

Durability

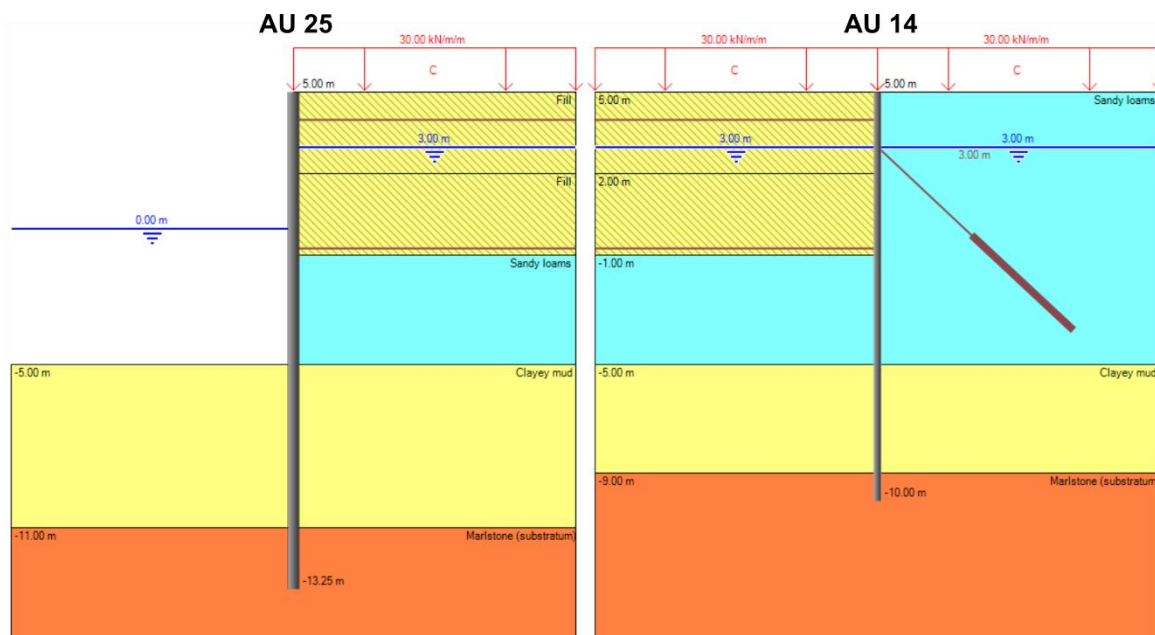
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1. Quay wall in a marine environment

1.1. Description

This example shows a quay wall in a marine environment located in Great Britain. Service life of the structure is 50 years.



AU 25 S 320 GP (head wall) and **AU 14 S 460 AP** (anchor wall) sections have been chosen in the design with a Subgrade Reaction Model (SSIM method implemented on AMRetain). The walls are separated by a distance of 12 m. An anchor is placed at the back of the anchor wall to hold it in place during the temporary stage construction.

The most significant load levels are as follows:

AU 25					AU 14				
z	MEd	VEd	NEd	e	z	MEd	VEd	NEd	e
m	kNm/m	kN/m	kN/m	mm	m	kNm/m	kN/m	kN/m	mm
2.00	37	-5	27	33	3.00	-118	94	97	6.3
-0.75	-191	317	68	38	-0.75	360	275	125	17
-4.40	389	-9	140	41	-7.00	123	2	120	0.3
-11.20	-330	-7	207	2.45					

We assume there is no corrosion protection.

Corrosion rates are according to the EN 1993-5, Table 4.1 and 4.2.

For AU 25:

- Front corrosion zone: *Sea water in temperate climate in the zone of permanent immersion or in the intertidal zone*
- Back corrosion zone: *Undisturbed natural soils*

Total cumulated loss of steel thickness is 1.75 mm (front) + 0.60 mm (back) = 2.35 mm with a standard steel grade.

For AU 14:

- Front corrosion zone: *Undisturbed natural soils*
- Back corrosion zone: *Undisturbed natural soils*

Total cumulated loss of steel thickness is 0.60 mm (front) + 0.60 mm (back) = 1.20 mm with a standard steel grade.

The Sheet Pile steel sections considered in this example will be verified according to ASD (Allowable Stress Design) and Eurocode 3-5.

Durability allows to run several calculations simultaneously in the same project, introduced under the form of *Scenarios*, and allows to compare their results. ASD approach will be defined in the first scenario and Eurocode 3-5 in the second one.

Scenario synthesis tab will summarize the results for each scenario.

Definition steps:

1. First of all, one has to choose the project geometry, the sheet pile section and its steel grade, define the loads and partial safety factors in **Sheet pile** tab.
2. After defining the Structure Service Life, one has to define the corrosion to be applied in **Corrosion** tab: either use Eurocode tables or manual definition (rates or total loss)
3. Finally, all numerical results are shown in **Results** tab for each loading level defined previously.

