ArcelorMittal

AMRetain

V2

A. Installation manual
B. User's manual
C. Technical manual
D. Tutorial manual

AMRETAIN v2 is a software developed for ArcelorMittal by

terrasol

setec

AMRetain

A. INSTALLATION MANUAL

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A.1. Minimum hardware requirements and required settings

A.1.1. Minimum hardware requirements

AMRetain installation file is designed and distributed by TERRASOL. It is adapted to work in the following environments: Microsoft Windows® 7/8/10. Intellectual property laws are fully applicable to the information included in the installation file.

Minimum hardware specifications to run AMRetain program are:

- 2 Gb de RAM;
- A screen device with resolution at least 1280x720 pixels and 32 000 colors;
- Microsoft Windows® Windows® 7/8/10, 32 or 64 bits;
- 500 Mb available hard disk space.

A.1.2. Requirements for AMRetain installation

- The user should be connected to his session and launch the installation with administrator rights in order to perform AMRetain installation.
- An Internet connection is required to proceed to online activation of the AMRetain license. In case your system is protected by a firewall or proxy, please make sure that port 443 is open. Offline activation is still possible if your proxy or firewall stops the online activation (see section A.3).

A.1.3. Requirements for AMRetain use

- An Internet connection is not compulsory when using AMRetain. However, AMRetain is provided with an updater tool (cf section A.4 and part B of the manual), and it is advised to use it with an Internet connection from time to time to get the latest updates through this updater tool.
- The user should have full control (read, write, etc.) on AMRetain v2 installation directory and of course also on the working directory (where AMRetain project files are saved). Otherwise, AMRetain will not works properly.

A.2. AMRetain installation

After requesting an AMRetain license through the relevant website, you'll receive an email including a link to the AMRetain installation file. Once you have downloaded and copied this file onto your hard disk, please follow this installation procedure:

- Run file Install_AMRetain.exe.
- Following window shows up, please choose English language and click on OK.

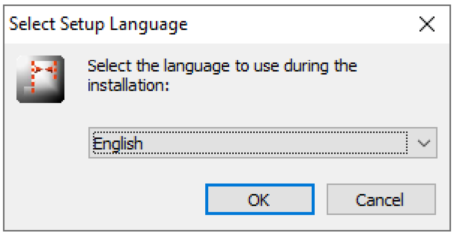


Figure 1: AMRetain Select Setup Language screen

- The next window is then displayed, please read the liability clauses. To accept them, select "I accept the agreement" and click on Next >.

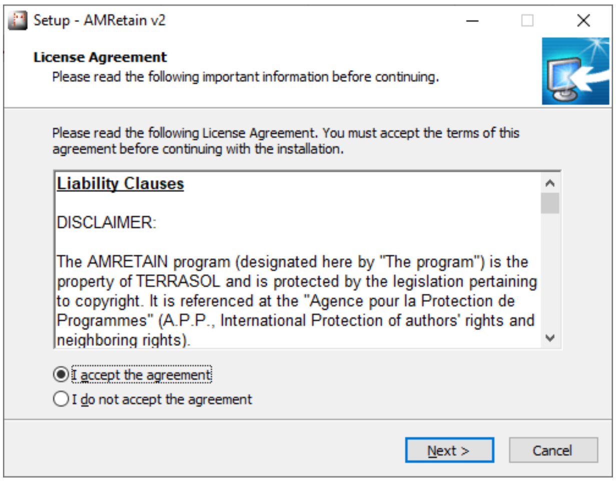


Figure 2: Liability clauses

- The following window appears, please fill in the requested information and click on Next >.

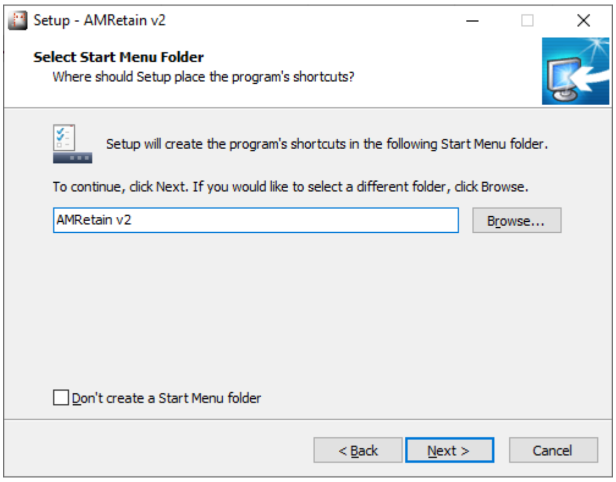


Figure 3: Information to be provided by the user

- Choose additional tasks to perform in the following window, then click on Next >.

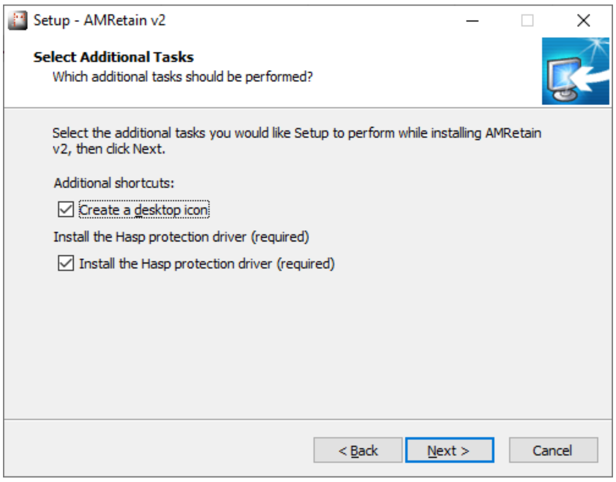


Figure 4: Installation additional tasks

- A confirmation screen appears to check the installation settings. Click on Install to proceed.

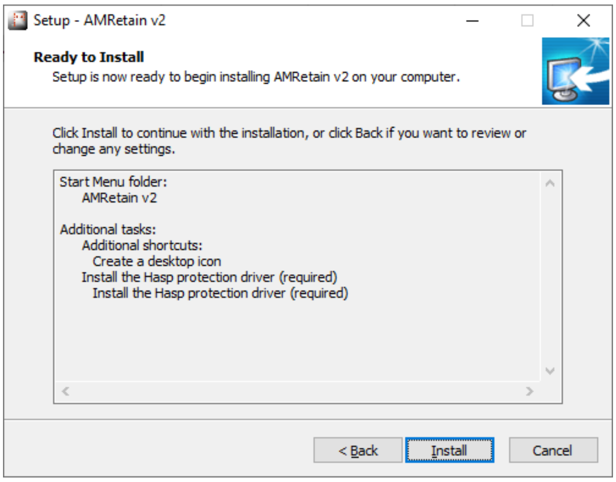


Figure 5: Confirmation before installation

- The installation starts itself:

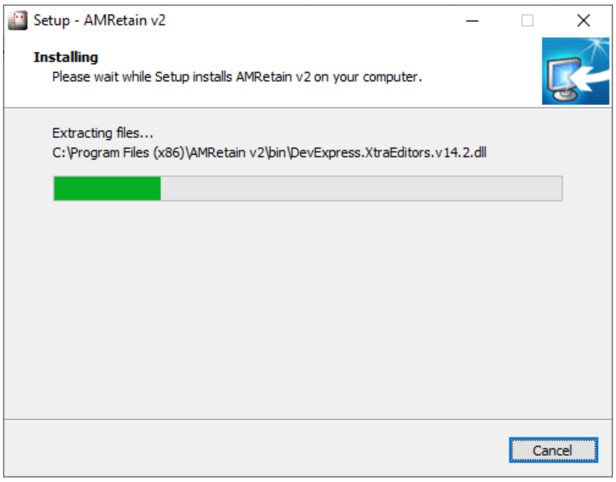


Figure 6: Installation in progress

- At the end of AMRetain installation, the installation of Sentinel Run-time Environment then starts:

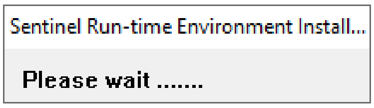


Figure 7: Sentinel Run-time environment installation

- The following message confirms the runtime installation is successfully completed. Click OK to close this window.

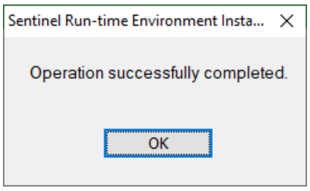


Figure 8: Sentinel Run-time environment installation confirmation

Click on Finish to terminate installation process.

Figure 9: Confirmation that AMRetain installation is finished

IMPORTANT: The user should have full control (read and write rights, etc.) on AMRetain installation directory and, of course, also on the working directory (where AMRetain project files will be saved). Otherwise, AMRetain will not work properly.

AMRetain installation is now complete.

Note: the large variety of materials and systems available on the market makes it impossible to detail all cases. In case the installation is interrupted, please answer carefully to the questions displayed by the system. The buttons “Next" or "Ignore" usually enable to complete the installation successfully.

<u>Additional information</u>:

- AMRetain program is provided with a tool called **Updater**, which enables to get automatically new updates of AMRetain and of the ArcelorMittal sheet pile catalogue included in AMRetain. Please refer to part B of the manual for more information about the Updater tool.
- After AMRetain installation, one shortcut for AMRetain (via the Updater) is available on the computer desktop, and 2 shortcuts are available from a new AMRETAIN item in the Menu/Start/All programs (one for AMRetain and one for User Manual).
- Example files are provided with AMRetain. They are stored in « Examples » folder (installation directory). For more details about these examples, please check part D of the manual.
- AMRetain manual (French and English versions) is provided in pdf format in « Manuals » folder (installation directory).

A.3. Activation of your AMRetain license

On your first use of AMRetain, your license must be “activated”. Indeed, the program is protected with a software dongle (Sentinel HASP), which should be activated.

A.3.1. Automatic / Online activation

For this activation:

- An Internet connection is compulsory when using AMRetain for the first time, in order to be able to activate your license. It is not compulsory later on.
- The license activation tool uses communication port 443. Your company network may prevents communications through this port (proxy or firewall). In such a case, the message « Your license could not be activated. Please check your internet connection and the Product Key. » will be displayed when attempting to activate your license. Please contact your IT department to open this port.

