Durability

A. User manual

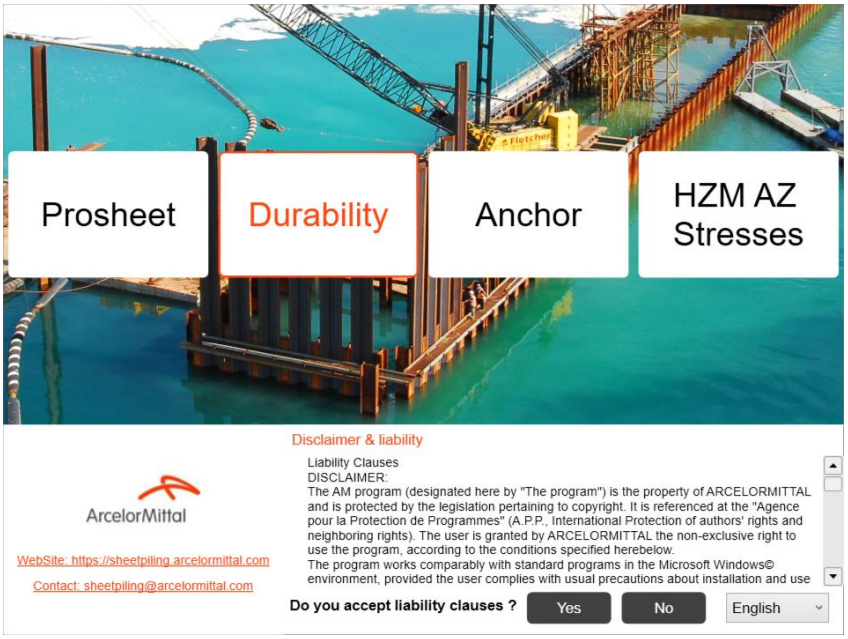
1. Introduction

The aim of ArcelorMittal is to provide the industry a valuable, user-friendly, and state-of-the-art software to design a cost-effective steel sheet pile wall.

The key objective of the design engineer is to choose the most cost-effective sheet pile solution considering the different aspects that influence the structure safety during its lifetime.

Durability is a software that simplifies the choice of a steel sheet pile section taking into account the durability of steel in different environment and the service life of the sheet pile structure.

Durability is integrated in a multi-modules software including Prosheet, HZ®-M/AZ Stresses and Anchor which aims to verify anchor systems.



Durability proposes many interesting features as listed below:

- Loads on the sheet pile wall sections can be defined throughout the sheet pile length
- Different corrosion zones may be defined as well as protection zones
- Water level may be different in front and at the back of sheet pile
- A complete project can be verified by defining the Head wall and Anchor wall
- Explicit numerical checks are presented for each level according to the calculation method chosen
- Several “Scenarios” may be tested and compared in the same project
- All sheet piles from ArcelorMittal catalogue may be checked automatically for the same loading conditions
- Anchor rods, plates and waling are also checked for several cases
- Imperial and metric unit system are implemented
- Available filters allow to easily find the valid sheet piles for the defined project
- Numerous input data controls are integrated in the software to avoid inconsistencies

It is important to note that the user has to read and validate **Disclaimer and liability** clauses before launch the software.

Durability may be launched in several languages, please choose the one that suits you best.

Please, don’t hesitate to contact ArcelorMittal team by mail (sheetpiling@arcelormittal.com) for further information or questions and don’t forget to visit ArcelorMittal website: https://sheetpiling.arcelormittal.com to check the updates.

2. Generalities

Durability propose a user-friendly interface to define and check several sheet pile solutions. Software is divided in two different calculations:

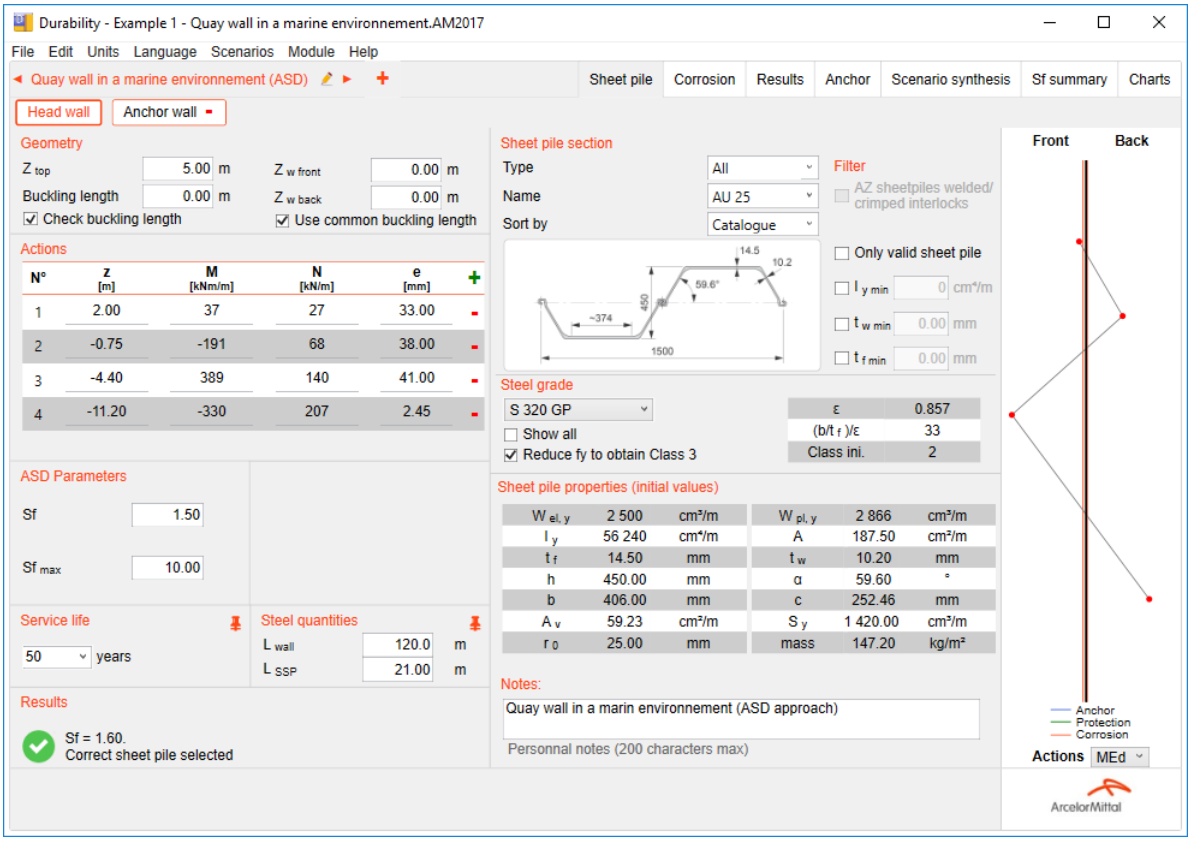
- Sheet pile verification
- Anchor fixation system verification

Sheet pile section may be checked by two different design approaches:

- **Eurocode 3 – Part 5** (EC3-5)
- **Allowable Stress Design** (ASD)

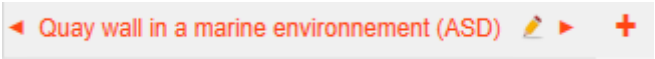
Anchor fixation system may be checked by Eurocode 3 – Part 5 and ASD for both types of the sheet pile section:

Following chapters will show the different options and assumptions that have been implemented in the software for each calculation method.



2.1. Scenario management

Durability allows multiple and independent calculations in the same project. Each independent calculation is called **Scenario**. The idea is to be able to compare several solutions for the same cross-section or the same project.



 To create a new scenario

 To edit scenario name

 To move from one scenario to another

Scenarios menu propose:

- Delete current scenario
- Duplicate current scenario: create a new current scenario with the same input data from current scenario

It's possible to define common or specific parameters as partial safety and reduction factors, service life and steel quantities with:

- Input parameters are common for all scenarios
- Input parameters are specific to the current scenario

If the parameters are common for all scenarios, they can be changed only in the first scenario.

Each scenario is organized in several tabs, each one dedicated for one purpose:

- **Sheet pile**: definition sheet pile section to be used in calculation.
- **Corrosion**: define loss of thickness of steel to deduce reduced properties.
- **Results**: show all explicit numerical checks for each loading level.
- **LCA**: provide an environmental product declaration.
- **Anchor**: provide all numerical checks required to verify all anchor system fixation items.
- **Scenario synthesis**: summarize all mean results of each scenario
- **Uf/Sf summary**: provide utilization factor or safety factor for each sheet pile section and steel grade available on ArcelorMittal catalogue
- **Charts**: show graphically and numerically some sheet pile section properties for different loss of thickness

Following chapters will show the different options available in each tab.

2.2. Calculation methods

User can choose between the two designs approaches:

1. **Allowable Stress Design (ASD)**
2. **Eurocode 3 – Part 5**

This choice has to be made in Scenario menu, then Design approach.

It's possible to switch between these two approaches at any time during the design. The data concerned by the two approaches will be kept.

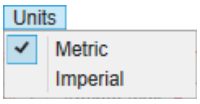
2.3. Walls

Durability include the possibility to handle two independent walls in the same scenario. This feature aims to calculate Head wall and Anchor wall in the same scenario. Head wall will be always be activated. Anchor wall is deactivated by default, but may be activated with + button and deleted with - button. The same input parameters will be required for the two walls, as well as results obtained.

2.4. Unit systems

The user can either work in **metric units** (SI system) or in **imperial units** (usual in the United States).

It's possible to switch unit system from Units menu.



2.5. ArcelorMittal catalogue

The last ArcelorMittal catalogue version is integrated. It's important to note that only "regular" hot rolled sheet piles Z-type and U-type are handled.

3. Sheet pile tab

Sheet pile tab is the first one to be filled. It allows to choose the sheet pile section and define all basic input data needed for calculation. It's composed by different section:

- Geometry
- Actions
- Service life
- Steel quantities
- Sheet pile section
- Steel grade
- Sheet pile properties (initial values)
- Notes
- Sketch

For ASD approach, there is an additional section:

- ASD Parameters

For EC3-5 approach, there are two additional sections:

- Partial safety
- Reduction factors

The following sub-chapters detail each input parameter.

3.1. Geometry

Sheet pile and water level will be characterized geometrically by following parameters:

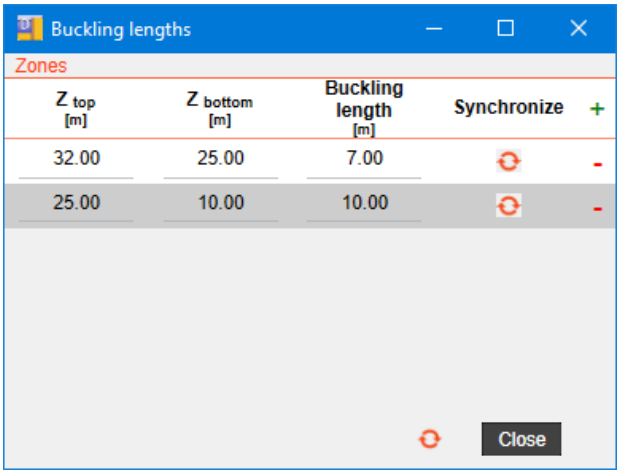
Property	Metric (SI)	Imperial	Description
z_{top}	m	ft	Top of the sheet pile
$z_{w,\,front}$	m	ft	Water level on the front of sheet pile
$z_{w,back}$	m	ft	Water level on the front of sheet pile

For EC3-5 approach, buckling length may be defined if there is any axial load N_{Ed} not null.

