interlock

Uniform corrosion of SSP in water

- State of the art in sea water corrosion:
  Mean corrosion rate along sheet-piling wall



Durability of steel structures

- Atmospheric corrosion is very low
- Corrosion in undisturbed natural soils is very low (exception peat, …)
- Corrosion in common fresh water is low
- Corrosion in sea water is different (splash zone, low water, immersed)

Loss of thickness: Table 4.1 & 4.2, prEN 1993-5 (2007)

design life (years)	5	25	**50**	75	100
undisturbed natural soils (sand, clay, …)	0.00	0.30	**0.60**	0.90	1.20
common fresh water: waterline	0.15	0.55	**0.90**	1.15	1.40
sea water: permanent immersion & intertidal	0.25	0.90	**1.75**	2.60	3.50
sea water: **splash** & low water zone	0.55	1.90	**3.75**	5.60	7.50

(mm)

Durability of steel structures

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Solutions:

- design ssp with maximal bending moment in zone with reduced corrosion rates
- ‘sacrificial’ thickness of steel
- higher steel grade ⇒ increases safety factor on steel
- surface protection (coating ⇒ aesthetics)
- cathodic protection (zones constantly in contact with water)
- concrete capping beam down to 1.0 m below low water

Capping beam / Coating

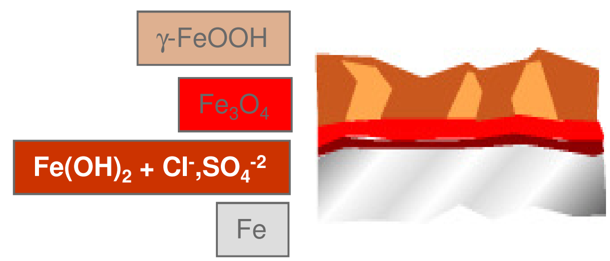
Protection of upper part of SSP quay wall including low water zone

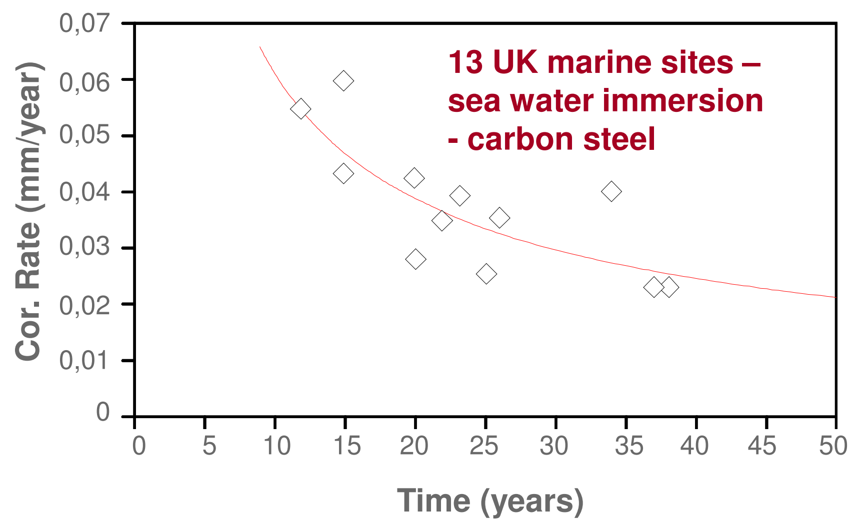
=> concrete capping beam / coating

Corrosion protection of SSP walls

- Passivation:
  - Self-protection by corrosion products
    - adhering the corrosion interface
    - forming a partial barrier to O_2 diffusion
  - Development of passivation layer leading to decrease of corrosion rate with time

Rust simplified





Corrosion resistance : A 690 Mariner Steel Grade

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Designation: A 690/A 690M – 00a

Standard Specification for High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments[1]

1. Scope

1.1 This specification covers high-strength low-alloy steel H-piles and sheet piling of structural quality for use in the construction of dock walls, sea walls, bulkheads, excavations, and like applications in marine environments.

1.2 The steel has approximately two to three times greater resistance to seawater "Splash Zone" corrosion than ordinary carbon steel (Specifications A 36/A 36M and A 328/A 328M) where exposed to the washing action of rain and the drying action of the wind or sun, or both. Where the steel is not boldly exposed, the usual provisions for the protection of ordinary carbon steel should be considered.

Designation A 690/A 690M – 05

INTERNATIONAL

Standard Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments[1]

1. Scope*

1.1 This specification covers high-strength low-alloy nickel, copper, phosphorus steel H-piles and sheet piling of structural quality for use in the construction of dock walls, sea walls, bulkheads, excavations, and like applications in marine environments.

1.2 The atmospheric corrosion resistance of this steel is substantially better than that of ordinary carbon steels with or without copper addition (see Note 1). The steel has also shown to have substantially greater resistance to seawater "Splash Zone" corrosion than ordinary carbon steel (Specifications A 36/A 36M and A 328/A 328M) where exposed to the washing action of rain and the drying action of the wind or sun, or both. Where the steel is not boldly exposed, the usual provisions for the protection of ordinary carbon steel should be considered.

Improved splash zone corrosion behaviour

Corrosion resistance : A 690 Mariner Steel Grade

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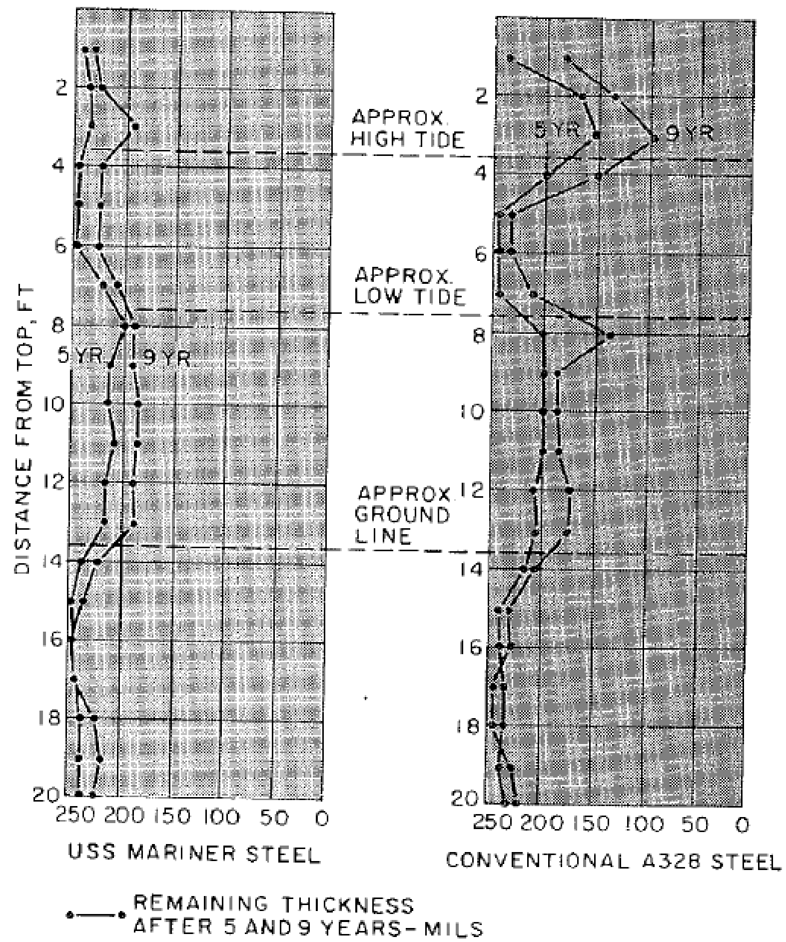


Figure 7. Comparative corrosion rates on two steels in marine environments.

TABLE 1 Chemical Requirements

Element	Composition, % Heat Analysis
Carbon, max	0.22
Manganese[A]	0.60–0.90
Phosphorus	0.08–0.15
Sulfur, max	0.04
Silicon, max	0.40
Copper, min	0.50
Nickel	0.40–0.75

[A] Manganese, for each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage points manganese above the specified maximum is permitted, up to a maximum of 1.10 %.