1.2. ASD approach

Head wall definition and calculation:

File Edit Units Language Scenarios Design approach Module Help

◀ Quay wall in a marine environment (ASD) ▶ +

Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Geometry

Z top 5.00 m

Actions

N°	z [m]	M [kNm/m]	N [kN/m]	e [mm]	
1	2.00	37	27	33	✕
2	-0.75	-191	68	38	✕
3	-4.40	389	140	41	✕
4	-11.20	-330	207	2	✕

Safety factors

S_{f, min} 1.50

S_{f, max} 10.00

Service life

50 years

Steel quantities

L_{wall} 120.0 m

L_{SSP} 18.25 m

Results

✓ Sf = 1.60
Correct sheet pile selected

Sheet pile section

Type All

Name AU 25

Sort by Catalogue

Filter

☐ Only valid sheet pile

☐ I_y min 0 cm⁴/m

☐ t_w min 0.00 mm

☐ t_f min 0.00 mm

Steel grade

S 320 GP

☐ Show all

Sheet pile properties (initial values)

W _{el, y}	2 500 cm ² /m	W _{pl, y}	2 866 cm ² /m
I _y	56 240 cm ⁴ /m	A	187.5 cm ² /m
t _f	14.50 mm	t _w	10.20 mm
h	450.0 mm	α	59.6 °
b	406.0 mm	c	252.5 mm
A _v	59.2 cm ² /m	S _y	1 420 cm ² /m
r ₀	25.0 mm	mass	147.2 kg/m ²
B	1 500 mm		

Notes:

Mur de quai en milieu maritime (ASD)

Personnal notes (200 characters max)

Front Back

Water
Anchor
Protection
Corrosion

Actions M

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◀ Quay wall in a marine environment (ASD) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Corrosion rates Show table

☒ Eurocode 3 - Part 5
☐ Manual

Eurocode 3 - Part 5. Table 4.1 and 4.2

Zone	z bottom [m]	Corrosion front [mm]		Corrosion back [mm]		Protection [years]		Total corrosion [mm]		+
		Front	Back	Front	Back	Front	Back	Front	Back	
1	3.00	Atm. Locations close to the se: 1.00	Soil. Compacted and non-aggr: 0.60	0	0	1.00	0.60	✕		
2	0.00	Atm. Locations close to the se: 1.00	Soil. Compacted and non-aggr: 0.60	0	0	1.00	0.60	✕		
3	-5.00	Water. Sea water in temperate: 1.75	Soil. Compacted and non-aggr: 0.60	0	0	1.75	0.60	✕		
4	-18.25	Soil. Compacted and non-aggr: 0.60	Soil. Compacted and non-aggr: 0.60	0	0	0.60	0.60	✕		

Front Back

Water Anchor Protection Corrosion

Actions M

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◀ Quay wall in a marine environment (ASD) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Results

N°	z [m]	ASD	Sf
1	2.00	✓	16.79 > 1.50
2	-0.75	✓	3.27 > 1.50
3	-4.40	✓	1.60 > 1.50
4	-11.20	✓	2.04 > 1.50

Synthesis ✓ 1.60

Section

Property	Value
f _y	320.0

Selected section properties

Property	Ini.	Red. Unit
W _{el, y}	2 500	2 095 cm ² /m
W _{pl, y}	2 866	... cm ² /m
I _y	56 240	47 020 cm ⁴ /m
A	187.5	156.0 cm ² /m
t _f	14.50	12.15 mm
t _w	10.20	7.85 mm
h	450.0	447.6 mm
a	59.6	-
b	406.0	- mm
c	252.5	- mm
A _v	59.2	45.6 cm ² /m
S _y	1 420	- cm ³ /m
r ₀	25.0	- mm

Numerical details : level n°3 (z = -4.40 m)

$$\sigma_{\text{applied}} = \frac{M}{W_{\text{el, red}}} + \frac{N \cdot e}{W_{\text{pl, red}}} + \frac{N}{A_{\text{red}}}$$

$$\sigma_{\text{applied}} = \frac{395 \text{ kNm/m}}{2095 \cdot 10^{-6} \text{ m}^3/\text{m}} + \frac{140 \text{ kN/m} \cdot 0.04 \text{ m}}{2095 \cdot 10^{-6} \text{ m}^3/\text{m}} + \frac{140 \text{ kN/m}}{156.0 \cdot 10^{-4} \text{ m}^2}$$

$$\sigma_{\text{applied}} = 200.1 \text{ MPa}$$

$$\sigma_{\text{allowable}} = \frac{f_y}{S_f} = \frac{320.0 \text{ MPa}}{1.50} = 213.3 \text{ MPa}$$

$$\sigma_{\text{applied}} = 200.1 \text{ MPa} \leq \sigma_{\text{allowable}} = 213.3 \text{ MPa}$$

$$S_f = 1.60 > 1.50$$

Steel quantities

Property	Value
SSP pairs	80
Wall length	120.00 m
Total	322.37 t

Results

✓ Sf = 1.60
Correct sheet pile selected

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Anchor wall definition and calculation:

File Edit Units Language Scenarios Design approach Module Help

◀ Quay wall in a marine environment (ASD) ▶ +

Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Geometry
Z top 5.00 m

Actions

N°	z [m]	M [kNm/m]	N [kN/m]	e [mm]	+
1	3.00	-118	97	6	✕
2	-0.75	360	125	17	✕
3	-7.00	123	120	1	✕

Safety factors

Sf, min 1.50

Sf, max 10.00

Service life

50 years

Steel quantities

L wall 120.0 m

L SSP 15.00 m

Results

✓ Sf = 1.51
Correct sheet pile selected

Sheet pile section

Type All

Name AU 14

Sort by Catalogue

Filter

☐ Only valid sheet pile

☐ I_y min 0 cm⁴/m

☐ t_w min 0.00 mm

☐ t_f min 0.00 mm

Steel grade

S 460 AP

☐ Show all

Sheet pile properties (initial values)

W _{el, y}	1 405 cm ² /m	W _{pl, y}	... cm ² /m
I _y	28 680 cm ⁴ /m	A	132.3 cm ² /m
t _f	10.00 mm	t _w	8.30 mm
h	408.0 mm	α	47.8 °
b	327.2 mm	c	268.6 mm
A _v	44.0 cm ² /m	S _y	820 cm ² /m
r ₀	25.0 mm	mass	103.8 kg/m ²
B	1 500 mm		

Notes:

Mur de quai en milieu maritime (ASD)

Personnal notes (200 characters max)

Front Back

Water
Anchor
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Actions M

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◀ Quay wall in a marine environment (ASD) ▶ +

Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Corrosion rates

Show table

● Eurocode 3 - Part 5

○ Manual

Eurocode 3 - Part 5. Table 4.1 and 4.2

Zone	z bottom [m]	Corrosion [mm]		Protection [years]		Total corrosion [mm]		+
		Front	Back	Front	Back	Front	Back	
1	-1.00	Soil. Compacted and non-aggr 0.60	Soil. Undisturbed natural soils 0.60	0	0	0.60	0.60	✕
2	-10.00	Soil. Undisturbed natural soils 0.60	Soil. Undisturbed natural soils 0.60	0	0	0.60	0.60	✕

Front Back

Water
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Actions M

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File Edit Units Language Scenarios Design approach Module Help

◀ Quay wall in a marine environment (ASD) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Sf summary Charts

Head wall Anchor wall ✕

Results

N°	Z [m]	ASD	Sf
1	3.00	✓	4.41 > 1.50
2	-0.75	✓	1.51 > 1.50
3	-7.00	✓	4.20 > 1.50

Synthesis ✓ **1.51**

Section

Property	Value
f_y	460.0

Selected section properties

Property	Ini.	Red. Unit
$W_{el,y}$	1 405	1 240 cm ² /m
$W_{pl,y}$ cm ² /m
I_y	28 680	25 260 cm ⁴ /m
A	132.3	117.3 cm ² /m
t_f	10.00	8.80 mm
t_w	8.30	7.10 mm
h	408.0	406.8 mm
a	47.8	- °
b	327.2	- mm
c	268.6	- mm
A_v	44.0	37.7 cm ² /m
S_y	820	- cm ³ /m
r _o	25.0	- mm

Numerical details : level n°2 (z = -0.75 m)

$$\sigma_{applied} = \frac{M}{W_{el,red}} + \frac{N \cdot e}{W_{el,red}} + \frac{N}{A_{red}}$$

$$\sigma_{applied} = \frac{362 \text{ kNm/m}}{1240 \cdot 10^{-6} \text{ m}^3/\text{m}} + \frac{125 \text{ kN/m} \cdot 0.02 \text{ m}}{1240 \cdot 10^{-6} \text{ m}^3/\text{m}} + \frac{125 \text{ kN/m}}{117.3 \cdot 10^{-4} \text{ m}^2}$$

$$\sigma_{applied} = 304.4 \text{ MPa}$$

$$\sigma_{allowable} = \frac{f_y}{S_f} = \frac{460.0 \text{ MPa}}{1.50} = 306.7 \text{ MPa}$$

$$\sigma_{applied} = 304.4 \text{ MPa} \leq \sigma_{allowable} = 306.7 \text{ MPa}$$


$$S_f = 1.51 > 1.50$$

Steel quantities

SSP pairs	80
Wall length	120.00 m
Total	186.84 t

Results

✓ Sf = 1.51
Correct sheet pile selected

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In conclusion, the proposed structures have a safety factor equal to $1.60 \geq 1.50$ for the head wall after 2.35 mm of loss of steel thickness, and $1.51 \geq 1.50$ for anchor wall after 1.20 mm of loss of steel thickness.

1.3. Eurocode 3 – 5

Eurocode 3-5 approach requires to consider design values of loads, which have already been multiplied in the geotechnical design (calculation done with AMRetain) by the applicable partial safety factor.

Additional calculation parameters required for head and anchor wall:

Partial safety factor	γ_{M0}	1.00
Partial safety factor	γ_{M1}	1.10
Reduction factor	β_B	0.80
Reduction factor	β_D	0.55

Table 1. Partial factors (default values)

For our specific example located in Great Britain, β_B and β_D values are taken from the British Standard National Annex.

British Standards. NA to BS EN 1993-5:2007. July 2009

Table NA.2 Reduction factors for U shaped sheet piles.

Type of U-pile unit	Number of structural support levels (see Note 1)	Reduction factors β_B and β_D referred to in 5.2.2 (2); 5.2.2 (9); 5.2.3 (2); 6.4 (3) (see Notes 2, 3, 4, and 5)					
		Highly unfavourable conditions (see Note 6)		Unfavourable conditions (see Note 7)		Favourable conditions (see Note 8)	
		β_B	β_D	β_B	β_D	β_B	β_D
Singles or uncrimped doubles	0	0,40	0,30	0,50	0,35	0,60	0,40
	1	0,55	0,35	0,60	0,40	0,70	0,45
	>1	0,65	0,45	0,70	0,50	0,80	0,55
Crimped or welded doubles	0	0,70	0,60	0,75	0,65	0,80	0,70
	1	0,80	0,70	0,85	0,75	0,95	0,80
	>1	0,90	0,80	0,95	0,85	1,00	0,90

Head wall definition and calculation:

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◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall X

Geometry

Z top 5.00 m Z w front 0.00 m
Buckling length 8.00 m Z w back 3.00 m
☒ Check buckling ☒ Use common buckling length

Actions

N°	Z [m]	M Ed [kNm/m]	V Ed [kN/m]	N Ed [kN/m]	e [mm]	
1	2.00	37	-5	27	33	X
2	-0.75	-191	317	68	38	X
3	-4.40	389	-9	140	41	X
4	-11.20	-330	-7	207	2	X

Partial safety factors

γ_{M0} 1.00
 γ_{M1} 1.00
NAD UK

Reduction factors (U-piles)