It's possible to consider the same value for all load levels with *Use common buckling length* checkbox.

3.1.1. Buckling lengths wizard

If we have chosen a buckling length which is not common, we can choose to define zones to be able to fill the buckling lengths by clicking on . A wizard will open allowing the user to configure zones for buckling lengths :



Screenshot of buckling length zone wizard

We can create lines in the table by clicking on the +. For each zone, we can define Z top, Z bottom and the desired buckling length. The user can then synchronize each zone or all of them at the same time by clicking on .

3.2. Actions

Several actions can be defined at different levels throughout the sheet pile.

Property	Metric (SI)	Imperial	Description
z	m	ft	Load level
M_{Ed}	kNm/m	kip*ft/ft	Design value of bending moment derived from geotechnical calculation
V_{Ed}	kN/m	kip/ft	Design value of shear derived from geotechnical calculation (only available for EC3-5 approach)
N_{Ed}	kN/m	kip/ft	Design value of axial force derived from geotechnical calculation (only compression is allowed)
Buckling length	m	ft	Buckling length (only if *Use common buckling length* is unchecked)
e	mm	in	Eccentricity of axial load

Levels can be ordered by clicking on *z* colon head.

3.3. Safety factors

This section is only available for ASD approach.

Property	Metric (SI)	Imperial	Description
$S_{f,\min}$	-	-	Target global safety factor (minimal desired value) on steel grade
$S_{f,\max}$	-	-	Maximal value of global safety factor on steel grade

3.4. Partial safety factors

This section is only available for EC3-5 approach.

These factors can either be determined by selecting a national application standard (NAD UK, NAD FR or EN 1993-5) or defined by the user (*Project specific*). When approach is selected, partial safety factors default values are provided.

Parameter	Unit	Imperial Unit	Description
γ_{M0}	-	-	Partial safety factor according to EC3-5 §5.1.1 (4)
γ_{M1}	-	-	Partial safety factor according to EC3-5 §5.1.1 (4)

It's possible to define common or specific partial safety factors among scenarios:

- Partial safety factors are common for all scenarios
- Partial safety factors are specific to the current scenario

3.5. Reduction factors

This section is only available for EC3-5 approach. Reduction factors will be used only for U-piles.

Parameter	Unit	Imperial Unit	Description
β_B	-	-	Applied to the bending moment resistance
β_D	-	-	Applied to the moment of inertia

Some tables are accessible clicking on *Show tables* to help user to choose the correct values. Currently, available tables are: Germany, France, Great Britain and Belgium. It's possible to switch from one to another in the pop-up by changing the country on the Durability main board.

It's important to know that even if Z-pile is choose, beta reduction factors will be applied U-piles evaluated in Uf/Sf summary tab, that's why they are requested.

It's possible to define common or specific reduction factors among scenarios:

- Reduction factors are common for all scenarios
- Reduction factors are specific to the current scenario

3.6. Service life

Service life of project is defined in years. It is used to deduce total corrosion in case of corrosion is defined by rates. There are some values suggested on the list, but user is able to define any integer value.

It's possible to define common or specific service life among scenarios:

- Service life is common for all scenarios
- Service life is specific to the current scenario

3.7. Steel quantities

This section allows to define wall dimensions for weight calculation and EPD design.

Parameter	Unit	Imperial Unit	Description
L_{wall}	m	ft-	Length of wall
L_{SSP}	m	ft	Length of sheet pile

It's possible to define common or specific steel quantities among scenarios:

- Steel quantities is common for all scenarios
- Steel quantities is specific to the current scenario

3.8. Sheet pile section

This section allows to choose the sheet pile section to be taken into account in calculation.

One can find here ArcelorMittal catalogue for "regular" hot rolled sheet piles Z-type and U-type, in particular:

- AZ-800
- AZ-750
- AZ-770/700
- AZ
- AU
- PU
- GU
- Old sections (not produced anymore but available to check old projects)

It is possible to write in the input fields, this makes it easier to find the desired profile.

They can be sorted by catalogue, by weight, by section modulus and by moment of inertia.

AZ common interlcokes crimped/welded will be available only if $\left|z_{w,\,front} - z_{w,back}\right| \geq 5\ m$. In the case of differential water pressure exceeding 5 m head for Z-piles and 20 m head for U-piles, the effects of water pressure on bending should be taken into account to determine the overall bending resistance. Reduction is quantified by ρ_P factor. If piles are welded or crimped, no reduction has to be considered, so $\rho_P = 1.0$.

EC3-5 authorizes to use plastic section modulus for Class 1 and 2. If user don't want do this choice, please uncheck ***Use Wel only***. Of course, this checkbox is only available for EC3-5 approach.

Durability integrates an interesting and useful feature named ***Only valid sheet pile***. If it's checked, Durability will suggest only sheet pile sections and steel grades that verify all requested conditions for each load level defined taken into account corrosion and protection defined in the Corrosion tab.

Some useful filters are also integrated to target sheet piles sections that respect one or more criteria simultaneously:

- a minimum value of moment of inertia
- a minimum value of wall thickness
- a minimum value of flange thickness

Charts tab shows different properties of all profiles and steel grades (W_{el} & W_{pl}, I_y, A, $M_{c,Rd}$, $M_{V,Rd}$) as function of loss of thickness.

Only available steel grades for the chosen sheet pile section are suggested. All steel grades appears if **Show all** option is checked, even if they are not available for the chosen sheet pile section.

Durability doesn't calculate Class 4 sections, but propose to handle them as Class 3 sections with reduced steel grade. More details are available in technical manual. If **Reduce fy to obtain Class 3** is unchecked, Class 4 section will not be calculated.

All initial property values are displayed in the table for the selected sheet pile, before corrosion is applied.

User can input some **notes** for each scenario to specify some additional information. This can be useful if the project is shared with someone.

As actions are defined, **graph** on the right is updated to indicate the position and value of the displayed action. This graph is also visible in the corrosion tab, that's why it also display corrosion and protection. A tooltip is shown when the mouse approach to the diagram.

Results section displays the most unfavourable:

- Safety factor for ASD approach (minimal value)
- Utilization factor for EC3-5 approach (maximal value)

If there is empty data, an information message will be displayed. A tooltip with more detailed information is shown when the mouse approach to the message.

4. Corrosion tab

This tab allows to define loss of steel thickness and protection to be considered throughout sheet pile. Durability handle different zones of corrosion and protection.

Corrosion and protection are defined by zones throughout the sheet pile and by side (Front/Back). Zones are characterized by its bottom level z_{bottom}. This is useful to distinguish several zones where sheet pile is in contact with different environnement as well as different protection is considered. Total corrosion columns, on the right, summarize total loss of thickness taken into account in calculation of reduced properties. Of course, one can define different corrosion and protection for the Head wall and Anchor wall. Diagram on the right will display total corrosion and protection values for each wall.

Corrosion rates can be defined either from Eurocode 3 – Part 5 or manually.

4.1. Corrosion

4.1.1. Eurocode 3 – Part 5 corrosion rates

- Eurocode 3 – Part 5 Table 4.1 and 4.2

Loss of steel

Years	0	5	25	50	75	100
Atmospheric						
Atm. Normal atmospheres	0.00	0.05	0.25	0.50	0.75	1.00
Atm. Locations close to the sea	0.00	0.10	0.50	1.00	1.50	2.00
Soil						
Soil. Undisturbed natural soils (sand, silt, clay, schist, ...)	0.00	0.00	0.30	0.60	0.90	1.20
Soil. Polluted natural soils and industrial grounds	0.00	0.15	0.75	1.50	2.25	3.00
Soil. Aggressive natural soils (swamp, marsch, peat, ...)	0.00	0.20	1.00	1.75	2.50	3.25
Soil. Non-compacted and non-aggressive fills (clay, schist, sand, silt, ...)	0.00	0.18	0.70	1.20	1.70	2.20
Soil. Non-compacted and aggressive fills (clay, schist, sand, silt, ...)	0.00	0.50	2.00	3.25	4.50	5.75
Soil. Compacted and non-aggressive fills (clay, schist, sand, silt, ...)	0.00	0.09	0.35	0.60	0.85	1.10
Soil. Compacted and aggressive fills (ashes, slag, ...)	0.00	0.25	1.00	1.63	2.25	2.88
Water						
Water. Common fresh water (river, ship canal, ...) in the zone of high attack (water line)	0.00	0.15	0.55	0.90	1.15	1.40
Water. Very polluted fresh water (sewage, industrial effluent, ...) in the zone of high attack (water line)	0.00	0.30	1.30	2.30	3.30	4.30
Water. Sea water in temperate climate in the zone of high attack (low water and splash zone)	0.00	0.55	1.90	3.75	5.60	7.50
Water. Sea water in temperate climate in the zone of permanent immersion or in the intertidal zone	0.00	0.25	0.90	1.75	2.60	3.50

- Eurocode 3 – Part 5 NAD UK (2010. Table 4.1 and 4.2

Loss of steel

Years	0	5	25	50	75	100	125
Atmospheric							
Atm. Normal atmospheres	0.00	0.05	0.25	0.50	0.75	1.00	1.25
Atm. Locations close to the sea	0.00	0.10	0.50	1.00	1.50	2.00	2.50
Soil							
Soil. Undisturbed natural soils (sand, silt, clay, schist, ...)	0.00	0.00	0.30	0.60	0.90	1.20	1.50
Soil. Polluted natural soils and industrial grounds	0.00	0.15	0.75	1.50	2.25	3.00	3.75
Soil. Aggressive natural soils (swamp, marsch, peat, ...)	0.00	0.20	1.00	1.75	2.50	3.25	4.00
Soil. Non-compacted and non-aggressive fills (clay, schist, sand, silt, ...)	0.00	0.18	0.70	1.20	1.70	2.20	2.70
Soil. Non-compacted and aggressive fills (clay, schist, sand, silt, ...)	0.00	0.50	2.00	3.25	4.50	5.75	7.00
Soil. Compacted and non-aggressive fills (clay, schist, sand, silt, ...)	0.00	0.09	0.35	0.60	0.85	1.10	1.35
Soil. Compacted and aggressive fills (ashes, slag, ...)	0.00	0.25	1.00	1.63	2.25	2.88	3.50
Water							
Water. Common fresh water (river, ship canal, ...) in the zone of high attack (water line)	0.00	0.15	0.55	0.90	1.15	1.40	1.65
Water. Very polluted fresh water (sewage, industrial effluent, ...) in the zone of high attack (water line)	0.00	0.30	1.30	2.30	3.30	4.30	5.30
Water. Sea water in temperate climate in the zone of high attack (low water and splash zone)	0.00	0.55	1.90	3.75	5.60	7.50	9.40
Water. Sea water in temperate climate in the zone of permanent immersion or in the intertidal zone	0.00	0.25	0.90	1.75	2.60	3.50	4.40

Show table button allows to display the table for the set value selected). All values correspond to the total loss for each length of time (in years) for each exposure category.