0,5% Cu 0,4% Ni - 0,1% P

Surface protection

- coatings (epoxy / glass flake)
- duplex systems

<u>Coatings:</u>

- blasting (shot, sand)
- primer
- 1st layer
- 2nd layer
  (before / after driving)

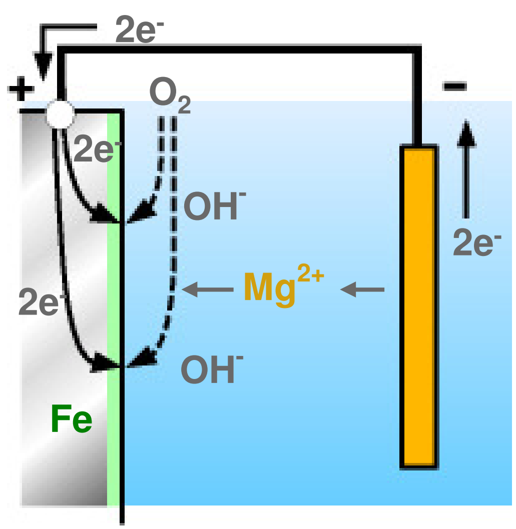
Coatings: EN ISO 12944 / BAW

- atmospheric: 240 µm
- fresh water: 380 µm
- sea water: 380 µm
- waste disposal: 480 µm

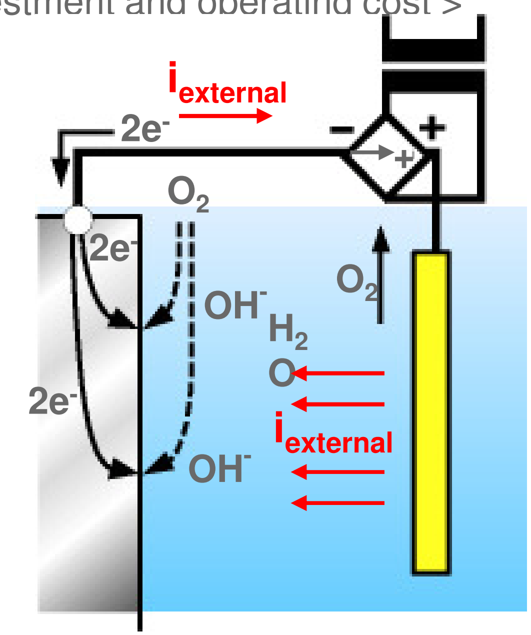
Cathodic Protection

- Basic principle : Setting steel potential in the immunity region

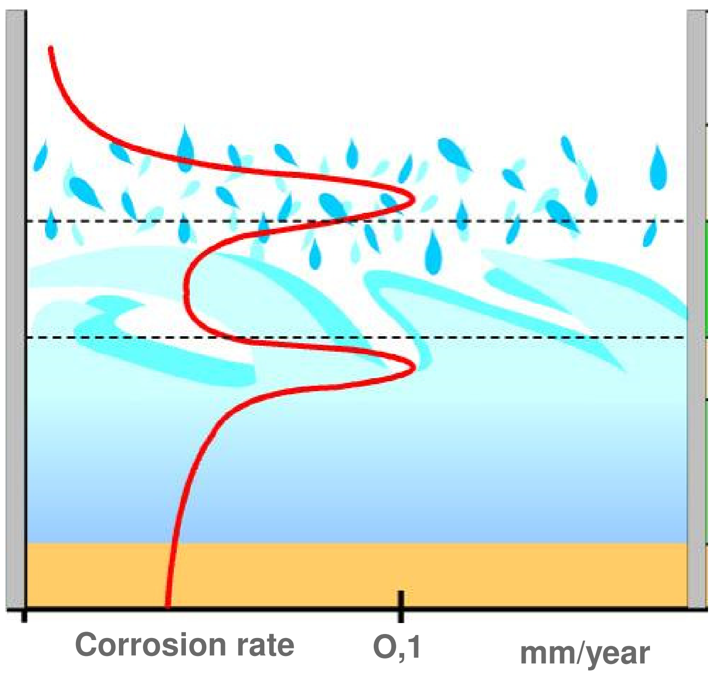
- Sacrificial anodes
  - Zn, Al, Mg anodes
  - Investment and operating costs <
  - Limited durability due to anodes consumption ---> replacement



- Impressed current
  - Graphite or high-silicon cast-iron anodes
  - Transformer/rectifier as direct current source
  - Investment and operating cost >



Corrosion Protection of SSP walls in different zones



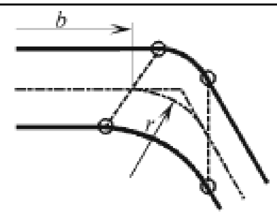
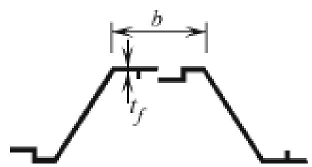
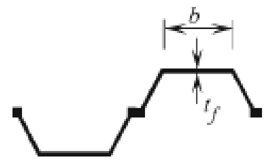
Painting
Concrete encasement
Sacrificial thickness
A690

Painting
Cathodic protection
Sacrificial thickness
AM-Locor

Steel sheet pile sections: classes acc. EC 3-5

EN 1993-5: 2007 (E)

Table 5-1: Classification of cross-sections

Classification	Z-profile	U-profile
		
Class 1	- the same boundaries as for class 2 apply - a rotation check has to be carried out	
Class 2	$\frac{b/t_f}{\varepsilon} \leq 45$	$\frac{b/t_f}{\varepsilon} \leq 37$
Class 3	$\frac{b/t_f}{\varepsilon} \leq 66$	$\frac{b/t_f}{\varepsilon} \leq 49$

$\varepsilon = \sqrt{\frac{235}{f_y}}$	f_y [N/mm²]	240	270	320	355	390	430
	ε	0,99	0,93	0,86	0,81	0,78	0,74

Key:

b: width of the flat portion of the flange, measured between the corner radii, provided that the ratio r/t_f is not greater than 5,0; otherwise a more precise approach should be used;
t_f: thickness of the flange for flanges with constant thickness;
r: midline radius of the corners between the webs and the flanges;
f_y: yield strength.

Steel sheet pile sections: classes acc. EC 3-5

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(2) The design moment resistance of the cross-section $M_{c,Rd}$ should be determined from the following:

- Class 1 or 2 cross-sections: $M_{c,Rd} = \beta_B W_{pl} f_y / \gamma_{M0}$ (5.2)

- Class 3 cross-sections: $M_{c,Rd} = \beta_B W_{el} f_y / \gamma_{M0}$ (5.3)

W_{el} is the elastic section modulus determined for a continuous wall;

W_{pl} is the plastic section modulus determined for a continuous wall;

γ_{M0} partial safety factor according to 5.1.1 (4);

β_B is a factor that takes account of a possible lack of shear force transmission in the interlocks and has the following values:

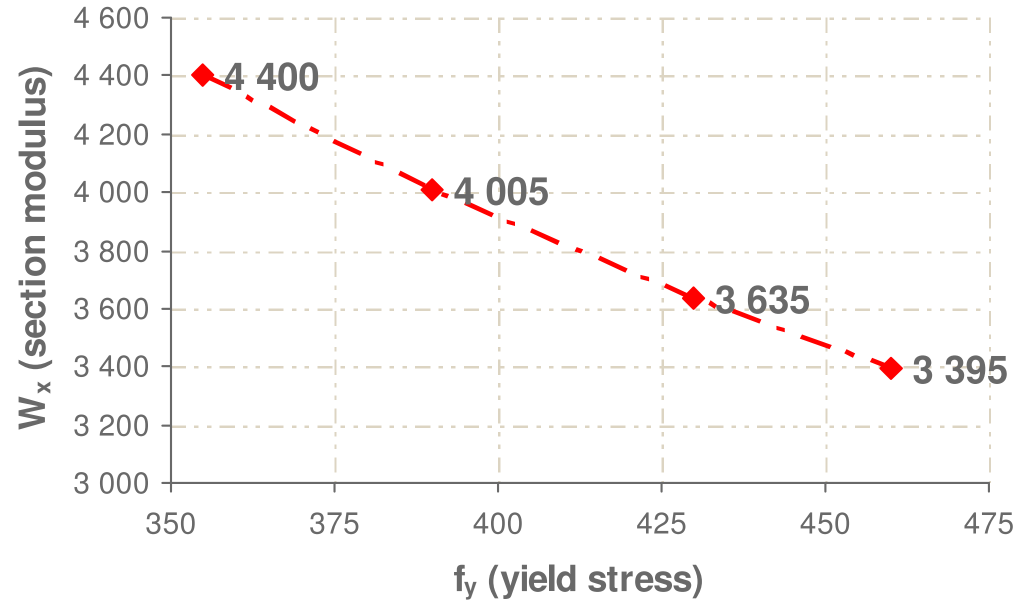
$\beta_B = 1,0$ for Z-piles and triple U-piles

$\beta_B \leq 1,0$ for single and double U-piles.

Optimized solutions in high yield steel grade

Advantages of steel grades with high yield strengths S 430 GP or S 460 AP

- Economical solution for high bending moments
- weight reductions of 20-30% can be achieved
- S 460 AP in next version of EN 10248 (S460GP)
- Advantageous for impact driving in hard ground (higher driving stresses possible without plastic deformation)
- Check drivability of thinner section
- Check section classification after corrosion



W_x (cm³/m)	f_y (MPa = N/mm²)	BMC (kNm/m)
4 400	355	1 562
4 005	390	1 562
3 635	430	1 563
3 395	460	1 562

Steel sheet pile sections: classes acc. EC 3-5

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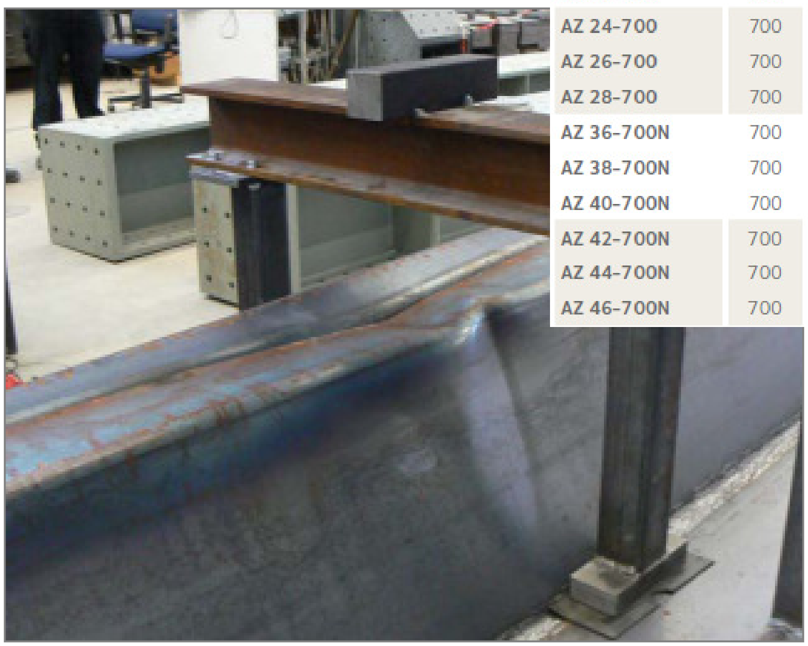
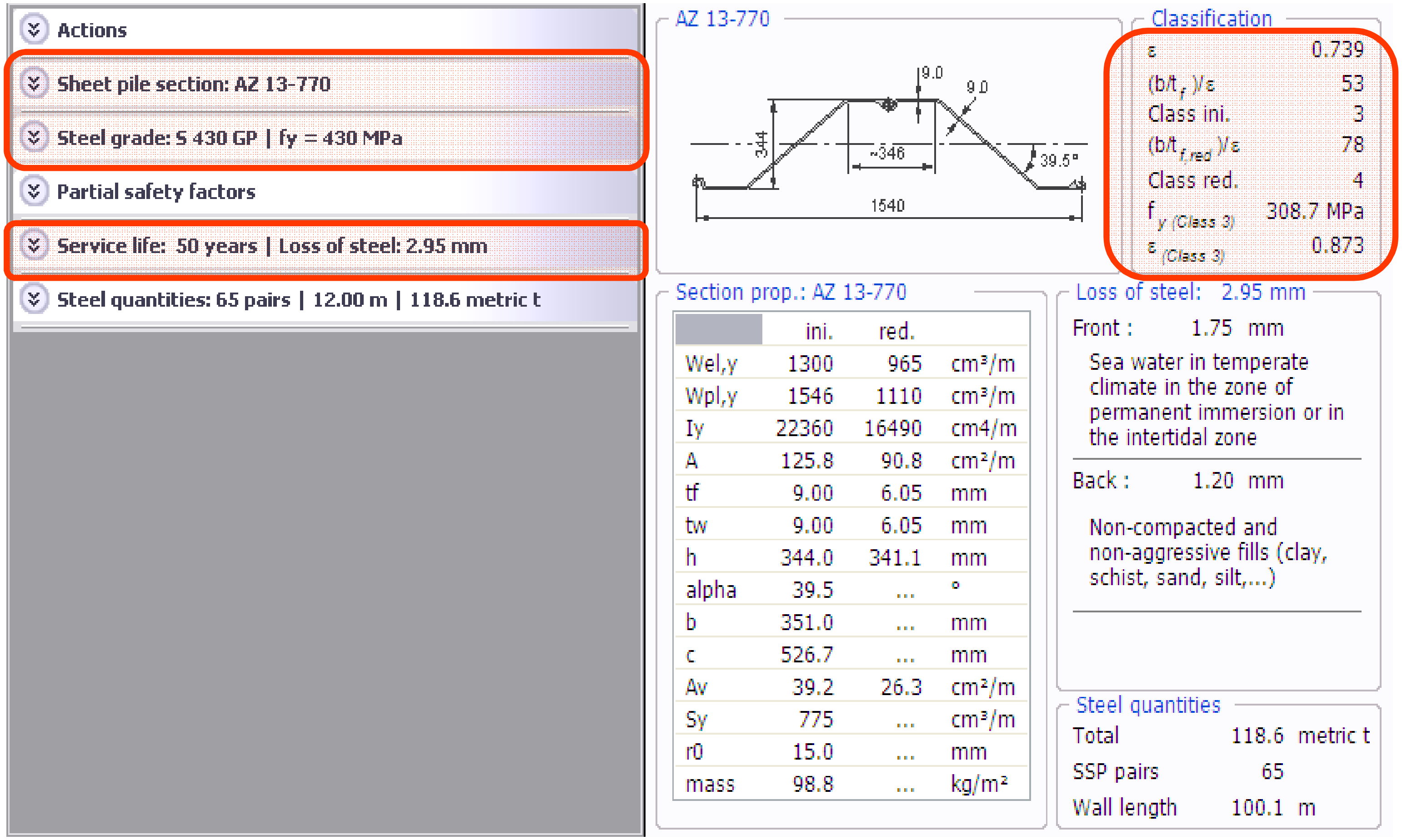
Section	Width b mm	Height h mm	Thickness t mm	Thickness s mm	Sectional area cm²/m	Mass single pile kg/m	Mass wall kg/m²	Moment of inertia cm⁴/m	Elastic section modulus cm³/m	Static moment cm³/m	Plastic section modulus cm³/m	Class[1) S 240 GP	S 270 GP	S 320 GP	S 355 GP	S 390 GP	S 430 GP	S 460 AP
AZ-700 and AZ-770																		
AZ 12-770	770	344	8.5	8.5	120	72.6	94	21430	1245	740	1480	2	2	3	3	3	3	3
AZ 13-770	770	344	9.0	9.0	126	76.1	99	22360	1300	775	1546	2	2	3	3	3	3	3
AZ 14-770	770	345	9.5	9.5	132	79.5	103	23300	1355	805	1611	2	2	2	2	3	3	3
AZ 14-770-10/10	770	345	10.0	10.0	137	82.9	108	24240	1405	840	1677	2	2	2	2	2	3	3
AZ 17-700	700	420	8.5	8.5	133	73.1	104	36230	1730	1015	2027	2	2	3	3	3	3	3
AZ 18-700	700	420	9.0	9.0	139	76.5	109	37800	1800	1060	2116	2	2	3	3	3	3	3
AZ 19-700	700	421	9.5	9.5	146	80.0	114	39380	1870	1105	2206	2	2	2	3	3	3	3
AZ 20-700	700	421	10.0	10.0	152	83.5	119	40960	1945	1150	2296	2	2	2	2	2	3	3
AZ 24-700	700	459	11.2	11.2	174	95.7	137	55820	2430	1435	2867	2	2	2	2	2	2	3
AZ 26-700	700	460	12.2	12.2	187	102.9	147	59720	2600	1535	3070	2	2	2	2	2	2	2
AZ 28-700	700	461	13.2	13.2	200	110.0	157	63620	2760	1635	3273	2	2	2	2	2	2	2
AZ 36-700N	700	499	15.0	11.2	216	118.6	169	89610	3590	2055	4110	2	2	2	2	2	2	2
AZ 38-700N	700	500	16.0	12.2	230	126.4	181	94840	3795	2180	4360	2	2	2	2	2	2	2
AZ 40-700N	700	501	17.0	13.2	244	134.2	192	100080	3995	2305	4605	2	2	2	2	2	2	2
AZ 42-700N	700	499	18.0	14.0	259	142.1	203	104930	4205	2425	4855	2	2	2	2	2	2	2
AZ 44-700N	700	500	19.0	15.0	273	149.9	214	110150	4405	2550	5105	2	2	2	2	2	2	2
AZ 46-700N	700	501	20.0	16.0	287	157.7	225	115370	4605	2675	5350	2	2	2	2	2	2	2