The activation procedure is the following:

- When running AMRetain for the first time, the following window appears:

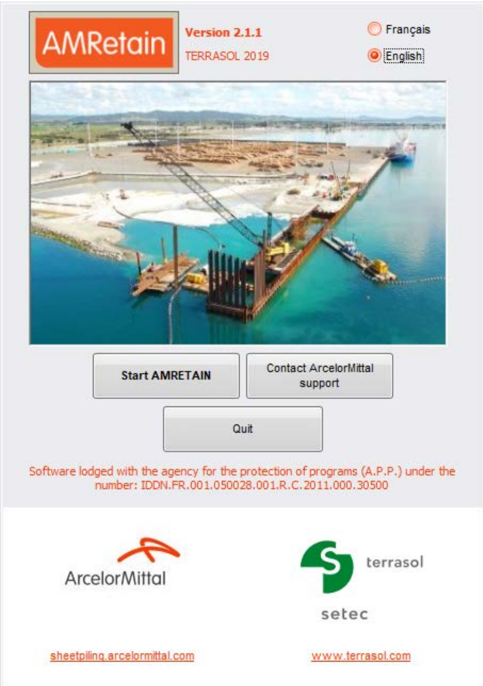


Figure 10: AMRetain welcome screen

- Please, click on **Start AMRETAIN** to start activation process.
- Following window is displayed. Please fill in the serial code, and click on **Activate**

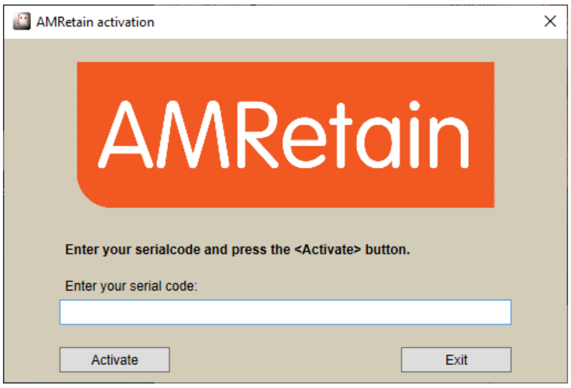


Figure 11: Providing the product code (i.e. serial code)

- The following message confirms that the activation was successfully completed:

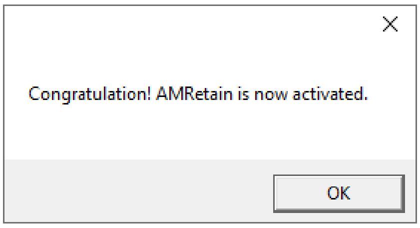


Figure 12: License activation confirmation

Note: each license is assigned to the computer on which it has been activated. So it is not possible to use the same product code (or serial code) to activate AMRetain on another computer. However, the code remains valid if you need to uninstall/reinstall AMRetain on the same computer.

A.3.2. Manual / Offline activation

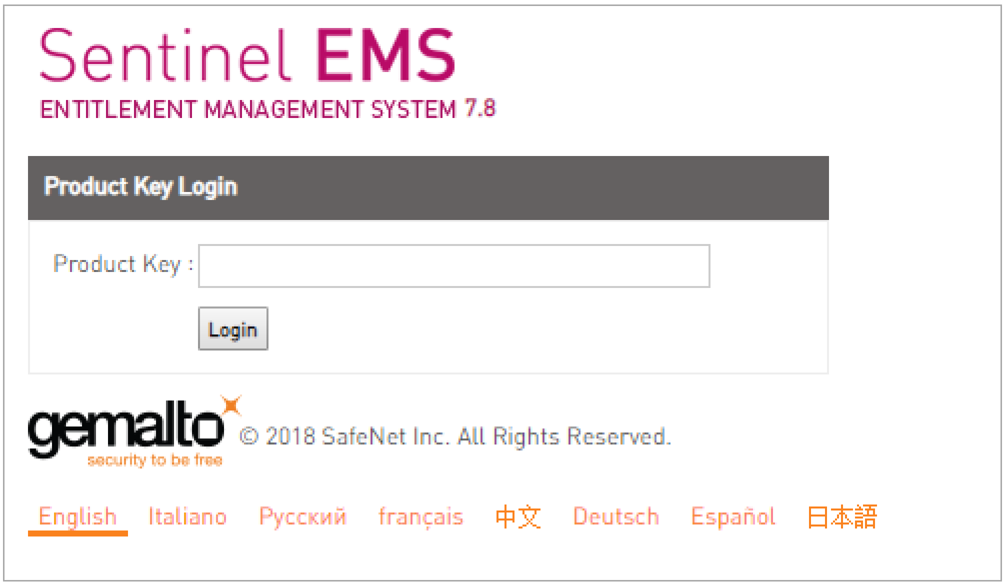
For this activation:

- An Internet connection is needed but not necessarily on the computer where AMRetain is installed.
- Be careful to create the computer fingerprint on the computer where AMRetain is installed.

The activation procedure is the following:

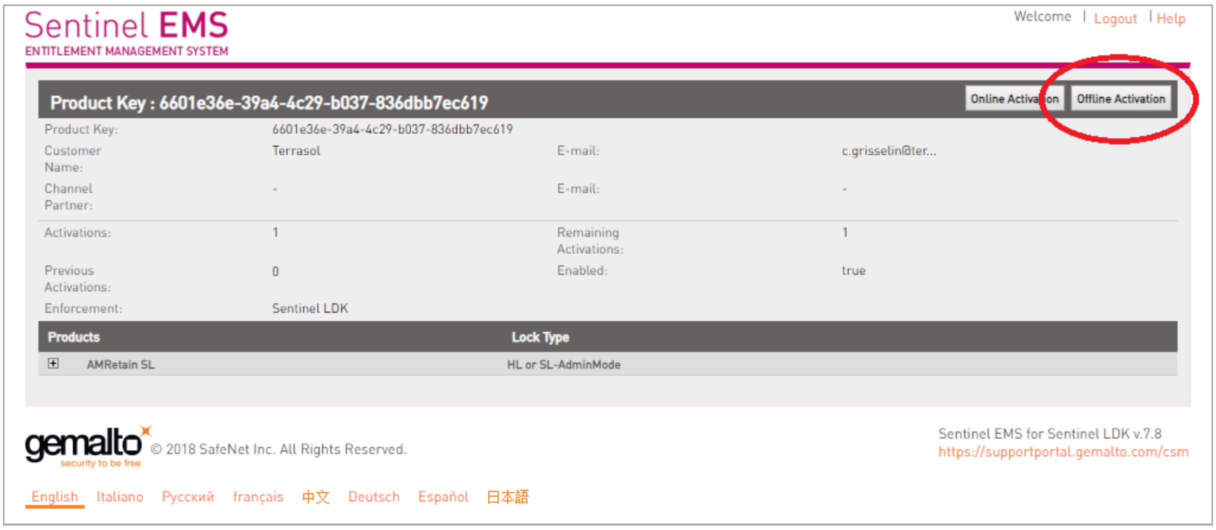
On the computer with Internet connection:

- Connect to URL https://terrasol.sentinelcloud.com/ems/customerLogin.html.

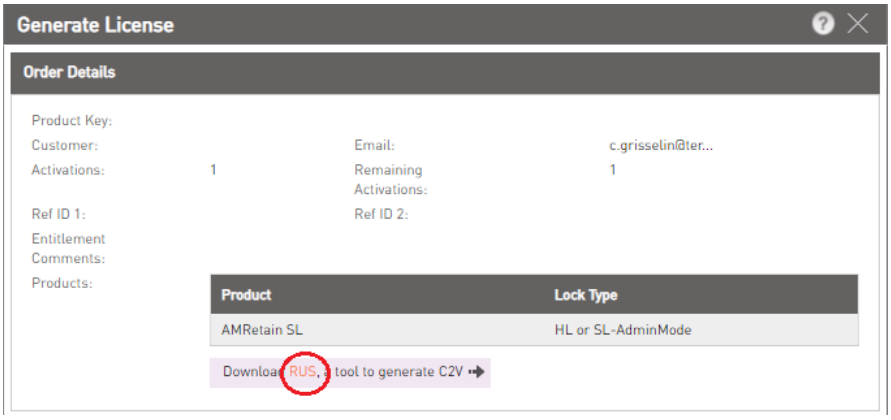


Please fill your serial code in the Product Key field and click Login.

The following page should appear. Please click on Offline Activation.

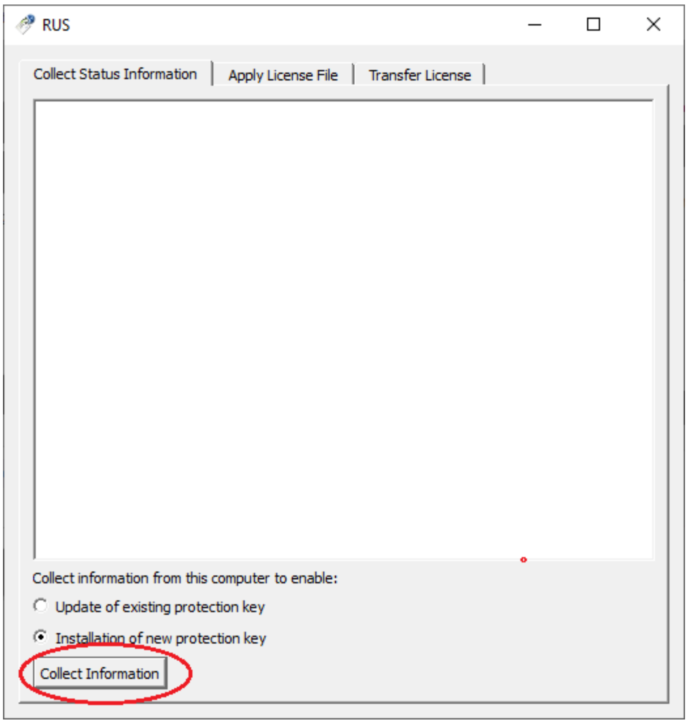


- Then click on the **RUS** link to download **RUS_WXOCX.exe** application.



On the computer where AMRetain is installed:

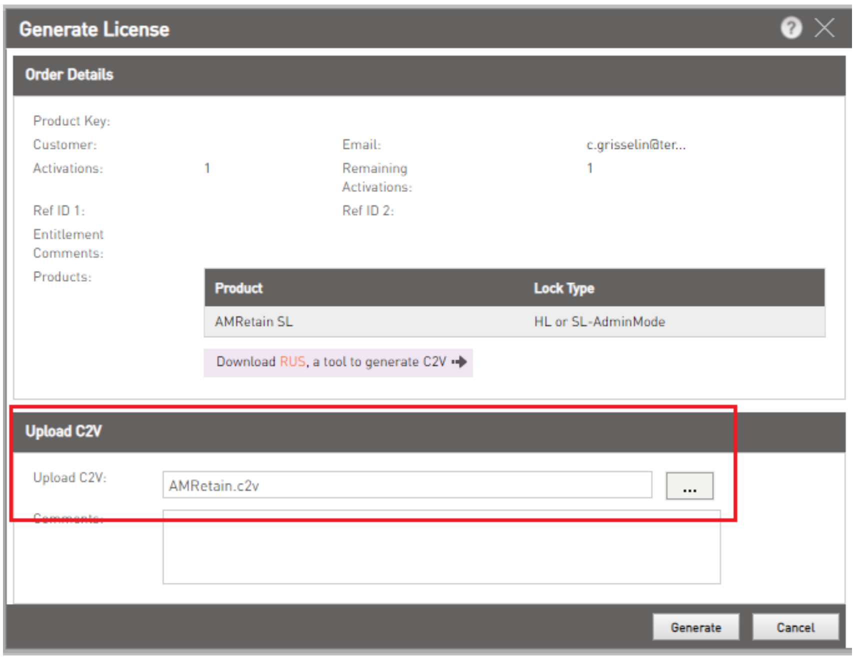
- Execute **RUS_WXOCX.exe** on the computer **where AMRetain is installed.**



Choose the “Installation of new protection key” option and click Collect Information to generate a c2v file.