β_B 0.80
 β_D 0.55
Standard Great Britain
Show table

Service life

50 years

Steel quantities

L wall 120.0 m
L SSP 18.25 m

Results

Uf = 0.74
Correct sheet pile selected

Sheet pile section

Type All
Name AU 25
Sort by Catalogue

AZ : common interlocks crimped/welded
☐ Use Wel only
☐ Only valid sheet pile
☐ I y min 0 cm²/m
☐ t w min 0.00 mm
☐ t f min 0.00 mm

Steel grade

S 320 GP
☐ Show all
☒ Reduce fy to obtain Class 3
ε 0.857
(b/t f)/ε 33
Class ini. 2

Sheet pile properties (initial values)

W el, y	2 500 cm²/m	W pl, y	2 866 cm²/m
I y	56 240 cm⁴/m	A	187.5 cm²/m
t f	14.50 mm	t w	10.20 mm
h	450.0 mm	α	59.6 °
b	406.0 mm	c	252.5 mm
A v	59.2 cm²/m	S y	1 420 cm²/m
r o	25.0 mm	mass	147.2 kg/m²
B	1 500 mm		

Notes:

Mur de quai en milieu maritime (EC3-5)

Personnal notes (200 characters max)

Front Back

Water
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Actions MEd

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◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall ✕

Corrosion rates Show table

● Eurocode 3 - Part 5 Eurocode 3 - Part 5, Table 4.1 and 4.2

○ Manual

Zone	z bottom [m]	Corrosion [mm]		Protection [years]		Total corrosion [mm]		+
		Front	Back	Front	Back	Front	Back	
1	3.00	Atm. Locations close to the se...	Soil. Compacted and non-aggr...	0	0	1.00	0.60	✕
2	0.00	Atm. Locations close to the se...	Soil. Compacted and non-aggr...	0	0	1.00	0.60	✕
3	-5.00	Water. Sea water in temperate	Soil. Compacted and non-aggr...	0	0	1.75	0.60	✕
4	-18.25	Soil. Compacted and non-aggr...	Soil. Compacted and non-aggr...	0	0	0.60	0.60	✕

Front Back

Water Anchor Protection Corrosion

Actions | MEd

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◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall ✕

Results

N°	z [m]	Bending	Bending & shear	Web shear buckling	Buckling	Bending & axial	Bending & shear & axial	Uf
1	2.00	✓	✓	✓	✓	✓	-	0.06
2	-0.75	✓	✓	✓	✓	✓	-	0.38
3	-4.40	✓	✓	✓	✓	✓	-	0.74
4	-11.20	✓	✓	✓	✓	✓	-	0.49

Synthesis

Property	Ini.	Red.
f_y	320.0	320.0
ϵ	0.857	0.857
$(b/t_f)/\epsilon$	33	39
Class	2	3

Section classification

Numerical details : level n°3 (z = -4.40 m)

Bending

$$M_{Ed} = 395 \text{ kNm/m} \leq M_{c,Rd} = \frac{\beta_B W_{pl,y} f_y}{\gamma_{M0}} = 536 \text{ kNm/m}$$

$$W_{pl,y} = 2095 \text{ cm}^3/\text{m}$$

Bending & shear

$$V_{Ed} = 9 \text{ kN/m} \leq V_{pl,Rd} = \frac{A_v f_y}{\sqrt{3} \gamma_{M0}} = 842 \text{ kN/m}$$

$$V_{Ed} = 9 \text{ kN/m} \leq 0.50 V_{pl,Rd} = 421 \text{ kN/m}$$

No further verification needed

Web shear buckling

$$\frac{c}{t_w \cdot \epsilon} = 37.5 \leq 72$$

No verification required. Ok!

Buckling

$$N_{Ed} = 140 \text{ kN/m} \leq N_{pl,Rd} = \frac{A_f f_y}{\gamma_{M0}} = 4992 \text{ kN/m}$$

$$N_{cr} = \frac{EI \beta_D \pi^2}{l^2} = 8375 \text{ kN/m}$$

$$0.04 \cdot N_{cr} = 335 \text{ kN/m} \geq N_{Ed} = 140 \text{ kN/m}$$

No further verification needed

Bending & axial

$$N_{Ed} = 140 \text{ kN/m} \leq k_1 N_{pl,Rd} = k_1 \frac{A_f f_y}{\gamma_{M0}} = 499 \text{ kN/m with } k_1 = 0.10$$

Steel quantities

SSP pairs	80
Wall length	120.00 m
Total	322.37 t

Results

✓ Uf = 0.74
Correct sheet pile selected

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In conclusion, the head wall has an utilisation factor equal to $0.74 \leq 1.00$ after 2.35 mm of loss of steel thickness.

Anchor wall definition and calculation:

File Edit Units Language Scenarios Design approach Module Help

◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall ✕

Geometry

Z top 5.00 m Z w front 3.00 m
 Buckling length 7.00 m Z w back 3.00 m
☒ Check buckling ☒ Use common buckling length

Actions

N°	Z [m]	M _{Ed} [kNm/m]	V _{Ed} [kN/m]	N _{Ed} [kN/m]	e [mm]	
1	3.00	-118	94	97	6	✕
2	-0.75	360	275	125	17	✕
3	-7.00	123	2	120	1	✕

Partial safety factors

γ_{M0} 1.00 γ_{M1} 1.00
 Standard Great Britain
 NAD UK Show table

Service life

50 years

Steel quantities

L_{wall} 120.0 m
 L_{SSP} 15.00 m

Results

Uf = 0.88
 Correct sheet pile selected

Sheet pile section

Type All
 Name AU 14
 Sort by Catalogue

Steel grade

S 460 AP
 ε 0.715
 (b/t_f) / ε 46
 Class ini. 3

Sheet pile properties (initial values)