Local buckling (class 4)

- width **b**
- thickness flange $\mathbf{t_f}$
- yield stress $\mathbf{f_y}$

Software tool “DURABILITY EC 3-5”

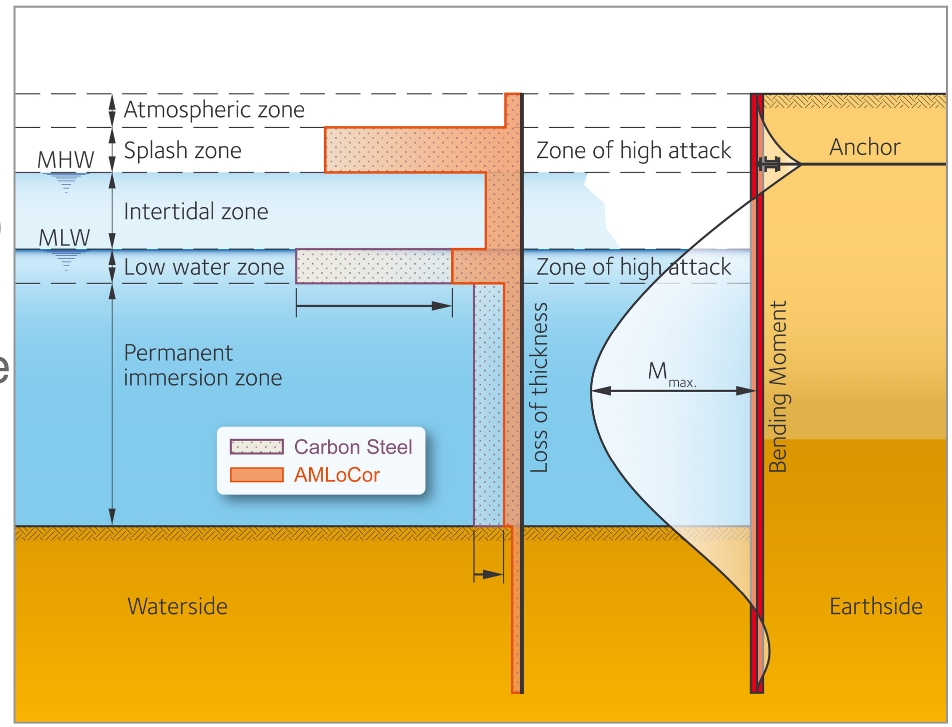


- Section classification changes after corrosion loss (reduction of flange thickness)
- In case of class 4 section, the “design yield stress” can be reduced accordingly to fulfill criteria of a class 3 section
- DURABILITY EC3-5 software tool for structural verification (beta-version available)

AMLoCor

Arcelor**M**ittal **Lo**w **Cor**rosion Steel Grade

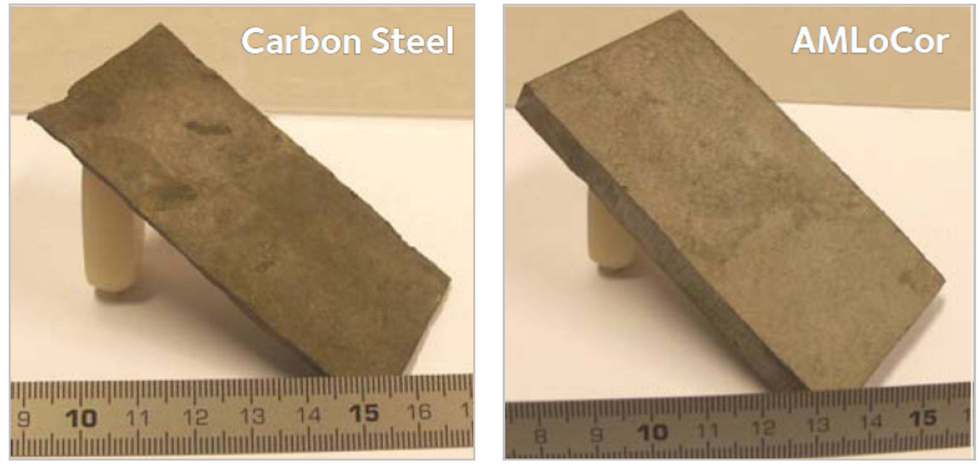
- **the solution to corrosion issues in the Low Water Zone & Permanent Immersion Zone (seawater)**
- exceptional performance based on 20 years of development & testing
- for all types of SSP-structures that are exposed to sea water
- alternative to cathodic protection systems (more cost efficient and environmentally friendly)
- Micro Alloyed Steel with increased Chrome and Aluminium content

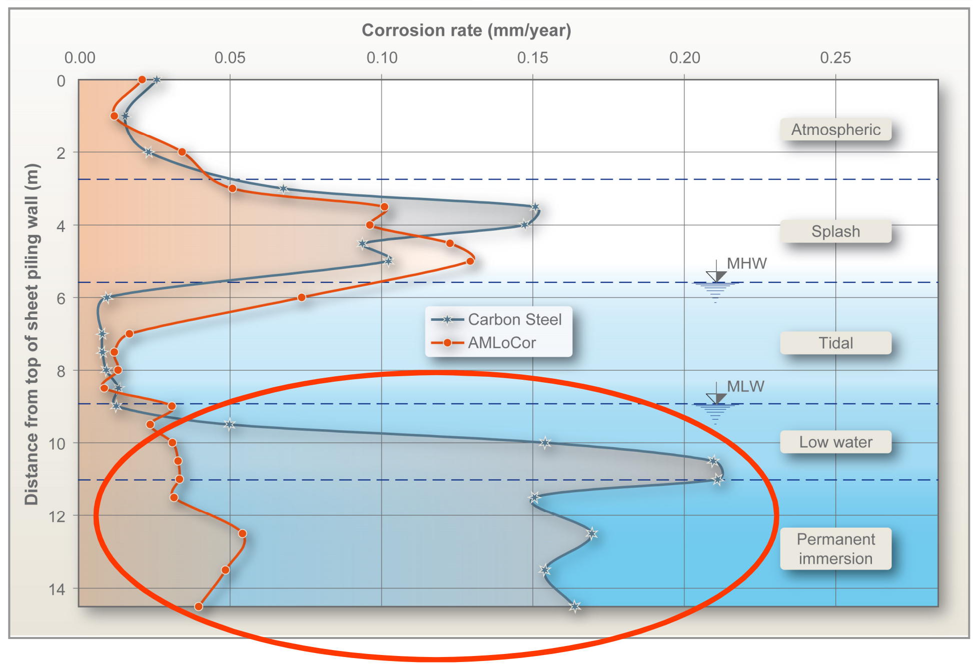


New steel grade: AMLoCor®

Higher corrosion resistance
(special chemical composition)