4.1.2. Manual definition

There are two possibilities:

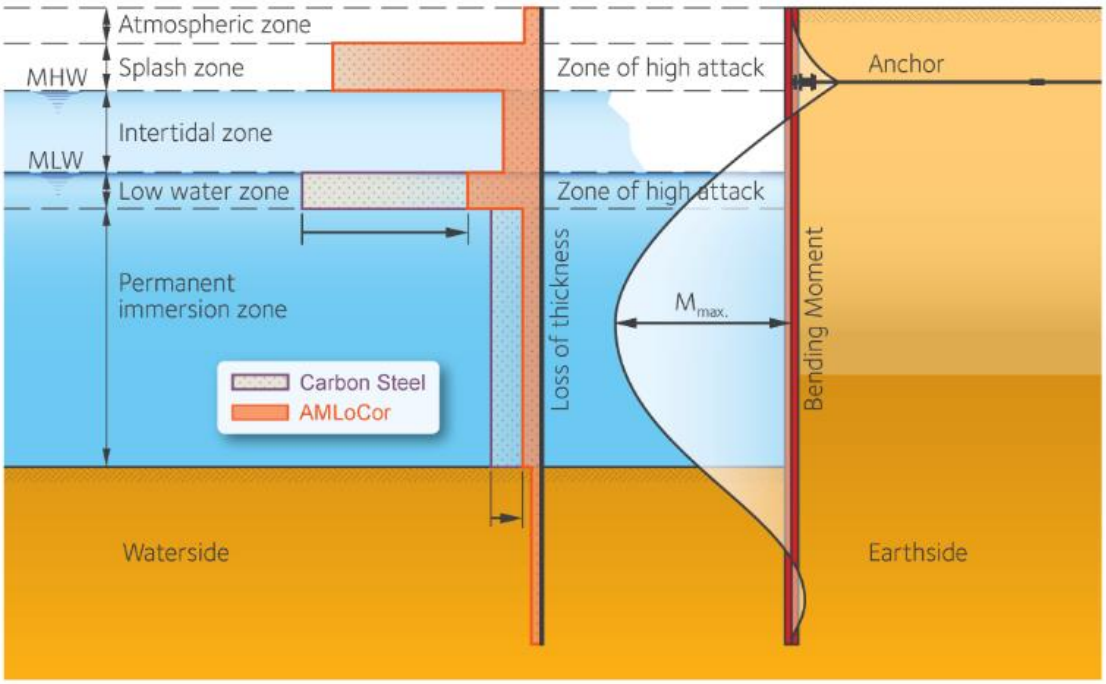
- Corrosion definition by **rates** (mm/year or mils): input value will be multiplied by service life defined previously in *Sheet pile tab* to obtained total loss.
- Corrosion **total loss** (mm o mils): in this case, it doesn't make sense to define protection, that's why two dedicated columns are hidden.

4.1.3. CIR

If AMLocor steel grade is chosen, one has to define Corrosion Impediment Ratio (please, read Technical manual for more information). One can define a different value of CIR for each side (Front/Back).

Please, note that CIR should be only applied on sea water zone, that's why its definition is only available for:

- *Sea water in temperate climate in the zone of high attack (low water and splash zone)*
- *Sea water in temperate climate in the zone of permanent immersion or in the intertidal zone*



4.2. Protection

Protection is measured in years and has to be defined per side. Its value will be taken into account as a reduction of period of time during which there is no loss of thickness. Therefore, total corrosion will be calculated as corrosion rate during service life minus protection time.

5. Results tab

Results tab show all numerical checks related with each loading level defined in *Sheet pile tab*. Obviously, numerical details will be different depending on the approach used (ASD or Eurocode 3 – Part 5).

First of all, one can find a table summarizing each loading level, every check associated and safety factor (Sf) for ASD or utilization factor (Uf) for Eurocode 3- Part 5.

- Eurocode 3 – Part 5 approach:

Results

N°	z [m]	Bending	Bending & shear	Web shear buckling	Buckling	Bending & axial	Bending & shear & axial	Uf
1	2.00	✓	✓	✓	✓	✓	-	0.07
2	-0.75	✓	✓	✓	✓	✓	-	0.38
3	-4.40	✓	✓	✓	✓	✓	-	0.73
4	-11.20	✓	✓	✓	✓	✓	-	0.62
Synthesis		✓	✓	✓	✓	✓	-	**0.73**

The most critical value of utilization factor (maximum value) is displayed in the synthesis line.

- ASD approach:

Results

N°	z [m]	ASD	Sf
1	2.00	✓	9.55 > 1.50
2	-0.75	✓	1.96 > 1.50
3	-4.40	✗	0.96 < 1.50
4	-11.20	✗	1.11 < 1.50
Synthesis		✗	**0.96**

The most critical value of safety factor (minimum value) is displayed in the synthesis line.

One can click on each line to display associated numerical details below (level is permanently specified).
A red-cross ✗ besides a result indicates that this criteria is not met with chosen combination section / steel grade.

Eurocode 3 – Part 5 approach

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

Bending

✗ $M_{Ed} = 2000\,kNm/m > M_{c,Rd} = 536\,kNm/m$

$W_{el} = 2094\,cm^3/m$

Bending & shear

$V_{Ed} = 317\,kN/m \leq V_{pl,Rd} = 842\,kN/m$

$V_{Ed} = 317\,kN/m \leq 0.50\,V_{pl,Rd} = 421\,kN/m$

No further verification needed

Web shear buckling

$\frac{c}{t_w \cdot \varepsilon} = 37.5 < 72$

No verification required. Ok!

Buckling

$N_{Ed} = 680\,kN/m \leq N_{pl,Rd} = 4992\,kN/m$

$N_{cr} = 8375\,kN/m$ $\quad \frac{N_{Ed}}{N_{cr}} = 0.081 > 0.04$

$\alpha = 0.760$ $\quad \bar{\lambda} = 0.772$ $\quad \phi = 1.015$ $\quad \chi = 0.597$

✗ $\frac{N_{Ed}}{\chi N_{pl,Rd}} + 1.15\frac{M_{Ed}}{M_{c,Rd}} = 4.52 > \frac{\gamma_{M0}}{\gamma_{M1}} = 0.91$

Bending & axial

$N_{Ed} = 680\,kN/m > k_1 N_{pl,Rd} = 499\,kN/m$ *with* $k_1 = 0.10$

$M_{N,Rd} = k_2 M_{c,Rd}(1 - \frac{N_{Ed}}{N_{pl,Rd}}) = 463\,kNm/m$ *with* $k_2 = 1.00$

✗ $M_{Ed} = 2000\,kNm/m > M_{N,Rd} = 463\,kNm/m$

Bending & shear & axial

$N_{Ed} = 680\,kN/m > k_1 N_{pl,Rd} = 499\,kN/m$ *with* $k_1 = 0.10$

$V_{Ed} = 317\,kN/m \leq 0.50\,V_{pl,Rd} = 421\,kN/m$

ASD approach

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

Allowable Stress Design (ASD)

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

$\sigma_{applied} = \frac{389\,kNm/m}{1249 \cdot 10^{-6}\,m^3/m} + \frac{140\,kN/m \cdot 0.04\,m}{1249 \cdot 10^{-6}\,m^3/m} + \frac{140\,kN/m}{84.85 \cdot 10^{-4}\,m^2}$

$\sigma_{applied} = = 332.6\,MPa$

$\sigma_{allowable} = \frac{f_y}{S_f} = \frac{320.00\,MPa}{1.50} = 213.3\,MPa$

✗ $\sigma_{applied} = 332.6\,MPa > \sigma_{allowable} = 213.3\,MPa$

$S_f = 0.96 \leq 1.50$

On the left, one can find calculation values of selected sheet pile properties.

In case of Eurocode 3 – Part 5 approach, one can find section classification properties, in particular the reduction from class 4 to class 3. In other words. In fact, this case can occur in two situations:

- If reduced class is 4, it will be converted to reduced class 3 with reduced f_y.

Section classification

Property	Ini.	Red.	Red. class 3
f_y	320.00	320.00	124.38
ε	0.857	0.857	1.375
$(b/t_f)/\varepsilon$	48	79	49
Class	3	4	3

Classification de la palplanche

Propriété	Ini.	Réd.	Classe 3 réd.
f_y	320.00	320.00	124.38
ε	0.857	0.857	1.375
$(b/t_f)/\varepsilon$	48	79	49
Classe	3	4	3

- If initial class is 4, it will be converted to initial class 3 with reduced f_y. The loss of thickness due to corrosion could result in a reduced class 4, which would be converted into reduced class 3 with reduced f_y.

Section classification

Property	Ini.	Red.	Ini. class 3	Red. class 3
f_y	430.00	430.00	395.22	206.90
ε	0.739	0.739	0.771	1.066
$(b/t_f)/\varepsilon$	69	96	66	66
Class	4	4	3	3

Classification de la palplanche

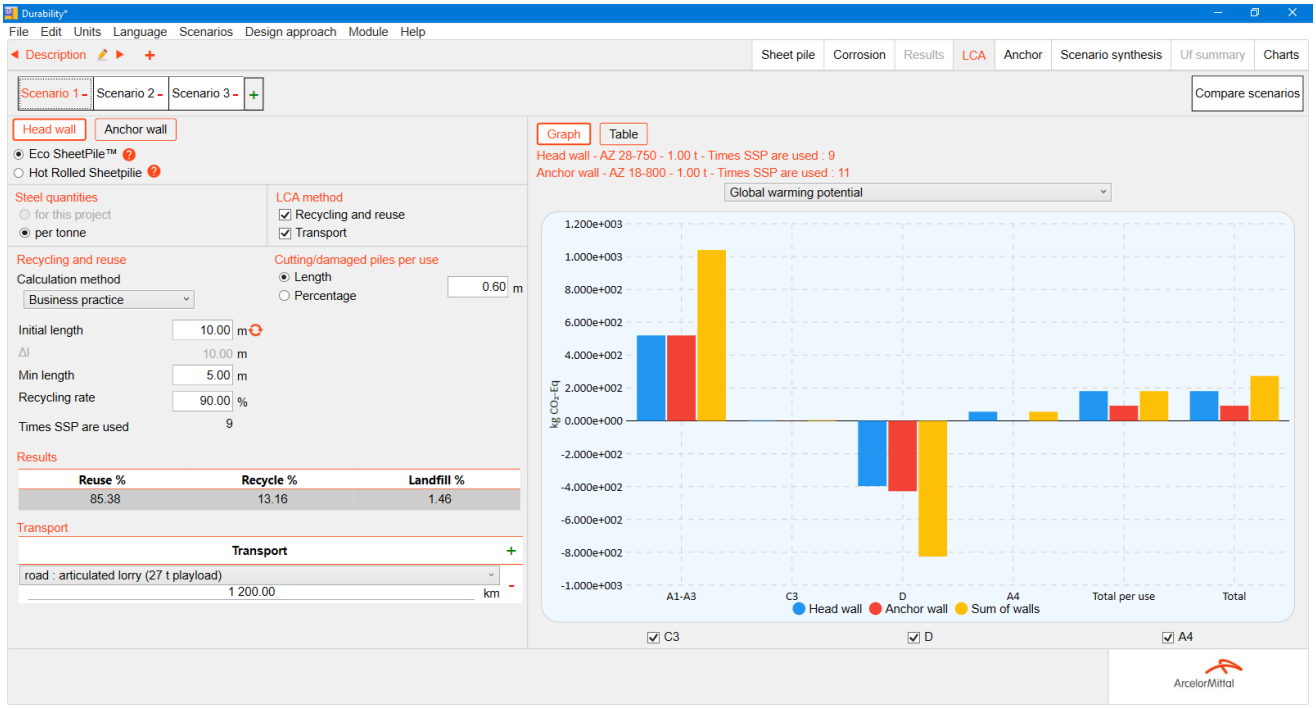
Propriété	Ini.	Réd.	Classe 3 Ini	Classe 3 réd.
f_y	430.00	430.00	395.22	206.90
ε	0.739	0.739	0.771	1.066
$(b/t_f)/\varepsilon$	69	96	66	66
Classe	4	4	3	3

Below, one can find initial and reduced properties for the selected sheet pile. Obviously, reduced properties only appears if corrosion has been defined on *Corrosion tab* for the selected loading level.