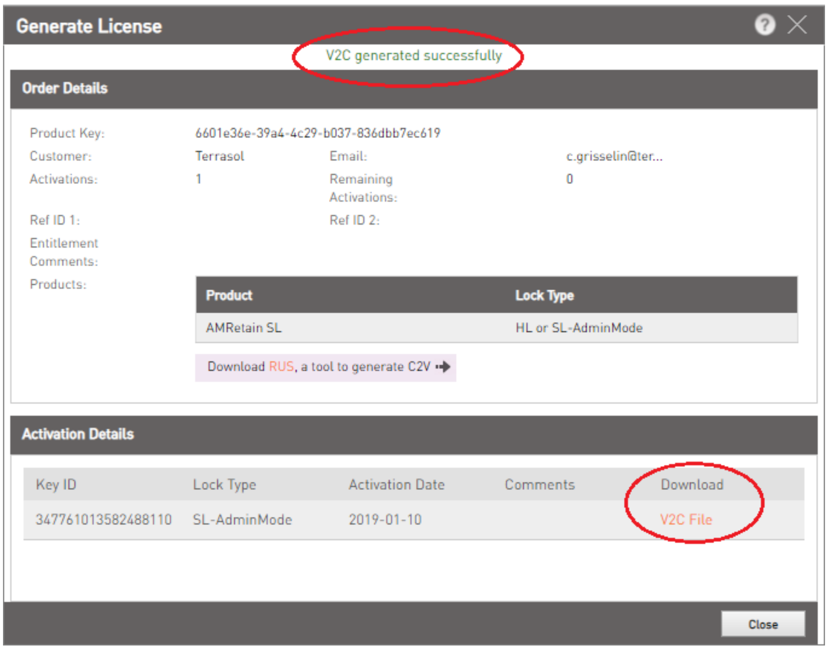
On the computer with Internet connection:

- Upload the c2v file onto the server and generate the license



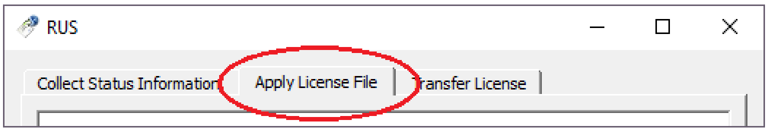
Click on ... button next to the field, browse the directory where your c2v file was saved and select it. After that, click on Generate.

- Download the v2c file.

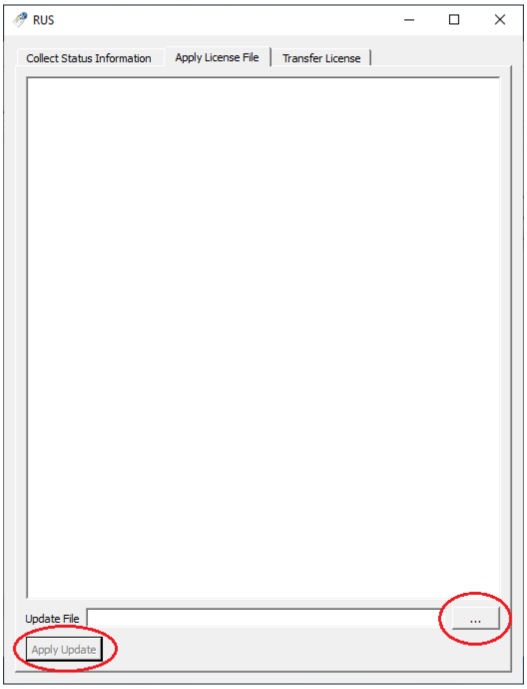


<u>**On the computer where AMRetain is installed:**</u>

- Run **RUS_WXOCX.exe** application again and select the Apply License File tab.



- If the **Update file** field is empty, browse the directory where the updated file (.v2c file) is located and select the file (click ... button next to the field).
- Click on Apply Update to apply the new license data.



Congratulations, your AMRetain license is now activated!

A.3.3. Transfer a license

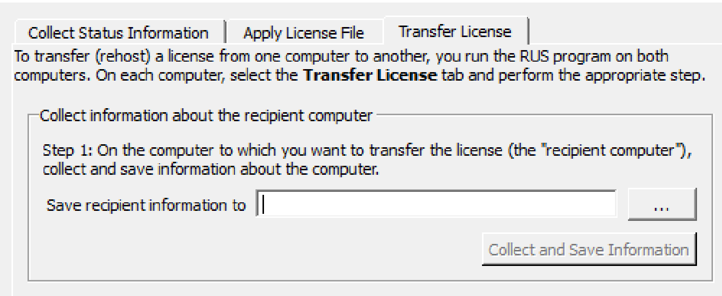
You can use **RUS_WXOCX.exe** utility to transfer a license from one computer (*source computer*) to another (*recipient computer*). This three-step procedure requires **RUS_WXOCX.exe** utility on both computers.

For this transfer procedure you need:

- An Internet connection.
- AMRetain installed on both computers.
- RUS_WXOCX.exe on both computers.

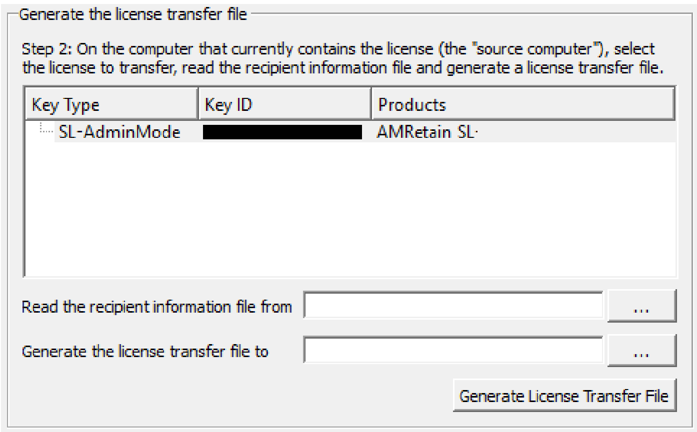
Step 1: Collect information about the recipient computer

- On the recipient computer, launch **RUS_WXOCX.exe** utility
- Click on **Transfert License** tab
- Follow the instructions labeled "Step 1" to collect information about the computer and save it to a file. Make sure that the file (or a copy of the file) is accessible on the source computer.



Step 2: Generate the License Transfer File

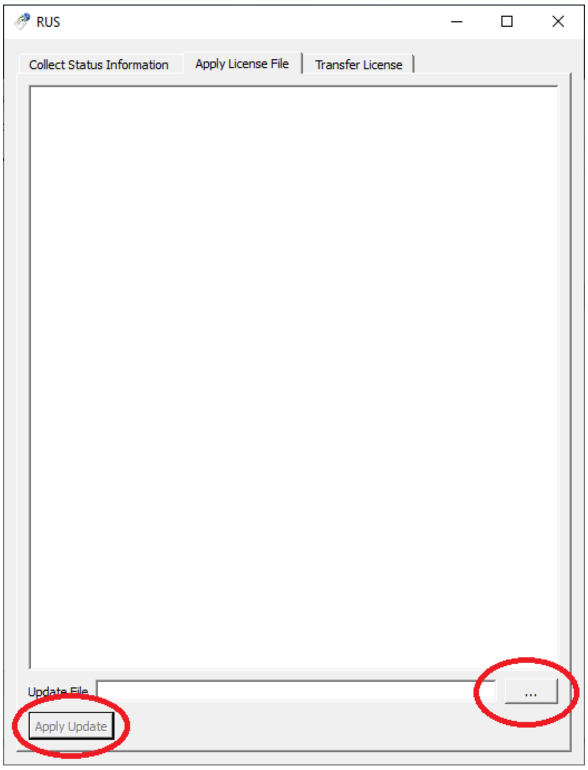
- On the source computer, launch **RUS_WXOCX.exe** utility.
- Click on **Transfer License** tab.
- Follow the instructions labeled "Step 2" to select the SL key to transfer, read the recipient information file, and generate a license transfer (h2h) file. Make sure that the license transfer file (or a copy of the file) is accessible on the recipient computer. After you perform this step, the SL key is no longer available on the source computer.



IMPORTANT:
Be sure to keep a copy of the transfer file until you have completed the transfer procedure.
If you lose this file, you lose your license!

Step 3: Apply the License Transfer File

- On the recipient computer, in **RUS utility**, click **Apply License File** tab
- In the Update File field, click on [...] and locate the license transfer (h2h) file.
- Click on [Apply Update]. The AMRetain SL key is installed on the recipient computer.



IMPORTANT:
To ensure the success of the transfer procedure, all the steps in the procedure should be completed within a few days.

A.4. AMRetain updates

AMRetain program is provided with a tool called Updater, which enables to get automatically new updates of AMRetain and of the ArcelorMittal sheet pile catalogue included in AMRetain (provided the computer is equipped with an Internet connection).

The Updater tool automatically connects to an updates server and checks for AMRetain updates. If so the user can choose to install them.

It is thus advised to use the shortcut to run AMRetain through the Updater, in order to ensure that you use at all times the latest version of AMRetain and of the ArcelorMittal sheet pile catalogue.

Please refer to part B of the manual (section B.2.6) for more detailed information about the Updater tool.

A.5. AMRetain uninstall

The AMRetain uninstall procedure was designed so that the program can be completely removed from your computer.

Please follow this procedure only if you decided to completely remove AMRetain from your computer. You will be able to install AMRetain again later on if necessary.

<u>Uninstall procedure</u>:

- Start the Windows© **Control panel**.
- Under "View by", select Large Icons, and then tap or click **Programs and features**.
- Click **AMRetain** and click **Uninstall**
- The following window is displayed:

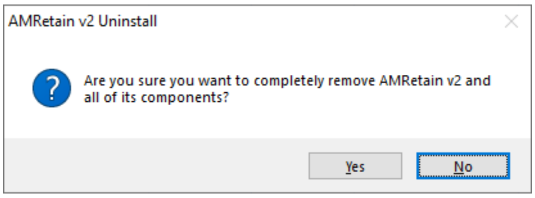


Figure 13: AMRetain uninstall

- Click on Yes in order to uninstall AMRetain.