CIR (corrosion impediment ratio)	
Low Water Zone	Permanent Immersion Zone
5	**3**

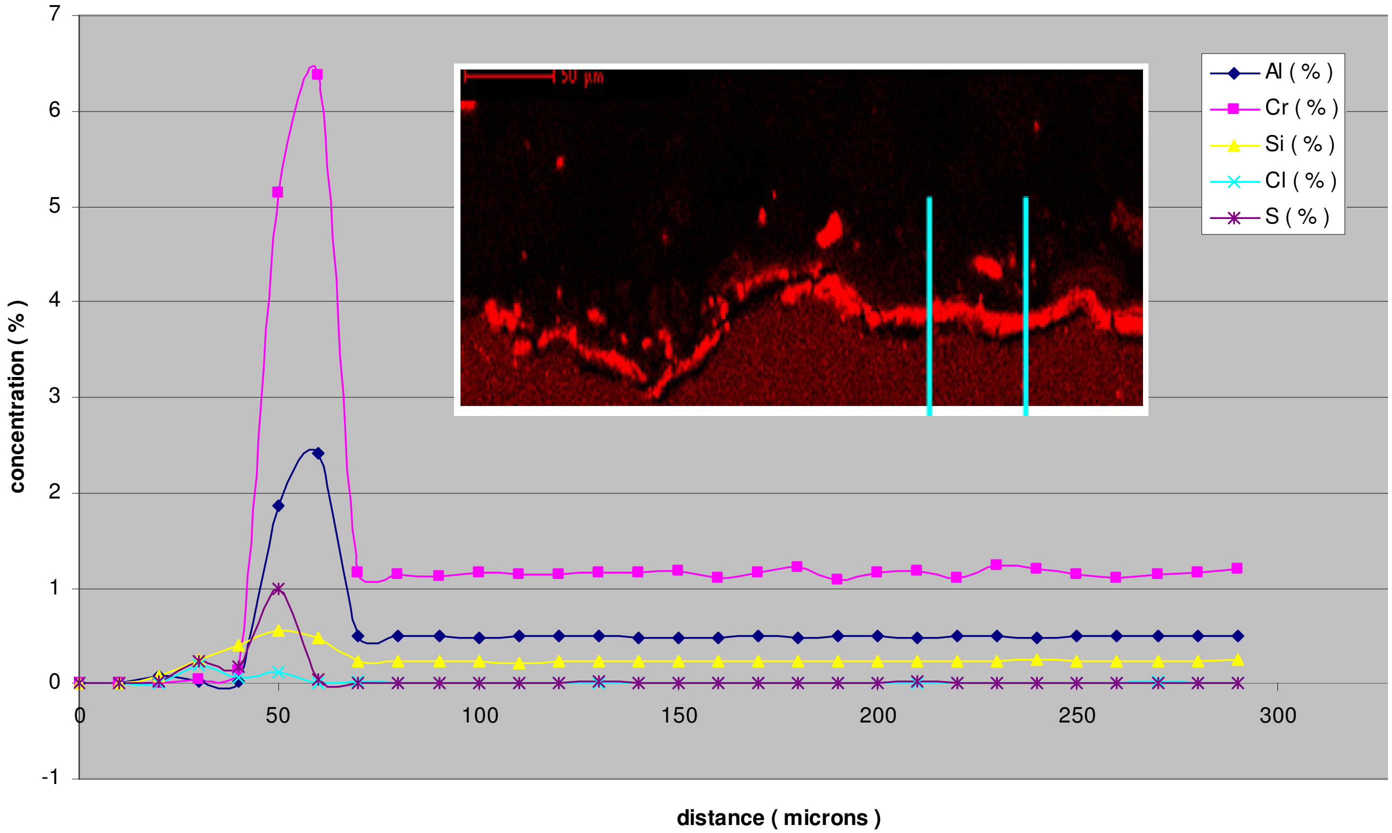




Measured corrosion rates in a port in UK (over 15 years)
U-channel

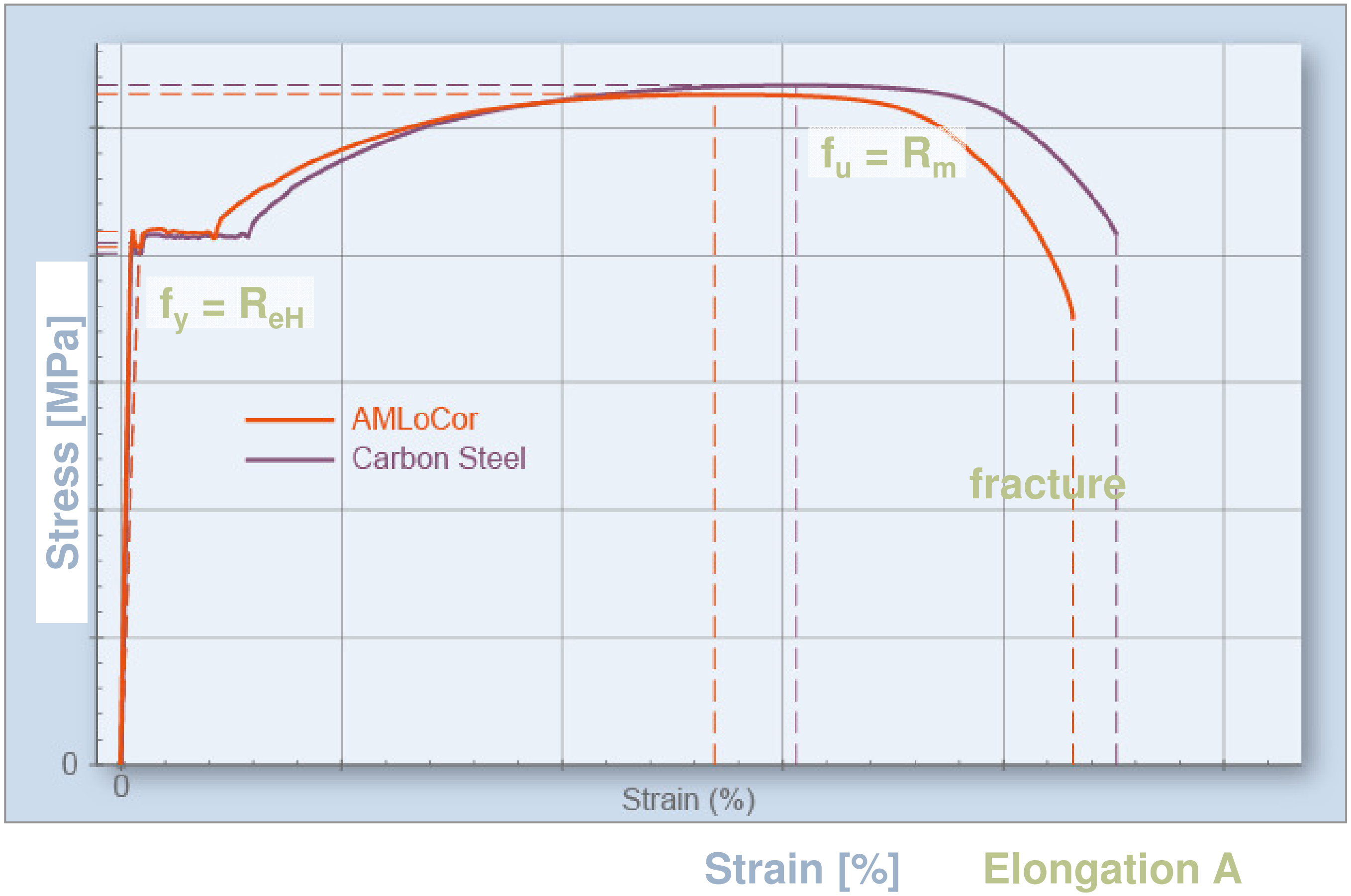
AM LoCor – How does it works

ESMA microscopic analysis of a sample



Concentration of alloying elements Cr and Al at the surface ➔ modified corrosion products from a protective layer

Fit-for-purpose for piling



Not in accordance with EN10248, but has a comparable behaviour and the well established design ruled for SSP can be applied (EAU, Eurocode, ...)

