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New steel grade with high corrosion resistance: AMLoCor

Spuns- & Rammedag 2012 – Anne Fagot

Copenhagen



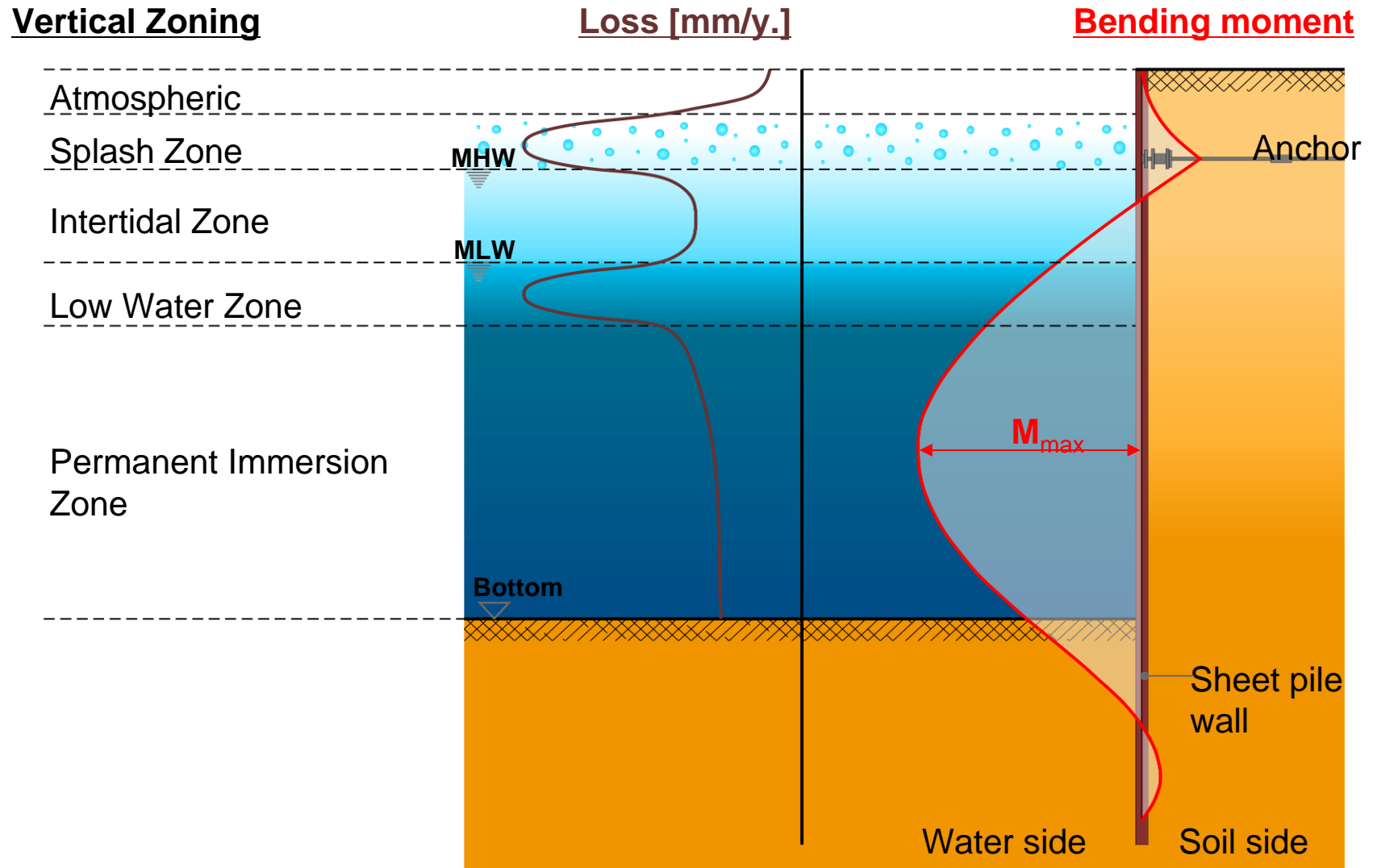
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AMLoCor : higher corrosion resistance in seawater

1. Corrosion of sheet pile walls in seawater
2. AMLoCor improved corrosion resistance
3. Key steps of its development
4. AMLoCor fit-for-purpose for piling?
5. Case study and Reference Projects
6. Summary



Corrosion Zones over the height of the sheet pile wall



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Current measures to assure the required design life time

✓ *Splash Zone:*

- Good accessibility for works / inspection
- Coating, Concrete encasement / capping beam, ASTM A690



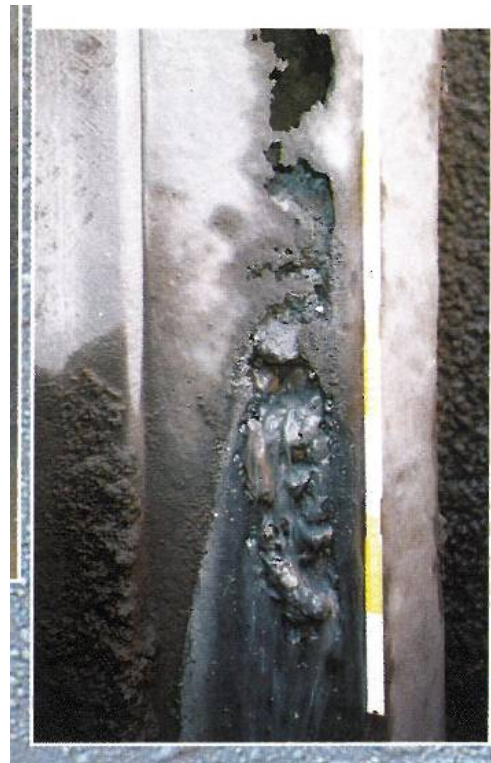
✓ *Low Water – and Immersion Zone:*

- Accessible only by divers
- Difficult and costly
- Sacrificial thickness due to corrosion, coating, Cathodic Protection



Special problem in the low water zone: ALWC

- ✓ ALWC = Accelerated Low Water Corrosion
- ✓ microbially induced corrosion (MIC)
- ✓ Very high corrosion rates (0,5 mm/y.)
- ✓ Since 1980's well intensively reported worldwide



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Corrosion summary in seawater environments

- ✓ **High corrosion locations:**
 - **Splash and low water zones**
- ✓ **Splash zone:**
 - **Existing efficient protective methods**
- ✓ **Low water zone:**
 - **High corrosion rates**
 - **Extreme corrosion rates in presence of ALWC**
- ✓ **Permanent immersion zone:**
 - **Lower corrosion rates but location of maximum bending moment**



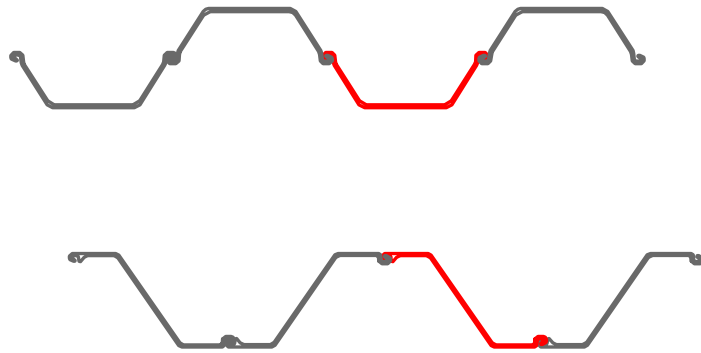
Objectives for AMLoCor

- ✓ **Corrosion compared to construction steel:**
 - **Low water zone: 5 x better**
 - **Permanent immersion zone : 3 x better**
 - **Splash zone: as good as construction steel**
- ✓ **Mechanical properties should be equivalent to construction steel**
- ✓ **good weldability with classical welding processes**
- ✓ **All piling products should be offered in AMLoCor keeping in mind that final solution should be economically attractive**