On the right, the most critical result among all loading levels is displayed, either safety factor (Sf) for ASD approach or utilization factor (Uf) for Eurocode 3 – Part 5.

6. LCA tab

This tab is dedicated to calculate EPD (Environmental Product Declaration). Several scenarios can be examined.



LCA tab screenshot

6.1. Definition parameters

User can choose if calculation has to be done either for steel quantities already defined in *Sheet pile* tab or per ton.

One can activate *recycling and reuse* calculation and *Transport*.

6.1.1. Options

Use can choose which wall he wants to calculate if the project contains a head wall and an anchor wall. If both walls are calculated, the sum of walls will appear on the graphs.

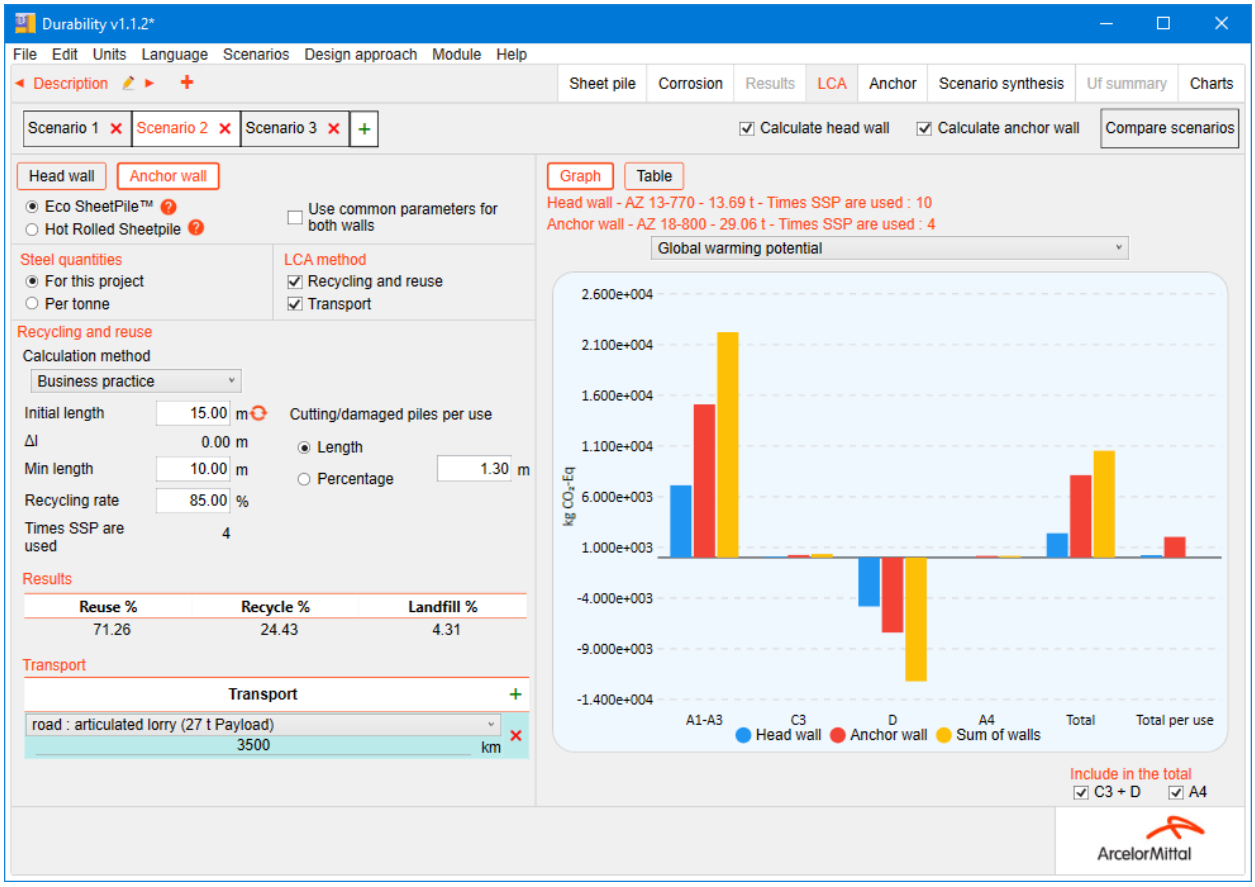
He can also choose to keep the same options on the anchor wall as the ones chosen on the head wall.

6.1.2. Recycling and reuse

3 calculation methods can be used :

- Business practice
- Reuse/recycle %
- Number of cycles

6.1.2.1. Business practice



Screenshot of LCA scenario with Business practice calculation method

Initial length can be taken from *Sheet pile* tab by clicking on ↻. It can be increased by ΔL to reach real length used for the project.

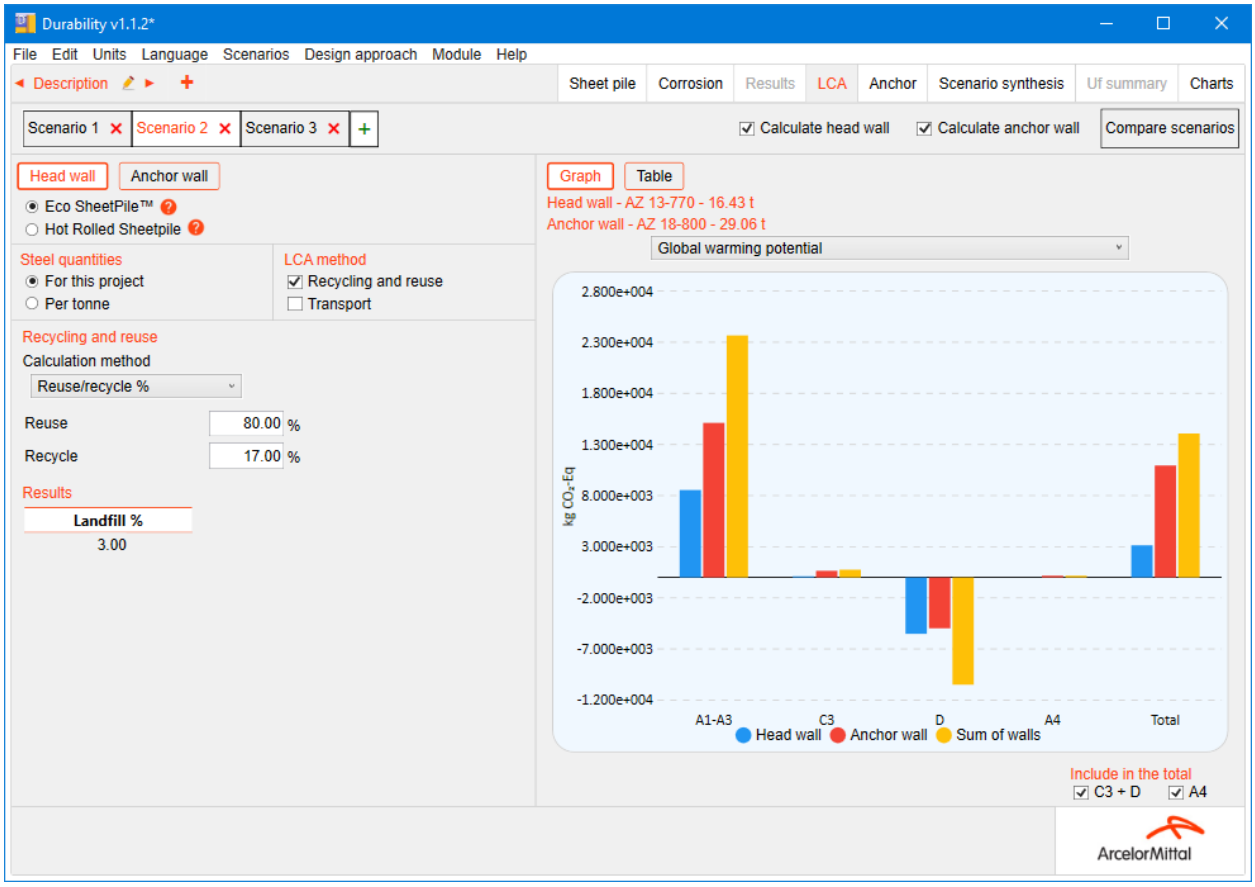
The min length is the minimum length of the sheet pile

Recycling rate corresponds to rate that cutting/damaged length may be recycled.

The times SSP are used is calculated based on the cutting length and the initial length.

Cutting/damaged piles per use can be defined either by length or by percentage of initial length.

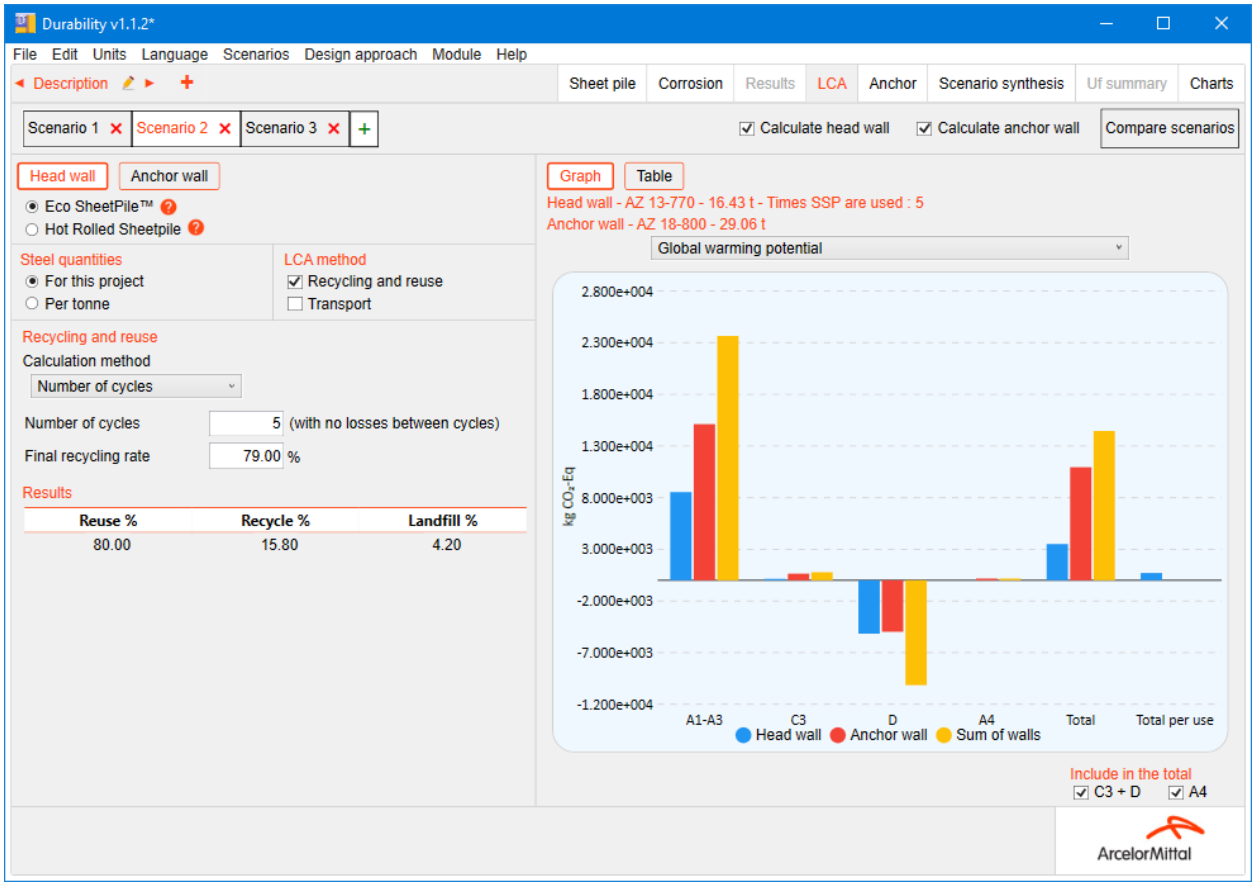
6.1.2.2. Reuse/recycle %



Screenshot of LCA scenario with Reuse/recycle % calculation method

On this method, only reuse and recycle % are asked. Landfill is calculated based on those two inputs.