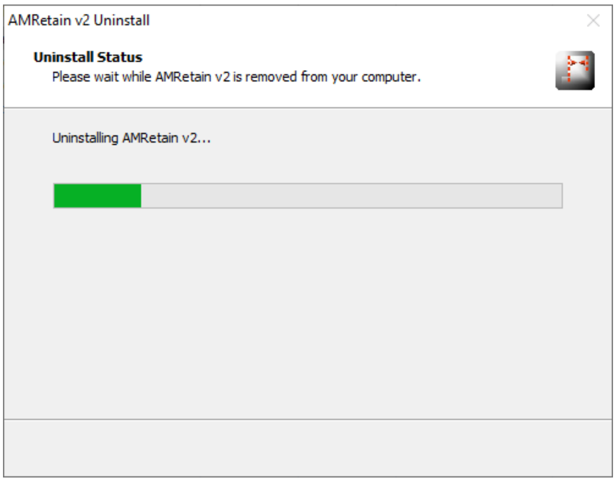
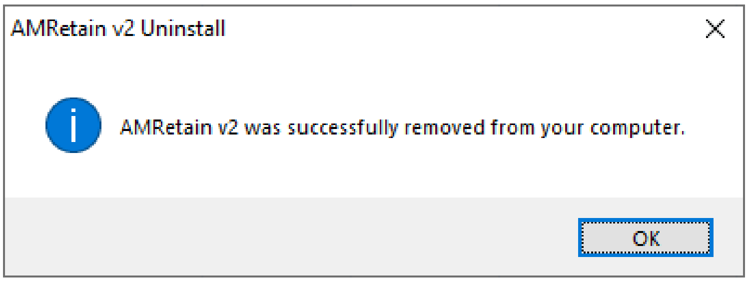


Figure 14: Full AMRetain uninstall

Please, wait until all AMRetain files have been removed, and click on OK to finish process.



In case you have changed or added manually files in « Examples » folder, the installation directory and some files will not be removed.

It is then advised to « manually » delete the AMRetain installation directory (by default « C:\Program Files (x86)\AMRetain v2 ») and its content using the files explorer. You may also remove AMRetain shortcuts from the Desktop and Start/Programs list, if any.

Uninstall is now complete.

AMRetain

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B.1. Introduction

B.1.1. Presentation of AMRetain

AMRetain is used to study the behaviour of planar or circular retaining walls subjected to a series of construction phases, using the reaction coefficients calculation method.

AMRetain analyses two types of projects:

- "**Single wall"** projects: for a single retaining wall;

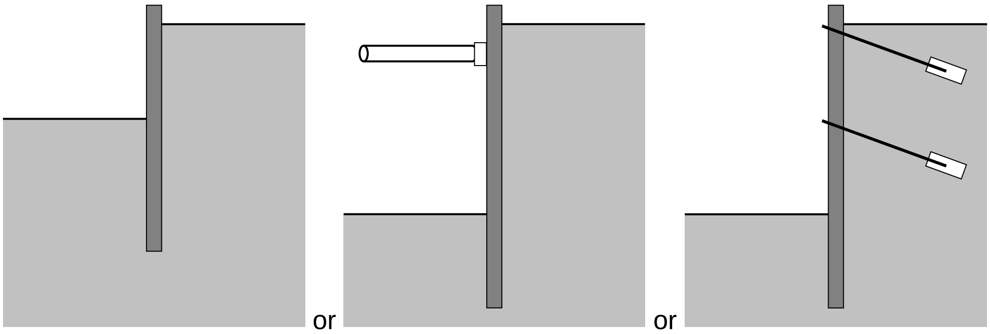


Figure B1 *: Examples of "single wall" projects*

- "**Double wall"** projects: for two walls joined by a set of anchors.

  Note: in this manual the term *double wall* refers to both double walls and back walls.

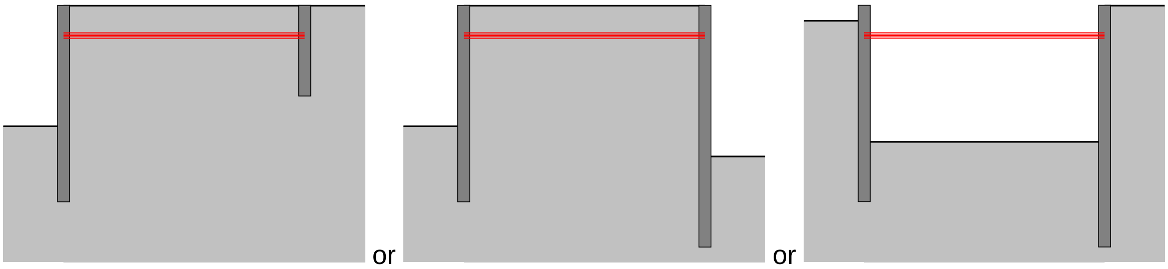


Figure B2 *: Examples of "double wall" projects*

AMRetain runs in a Windows® environment, which makes the interface intuitive and particularly simple to use for data input. In addition, the graphical display of the calculation phasing allows "real time" monitoring of the input of validated actions.

The main steps in the definition of a project are as follows:

1. Define general project data: project type (single wall or double wall), units system (metric or imperial), hydraulic options, consideration of 2nd order moments and activation of ULS checks;
2. Define characteristics of soil layers (numerous wizards are available);
3. Define wall properties (several wizards are available);
4. Define calculation phasing: creation of phases and choice of actions in each phase (excavations, installation of anchors, etc.);
5. Start calculations;
6. Display results.

Part A of the manual is devoted to installation of the AMRetain software.

This part B presents all the interface elements and summarises the operations to be performed for defining and exploiting an AMRetain project.

Part C of the manual is devoted to the technical manual defining the theoretical framework of the calculation methods used in AMRetain.

Part D gives application examples, tutorials and details AMRetain interface operations.

B.1.2. Conventions

B.1.2.1. Units

Two units systems are available in AMRetain: the metric system and the imperial system. The metric system can itself be broken down into 3 subsystems based on kN, MN or t. The units system is chosen for each project in the **Data, Title and Options** Menu.

The AMRetain calculations are performed for a unit length of wall, so virtually all the data and results are relative to this convention. The /m (per linear metre) or /ft (per linear foot) unit is explicitly recalled for all the parameters defined per unit length (data and results). If this suffix (/m or /ft) is absent, this means that the parameter in question is not expressed in terms of unit length.

The following table gives the correspondences for each type of physical quantity between the "metric (kN)" and "imperial" units systems. The (/m) or (/ft) suffix is also added to the physical quantities expressed per unit of length or surface.

Physical quantity	Unit in the metric system	Unit in the imperial system
Distance or elevation	m	Ft
Displacement	mm	In
Force	kN/m	kip/ft
Pressure	kN/m/m	kip/ft/ft
Unit weight	kN/m^3	Kcf
Product of inertia	kNm^2/m	kip.ft^2/ft
Linear stiffness	kN/m/m	kip/ft/ft
Surface stiffness	kN/m^2/m	ksf/ft
Moment	kN.m/m	kip.ft/ft

Table B 1: Correspondence between metric and imperial units systems

In this manual, the units corresponding to each type of data or result will be given in "metric (kN)" system and "imperial" system. However the "metric (MN)" and "metric (t)" systems are also available in the software.

B.1.2.2. Double wall projects

For double wall projects, AMRetain uses the notation **Wall 1** to designate the **left-hand** wall and the **Wall 2** to designate the **right-hand** wall.
For wall 1 it is advisable to define that which will have the longest construction phasing. This is not an obligation, but a simple recommendation for optimising the operations during definition of the phasing.

For a double wall project, each side of each wall is identified by convention using the following notation:

- "**Left"** or "**Right/E.2R"** for wall 1 (left-hand wall);
- "**Left/E.2R"** or "**Right**" for wall 2 (right-hand wall).

B.1.2.3. Sign conventions

These are described in part C of the manual.

B.1.2.4. Conventions concerning phasing actions

All the phasing actions are graphically represented in the AMRetain interface. What is taken into account in the calculation therefore corresponds to what is represented on the screen.

All AMRetain projects consist of an initial phase and a set of standard phases. As indicated by its name, the initial phase is used to define the status of the soil prior to any interaction with the wall; in other words, this is a stress and resistance initialisation phase. The only action applicable during this particular phase is the Caquot Overload.

During the standard phases, a large number of actions is proposed. These are placed in action groups, each dealing with a particular aspect of the problem being studied.

These actions are summarised in the following table:

Hydraulic	Hydraulic action
Earthworks	Excavation Fill
Soil properties	Redefinition of soil layers
Wall properties	Corrosion wizard Modification of Beta D factor (4)
Anchors	Tie Strut Rotational spring Linking anchor (2)
Loads, forces, moments	Caquot overload (1) Boussinesq overload Apply a line force Apply a moment Horizontal load on wall
Actions created automatically	LEM options (3) ULS options (SSIM) (3) Earthquake (Seismic calculation) (3)

(1) This action exists in the initial and other phases;
(2) This action is exclusively available for double wall type projects;
(3) This action is automatically created by AMRetain according to the status of the options detailed in § B.4.3. The user must always check the pre-defined parameters, or even modify and supplement them if such an action is present.
The remainder of the actions only exists in the standard phases, or in all the phases except for the initial phase.
(4) Only available for Standard U pile

All the actions are presented in detail in chapter B.5.

B.1.3. AMRetain v2 data file extension

The extension of the AMRetain v2 data files is **.AM2.** Only this file is necessary when you wish to exchange your calculation data with another AMRetain v2 user.

AMRetain v2 can be used to read and import AMRetain v1 projects. The extension of the AMRetain v3.1 data files is **.KPJ**.