AMLoCor product range

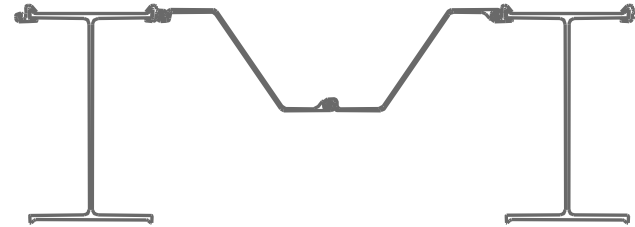


U/Z sheet piles wall

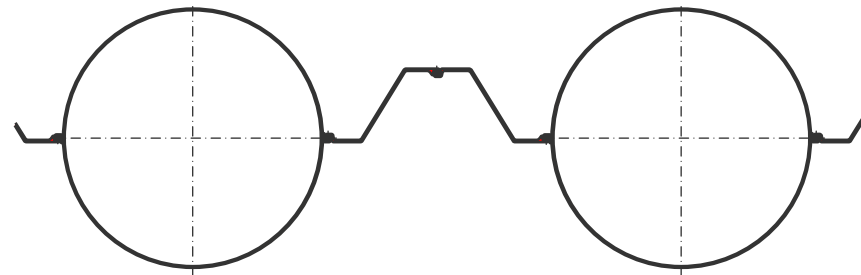


Combined wall

HZM - AZ



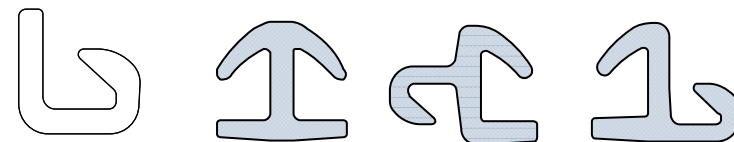
Tube - AZ



Product standards:

- EN 10248:1995
- prEN10248:2006
- EN 10219:2005
- (API 5L-PSL 1: 2008)

Connectors



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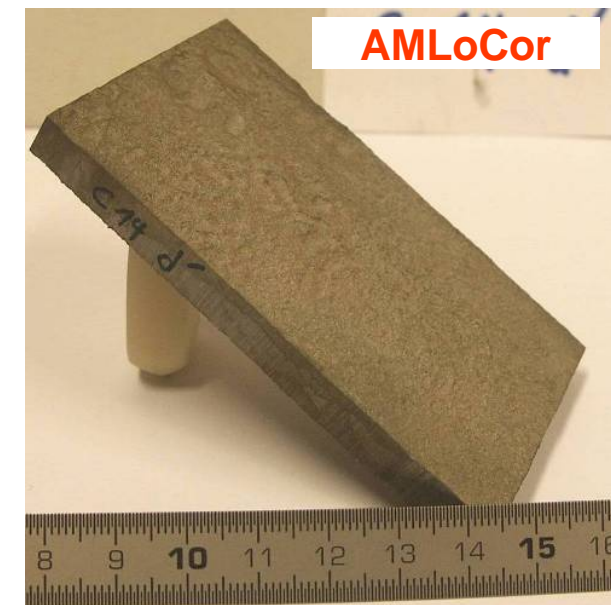


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In situ testing in UK

15 m lange coupons in ALWC suspected area

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Exposed in suspected ALWC area, 15 years

In situ testing in UK

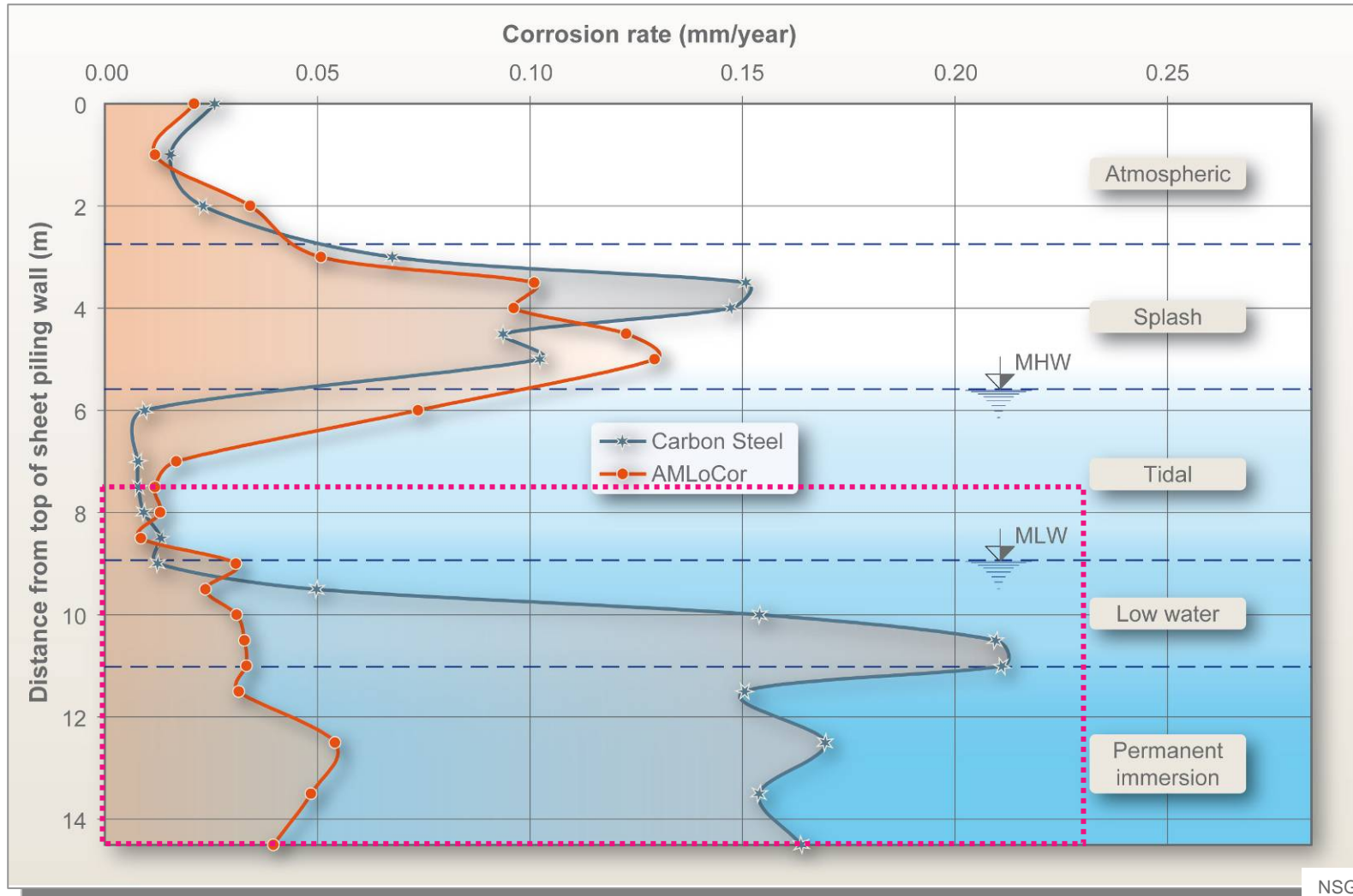
15 m lange coupons in ALWC suspected area