ETA European Technical Agreement in progress

Chemical composition

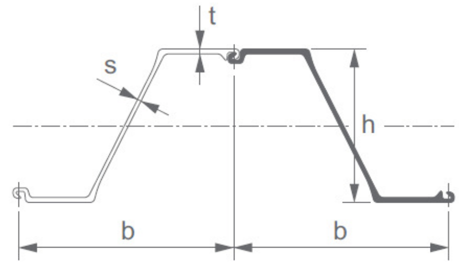
Steel grades of sheet pile sections

Steel grade EN 10248	Min. yield strength R_{eH} MPa	Min. tensile strength R_m MPa	Min. elongation $L_o=5.65\sqrt{S_o}$ %	Chemical composition (% max) C	Mn	Si	P	S	N
S 240 GP	240	340	26	0.25	–	–	0.055	0.055	0.011
S 270 GP	270	410	24	0.27	–	–	0.055	0.055	0.011
S 320 GP	320	440	23	0.27	1.70	0.60	0.055	0.055	0.011
S 355 GP	355	480	22	0.27	1.70	0.60	0.055	0.055	0.011
S 390 GP	390	490	20	0.27	1.70	0.60	0.050	0.050	0.011
S 430 GP	430	510	19	0.27	1.70	0.60	0.050	0.050	0.011
ArcelorMittal mill specification									
S 460 AP	460	550	17	0.27	1.70	0.60	0.050	0.050	0.011

AMLoCor	Min. yield strength R_{eH} MPa	Min. tensile strength R_m MPa	Min. elongation $L_o=5.65\sqrt{S_o}$ %	Chemical composition (% max) C	Mn	Si	P	S	N	Cr	Al
Blue 320	320	440	23	0.27	1.70	0.60	0.05	0.05	0.011	1.50	0.65
Blue 355	355	480	22	0.27	1.70	0.60	0.05	0.05	0.011	1.50	0.65
Blue 390	390	490	20	0.27	1.70	0.60	0.05	0.05	0.011	1.50	0.65

- Target was to have similar chemical composition and mechanical properties as a carbon steel according to EN10248
- Main difference is addition of Chrome and Aluminium
- Currently AZ-sections having a yield point up to 390 N/mm2 available
- Further increase of the range and yield strength in the future

Available range of products – to be extended

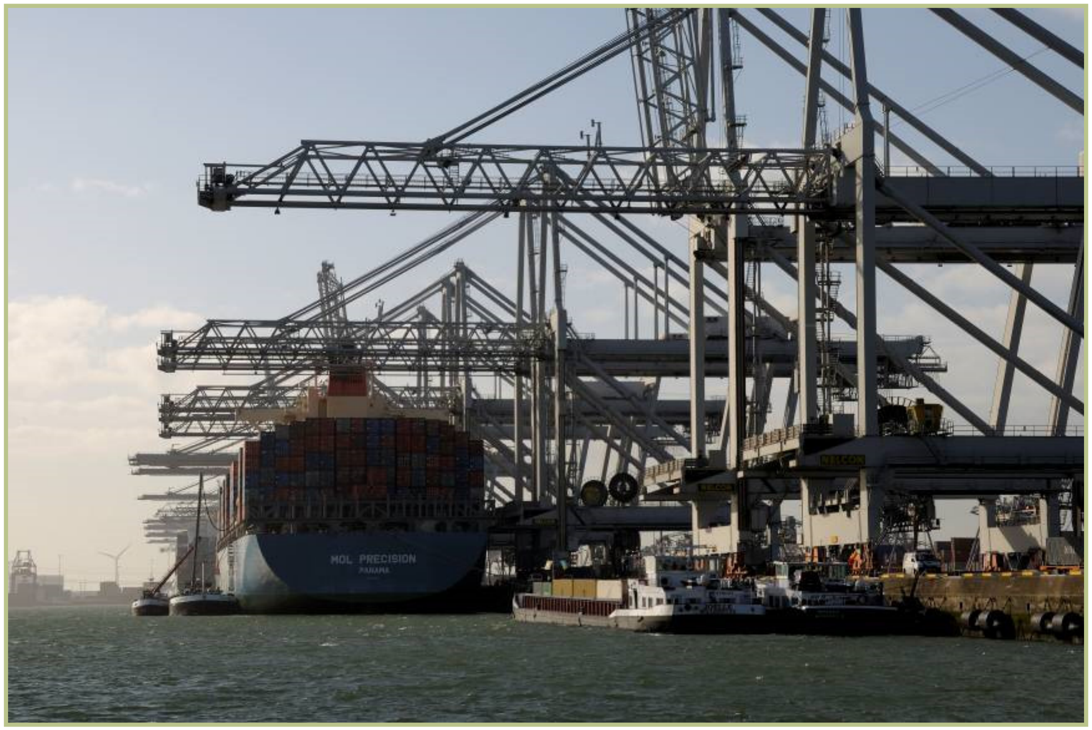


Section	b (mm)	h (mm)	t (mm)	s (mm)	G (kg/m²)	$W_{y,el}$ (cm³/m)	Blue 320	Blue 355	Blue 390
AZ 19-700	700	421	9.5	9.5	**114**	**1 870**	✓	✓	✓
AZ 20-700	700	421	10.0	10.0	**119**	**1 945**	✓	✓	✓
AZ 26-700	700	460	12.2	12.2	**147**	**2 600**	✓	✓	✓
AZ 28-700	700	461	13.2	13.2	**157**	**2 760**	✓	✓	×
AZ 26-700N	700	460	13.5	10.0	**138**	**2 600**	✓	✓	✓
AZ 28-700N	700	461	14.5	11.0	**149**	**2 765**	✓	✓	×
AZ 38-700N	700	500	16.0	12.2	**181**	**3 795**	✓	×	×
AZ 40-700N	700	501	17.0	13.2	**192**	**3 995**	✓	×	×
AZ 44-700N	700	500	19.0	15.0	**214**	**4 405**	✓	×	×
AZ 46-700N	700	501	20.0	16.0	**225**	**4 605**	✓	×	×
AZ 26	630	427	13.0	12.2	**155**	**2 600**	✓	✓	✓

b width
h height
b width
h height
G mass per m of wall
$W_{y,el}$ elastic section modulus
✓ available
× currently unavailable

Please check our website for latest updates.
Combi-walls will be offered in the future.