W _{el, y}	1405 cm ² /m	W _{pl, y}	... cm ² /m
I _y	28 680 cm ⁴ /m	A	132.3 cm ² /m
t _f	10.00 mm	t _w	8.30 mm
h	408.0 mm	α	47.8 °
b	327.2 mm	c	268.6 mm
A _v	44.0 cm ² /m	S _y	820 cm ² /m
r ₀	25.0 mm	mass	103.8 kg/m ²
B	1500 mm		

Notes:

Personnal notes (200 characters max)

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Actions MEd

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◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall ✕

Corrosion rates

● Eurocode 3 - Part 5
 ○ Manual

Show table Eurocode 3 - Part 5, Table 4.1 and 4.2

Zone	Z bottom [m]	Corrosion front [mm]		Corrosion back [mm]		Protection		Total corrosion		
		Soil. Compacted and non-aggr	Soil. Undisturbed natural soils	Front [years]	Back [years]	Front [mm]	Back [mm]			
1	-1.00	0.60	0.60	0	0	0.60	0.60	✕		
2	-10.00	0.60	0.60	0	0	0.60	0.60	✕		

Front Back

Water
 Anchor
 Protection
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Actions MEd

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File Edit Units Language Scenarios Design approach Module Help

◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts

Head wall Anchor wall ✕

Results

N°	z [m]	Bending	Bending & shear	Web shear buckling	Buckling	Bending & axial	Bending & shear & axial	Uf
1	3.00	✓	✓	✓	✓	✓	-	0.29
2	-0.75	✓	✓	✓	✓	✓	-	0.88
3	-7.00	✓	✓	✓	✓	✓	-	0.30

Synthesis

Property	Ini.	Red.	Red. class
f_y	460.0	460.0	416.3
ϵ	0.715	0.715	0.751
$(b/t_f)/\epsilon$	46	52	49
Class	3	4	3

Selected section properties

Property	Ini.	Red.	Unit
$W_{el,y}$	1 405	1 240	cm³/m
$W_{pl,y}$	cm³/m
I_y	28 680	25 260	cm⁴/m
A	132.3	117.3	cm²/m
t_f	10.00	8.80	mm
t_w	8.30	7.10	mm
h	408.0	406.8	mm
α	47.8	-	°
b	327.2	-	mm
c	268.6	-	mm
A_v	44.0	37.7	cm²/m
S_y	820	-	cm³/m
r_0	25.0	-	mm
mass	103.8	-	kg/m²
B	1 500	-	mm

Numerical details : level n°2 (z = -0.75 m)

Bending

$$M_{Ed} = 362 \text{ kNm/m} \leq M_{c,Rd} = \frac{\beta_B W_{el} f_y}{\gamma_{M0}} = 413 \text{ kNm/m}$$

$$W_{el} = 1240 \text{ cm}^3/\text{m}$$

Bending & shear

$$V_{Ed} = 275 \text{ kN/m} \leq V_{pl,Rd} = \frac{A_v f_y}{\sqrt{3} \gamma_{M0}} = 906 \text{ kN/m}$$

$$V_{Ed} = 275 \text{ kN/m} \leq 0.50 V_{pl,Rd} = 453 \text{ kN/m}$$

No further verification needed

Web shear buckling

$$\frac{c}{t_w \cdot \epsilon} = 50.4 \leq 72$$

No verification required. Ok!

Buckling

$$N_{Ed} = 125 \text{ kN/m} \leq N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}} = 4882 \text{ kN/m}$$

$$N_{cr} = \frac{EI \beta_D \pi^2}{l^2} = 5877 \text{ kN/m}$$

$$0.04 \cdot N_{cr} = 235 \text{ kN/m} \geq N_{Ed} = 125 \text{ kN/m}$$

No further verification needed

Bending & axial

$$N_{Ed} = 125 \text{ kN/m} \leq k_1 N_{pl,Rd} = k_1 \frac{A f_y}{\gamma_{M0}} = 488 \text{ kN/m with } k_1 = 0.10$$

Steel quantities

SSP pairs	80
Wall length	120.00 m
Total	186.84 t

Results

✓ Uf = 0.88
Correct sheet pile selected

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In conclusion, the anchor wall has an utilisation factor equal to $0.88 \leq 1.00$ after 1.20 mm of loss of steel thickness.

1.4. Additional features

- **Scenario synthesis** tab allows to compare the different scenario results.

Scenario synthesis												
Description	Calculation method	Wall	Sheet pile	Steel grade	Wall length [m]	L SSP [m]	Steel weight [t]	S _f	U _f	Scenario results	Anchor results	Retained scenarios
Quay wall in a marine environment (Eurocode 3-5)	Eurocode 3 - 5	Head wall	AU 25	S 320 GP	120.00	18.25	322.37	-	0.74	✓	-	☑
		Anchor wall	AU 14	S 460 AP	120.00	15.00	186.84	-	0.88	✓	-	
Quay wall in a marine environment (ASD)	ASD	Head wall	AU 25	S 320 GP	120.00	18.25	322.37	1.60	-	✓	-	☐
		Anchor wall	AU 14	S 460 AP	120.00	15.00	186.84	1.51	-	✓	-	
Total	-	-	-	-	-	-	509.21	-	-	-	-	-

- **Sf/Uf summary** tab allows to check every sheet pile section for each steel grade and calculates either Safety factor (Sf) for ASD approach or Utilisation factor (Uf) for Eurocode 3-5 approach.