U channel, 15 years exposure in UK Port



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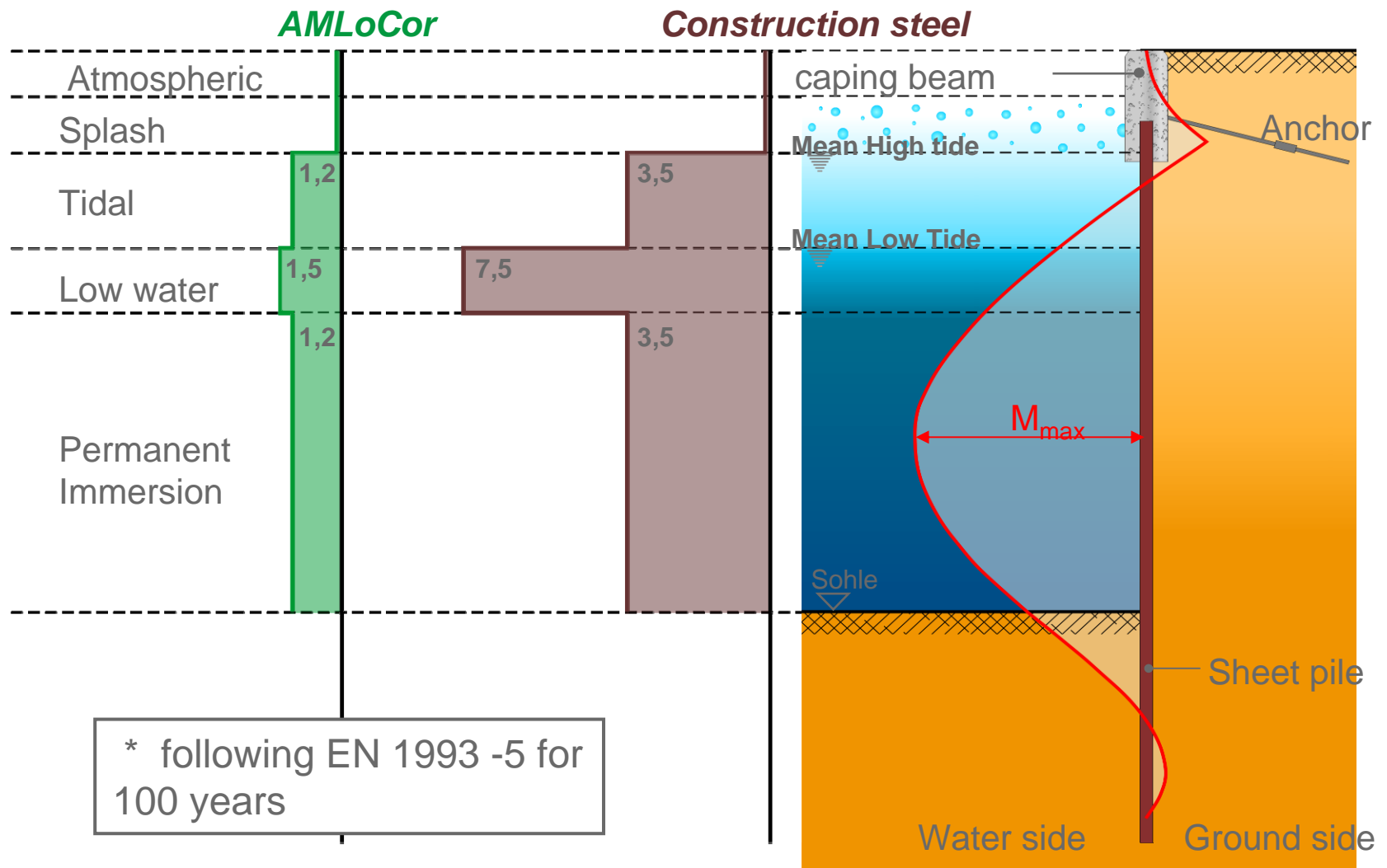


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depth

Loss of thickness [mm]

M - trend

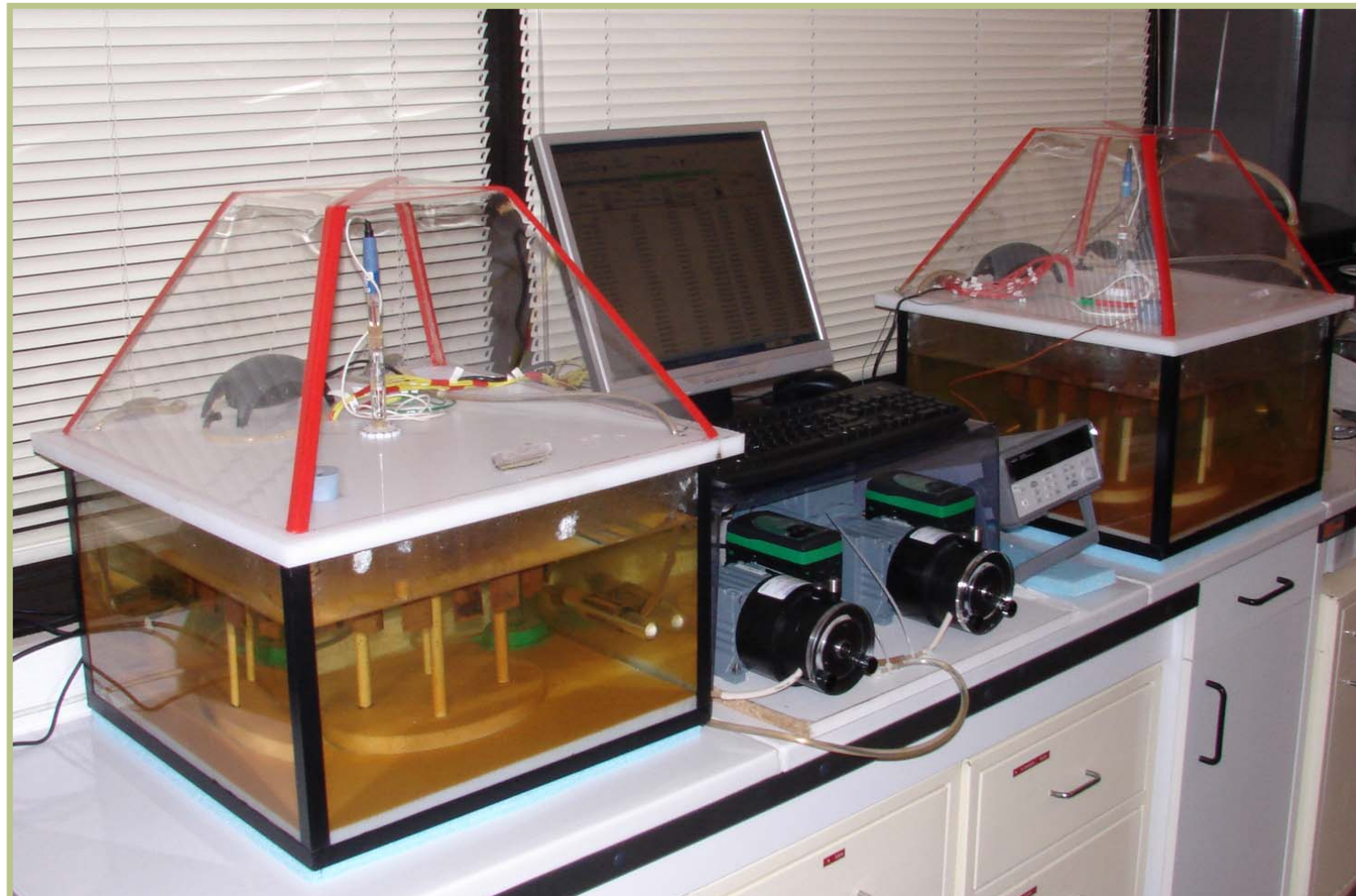


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Design of an experimental system with Corrodys