6.1.2.3. Number of cycles



Screenshot of LCA scenario with number of cycles calculation method

The number of cycles method allows the used to enter the number of cycles and the final recycling rate.

6.1.3. Transport

Different transports may be taken into account in EPD calculation (road, rail and water).

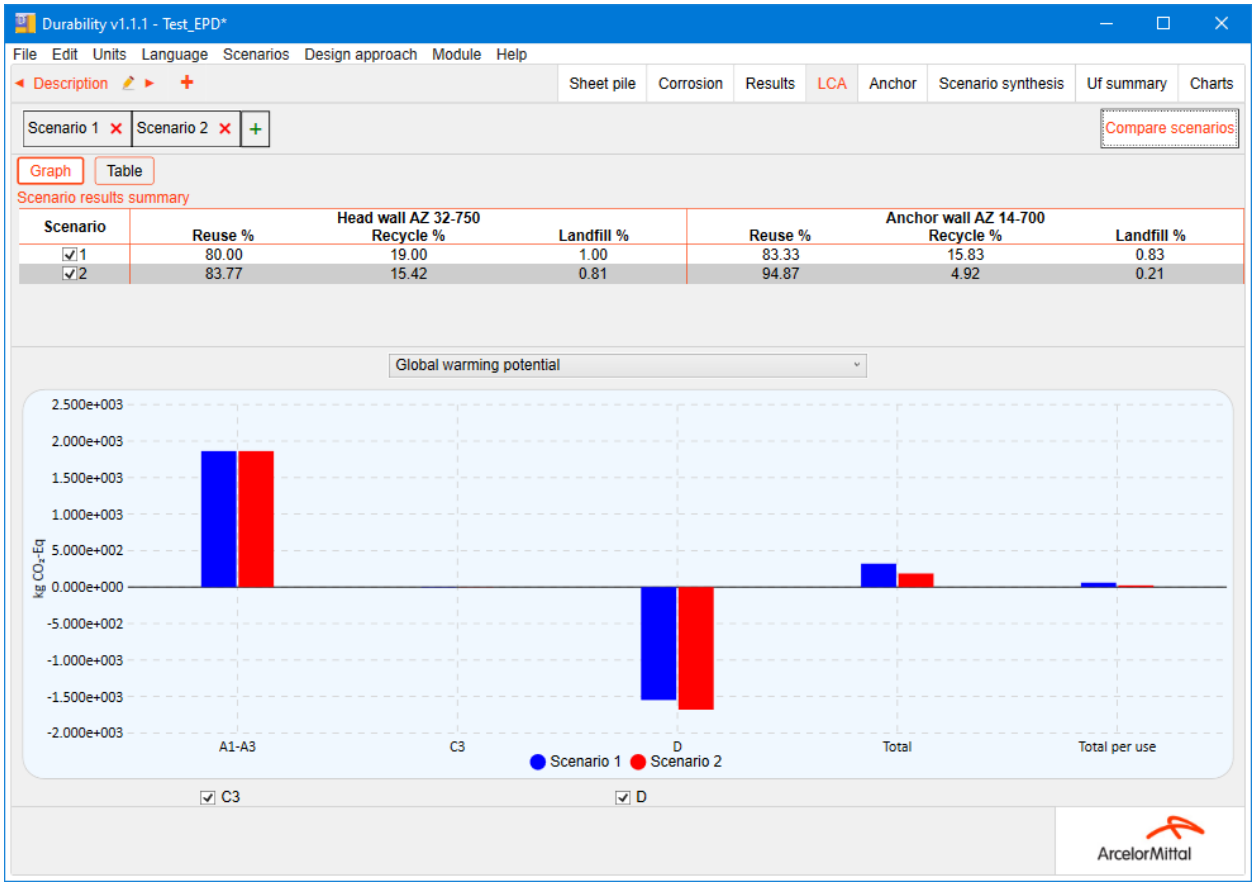
Every transport can be associated to a different total distance among all times sheet pile is used.

6.2. Results

Reuse, recycle and landfill are calculated from input values. See Part B of this manual for technical information about calculation.

On the right side, one can find graph and table values after calculation. Individual quantities may be shown directly on the graph for Head wall and Anchor wall as well as total per use and absolute total.

Comparison button allows to compare several scenario at the same time (graph and tables are available). It's important to note that sum of quantities associated to Head wall and Anchor wall are shown on the graph for each scenario.



7. Anchor tab

This tab is dedicated to all the checks related to anchoring.

In anchor tab, one can find two tabs inside:

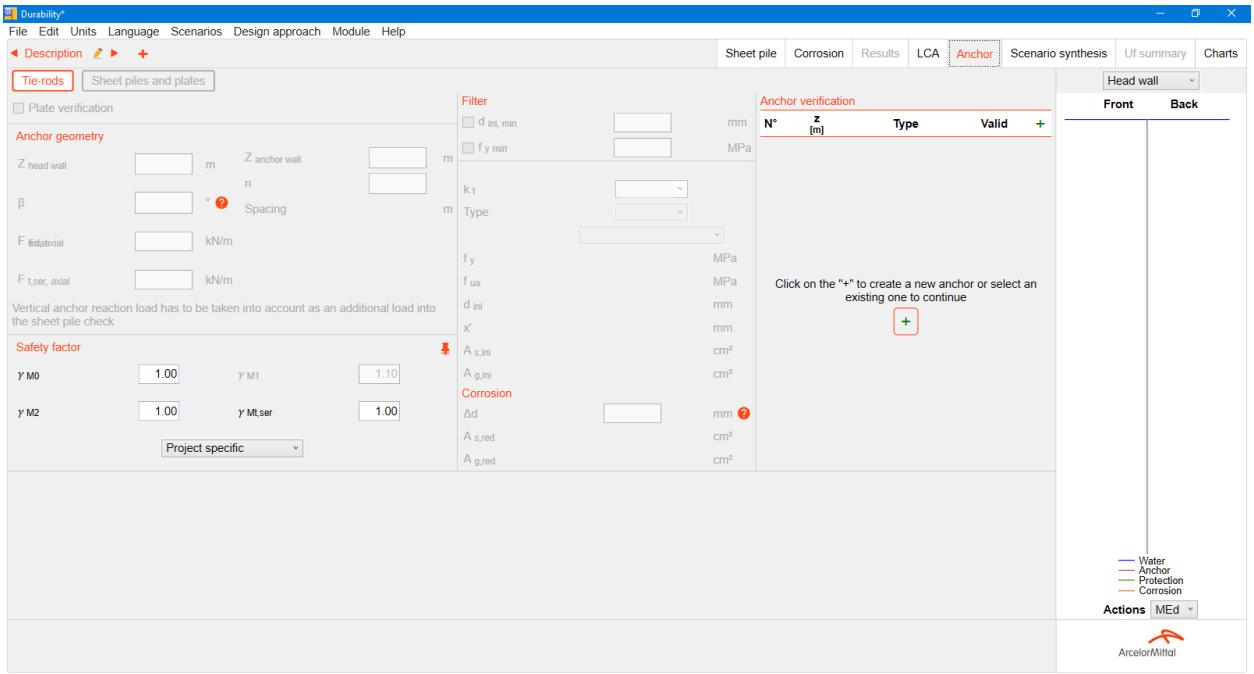
- **Anchor**: input data for anchorage and anchor and bolt checks.
- **Sheet piles and plates**: check of all items related to anchorage (bearing plates, swivel plates, sheet pile, waling) concerning Head wall as well as Anchor wall.

Technical information is available in Part B of this manual.

Please, don't hesitate to show help images by clicking on ❓ buttons, especially for *Sheet piles and plates* tab inside *Anchor tab.*

7.1. Anchor tab

First of all, one has to create a new anchor level with ➕ button place on the right of window.



Screenshot of the anchor tab when first opened

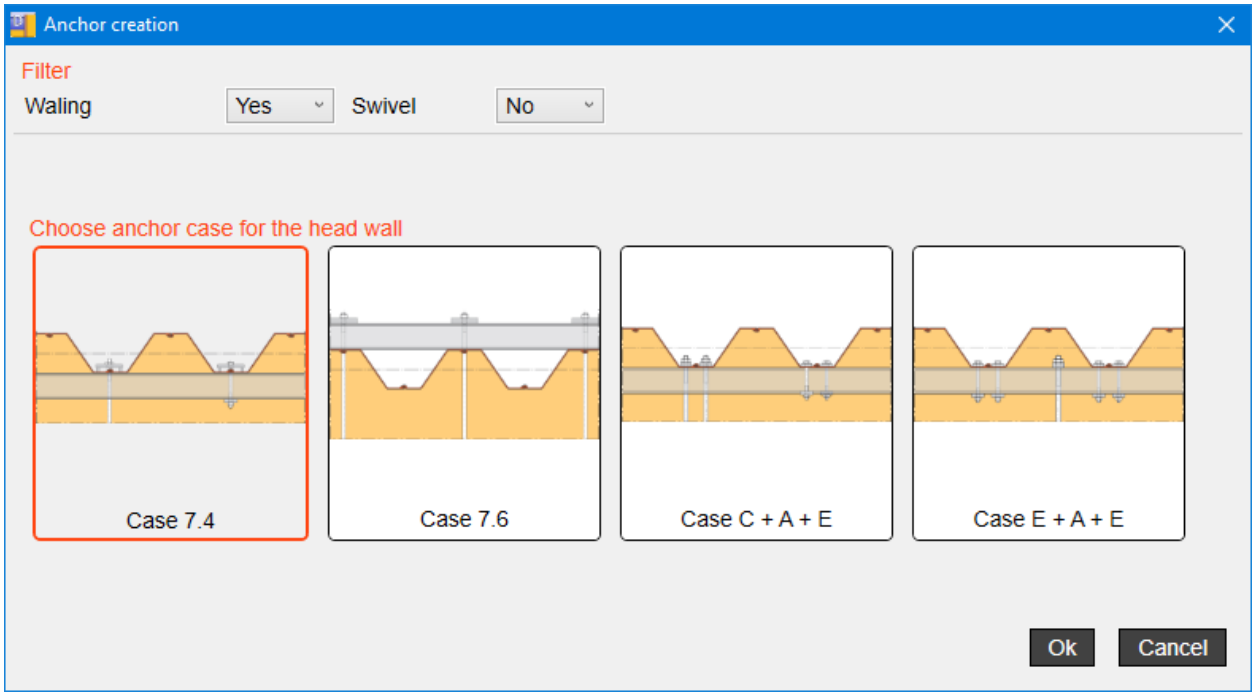
One can chose if plate verifications has to be done.