B.2. General presentation of interface

B.2.1. Start window

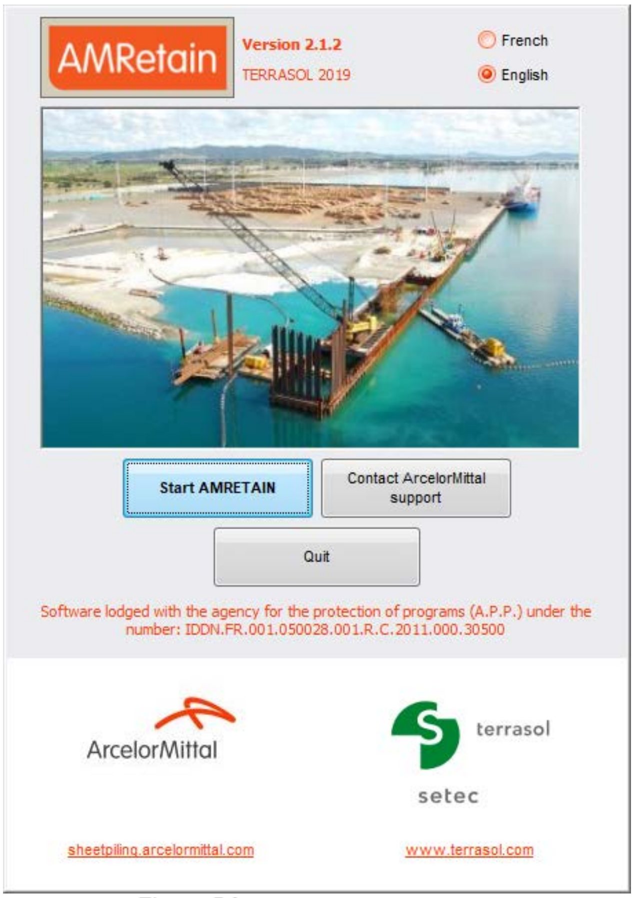


Figure B3 *: AMRetain start window*

The start window is used to:

- Choose the language to be used by the AMRetain interface;
- Start the AMRetain software. If you do not have a licence, you will only be able to access the demonstration mode;
- Contact the ArcelorMittal support clicking on the button 

;
- Access the Terrasol website (click the Terrasol logo) ;
- Access to Arcelor website (click the ArcelorMittal logo)

The installed version of AMRetain is also indicated.

B.2.2. Main window

The main window of AMRetain is used to access all the functions available for defining a project. The secondary windows correspond to the data input windows, wizards or results.

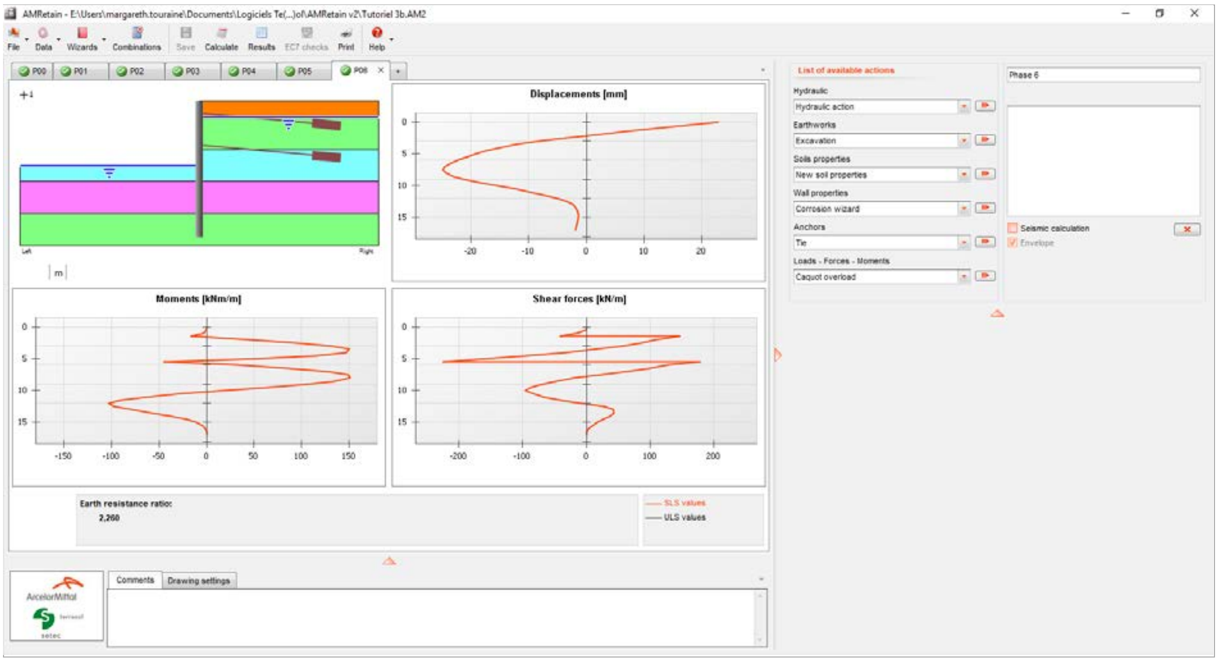


Figure B4 *: Main window*

The following are displayed in the main window:

- The title bar specifying the project name and file path;
- The menu bar, described in detail in chapter B.2.3;
- The buttons bar and menu lines, presented in chapter B.2.4;
- The project cross-section, presented in the form of a tab per phase;
- The phasing management frame, detailed in chapter B.4;
- A "Comments" tab, which will be printed in the graphic summary of the phase (1 comment per phase);
- A "Drawing settings" tab, used to display the characteristics of the actions. This tab concerns the entire project;
- The unit and elevation (or depth), corresponding to the position of the mouse when it is on the drawing of the project cross-section, shown at the bottom left of the graphic.

B.2.3. Menus

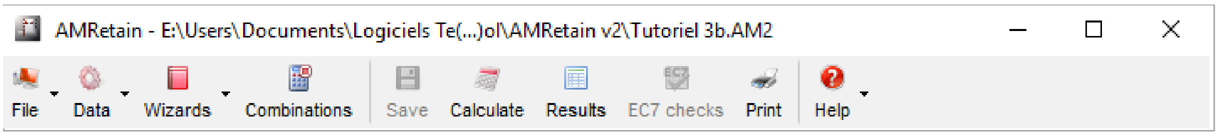


Figure B5 : *Main menu*

The menus are accessible simply by clicking their title and can call up sub-menus. They are used to manage all the functions linked to the Windows® environment and those specific to AMRetain.

B.2.3.1. File menu

This menu allows access to various file and print options.

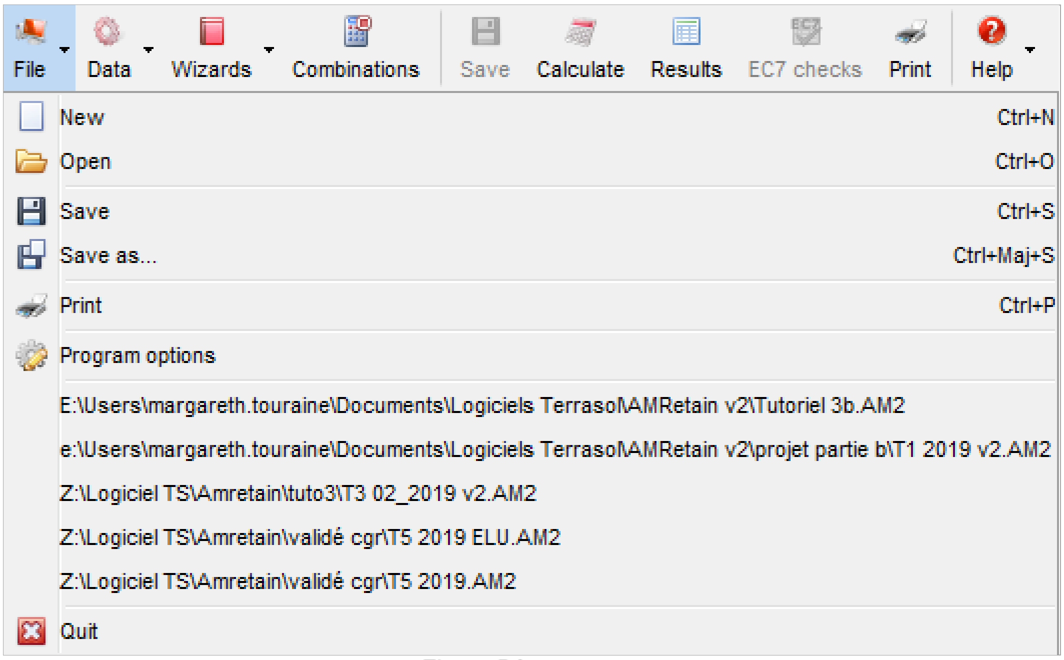


Figure B6 : *File menu*

The sub-menus are described below:

- New: define a new project by accessing the first AMRetain dialogue box (Title and Options).
- Open: access the operating system tree to select an existing project to be opened. The project file extension in AMRetain v2 is ".AM2". It is also possible to import projects created with older versions 1 of AMRetain, for which the project files carry extensions ".KPJ", by changing the extension filter (drop-down list at bottom-right of window).
- Save: save the data input in the file corresponding to the current project.
- Save as: save the data input in a file other than that active one. The name given to the new file must comply with Windows® writing format.
- **Print**: access the print dialogue box. This function is only accessible if the project has already been calculated.
- **Program** options: display the default settings: the folder in which the project files are saved and the unit system:

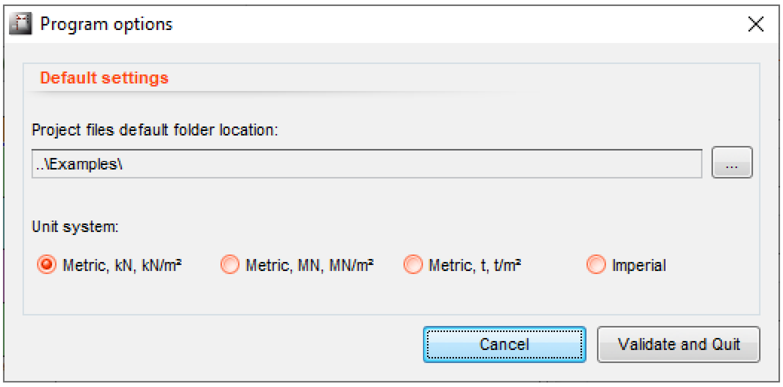


Figure B7 : *Program options*

- History: this display groups shortcuts for the last five projects opened. Direct access is only possible provided they have not been moved or deleted.
- Quit: quit current project.

B.2.3.2. Data menu

This menu gives access to the dialogue boxes defining the project data: the project type (single wall or double wall), the calculation options, the characteristics of the soils and of the wall(s). The content of these boxes and their use are described in detail in chapter B.3.

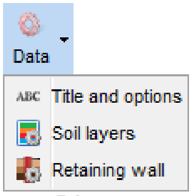


Figure B8 : *Data Menu*

- Title and Options: choice of the project type, input of a title and definition of the calculation options (units, calculation pitch, ULS checks, 2nd order moments, advanced options, etc.).
- Soil layers definition: definition of the characteristics of the soil layers (intrinsic parameters, characteristics of the soil-wall interaction). In the case of double wall projects, a "soil model" is allocated to each wall so as to be able to differentiate between the layers specific to wall 1 and those specific to wall 2.
- Retaining wall definition: definition of the characteristics of the wall(s) (dimensions, properties).