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- Objective : *to compare resistance to corrosion of several steels in contaminated and bacteria free seawaters*



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In situ corrosion testing

Coupons in low water zone in Rotterdam harbour

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Samples in AMLoCor und carbon steel
in immersion



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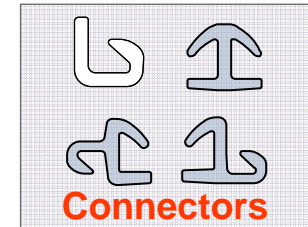
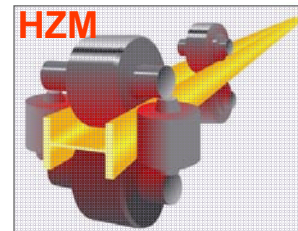
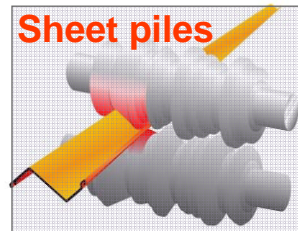
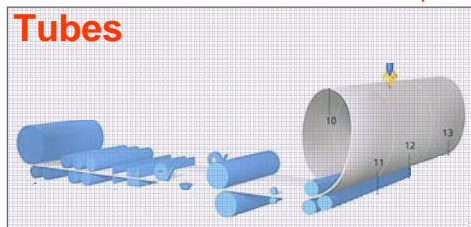
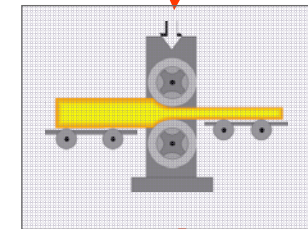
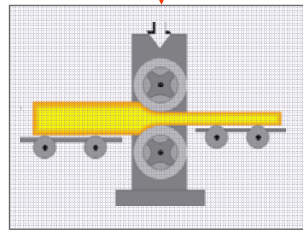
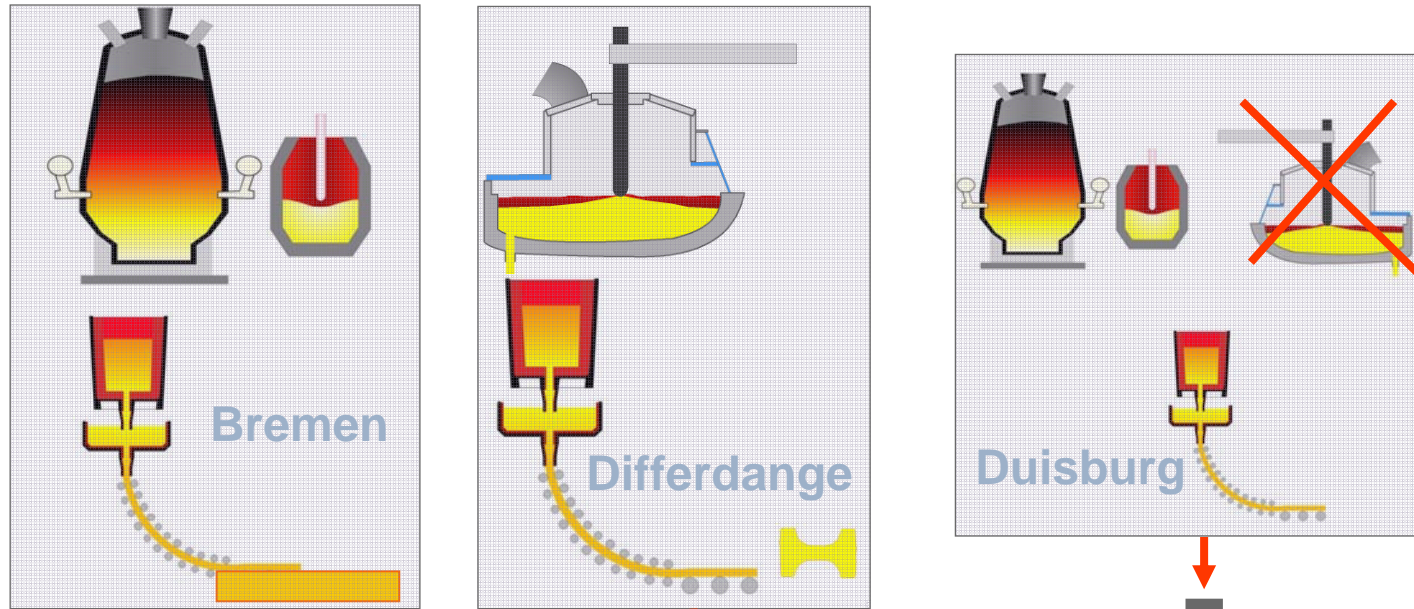
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AMLoCor complexity or why it took us so long?



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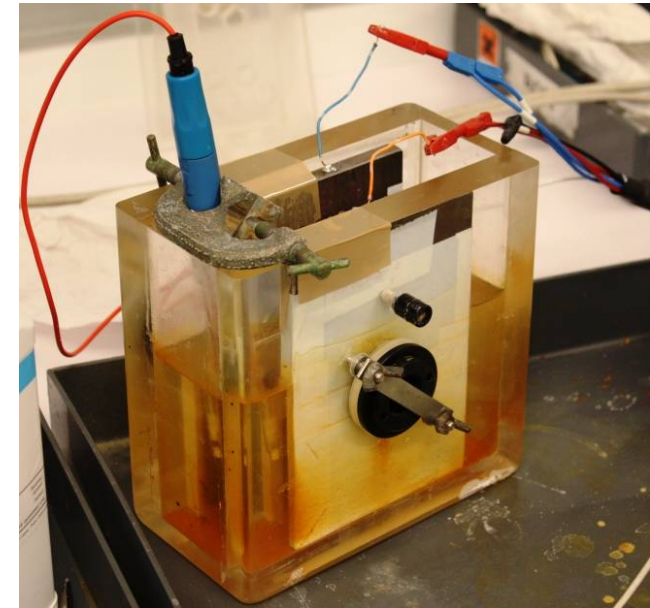
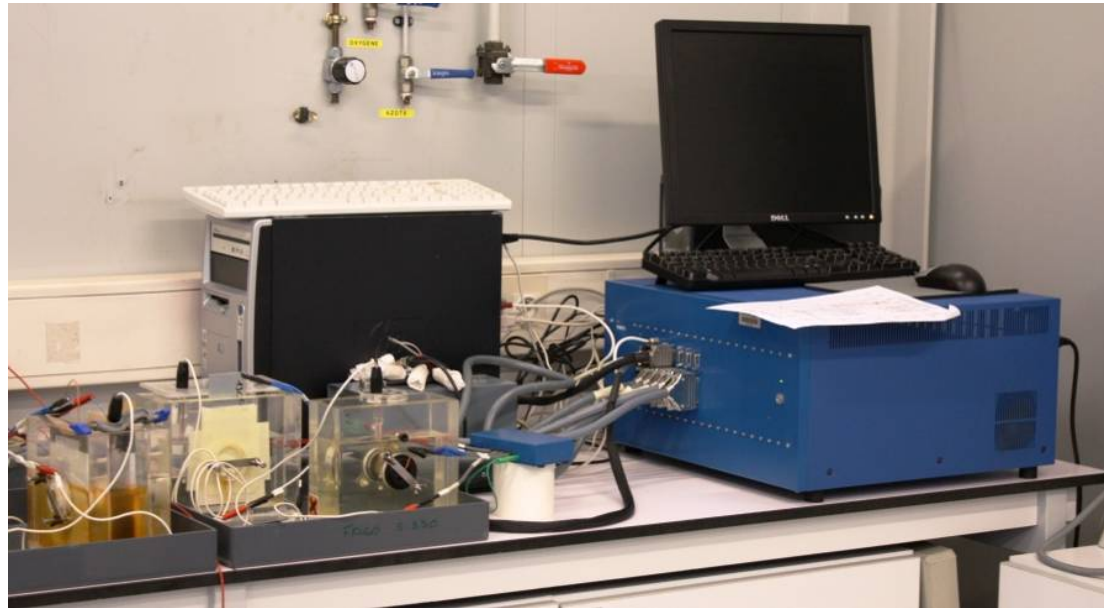


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AM LoCor and carbon steel: galvanic corrosion?