It's possible to consider seismic conditions in calculations for ASD method. See Part-B of this manual (technical part) for more information about how seismic conditions are taken into account.

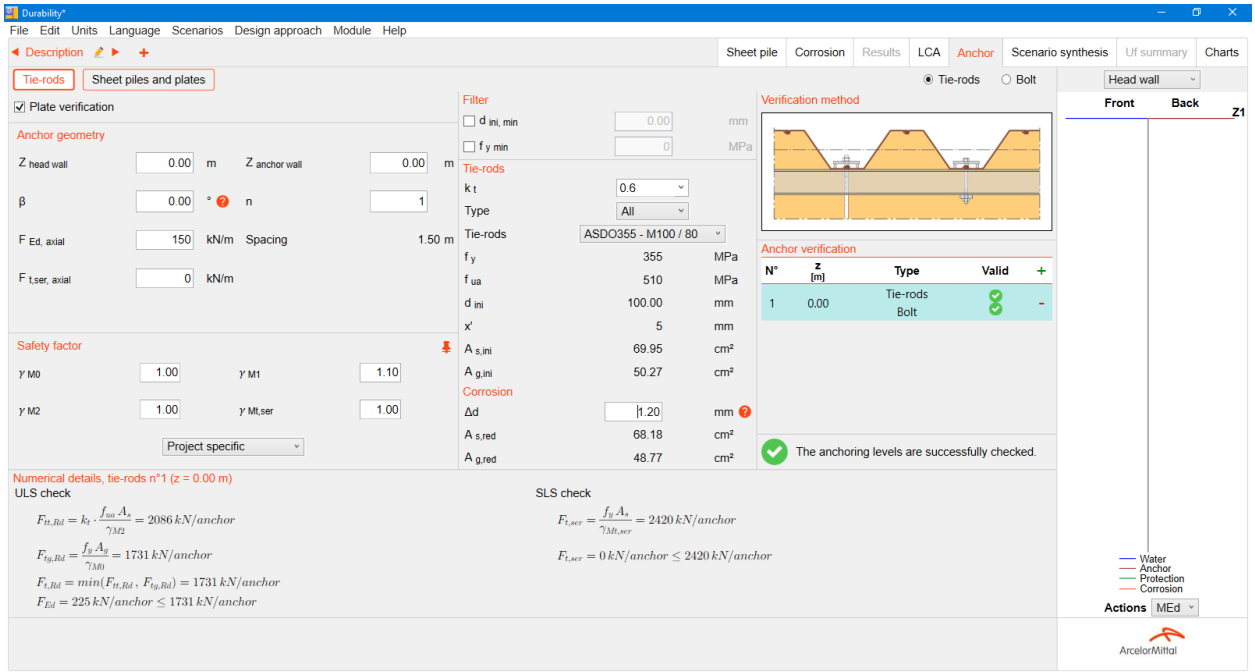
A pop-up window allows to choose the case to be checked. Some filters can be applied to choose if the case has to have a waling or a swivel :

- Case 7.4 Anchoring with a waling behind the sheet pile wall
- Case 7.5a Anchoring without a waling (anchor located in an in-pan of the sheet pile wall)
- Case 7.5b Anchoring without a waling (anchor located on an out-pan of the sheet pile wall)
- Case 7.6 Anchoring with waling in front of the sheet pile wall
- Case C + A + E Double anchoring with a waling and double bolts
- Case E + A + E Anchoring with double bolts
- Case D + A + E Double anchoring with a waling, double bolts and swivels on anchor plates
- Case F + A + E Anchoring with double bolts and swivels on anchor plates

One has to specify anchor level and the presence of swivel plate on the Anchor wall.



Anchor tab looks like following screen-shot once an anchor level is defined:



7.1.1. Anchor geometry

Parameter	Metric (SI)	Imperial	Description
$z_{head\ wall}$	m	ft	Anchor level at Head wall
$z_{anchor\ wall}$	m	ft	Anchor level at Anchor wall
β	°	°	Anchor inclination with respect to the horizontal
F_{Ed}	kN/m	kip/ft	ULS value of anchor reaction derived from geotechnical calculation
$F_{t,ser}$	kN/m	kip/ft	SLS value of anchor reaction derived from geotechnical calculation (only available for EC3-5 method)
n	-	-	Number of sheet pile system between anchors (no unit)

Spacing between anchors is deduced according to chosen section in *Sheet pile tab*.

7.1.2. Safety factors

Parameter	Metric (SI)	Imperial	Description
γ_{M0}	-	-	Partial factor according to 7.1 (4)
γ_{M2}	-	-	Partial factor according to 7.1 (4)
$\gamma_{Mt,ser}$	-	-	Partial factor according to 7.1 (4)

Specific values can be defined with *Project specific* option, but some safety factor sets according to different standards are provided:

- NAD UK
- NAD FR
- EN 1993-5 (2007)

7.1.3. Anchor definition

Durability propose ASDO and AMTB anchors and bolts.

Parameter	Unit	Imperial Unit	Description
k_t	-	-	Numerical parameter
f_y	MPa	ksi	Steel grade
f_{ua}	MPa	ksi	Tensile strength of the steel anchor
$A_{s,ini}$	cm²	in²	Initial tensile stress area at the threads
$A_{g,ini}$	cm²	in²	Initial gross cross-sectional area of the anchor rod
Δd	mm	in	Reduction of diameter because of corrosion
x'	mm	in	Tolerance of the plate hole
$A_{s,red}$	cm²	in²	Reduced tensile stress area at the threads
$A_{g,red}$	cm²	in²	Reduced Initial gross cross-sectional area of the anchor rod

7.1.4. Anchor/bolt check

Check calculation is different for ASD and Eurocode approach.

Please, see Part B of this manual for more details calculations.

7.2. Sheet piles and plates tab

In this tab, one can find all checks related with plates, swivel plates, waling and sheet pile related to anchor level selected in previous tab on the Head wall and on the Anchor wall.

First of all, sheet pile properties needed for calculations are displayed.

Then, there is always a picture to represent case calculated. After that, one can define all properties related to plates, nut, swivel plate and waling, in particular steel grades and geometry.

Durability is able to suggest geometrical properties for plates and nuts by clicking on button.

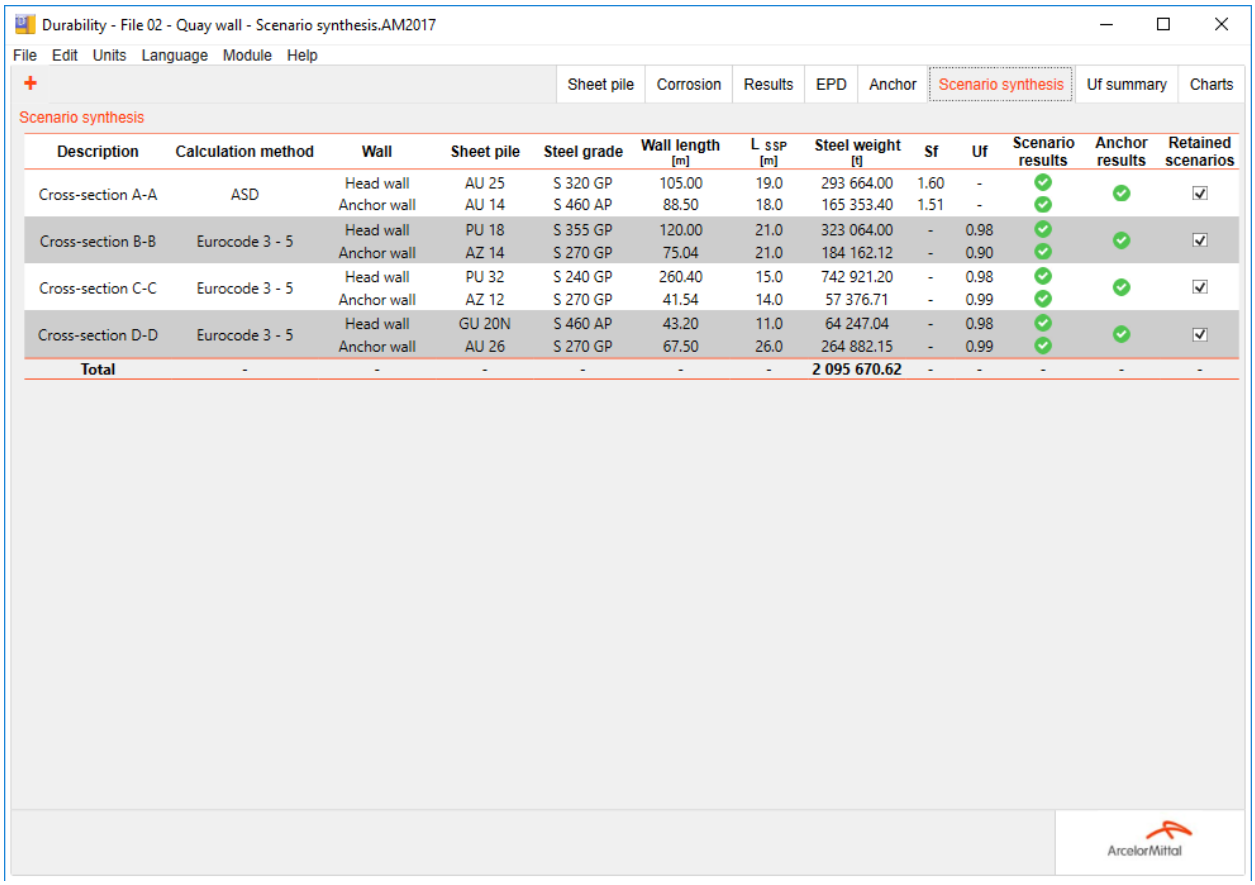
Sheet pile checks require loading levels from *Sheet pile tab* to check each section taking into account anchor reaction.

All numerical checks are provided explicitly for every case.

8. Scenario synthesis tab

This tab summarize all main information for each scenario, in particular:

- Description of scenario (name)
- Calculation method: ASD or Eurocode 3 – 5
- For each wall:
  - Sheet pile section
  - Steel grade
  - Wall length
  - Sheet pile length (L_{SSP})
  - Total weight
  - Safety factor or Utilization factor
  - Global check
- Anchor global check



Description	Calculation method	Wall	Sheet pile	Steel grade	Wall length [m]	L SSP [m]	Steel weight [t]	Sf	Uf	Scenario results	Anchor results	Retained scenarios
Cross-section A-A	ASD	Head wall	AU 25	S 320 GP	105.00	19.0	293 664.00	1.60	-	✓	✓	☑
		Anchor wall	AU 14	S 460 AP	88.50	18.0	165 353.40	1.51	-	✓		
Cross-section B-B	Eurocode 3 - 5	Head wall	PU 18	S 355 GP	120.00	21.0	323 064.00	-	0.98	✓	✓	☑
		Anchor wall	AZ 14	S 270 GP	75.04	21.0	184 162.12	-	0.90	✓		
Cross-section C-C	Eurocode 3 - 5	Head wall	PU 32	S 240 GP	260.40	15.0	742 921.20	-	0.98	✓	✓	☑
		Anchor wall	AZ 12	S 270 GP	41.54	14.0	57 376.71	-	0.99	✓		
Cross-section D-D	Eurocode 3 - 5	Head wall	GU 20N	S 460 AP	43.20	11.0	64 247.04	-	0.98	✓	✓	☑
		Anchor wall	AU 26	S 270 GP	67.50	26.0	264 882.15	-	0.99	✓		
Total	-	-	-	-	-	-	**2 095 670.62**	-	-	-	-	-

Retained scenarios column allows to select one or more scenarios to obtain cumulated steel weight.