B.2.3.3. Wizards Menu

This menu is used to access the wizards dialogue boxes to determine the active/passive earth pressure coefficients and the reaction coefficient, as well as to define the load cases. The content of these boxes and how they are used are described in detail in paragraphs §B.3.2 and §B.3.5.

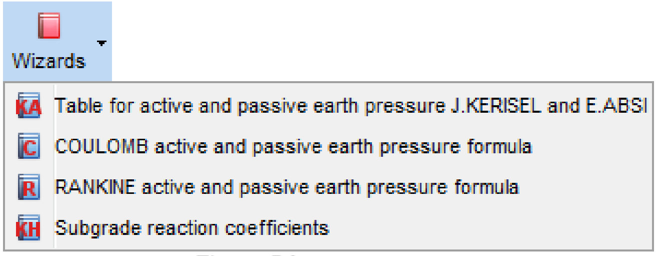


Figure B9 *: Wizards Menu*

- Table for active and passive earth pressure J. KERISEL and E. ABSI: determine the active and passive earth pressure coefficients as a function of the internal friction angle and the characteristic values needed for reading of the J. Kérisel and E. Absi tables (see § B.3.2.2 and part C of the manual);
- COULOMB active and passive earth pressure formula**:** calculate the active and passive earth pressure coefficients using the sliding wedge method (see § B.3.2.2 and part C of the manual);
- RANKINE active and passive earth pressure formula: calculate the active and passive earth pressure coefficients using the Rankine formula (see § B.3.2.2 and part C of the manual);
- Subgrade reaction coefficients: evaluate the reaction coefficient using the Balay or Schmitt formulas or by reading the Chadeisson curves (see § B.3.2.4 and part C of the manual);

B.2.3.4. Combinations Menu

This menu let us create families of combinations of loads, useful in examination of the influence of several combinations in one project. (cf. § B.3.5 and Part C of the manual).

Calculate / Results and EC7 Checks Menus

B.2.3.5. Calculate/Results/EC7 checks Menus

The 3 menus enable to start the calculation and explore the results.

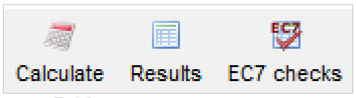


Figure B10 *: Calculation/Results Menu*

This menu is used to manage the calculations and results.

- Calculate: start calculation of the whole project;
- Results: open a window containing the summary of results and the envelope curves, preceded by a summary of the data and followed by results per phase in the form of graphics and tables;
- **EC7 checks**: open the EC7 checks if they were activated in "Title and Options". Three types of checks are available: passive earth pressure safety check, vertical equilibrium and stability of the anchoring block.

B.2.3.6. Help Menu

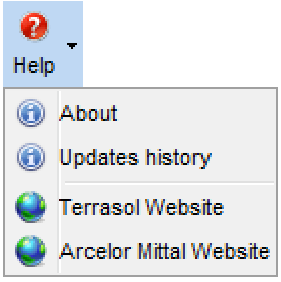


Figure B11 *: Help Menu*

This menu is used to access the following options:

- **About**: gives information about the software (the version number in particular) and access to information about the system;
- **Updates history** opens the file logging the various software updates;
- **Terrasol website**: link to the Terrasol website;
- **Arcelor Mittal Website:** link to the Arcelor Mittal website

B.2.3.7. Phasing management

Phasing is managed using the context menu on the tabs of each calculation phase (right click).

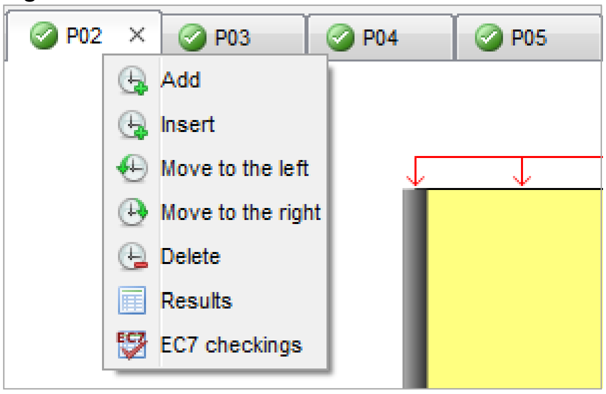


Figure B12 *: Phasing management Menu*

- Add: creates a new calculation phase after the last phase created. It is also possible to add a phase by clicking the tab to the right of the last phase + ;
- Insert**:** inserts a new calculation phase before the phase selected;
- Move to the right: modifies the calculation phases sequence by moving the selected phase forward by a single position in relation to the others;
- Move to the left: modifies the calculation phases sequence by moving the selected phase backward by a single position in relation to the others;
- Delete: deletes the selected calculation phase after confirmation;
- **Results**: opens the results window for the selected phase, accessible if the project has already been calculated;
- **EC7 cheks**: opens the checks window for the selected phase;

These modifications are applied in the context of phasing management presented in chapter B.4.2.

B.2.3.8. Keyboard short-cuts

Some of the menu options previously described can be accessed directly. The following list summarises all the keyboard shortcuts available in AMRetain (some of them are also explained in the menus):

- **Ctrl+N**: creates a new project;
- **Ctrl+O**: opens a file to be selected from the file explorer;
- **Ctrl+S**: saves the current file;
- **Ctrl+Shift+S**: saves the current file under a new name;
- **Ctrl+P**: opens the print wizard dialogue box;
- **Ctrl+Q**: starts calculations;
- **Ctrl+A**: interrupts calculations;
- **Ctrl+R**: opens the results window.

B.2.3.9. Context menus

These additional menus are not permanently displayed in the AMRetain main window. Right-clicking certain zones calls them up.

<u>**Context menu for graphics and tables**</u>

Each results graphic or table has a specific context menu. This context menu is accessible by right-clicking the graphic or table in question.

A right click inside the frame of a graph calls up an export wizard for exporting the graphic in image format:

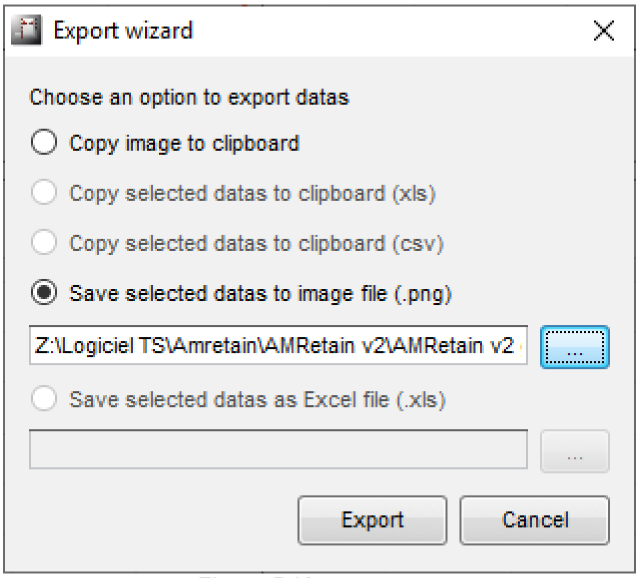


Figure B13 : *Help Menu*

- **Copy to clipboard as an image:** copies the graphic in image format to the Windows® clipboard so that it can be pasted into a document (Microsoft Excel®, Microsoft Word®, etc.);
- **Save as image (.png)**: creates an image file with extension ".png" in your environment.

<u>Note</u>: the other export formats are shaded because not applicable to graphics. They are functional when exporting tables.

Right clicking in a table (see figure below) calls up a table export wizard:

- **Copy selected data to clipboard (xls)** ⇨ copies the selected table in Excel format to the Windows® clipboard so that it can be pasted into a document (Microsoft Excel®, Microsoft Word®, etc.);
- **Copy selected data to clipboard (csv)** ⇨ copies the selected table in CSV format (values separated by decimal points) to the Windows® clipboard so that it can be pasted into a document (Microsoft Excel®, Microsoft Word®, etc.);
- **Save selected data as Excel file (.xls)** ⇨ creates an Excel file with extension ".xls", containing the selected data.

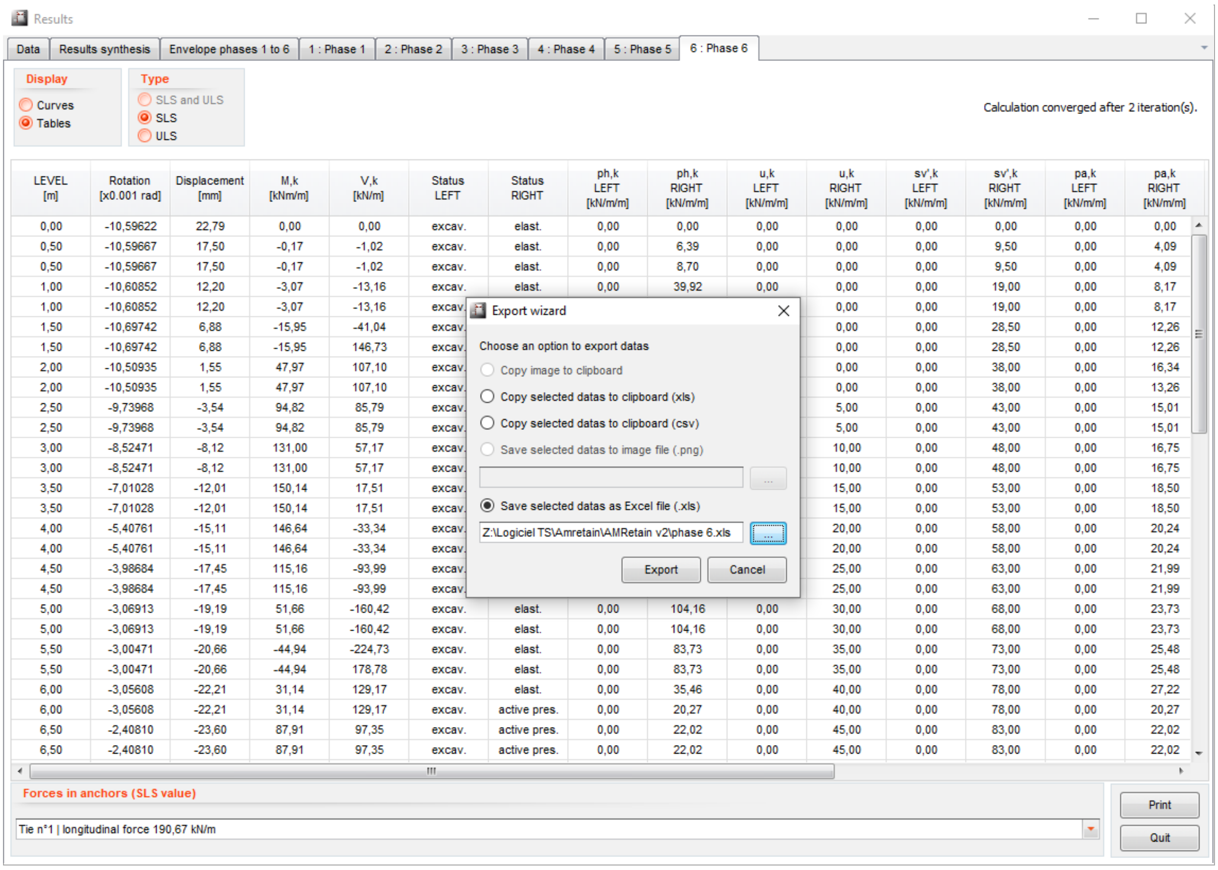


Figure B14 *: Results table context menu*

Summary tables context menu

The same menu as described above appears when right clicking on the table in the data tab, where it is possible to export the definition of soil layers. The copy to clipboard option is also accessible for the wall definition table.