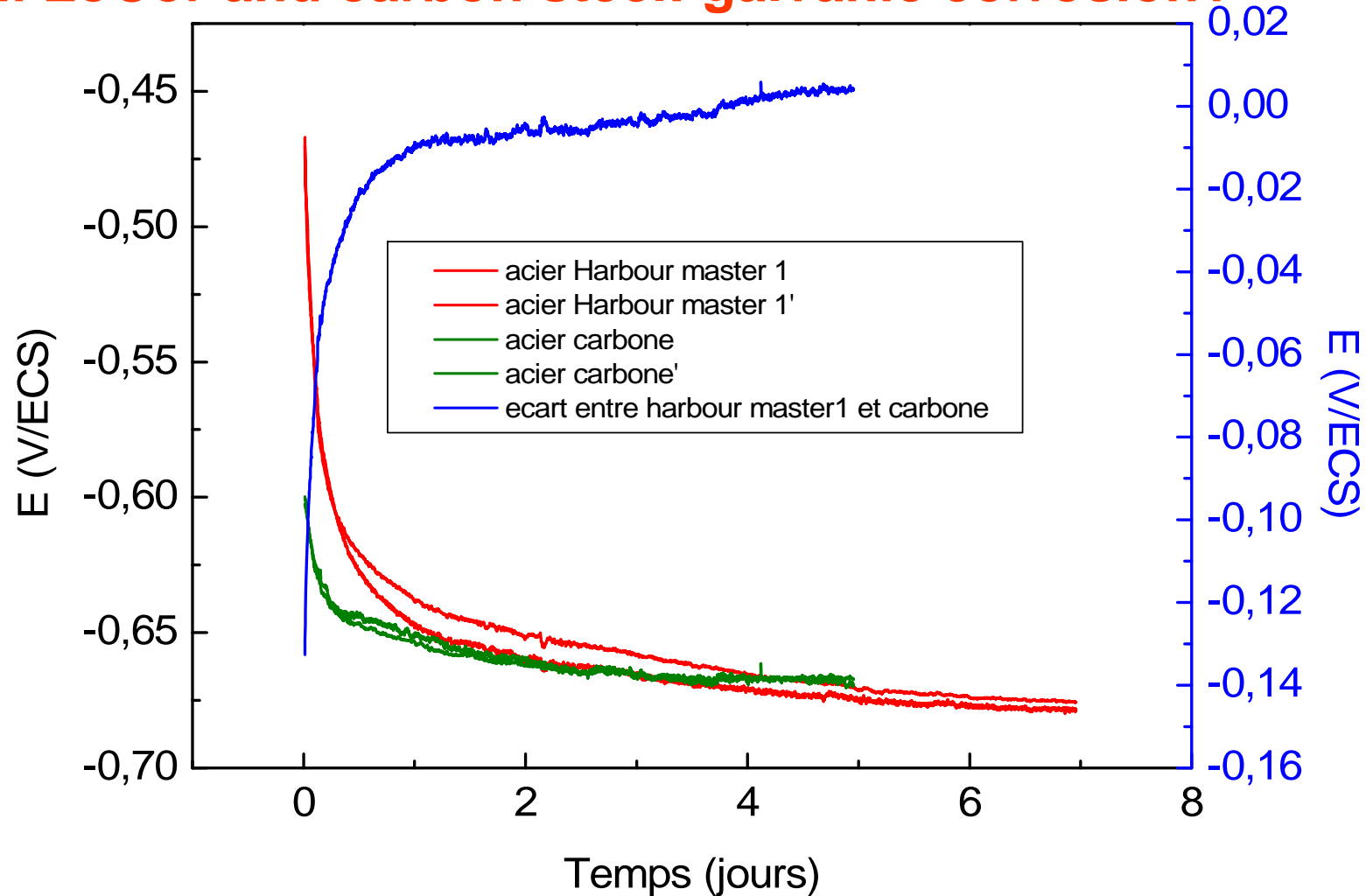


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- ✓ **Issue: carbon steel to corrode faster in contact with AM LoCor:**
 - **Even faster if C steel surface is the smallest one**
- ✓ **Electrochemical tests in artificial seawater**
 - **Only instant corrosion**
- ✓ **Same surface for carbon steel and AM LoCor samples**



AM LoCor and carbon steel: galvanic corrosion?



After less than 2 hours, potential difference below 80mV - > low risk of galvanic corrosion



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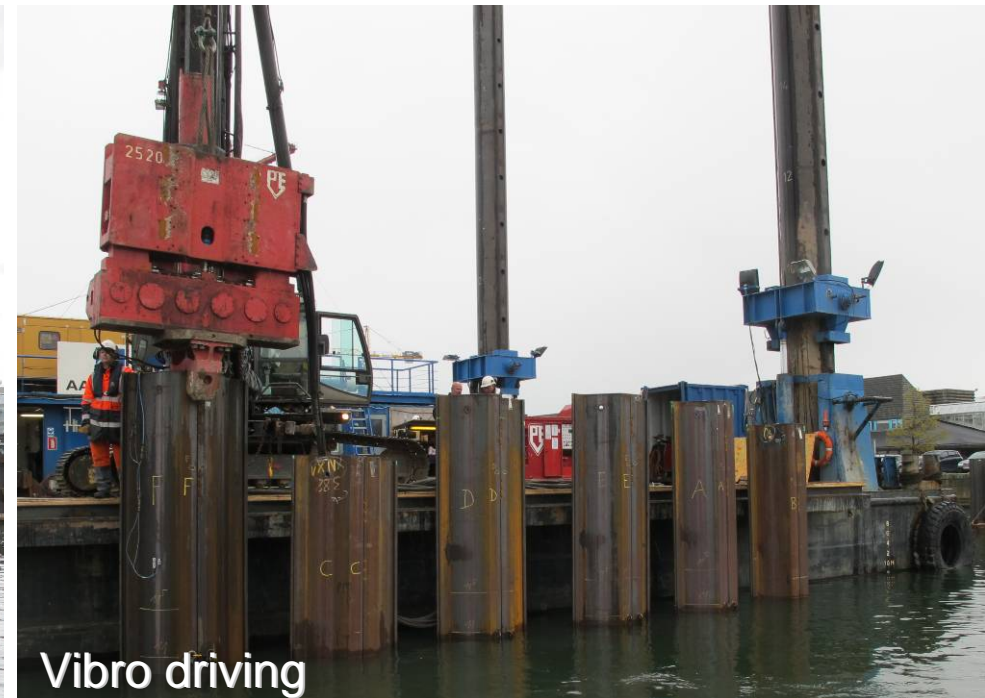
Driveability : trials in Copenhagen

- ✓ Comparative driving on AZ26-700:
 - « hard » soil: Marine deposits on limestone and moraine cobbles