This feature has been designed to simulate several cross-sections of the same project in the form of independent scenarios and to be able to obtain the total weight of steel.

9. Sf/Uf summary tab

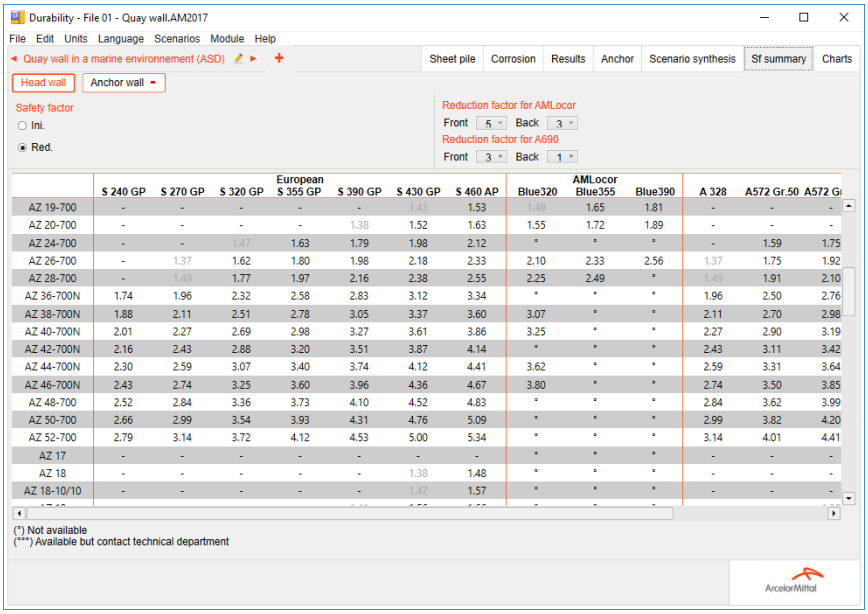
Sf summary tab is available for ASD approach and *Uf summary tab* for Eurocode 3 – Part 5.

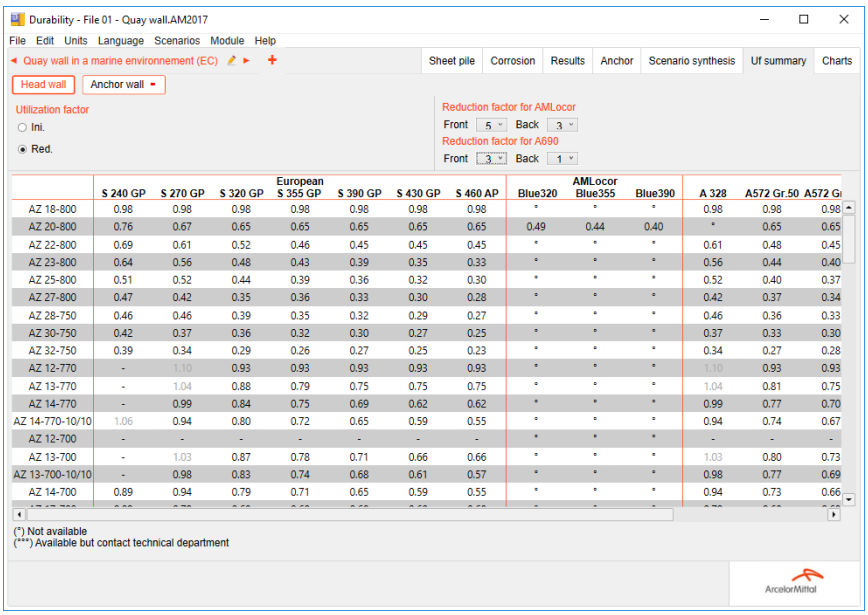
This tab summarizes the either safety factor or utilization factor for all the sheet pile section (or a reduced range if corresponding filter is on). This is the best tool to choose the most cost-effective solution, for the initial and corroded situation. The combinations are classified into 3 groups: European, AMLoCor and ASTM. Reduction factor AMLoCor and A690 (CIR) can be selected independently to the initial choice in the *Sheet pile tab*.

For ASD approach, combinations section / steel grade that do not match the criteria have a safety factor less than $S_{f,min}$. Their values are only displayed if they are above 1.0 (grey values), otherwise they are not shown (-).

For Eurocode 3 – Part 5 approach, combinations section / steel grade that do not match the criteria have an utilisation factor above 1.0. Their values are only displayed if they are slightly above 1.0 (grey values), otherwise they are not shown (-).

Not available combinations section / steel grade are indicate with (°). Please, contact technical department for the combinations marked with (°°°).



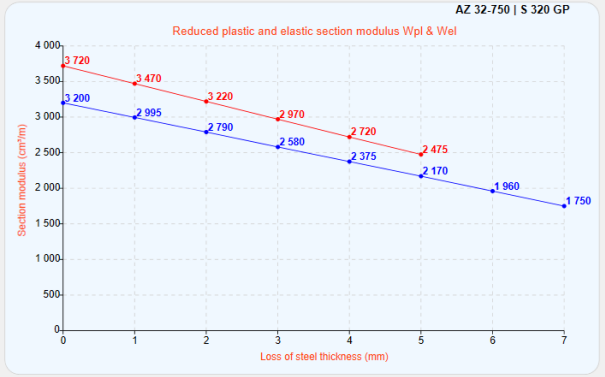


10. Charts tab

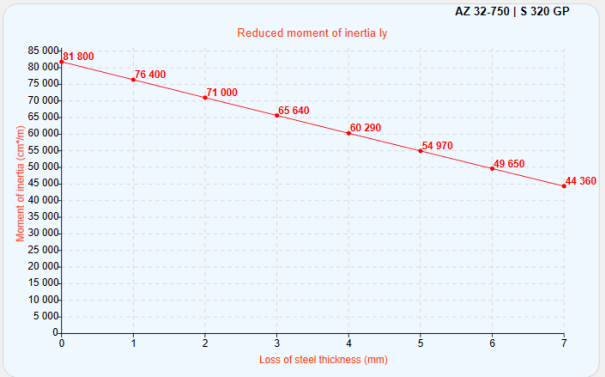
The chart is a nice tool to analyse the behaviour of a section based on loss of steel thickness and steel grades. One can also compare different sections. Current combination section / steel grade in this tab may be retained and exported to *Sheet pile tab* to be used in numerical checks (button *Use this sheet section pile*).

There are several tabs inside the graph:

- Section modulus (elastic and plastic)

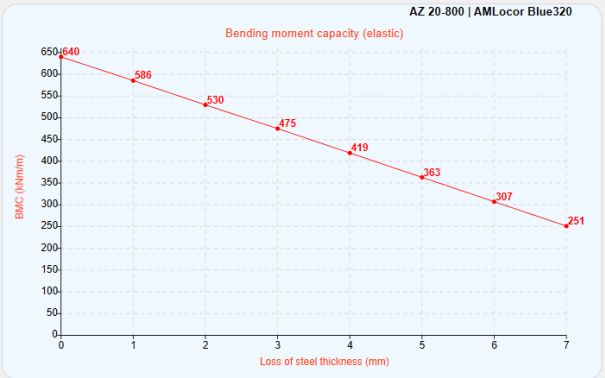


- Moment of inertia

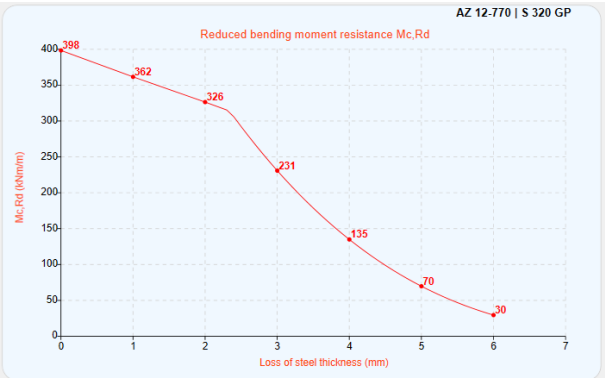


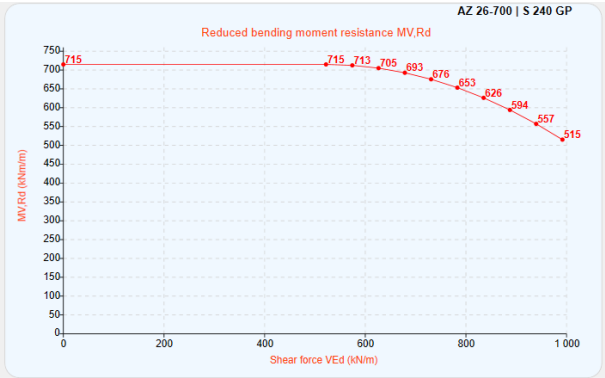
- Cross-sectional area

- Bending moment capacity (only for ASD)



- Interaction between bending moment and shear forces (only for EC3-5)





11. Ergonomic features

11.1. Save and load a project

Once project has been defined, one can save it as a file that can be open later. The extension of file is .AM2017.

11.2. Shortcuts

Some shortcuts are available in Durability to navigate easily :

- **Ctrl + N** New project
- **Ctrl + S** Save project
- **Ctrl + Shift + S** Save project as
- **Ctrl + O** Open project
- **Ctrl + P** Open the print wizard window
- **Alt + F4** Close the software
- **Ctrl + Z** Undo
- **Ctrl + Y** Redo
- **Ctrl + C** Copy
- **Ctrl + V** Paste
- **Ctrl + T** When the selection is inside an editable table, it adds a new line at the end of it

11.3. Undo/Redo

An Undo/Redo feature is available on the software:

- Ctrl +Z to Undo
- Ctrl + Y to Redo

This Undo/Redo is independent between each tabs of the software. This means that an action on the Sheet pile tab can be undone/redone only if the user is currently on this tab.

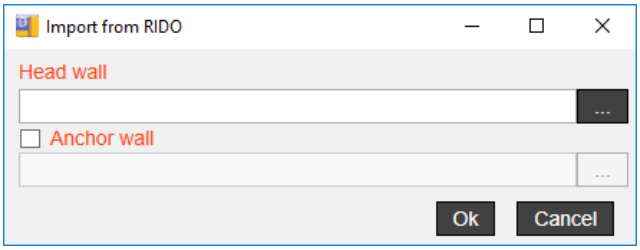
11.4. Excel import from Rido

Input data may be imported from Excel spreadsheet (File menu / Import). This is very useful to check all loading levels obtained from geotechnical analysis to ensure that retained sheet pile section verifies all required conditions at every level.

To do this, first of all we need to prepare Excel file. The template file is available with Durability package. This file can be generated for instance with Rido. Please, note that some additional information is required in this file, in particular:

- Water level on the front side
- Water level at the back
- Position of anchors (if there is any)

Then, please click on File menu / Import and chose excel file. Of course, this process can be done for the Head wall and for Anchor wall.



Please, note that it's possible to inform Durability which anchor of Head wall corresponds to Anchor wall one. This can easily be done using the same number identification in two excel files at the corresponding level respectively.

11.5. AMRetain import

It is possible to import AMRetain projects into Durability. The AMRetain project must have its result file in the same folder and the ULS calculation needs to be activated in the project to be imported.