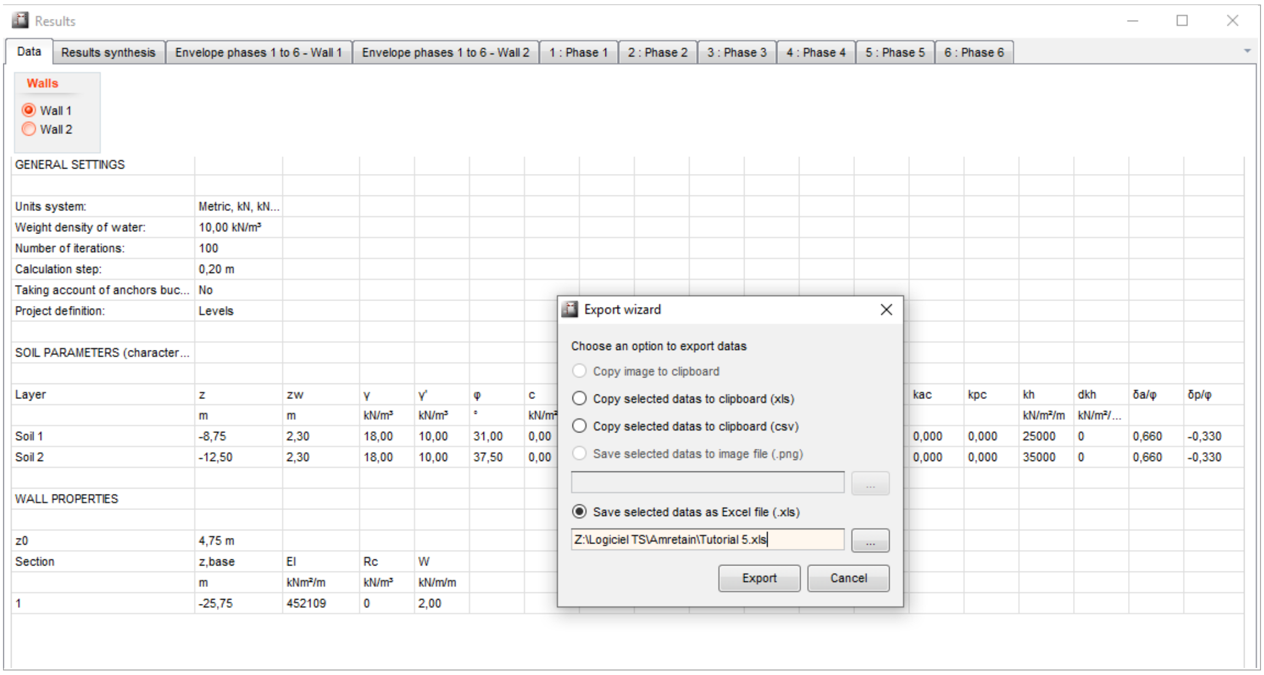


Figure B15 *: Soil layers definition table context menu*

B.2.4. Buttons bar and menu items

Each menu item has an icon illustrating the corresponding action. They are listed below:

Buttons corresponding to the items of the **File** menu :

- **New:** Initialises creation of a new project;
- **Open:** Opens an existing project from file explorer;
- **Save:** Saves changes to current project;
- **Save as:** Saves current project under a new name and/or path;
- **Print:** Opens print dialogue box (only accessible if the project has already been calculated);
- **Program Options:** Opens the "Program options" dialogue box (default choice of project files folder and unit system);
- **Quit:** Closes current project.

Buttons corresponding to items of **Data** menu:

- **Title and options:** Opens the "Title and Options" dialogue box;
- **Soil layers:** Opens the "Soil layers" definition dialogue box;
- **Retaining wall:** Opens the "Retaining wall" definition dialogue box.

Buttons corresponding to items of **Wizards** menu:

- **KERISEL and ABSI** active and passive earth pressure coefficients wizard;
- **COULOMB** active and passive earth pressure coefficients wizard;
- **RANKINE** active and passive earth pressure coefficients wizard;
- Subgrade **reaction coefficients** wizard**;**

Buttons corresponding to items of Help menu:

- Opens the "About" AMRetain window;
- Opens the updates history;
- Opens the Terrasol website;
- Opens the Arcelor Mittal website.

Buttons

- **Save**: saves the current project;
- **Calculate**: starts the calculations for the current project;
- **Results**: displays the project results (only accessible if the project has already been calculated);
- **EC7 checks**: displays the results of the Eurocode 7 checks (only accessible if the project has already been calculated), if they were requested upstream in the "Title and Options" window.
- **Combinations**: Load cases wizard.

B.2.5. Overall procedure for defining a new project

This paragraph summarises the procedure to be followed for defining data, running the calculation and viewing the results of a AMRetain project:

1. Start AMRetain and click on [Start AMRETAIN] ;
2. Click on [Agree to the terms]
3. Choose **New Project**;
4. In the **Title and Options** dialogue box, define the type of project (**Single wall** or **Double wall**) and fill out the general project options. If necessary, activate consideration of 2nd order moments, ULS checks and define the corresponding parameters. Then click [Validate and Quit];
5. Save the project.

If a Single wall project was selected:

6. In the **Soil layers** definition dialogue box, define the parameters of the various soil layers using the available wizards. These data can be imported from the general soils database or conversely saved in the database, then click: [Validate and Quit];
7. In the **Retaining wall** definition dialogue box, define the characteristics of the wall using the wizard, then click: [Validate and Quit];
8. Apply the actions of the initial phase via the **Choice of actions** frame. Once the action has been correctly defined, its graphical representation appears in the phasing management tab. At the same time, the action is given a green tick in place of the red cross, the behaviour of the associated phase tab is the same if all the actions have been correctly defined;
9. Click tab [+] in the phasing management frame to add a phase. Apply the required actions to the new phase via the **List of available actions** frame**;**
10. Repeat the previous step until the final phase is performed;
11. Start calculations by clicking the **Calculate** button on the buttons bar;
12. Finally, click the **Results** button on the buttons bar to view the results. They contain a synthesis, envelopes and results detailed per phase. If the ULS checks were activated in "Title and Options", the results of these checks can also be accessed via button "EC7"

<u>If a Double wall project was selected:</u>

The principle is the same as for a Single wall project. By convention;

- Wall 1 corresponds to the left-hand wall, its actions are shown in black in the actions definition frame;
- Wall 2 corresponds to the right-hand wall, its actions are shown in blue in the actions definition frame.

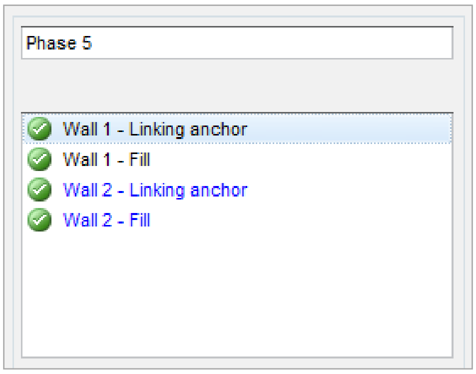


Figure B16 : *Double wall project: List of actions*

6. In the **Soil layers** definition dialogue box, fill out the soil model parameters for wall 1, using the available wizards. These data can be imported from the general soils database or conversely saved in the database;
7. Choose tab "Wall 2", define the soil model for wall 2 repeating the same approach as followed for wall 1, or click Import model to import the soil model of wall 1, then click Validate and Quit;
8. In the **Retaining wall** definition dialogue box, define the characteristics of wall 1 using the wizard if necessary;
9. Choose tab "Wall 2", do the same as for definition of the characteristics of wall 1 or click Import model to import the properties of wall 1 to those of wall 2, then click Validate and Quit;
10. Phasing management follows the same procedure as for a single wall (add a phase by clicking tab +). The only difference lies in the definition of actions, each of which also needs to be assigned to one of the two walls;
11. Start calculations by clicking the **Calculate** button on the buttons bar;
12. Finally, click the **Results** button on the buttons bar to consult the results. On each of the tabs in the results window, it is possible to switch between the wall 1 and wall 2 results.

This summarised procedure is described in detail in the rest of this document and through the tutorials provided in part D of the manual.

B.2.6. Operation of the updater

By default, the AMRetain shortcut activated at initial installation of the software starts **AMRetain (TerrasolUpdater)**.

The Updater allows for automatic updating of the AMRetain software. The TerrasolUpdater utility automatically logs into an updates server to check whether a new version of the AMRetain software is available. If it is, it prompts the user to update their software and they may then either accept or refuse.

- If they accept, the Updater downloads and installs the update then automatically starts the AMRetain software;
- If they refuse, the Updater does not install any update and automatically starts the AMRetain software.

Finally, if no new update is available, the Updater automatically starts the AMRetain software.

If a user is several updates late when starting the Updater, they are all proposed in turn. If the user refuses a given update “n”, the following ones (n+1, etc.) are not proposed, until update “n” has been accepted.

When no internet connection is available, or the various security gateways prevent access to the updates server, the Updater does not appear and starts the AMRetain software directly.

B.3. Project data

Data input, except for phasing, is performed through 3 dialogue boxes: **Title and Options**, **Soil layers** definition and **Retaining wall** definition, all accessible from the Data menu. An additional dialogue box, in the Wizards menu, can be used for **Load cases definition**.

Chapters B.3.1 to B.3.3 describe the working of the Data menu dialogue boxes using the case of a single wall project.

Chapter B.3.4 gives the input particularities of double wall projects.

Chapter B.3.5 is devoted to the definition of load combinations.

B.3.1. Title and Options

B.3.1.1. General options

The project general options are to be defined in the **Title and Options** dialogue box accessible from the **Data** menu.