AMLocor long time survey in harbour environments



- Comparison between Carbon steel and AMLocor
- ongoing tests on plates and individual sheet piles

Survey in fresh water sites with known corrosion issues

- Exposure of AMLoCor coupons in fresh waters
  - For inland waterways
  - In case of suspected highest corrosion rates than normally

Coupons exposure testing with Voies Navigables de France

Driving test. Copenhagen, DK, 2010

- location: Marmormolen, Copenhagen.
- 6 double piles AZ 26-700, 14.0 m long
- 3 AMLoCor Blue355, 3 S355GP
- 2 of each steel grade driven with impact hammer (UddComb H6H), one with vibratory hammer (PVE2520)
- driving through marine deposit, coarse gravel into limestone with cobbles / boulders
- PDA measurements (dynamic stresses during driving) and CAPWAP (estimation of bearing capacity) by independent Danish company

Results:

- Both steel grades show an excellent ductile behaviour.
- Similar behaviour. No major damages to the sheet piles.

Weldability

- Carbon Equivalent Value (CEV), similar to carbon steel

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

- welding
  - tubes (SAW)
  - C9 (MAG)
  - sheet piles (MAG & SAW)

- qualification of welding processes
- qualification of welders

(Note: steel not standardized)

⇨ No 'incidental' welding on job site

Weldability – WPS for AM-Locor

ArcelorMittal

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Welding Procedure Specification

WPS-01/2012	Revision 0	Date	By
	Authorised by	Date	20/03/13

Company Name :	To whom it may concern	Project:	
Welding Process(es) :	135- MAG		
Supporting PQR No.(s) :	/		
JOINT DESIGN USED		POSITION	
Type : Single	X; Double weld	Position of Groove	
Backing: Yes	No X	Vertical progression	Up; Down
Backing Material :	None	ELECTRICAL CHARACTERISTICS	
Root Opening: Min 45°	Root Face Dimension: See page 2	Transfer mode (GMAW)	
Groove Angle: see page 2	Radius not applicable	Current	AC; DC+; DCEP; DCEN; Pulsed
Back Gouging: No		Other	
BASE METALS		Tungsten Electrode (GTAW)	not applicable
Material Spec.	AZ26-700 double piles	Size	/
Type or Grade	AMLoCor Blue S320	Type	/
Thickness 12,2mm	Groove X; Fillet	TECHNIQUE	
		Stringer or Weave Bead	Stringer Bead
Diameter (Pipe)		Multi-pass or Single pass (per side)	Multi-pass
FILLER METALS	UNION NiMoCr	Number of electrodes	
EN Classification/ Specification	EN ISO 16834A- G696M Mn4Ni1.5CRMo		
AWS Classification/ Specification	AWS A.5.28-05:ER100S-G	Electrode Spacing	Longitudinal
			Lateral
SHIELDING			Angle
Flux	Gas: 82% Ar / 18% CO2; Type M21	Contact Tube to Work Distance	
Electrode-Flux (Class)	Flow Rate	Peening	
	Gas Cup Size	Interpass Cleaning	Wire brushing
PREHEAT		POSTWELD HEATTREATMENT	
Preheat Temp. Min.	- (if air temp. < 5°C, preheat temp. min. 80 °C)	Temp.	/
Interpass Temp., Min.:	- ; Max.: 200°C	Time	/

WELDING PROCEDURE

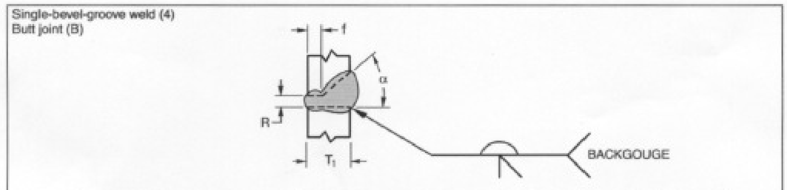
Pass or Layer	Process	Filler Metals		Courant (A)		Voltage (V)	Travel Speed	Joint Details
		Class	Diam.	Type & Polarity	Amps or Wire Feed Speed			
1 to 7	135		1.2	DC+	330± 10%	28± 10%	9.6m/min	Joint preparation see **AWS D1-1** in page 2

ArcelorMittal

Welding Procedure Specification

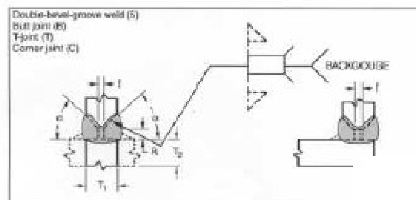
WPS-01/2009	Revision 0	Date	By
	Authorised by C. Wenger	Date	20/03/13

AWS D1.1



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T1	T2	Groove Preparation: Root Opening Root Face Groove Angle	Tolerances: As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U4b	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, −0 +1/16, −0 +10°, −0°	+1/16, −1/8 Not limited 10°, −5°	All	—	3, 4, 5, 10
GMAW FCAW	B-U4b-GF	U	—				All	Not required	1, 3, 4, 10
SAW	B-U4b-S	U	U	R = 0 f = 1/4 max α = 60°	±0 +0, −1/8 +10°, −0°	+1/4, −0 ±1/16 10°, −5°	F	—	3, 4, 10

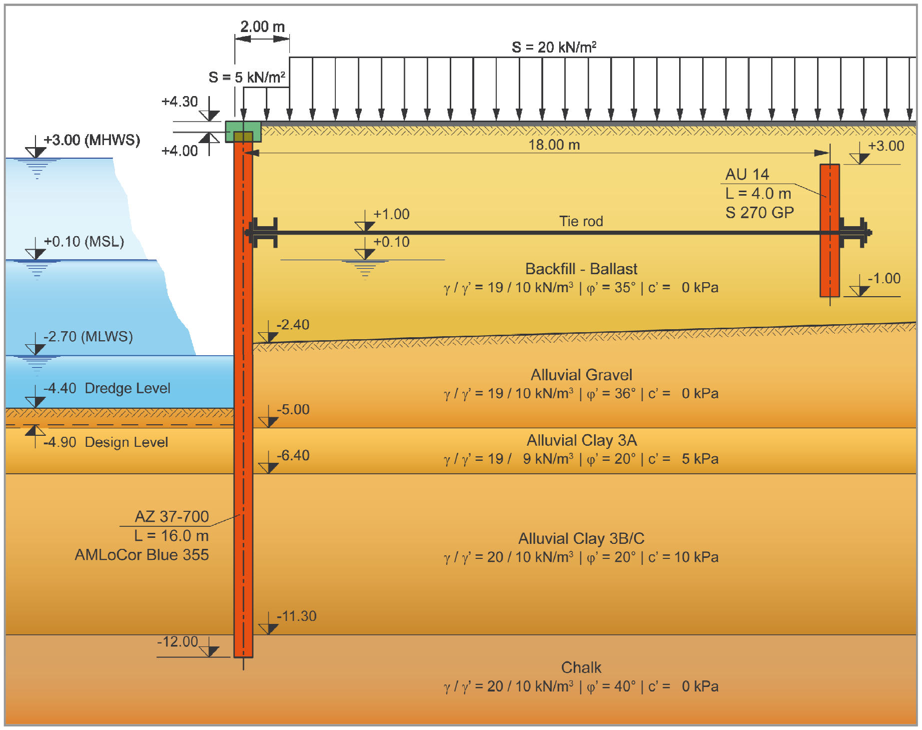
Alternatively type B-U5



	Tolerances: As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
	R = ±0	+1/4, −0
	f = +1/16, −0	±1/16
	α = +10°, −0°	+10°, −5°
Spacer	+1/16, −0	+1/8, −0

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T1	T2	Groove Preparation: Root Opening	Root Face	Groove Angle	Allowed Welding Positions	Gas Shielding for FCAW	Notes
SMAW	B-U5b	U Spacer = 1/8 × R	U	R = 1/4	f = 0 to 1/8	α = 45°	All	—	3, 4, 5, 8, 10
	TC-U5a	U Spacer = 1/4 × R	U	R = 1/4	f = 0 to 1/8	α = 45°	All	—	4, 5, 7, 8, 10, 11
				R = 3/8	f = 0 to 1/8	α = 30°	F, OH	—	4, 5, 7, 8, 10, 11