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Impact driving



Vibro driving

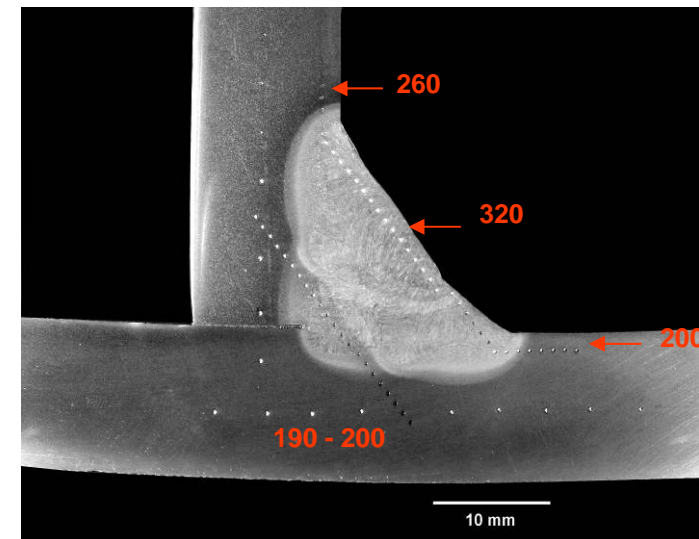
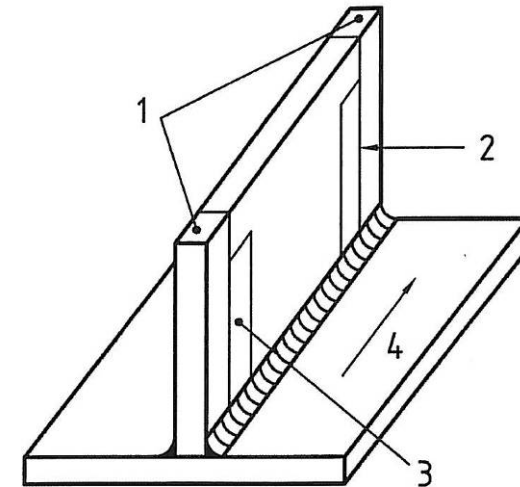
PDA Measurements indicate similar behaviour of AMLoCor Blue 355 and S355GP during driving



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AMLoCor: weldability

- ✓ **Welding studies with**
 - Metal Active Gas welding(135)
 - Submerged Arc Welding (SAW, 12)
- ✓ **Despite high energy used (18 kJ/cm), EN ISO 15 614-1 requirements are met (< HV 380)**
- ✓ **No pre or post heating are required**
- ✓ **Finally very good weldability**





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AMLoCor: Chemical composition

weight %	C	Mn	Si	P	S	N	Cr	Al
AM LoCor	0,11	0,87	0,38	0,013	0,003	0,007	1	0,65
S355 GP (example)	0,14 0,27	1,14 1,60	0,17 0,60	0,026 0,050	0,025 0,050	0,01 0,011	0,1	0,002

- Steel designation to EN 10 020
 - S355GP = non alloy steel
 - AMLoCor = alloy steel, ‘microalloyed’

% lim	% lim	% lim	% lim
Al 0,30	Cu 0,40	Pb 0,40	V 0,10
B 0,0008	Mn 1,65	Se 0,10	W 0,30
Bi 0,10	Mo 0,08	Si 0,60	Zr 0,05
Co 0,30	Nb 0,06	Te 0,10	Autres sauf C, N, S, P 0,10
Cr 0,30	Ni 0,30	Ti 0,05	

Tableau 1. Teneurs limites des divers éléments (% massique)

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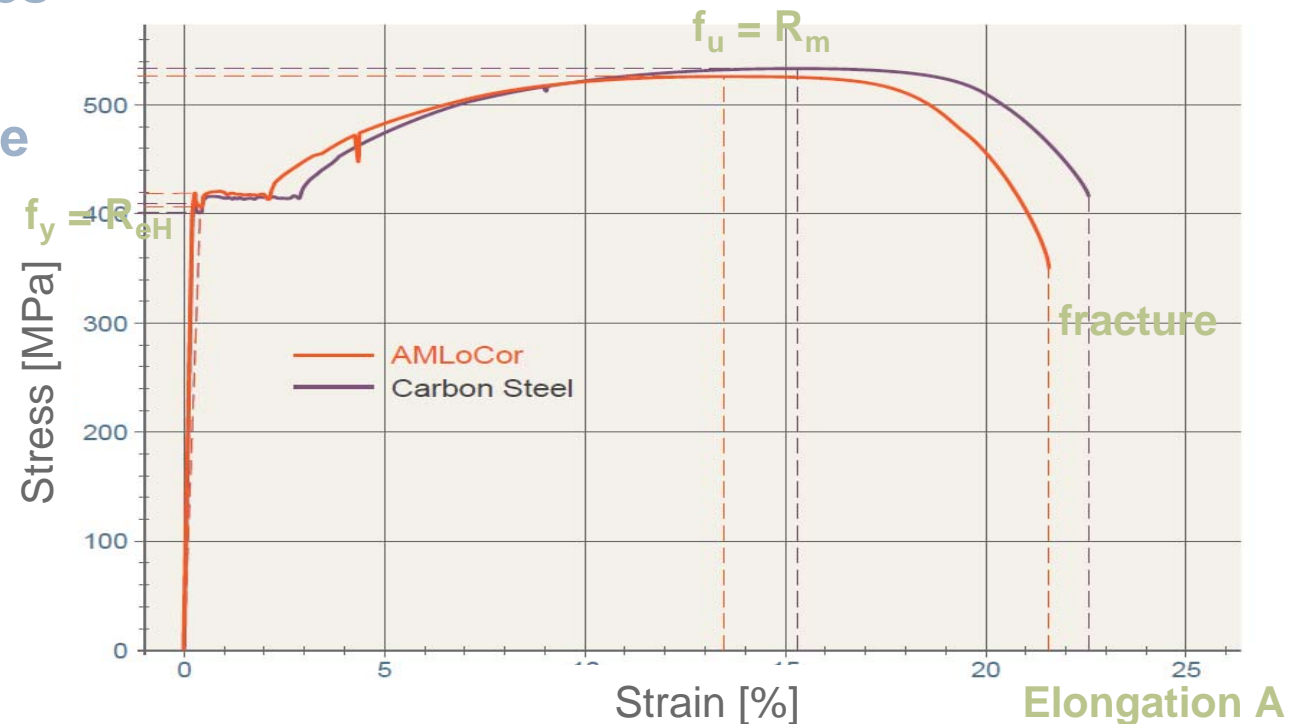
Mechanical properties

- ✓ Although not a construction steel, AMLoCor structures can be designed with traditional design codes for piling products
 - With reduced thickness sacrificed to corrosion

- ✓ AMLoCor mechanical properties are equivalent to current non alloy piling grades