File Edit Units Language Scenarios Design approach Module Help												
◀ Quay wall in a marine environment (Eurocode 3-5) ▶ + Sheet pile Corrosion Results LCA Anchor Scenario synthesis Uf summary Charts												
Head wall Anchor wall ✕												
Utilization factor												
<input type="radio"/> Ini. <input checked="" type="radio"/> Red.												
Reduction factor for AMLocor												
Front 1 Back 1												
Reduction factor for A690												
Front 1 Back 1												
	S 240 GP	S 270 GP	S 320 GP	European S 355 GP	S 390 GP	S 430 GP	S 460 AP	Blue320	AMLocor Blue355	Blue390	A 328	A572 Gr.
AZ 18-800	0.93	0.82	0.76	0.76	0.76	0.76	0.76	°	°	°	0.82	0.76
AZ 20-800	0.84	0.75	0.63	0.57	0.54	0.54	0.54	0.63	0.57	0.54	°	0.58
AZ 22-800	0.77	0.69	0.58	0.52	0.47	0.43	0.40	°	°	°	0.69	0.54
AZ 23-800	0.62	0.55	0.54	0.48	0.44	0.40	0.37	°	°	°	0.55	0.50
AZ 25-800	0.57	0.51	0.43	0.45	0.41	0.37	0.34	°	°	°	0.51	0.46
AZ 27-800	0.53	0.47	0.40	0.36	0.33	0.34	0.32	°	°	°	0.47	0.37
AZ 28-750	0.51	0.46	0.44	0.40	0.36	0.33	0.31	°	°	°	0.46	0.41
AZ 30-750	0.47	0.42	0.36	0.32	0.34	0.31	0.29	°	°	°	0.42	0.33
AZ 32-750	0.44	0.39	0.33	0.30	0.27	0.25	0.27	°	°	°	0.39	0.31
AZ 12-770	-	-	1.02	0.92	0.84	0.76	0.73	°	°	°	-	0.95
AZ 13-770	-	-	0.98	0.88	0.80	0.73	0.68	°	°	°	-	0.90
AZ 14-770	1.05	0.93	0.93	0.84	0.76	0.69	0.65	°	°	°	0.93	0.86
AZ 14-770-10/10	1.00	0.89	0.89	0.80	0.73	0.66	0.62	°	°	°	0.89	0.83
AZ 12-700	-	-	1.05	0.95	0.86	0.78	0.77	°	°	°	-	0.98
AZ 13-700	1.09	-	0.96	0.87	0.79	0.72	0.67	°	°	°	-	0.89
AZ 13-700-10/10	1.04	0.93	0.92	0.83	0.76	0.69	0.64	°	°	°	0.93	0.86
AZ 14-700	1.00	0.89	0.75	0.80	0.73	0.66	0.62	°	°	°	0.89	0.82
AZ 17-700	0.98	0.87	0.73	0.66	0.60	0.55	0.53	°	°	°	0.87	0.68
AZ 18-700	0.93	0.83	0.70	0.63	0.57	0.52	0.49	°	°	°	0.83	0.65
AZ 19-700	0.76	0.80	0.67	0.61	0.55	0.50	0.47	0.67	0.61	0.55	0.80	0.62
AZ 20-700	0.73	0.65	0.64	0.58	0.53	0.48	0.45	0.64	0.58	0.53	0.65	0.60
AZ 24-700	0.58	0.51	0.43	0.46	0.42	0.38	0.35	°	°	°	0.51	0.40

- **Charts** tab shows graphically the reduction of the section design parameters, with the increase of the thickness loss due to corrosion. User is able to choose another sheet pile section in this tab and replace initial section previously considered.



2. Checking of the anchorage system

2.1. Description

This example aims to show how to check anchor system with Durability according to Eurocode Standards.

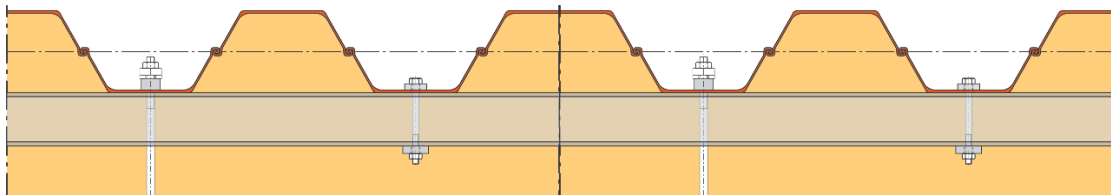
The verification of an anchoring system consists of checking the internal balance of all the steel parts used to take up the force mobilised in the anchorage (tie-rods, waling, plates, swivel plates and forces localised in the sheet pile section).

PU 18+1 S 430 GP has been chosen for head wall. No corrosion is considered.

Anchorage system is composed of:

- Waling behind head wall: **2 x UPN 260 S 235 JR, spacing = 286 mm**
- An horizontal anchor every 2 sheet pile systems: **ASDO355 – M68/52**
 - Front plate
 - Swivel plate supported by bearing plate
- A bolt between 2 anchors fixed to hold sheet pile to the waling : **M45 – ASDO 355**
 - Front plate supported by the sheet pile
 - Back plate supported by the waling

Our case corresponds to Case 7.4 defined by Eurocode 3 – Part 5:



This application considers French standard for safety factor definition.

Geotechnical analysis provides tie-rod axial reaction: 250 kN/m (ULS) and 185 kN/m (SLS).

2.2. Anchor and bolt check

First of all, one has to check the anchor and bolt.