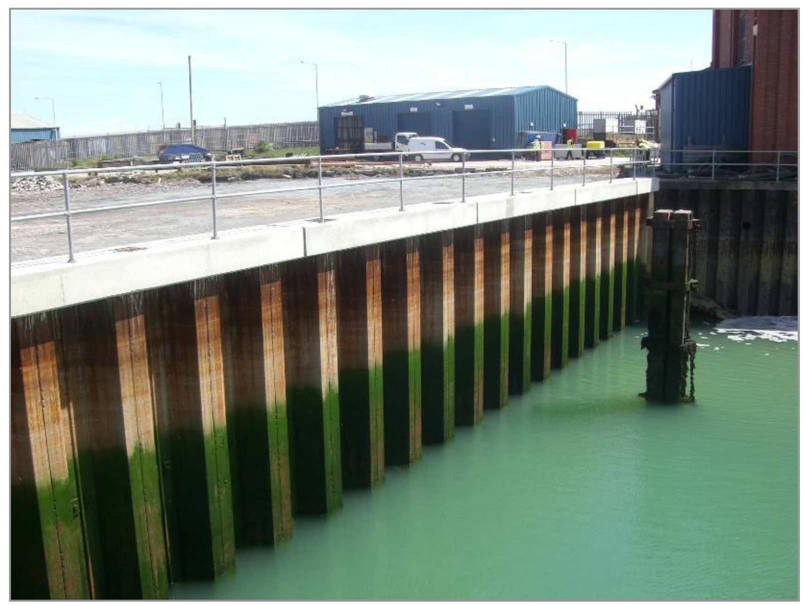
Pilot project. Shoreham, UK (2010)



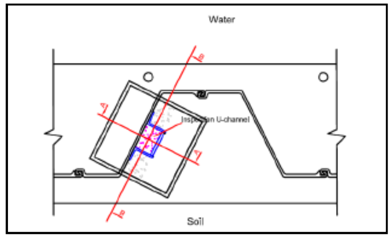
Single-anchored quay ~30 m long
retained height of 8.7 m
AZ 38-700, **16.0 m** long, **AMLoCor Blue355**.

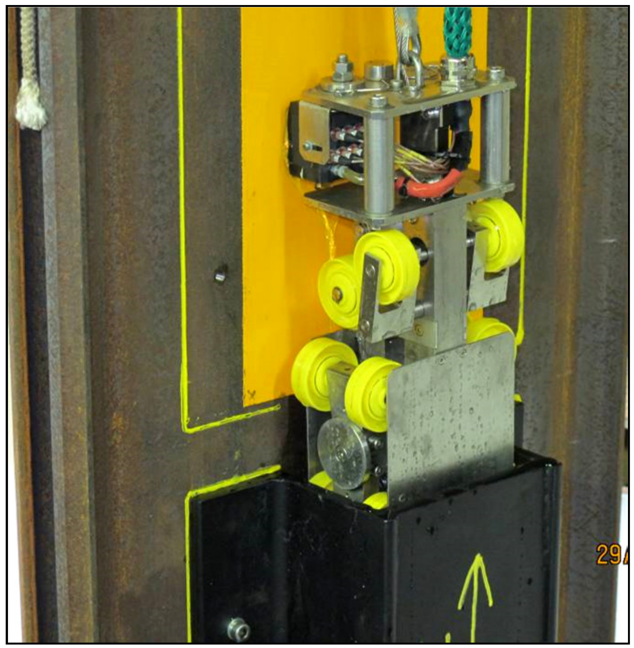
4 sheet piles equipped with additional channel elements required for the inspection of the residual thickness in the future.

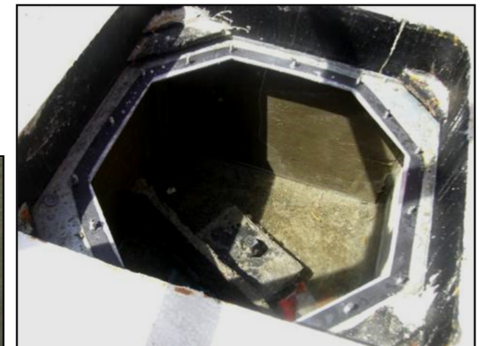
2 standard S 355 GP sheet piles serve as reference samples.

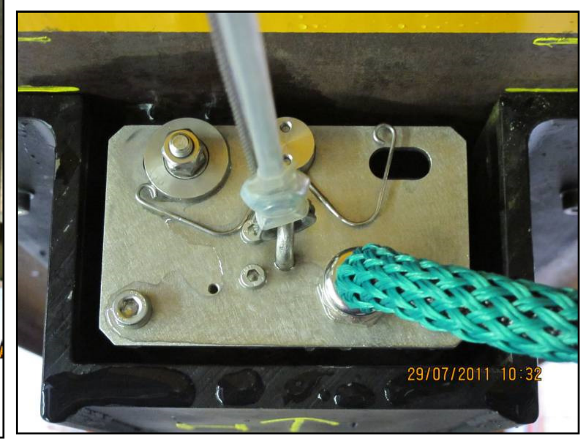


AM LoCor - Pilot Project in Port of Shoreham, UK – AZ38-700



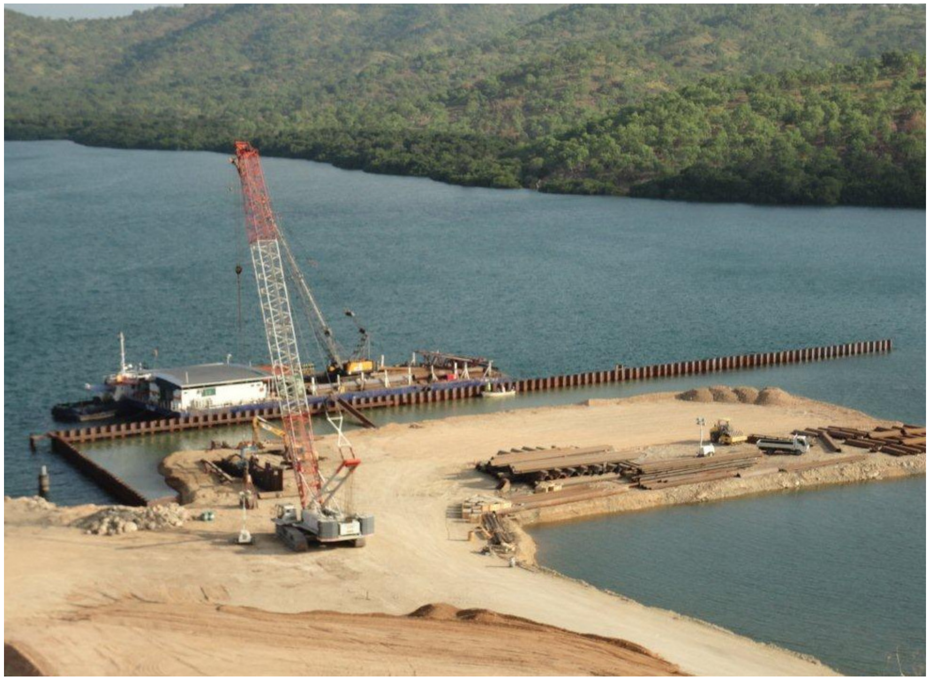






- special measuring probe for continuous long term measurements
- first results after 5 years

AMLocor Projects



Quay Wall in Ravavu – Papua New Guinea

AZ 26-700, 16.0 m long, AMLoCor Blue355 – 800 tons

Quay Wall at Mairs Yard, Lerwick, Shetland Islands

AZ 44-700, 11.5 m -15.5 m long, AMLoCor Blue320 – 600 tons.

- pretreatment of basaltic rock by blasting
- piles have been driven 2 m deep into the blasted rock

AM-Locor Conclusions

- Alternative for Cathodic Protection Systems (no maintainance / more environmentally friendly)
- Especially interesting for lighter walls (cost for CP per square meter / AM-Locor per ton – about 10% more in comparison to carbon steel)
- Broader range of sections and increase of available yield strength foreseen

Many thanks for you attention

sheetpiling.arcelormittal.com