- ✓ Excellent fracture toughness

- ✓ ETA process





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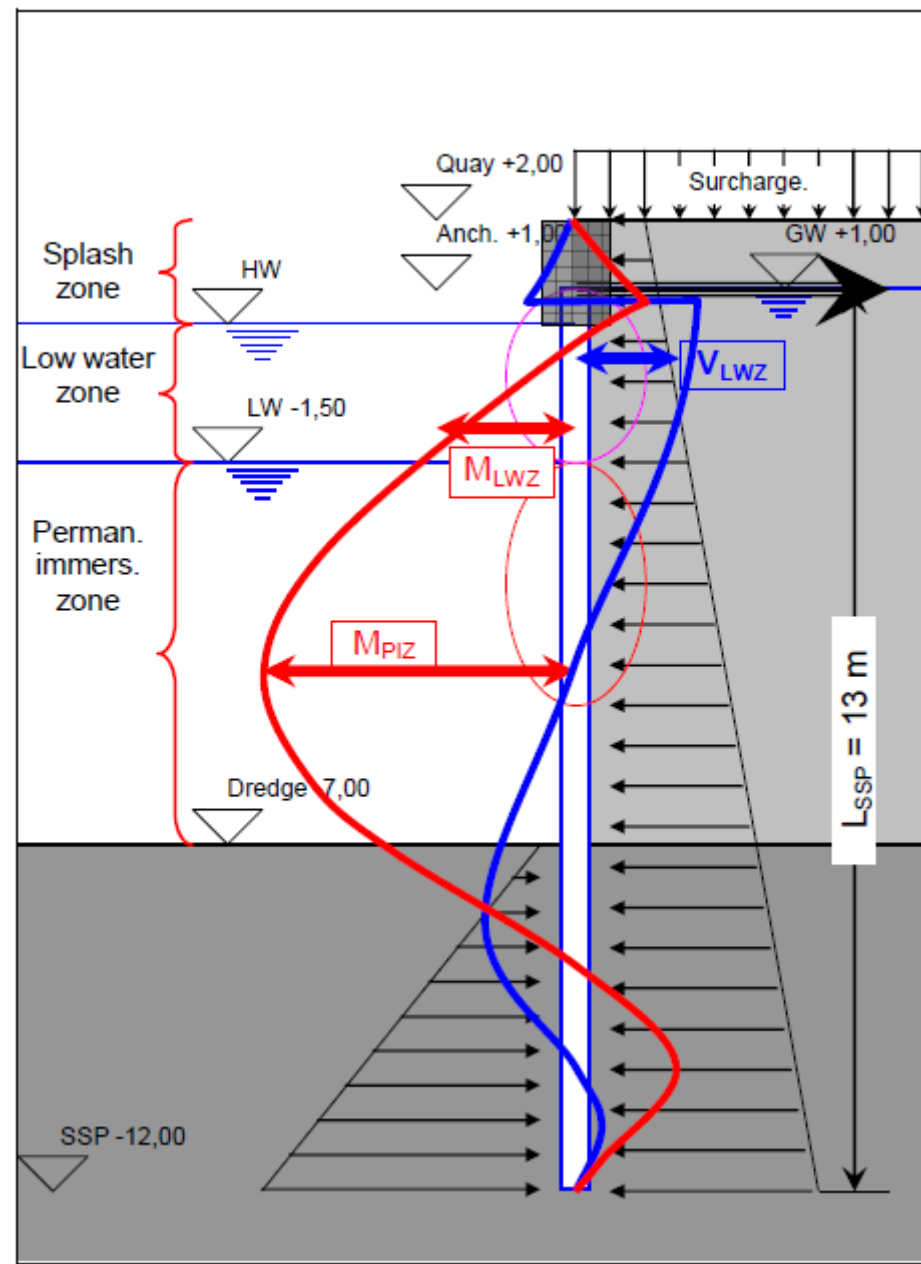


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Marina quay wall application

- ✓ Design life : 100y
- ✓ Design Eurocode 3 – part 5
 - $V_{LWZ} = 350\text{kN/m}$
 - $M_{LWZ} = 600\text{kN/m}$
 - $M_{PIZ} = 950\text{kN/m}$
 - No axial forces
- ✓ Equivalent S355 GP
- ✓ AZ series

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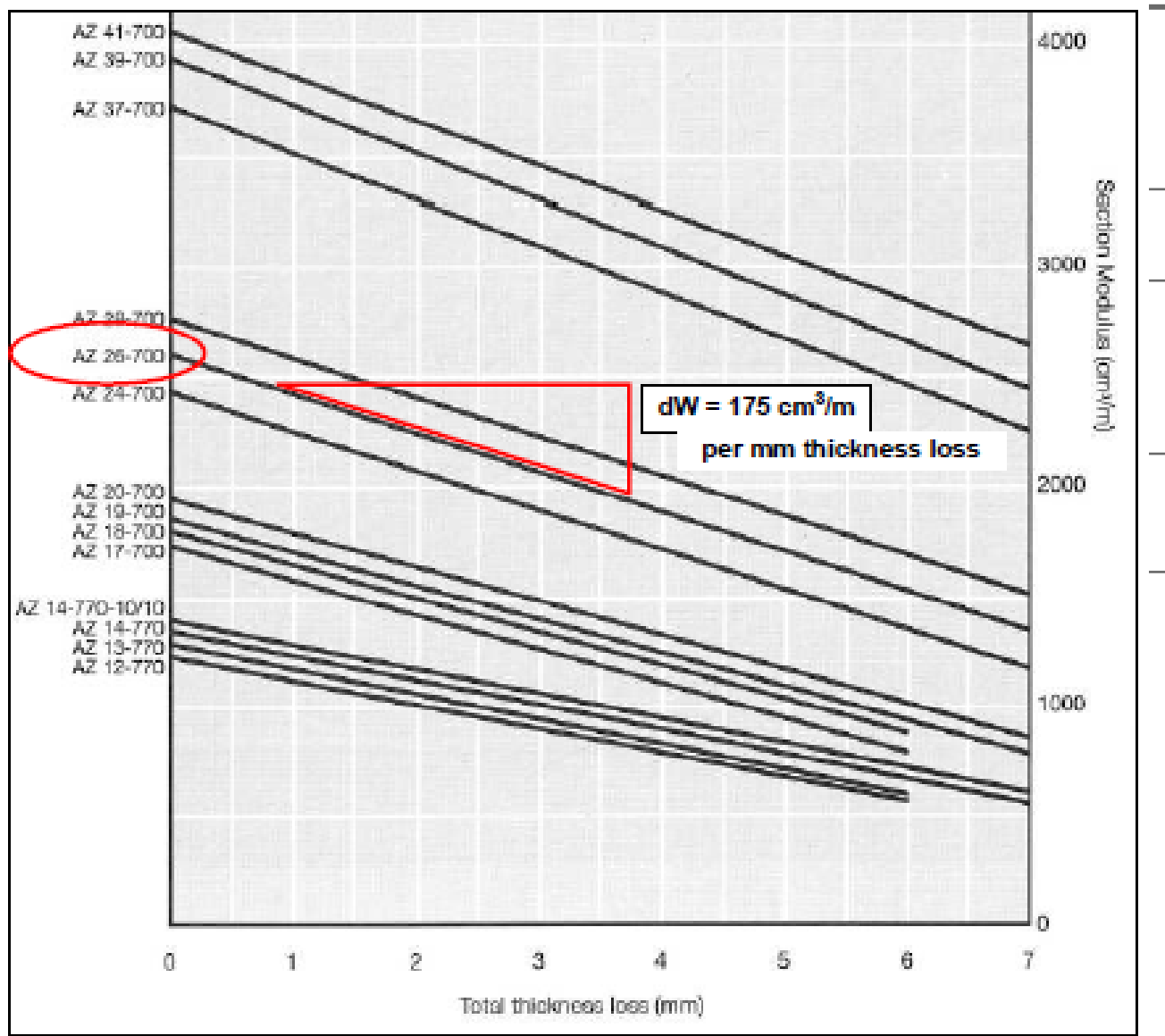