◀ Checking of the anchorage system ▶ +

Sheet pile Corrosion Results LCA **Anchor** Scenario synthesis Uf summary Charts

Tie-rods Sheet piles and plates

☒ Plate verification

Anchor geometry

Z head wall 155.00 m n 2

β 0.00 ° ? Spacing 2.40 m

F Ed, axial 250 kN/m

F t,ser, axial 185 kN/m

Safety factor

γ_{M0} 1.00 γ_{M2} 1.25

γ_{M1} 1.00 $\gamma_{Mt,ser}$ 1.10

Filter

☐ d ini, min 0.00 mm

☐ f y min 0 MPa

Tie-rods

k t 0.60

Tie-rods ASD0355 - M68 / 52

f y 355 MPa

f ua 510 MPa

d ini 68.00 mm

x' 4 mm

A s,ini 30.55 cm²

A g,ini 21.24 cm²

Corrosion

Δd 0.00 mm ?

Verification method

Case 7.4

Anchor verification

N°	Z [m]	Type	Valid	+
1	155.00	Anchor Bolt	✓	✗

✓ The anchoring levels are successfully checked.

Numerical details, tie-rods n°1 (z = 155.00 m)

ULS check

$$F_{t, Rd} = k_t \cdot \frac{f_{ua} A_s}{\gamma_{M2}} = 748 \text{ kN/anchor}$$

$$F_{t, Rd} = \frac{f_y A_g}{\gamma_{M0}} = 754 \text{ kN/anchor}$$

$$F_{t, Rd} = \min(F_{t, Rd}, F_{t, Rd}) = 748 \text{ kN/anchor}$$

$$F_{Ed} = 600 \text{ kN/anchor} \leq 748 \text{ kN/anchor}$$

SLS check

$$F_{t, ser} \leq \frac{f_y A_s}{\gamma_{Mt, ser}} = 986 \text{ kN/anchor}$$

$$F_{t, ser} = 444 \text{ kN/anchor} \leq 986 \text{ kN/anchor}$$

Front Back Z1

Water Anchor Protection Corrosion

Actions MEd

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◀ Checking of the anchorage system ▶ +

Sheet pile Corrosion Results LCA **Anchor** Scenario synthesis Uf summary Charts

Tie-rods Sheet piles and plates

☒ Plate verification

Anchor geometry

Z head wall 155.00 m Spacing 2.40 m

β 0.00 ° ?

F Ed, axial 250 kN/m

F t,ser, axial 185 kN/m

Safety factor

γ_{M0} 1.00 γ_{M2} 1.25

γ_{M1} 1.00 $\gamma_{Mt,ser}$ 1.10

Filter

☐ d ini, min 0.00 mm

☐ f y min 0 MPa

Bolt

k t 0.60

Type All

Bolt M 45 - ASD0 355

f y 355 MPa

f ua 510 MPa

d ini 45.00 mm

x' 3 mm

A s,ini 13.06 cm²

A g,ini 15.90 cm²

Corrosion

Δd 0.00 mm ?

Verification method

Case 7.4

Anchor verification

N°	Z [m]	Type	Valid	+
1	155.00	Anchor Bolt	✓	✗

✓ The anchoring levels are successfully checked.

Numerical details, bolt n°1 (z = 155.00 m)

ULS check

$$F_{t, Rd} = k_t \cdot \frac{f_{ua} A_s}{\gamma_{M2}} = 320 \text{ kN/bolt}$$

$$F_{t, Rd} = \frac{f_y A_g}{\gamma_{M0}} = 565 \text{ kN/bolt}$$

$$F_{t, Rd} = \min(F_{t, Rd}, F_{t, Rd}) = 320 \text{ kN/bolt}$$

$$F_{Ed} = 300 \text{ kN/bolt} \leq 320 \text{ kN/bolt}$$

SLS check

$$F_{t, ser} \leq \frac{f_y A_s}{\gamma_{Mt, ser}} = 421 \text{ kN/bolt}$$

$$F_{t, ser} = 222 \text{ kN/bolt} \leq 421 \text{ kN/bolt}$$

Front Back Z1

Water Anchor Protection Corrosion

Actions MEd

ArcelorMittal

Anchor and bolt are successfully checked.

2.3. Sheet pile and plates check

In **Sheet pile and plates** tab, one may find:

- Synthesis of all the checks to be done and sheet pile properties used in calculation:

Tie-rods **Sheet piles and plates** ☐ Tie-rods ☒ Bolt

Eurocode check details

Sheet pile		Head wall		Bolt fixing	
Shear resistance of flange	Tensile resistance of webs	Tie-rods fixing		Front plate	Back plate
		Front plate	Front swivel		
✓	✓	✓	✓	✓	✓

Head wall
PU 18+1.0

$t_{f, ini}$	12.20 mm	$t_{w, ini}$	9.50 mm
$W_{el, ini}$	1 920 cm ³ /m	$W_{pl, ini}$	2 280 cm ³ /m
b	288.5 mm	α	57.5 °
f_y	430.0 MPa	Class	2 -
h	430.0 mm	c	247.7 mm
r_0	15.0 mm	b_c	mm

- Front bearing plate check for anchor:

Plate **Front**

Steel grade: S 235 f_y 215 MPa

b_a 231 mm h_a 346 mm

t_a 51 mm d 72 mm

Plate

Geometry

$b_a = 231 \text{ mm} \geq 0.8b = 231 \text{ mm}$
 $h_a = 346 \text{ mm} \leq 1.5b_a = 347 \text{ mm}$
 $t_a = 51 \text{ mm} \geq \max\left(\frac{d_A}{3}; 2t_f\right) = 24 \text{ mm}$

Loads

$F_{P,Ed} = 300 \text{ kN} \leq F_{P,M,Rd} = 2t_a^2 \frac{h_a - d}{2b_a - b_{sp} - d} \frac{f_y}{\gamma_{M0}} = 1179 \text{ kN}$
 $F_{P,Ed} = 300 \text{ kN} \leq F_{P,V,Rd} = \frac{2}{\sqrt{3}} h_a t_a \frac{f_y}{\gamma_{M0}} = 4381 \text{ kN}$
 $F_{W,Ed} = 300 \text{ kN} \leq F_{W,M,V,Rd} =$
 $= \frac{2}{3} (-s + \sqrt{s^2 + 3t_a^2})(b_a - d) \frac{f_y}{\gamma_{M0}} = 304 \text{ kN}$

It's important to note that Durability is able to suggest plate dimensions which satisfy all requested criteria (🔴)

According to EN1993-1-1, steel grade have to be reduced when the plate thickness is greater than 40 mm, that's why $f_y=215 \text{ MPa}$ whereas steel grade is S 235.