11.6. Print current scenario

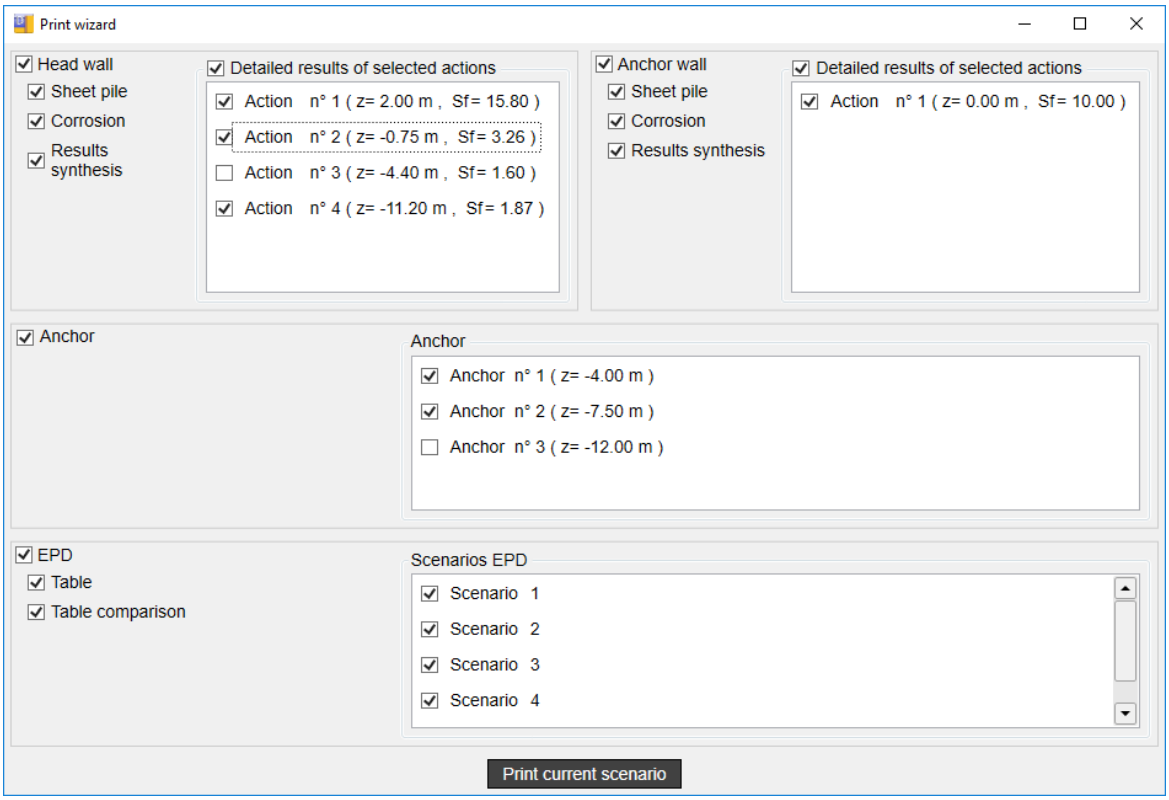
Current scenario can be easily be printed to generate a rapport with all input data and all explicit numerical checks for each loading level and for each anchor level.

Head wall and Anchor wall are handled separately, so it's easy to print only one of them if required.

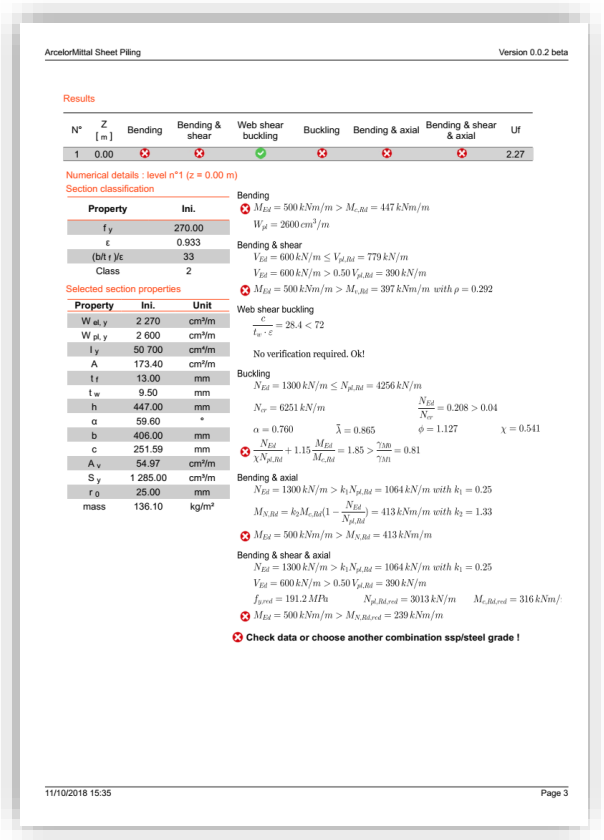
One can choose which elements have to be printed, in particular:

- Sheet pile input data
- Corrosion and protection input data
- Results synthesis (summarizing table of *Results tab*)
- Every numerical checks associated to each loading level
- EPD calculation
- Every numerical check associated to each anchor level

Print wizard:



The generated report looks like this:


ArcelorMittal Sheet Piling Version 0.0.2 beta

Results

N°	Z [m]	Bending	Bending & shear	Web shear buckling	Buckling	Bending & axial	Bending & shear & axial	Uf
1	0.00	⊗	⊗	✓	⊗	⊗	⊗	2.27

Numerical details : level n°1 (z = 0.00 m)

Section classification

Property	Ini.
f y	270.00
ε	0.933
(b/t f)/ε	33
Class	2

Selected section properties

Property	Ini.	Unit
W el, y	2 270	cm³/m
W pl, y	2 600	cm³/m
I y	50 700	cm⁴/m
A	173.40	cm²/m
t f	13.00	mm
t w	9.50	mm
h	447.00	mm
α	59.60	°
b	406.00	mm
c	251.59	mm
A v	54.97	cm²/m
S y	1 285.00	cm³/m
r o	25.00	mm
mass	136.10	kg/m²

Bending

⊗ $M_{Ed} = 500\,kNm/m > M_{c,Rd} = 447\,kNm/m$

$W_{el} = 2600\,cm^3/m$

Bending & shear

$V_{Ed} = 600\,kN/m \leq V_{pl,Rd} = 779\,kN/m$

$V_{Ed} = 600\,kN/m > 0.50\,V_{pl,Rd} = 390\,kN/m$

⊗ $M_{Ed} = 500\,kNm/m > M_{c,Rd} = 397\,kNm/m$ with $\rho = 0.292$

Web shear buckling

$\frac{c}{t_w \cdot \varepsilon} = 28.4 < 72$

No verification required. Ok!

Buckling

$N_{Ed} = 1300\,kN/m \leq N_{pl,Rd} = 4256\,kN/m$

$N_{cr} = 6251\,kN/m$ $\frac{N_{Ed}}{N_{cr}} = 0.208 > 0.04$

$\alpha = 0.760$ $\bar{\lambda} = 0.865$ $\phi = 1.127$ $\chi = 0.541$

⊗ $\frac{N_{Ed}}{\chi N_{pl,Rd}} + 1.15\frac{M_{Ed}}{M_{c,Rd}} = 1.85 > \frac{\gamma_{M0}}{\gamma_{M1}} = 0.81$

Bending & axial

$N_{Ed} = 1300\,kN/m > k_1 N_{pl,Rd} = 1064\,kN/m$ with $k_1 = 0.25$

$M_{N,Rd} = k_2 M_{c,Rd}(1 - \frac{N_{Ed}}{N_{pl,Rd}}) = 413\,kNm/m$ with $k_2 = 1.33$

⊗ $M_{Ed} = 500\,kNm/m > M_{N,Rd} = 413\,kNm/m$

Bending & shear & axial

$N_{Ed} = 1300\,kN/m > k_1 N_{pl,Rd} = 1064\,kN/m$ with $k_1 = 0.25$

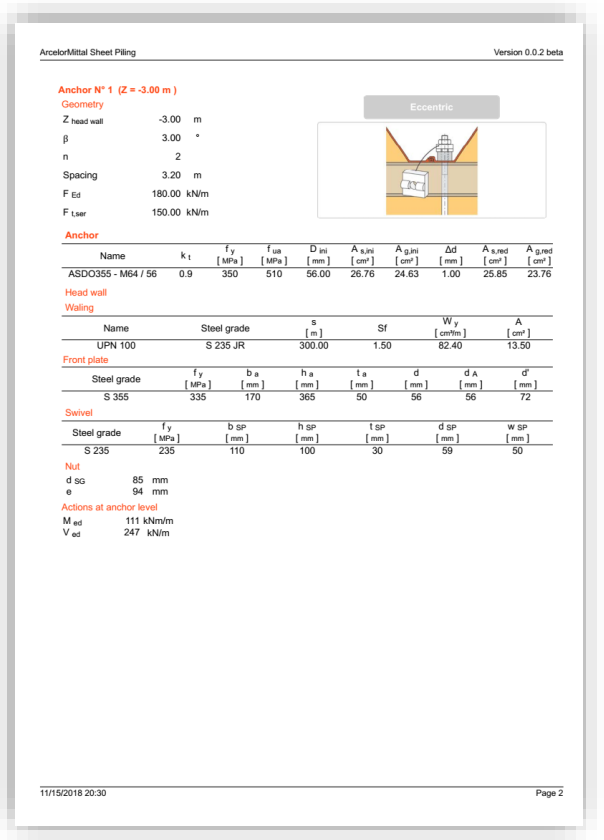
$V_{Ed} = 600\,kN/m > 0.50\,V_{pl,Rd} = 390\,kN/m$

$f_{y,red} = 191.2\,MPa$ $N_{pl,Rd,red} = 3013\,kN/m$ $M_{c,Rd,red} = 316\,kNm/$

⊗ $M_{Ed} = 500\,kNm/m > M_{N,Rd,red} = 239\,kNm/m$

⊗ **Check data or choose another combination ssp/steel grade !**

11/10/2018 15:35 Page 3


ArcelorMittal Sheet Piling Version 0.0.2 beta

Anchor N° 1 (Z = -3.00 m)

Geometry

Z head wall	-3.00	m
β	3.00	°
n	2	
Spacing	3.20	m
F Ed	180.00	kN/m
F t,ser	150.00	kN/m

Eccentric

Anchor

Name	k t	f y [MPa]	f ua [MPa]	D ini [mm]	A s,ini [cm²]	A g,ini [cm²]	Δd [mm]	A s,red [cm²]	A g,red [cm²]
ASDO355 - M64 / 56	0.9	350	510	56.00	26.76	24.63	1.00	25.85	23.76

Head wall

Waling

Name	Steel grade	s [m]	Sf	W y [cm³/m]	A [cm²]
UPN 100	S 235 JR	300.00	1.50	82.40	13.50

Front plate

Steel grade	f y [MPa]	b a [mm]	h a [mm]	t a [mm]	d [mm]	d A [mm]	d' [mm]
S 355	335	170	365	50	56	56	72

Swivel

Steel grade	f y [MPa]	b SP [mm]	h SP [mm]	t SP [mm]	d SP [mm]	w SP [mm]
S 235	235	110	100	30	59	50

Nut

d SG	85	mm
e	94	mm

Actions at anchor level

M ed	111	kNm/m
V ed	247	kN/m

11/15/2018 20:30 Page 2