Basic Scenarios for 100 years

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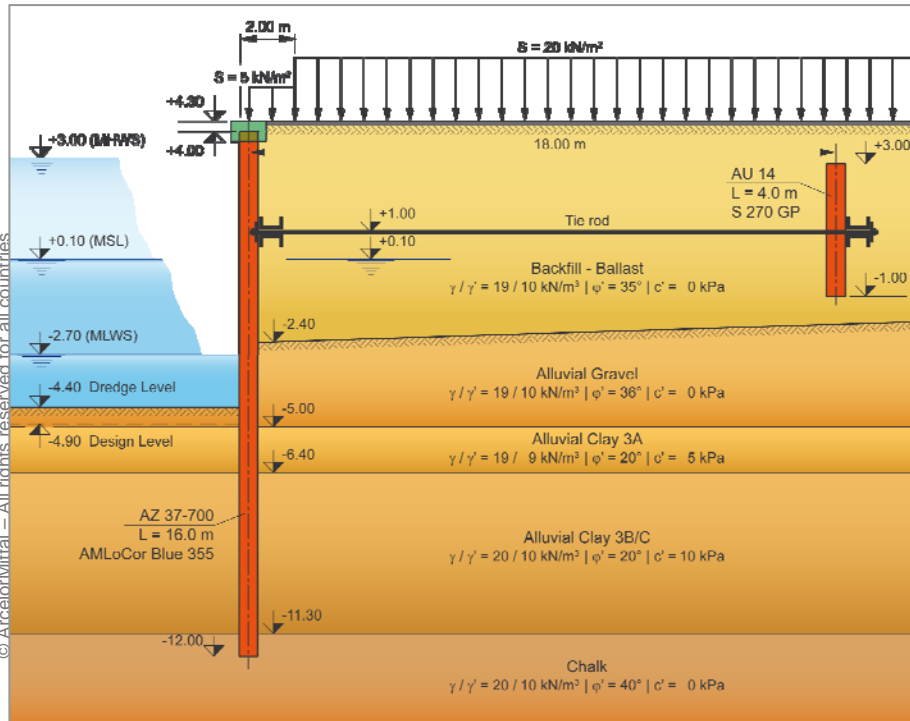
Scenarii
Splash zone
Immersion zone
Low water zone



*Thickness losses fi



Pilot project. Shoreham, UK (2010)

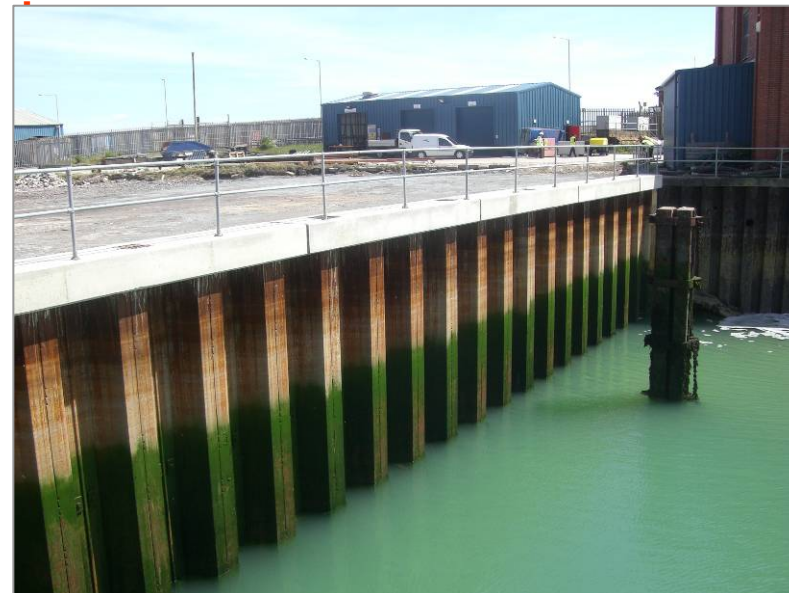


Single-anchored quay ~30 m long
retained height of 8.7 m

AZ 37-700, 16.0 m long, AMLoCor Blue355.

Vibratory hammer PVE '2315'. If required,
double acting hydraulic impact hammer BSP
'SL 30'.

Driving through alluvial gravel layer (SPT
up to 25) down into a **stiff alluvial clay
layer**. Some sheets penetrated the **chalk**



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

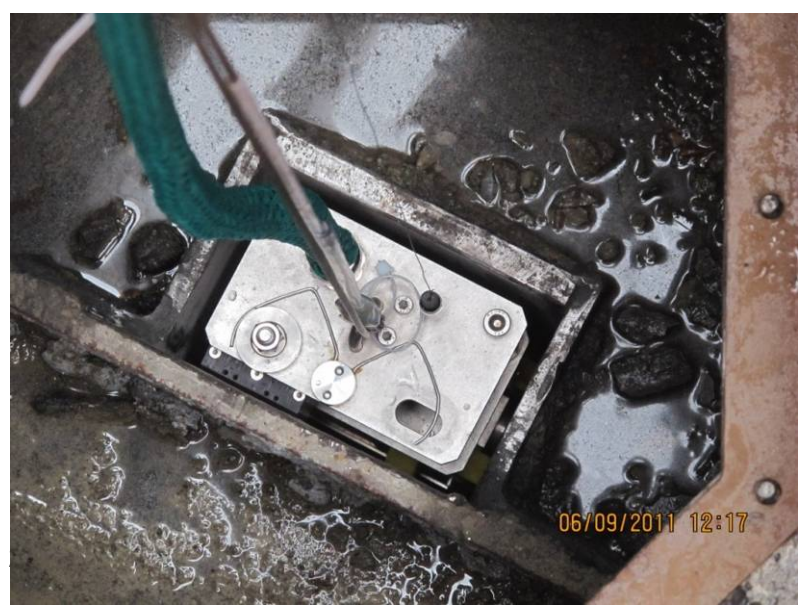
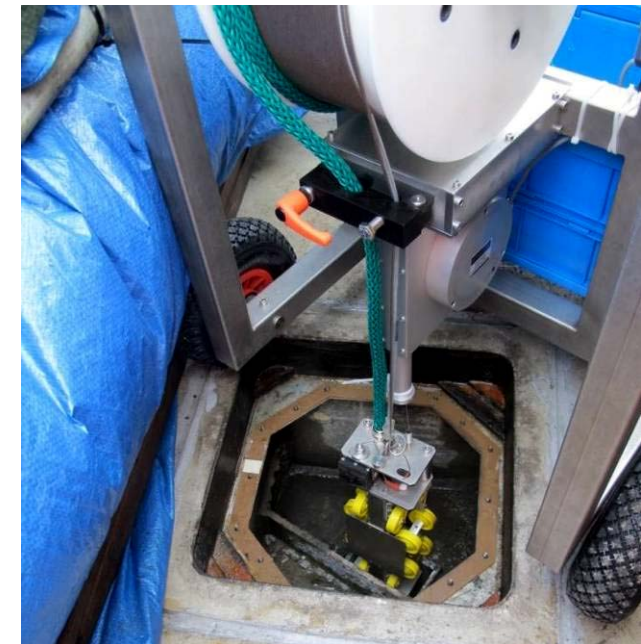
2 standard S 355 GP sheet piles serve as
reference samples.



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Shoreham: In situ measuring campaign

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AMLoCor in summary

- ✓ **steel grade with improved corrosion resistance**
 - **3 to 5 x better in immersion zone**
- ✓ **Fit-for-purpose mechanical properties for piling applications**
 - **No change in design rules but reduced sacrificial thicknesses**
- ✓ **Good weldability for classical processes**
- ✓ **its use may lead to:**
 - **significant tonnage and cost reduction** / non alloy steel
 - **significant cost savings** / non alloy steel solution with CP

While considering Global costing
- ✓ **European Technical Approval process started with DIBt (Germany)**



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