- Swivel plate for anchor check:

Swivel

Steel grade: S 235 f_y 215 MPa

b_{SP} 130 mm h_{SP} 110 mm

t_{SP} 50 mm d_{SP} 72 mm

W_{SP} 50 mm

Nut

d_{SG} 100 mm e 111 mm

Swivel

Geometry

$b_{SP} = 130 \text{ mm} \leq \max(d_{SG} + 2t_{SP}; e) = 200 \text{ mm}$
 $h_{SP} = 110 \text{ mm} \leq \max(d_{SG} + 2t_{SP}; e) = 200 \text{ mm}$
 $t_{SP} = 50 \text{ mm} \geq \frac{d_A}{2} = 34 \text{ mm}$

Loads

$F_{Ed} = 600 \text{ kN} \leq F_{Rd,1} = \frac{\pi}{2\sqrt{2}} (d_{SG}^2 - w_{SP}^2) \frac{f_y}{\gamma_{M0}} = 1791 \text{ kN}$
 $F_{Rd,1} = 1791 \text{ kN} \leq F_{Rd,2} = \frac{1}{\sqrt{3}} \pi d_{SG} t_{SP} \frac{f_y}{\gamma_{M0}} = 1950 \text{ kN}$
 $F_{Ed} = 600 \text{ kN} \leq F_{loc} = w_{SP}(b_{sp} - d) \frac{f_y}{\gamma_{M0}} = 624 \text{ kN}$

- Bearing plates for bolt definition and check:

Plate ?				Back ?			
Front ?				Back ?			
Steel grade	S 235	f_y	235 MPa	Steel grade	S 235	f_y	235 MPa
b_a	231 mm	h_a	346 mm	b_a	231 mm	h_a	346 mm
t_a	28 mm	d	48 mm	t_a	28 mm	d	48 mm
Nut ?				Nut ?			
d_{SG}	70 mm			d_{SG}	70 mm		

It's important to note that Durability is able to suggest plate dimensions which satisfy all requested criteria (🔄)

Front plate

Geometry

$$b_a = 231 \text{ mm} \geq 0.8b = 231 \text{ mm}$$

$$h_a = 346 \text{ mm} \leq 1.5b_a = 347 \text{ mm}$$

$$t_a = 28 \text{ mm} \geq \max\left(\frac{d_A}{3}; 2t_f\right) = 24 \text{ mm}$$

Loads

$$F_{Ed} = 300 \text{ kN} \leq F_{M,N,Rd} =$$

$$= \frac{2}{3} \left[-(b_a - d') + \sqrt{(b_a - d')^2 + 3t_a^2} \right] (h_a - d) \frac{f_y}{\gamma_{M0}} = 313 \text{ kN}$$

$$F_{Ed} = 300 \text{ kN} \leq F_{Rd,I,1} = \frac{\pi}{2\sqrt{2}} (d_{SG}^2 - d^2) \frac{f_y}{\gamma_{M0}} = 678 \text{ kN}$$

$$F_{Rd,I,1} = 678 \text{ kN} \leq F_{Rd,I,2} = \frac{1}{\sqrt{3}} \pi \cdot d_{SG} \cdot t_a \frac{f_y}{\gamma_{M0}} = 835 \text{ kN}$$

Back plate

Geometry

$$b_a = 231 \text{ mm} \geq 0.8b = 231 \text{ mm}$$

$$h_a = 346 \text{ mm} \leq 1.5b_a = 347 \text{ mm}$$

$$t_a = 28 \text{ mm} \geq \max\left(\frac{d_A}{3}; 2t_f\right) = 24 \text{ mm}$$

Loads

$$F_{Ed} = 300 \text{ kN} \leq F_{M,N,Rd} =$$

$$= \frac{2}{3} \left[-(b_a - d') + \sqrt{(b_a - d')^2 + 3t_a^2} \right] (h_a - d) \frac{f_y}{\gamma_{M0}} = 313 \text{ kN}$$

$$F_{Ed} = 300 \text{ kN} \leq F_{Rd,I,1} = \frac{\pi}{2\sqrt{2}} (d_{SG}^2 - d^2) \frac{f_y}{\gamma_{M0}} = 678 \text{ kN}$$

- Sheet pile check at the anchor level

Sheet pile

Shear resistance of flange (EC3-5 §7.4.3 (3a))

$$R_{Vf,Rd} = 2(b_a + h_a)t_f \frac{f_y}{\sqrt{3}\gamma_{M0}} = 3495 \text{ kN}$$

$$F_{Ed} = 300 \text{ kN} \leq R_{Vf,Rd} = 3495 \text{ kN}$$

Tensile resistance of webs (EC3-5 §7.4.3 (3b))

$$R_{tw,Rd} = 2h_a t_w \frac{f_y}{\gamma_{M0}} = 2827 \text{ kN}$$

$$F_{Ed} = 300 \text{ kN} \leq R_{tw,Rd} = 2827 \text{ kN}$$