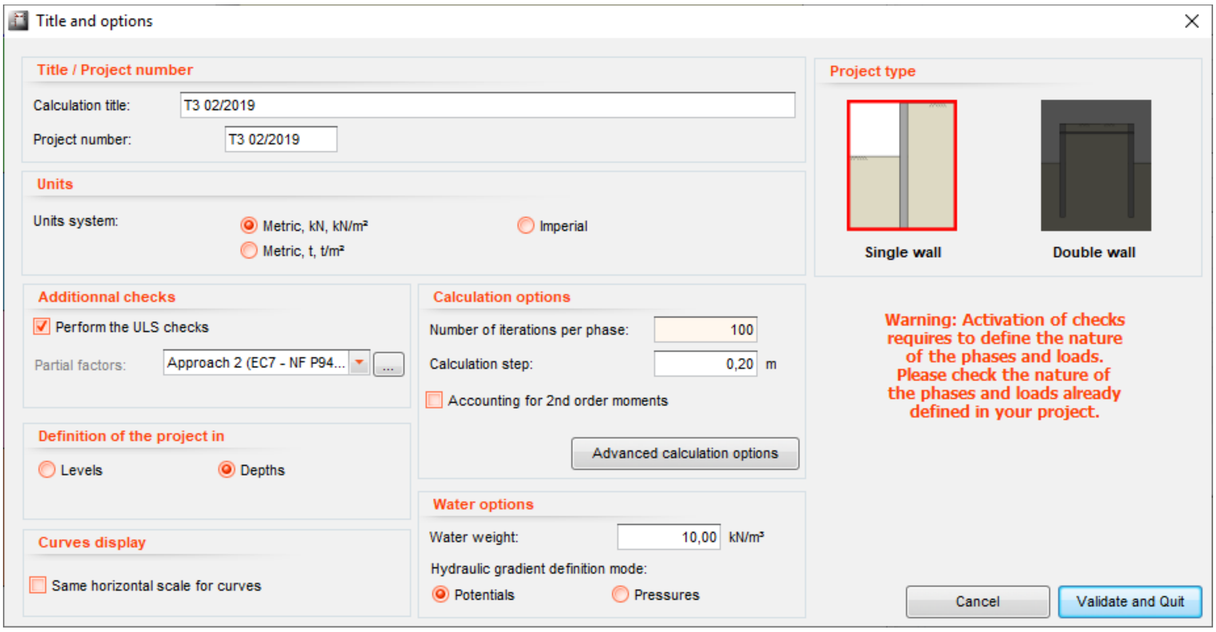


Figure B17 : *"Title and Options" dialogue box (single wall project)*

This dialogue box is divided into frames presented below:

- **Title / Project number:** this zone is used to input a Title and a project reference (filling out not mandatory);
- **Units:** it is possible to work in the metric system (kN, MN or t) or the imperial system. The units chosen are valid for the input data and results. If the project input data already exist, AMRetain converts these values to the new system of units;
- **Definition of the project in:** this option is used to orient the vertical axis upwards "Levels" or downwards "Depths". It is valid for all project levels and can no longer be modified once the project has been created. The "Levels" option is selected by default;

- **Additional checks**: this frame is used to activate the <u>ULS checks</u>, in particular concerning the passive earth pressure safety checks, vertical equilibrium and stability of the anchoring block. The set of <u>partial factors</u> chosen by default corresponds to the 2/2* approach of standard NF P94-282, although the sets resulting from the other Eurocode 7 approaches are also available. Modification of an existing set or creation of a personalised set is feasible by clicking the button to the right of the drop-down list ... (see chapter B.3.1.2);

  These checks are accessible for both single wall and double wall projects.

- **Calculation options**: in this frame it is possible to take account of 2nd order effects (see Part C of the manual) by simply ticking the corresponding box ("Accounting for 2nd order moments", which is unticked by default). It is also possible to modify the maximum number of iterations per phase, by default equal to 100, as well as the calculation step, corresponding to the wall breakdown step, by default given a value of 0.20 m (or 0.66 ft in the imperial system).

  In this same frame, a button gives access to the <u>advanced calculation options</u>, the content of which is illustrated in the following figure.

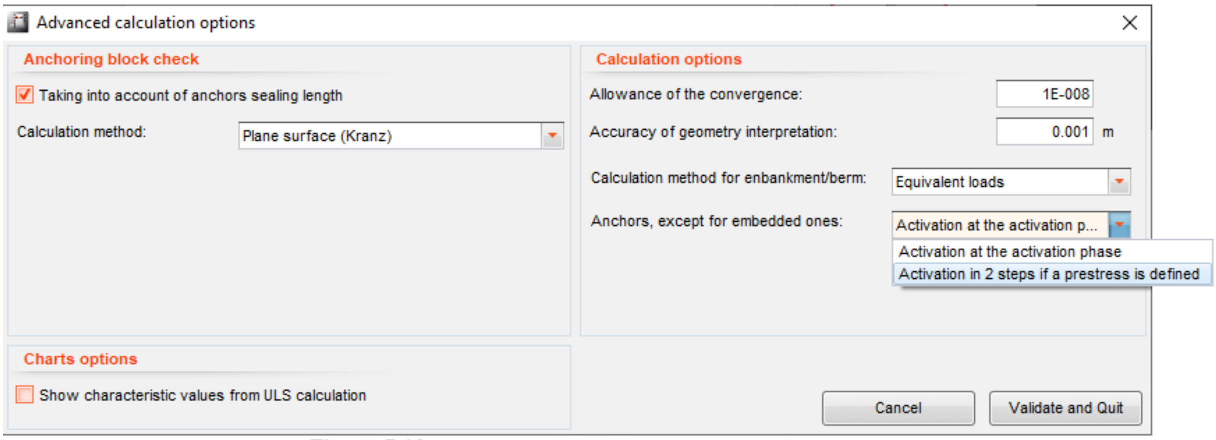


Figure B18 *: "Advanced calculation options" dialogue box*

The "Calculation options" frame is used to specify the following:

- o The relative tolerance controlling convergence, by default set at 10^{-4};
- o The accuracy of geometry interpretation (in m), by default equal to 10^{-3} m, or one mm;
- o The choice of calculation method for banks and berms:
  - ▪ <u>Equivalent loads</u>: the effect of a bank or berm is simulated by superposing overloads equivalent to their weight. This approach is not recommended, in accordance with standard NF P94-282;
  - ▪ <u>Simplified method</u>: the effect of a bank or berm is simulated in accordance with the approaches proposed in appendix D to standard NF P94-282;
- o <u>Anchors work mode (except for embedded anchors)</u>: it is possible to choose between operation as of the activation phase or operation only as of the next phase (then only pre-stressing is taken into account in the activation phase). This choice applies to all the anchors which will be defined in the project (see part C of the Manual for the theoretical differences between to these two options);

- o The "Anchoring bloc check" frame defines the parameters for checking the stability of the anchoring block:
  - ▪ Taking account of anchors embedded length in the equivalent anchor force calculation for a wall anchored by several tie-rods. This option is activated by default.
  - ▪ Calculation method: plane surface (Kranz) or logarithmic spiral surface (Jelinek). For the logarithmic spiral arc surface (Jelinek), two additional parameters are to be filled in:
    - o Number of slices for the anchor block
    - o Step calculation of the central angle associated to the logarithmic spiral
- o The "Charts options" frame:
  - ▪ This checks box displays the characteristics values in order to generate the ULS calculation

The theoretical aspects of these options are detailed in part C of the manual.

- **Curves display:** by ticking the "Same horizontal scale for curves" box, a common scale is assigned to all the graphics presenting the same type of result. By default, this box is not ticked.
- **Water options:** this frame is used to declare the water weight and the hydraulic gradient definition mode (Potentials or Pressures). By default the water weight is taken as equal to 10 kN/m^3 (0.0624 kcf in imperial system) and the hydraulic gradient is defined in terms of hydraulic potentials.
- **Project type:** this frame is reserved for the choice of the type of project (Single wall or Double wall) by selecting the corresponding icon. If a double wall project is selected, AMRetain asks for input of the distance between the two walls, in the **Double wall options** frame. As this chapter is devoted to the single wall case, refer to chapter B.3.4 for the particularities of double wall projects.

B.3.1.2. Definition of partial factors dialogue box

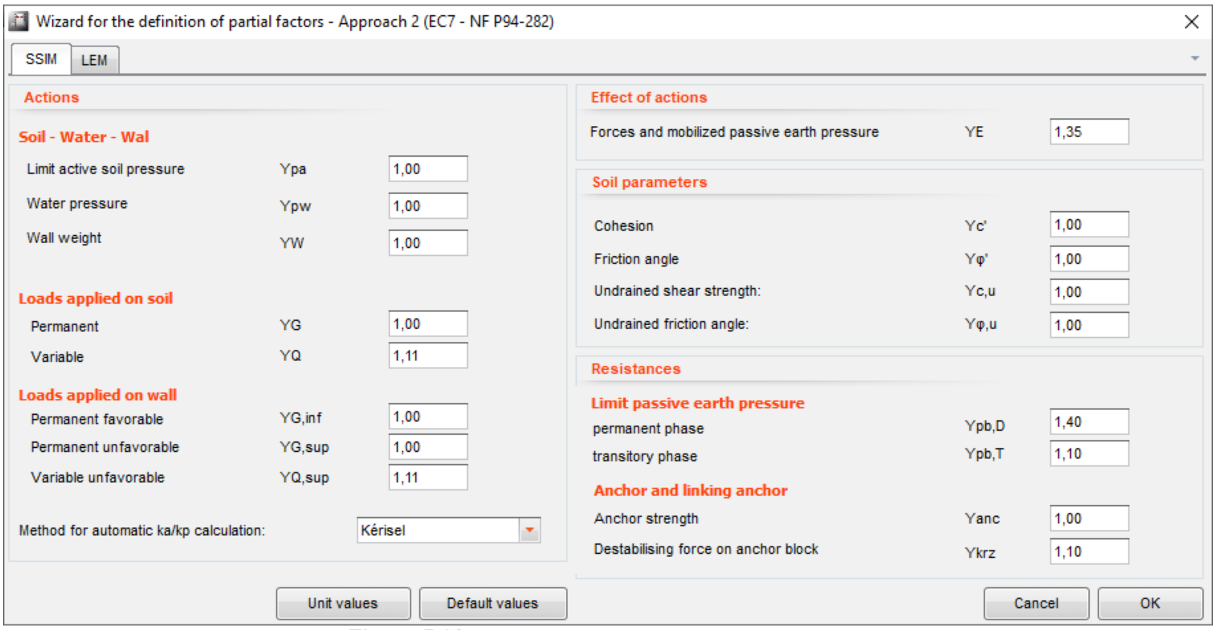


Figure B19 : *Partial factors definition dialogue box*

This window is used to view and modify the partial safety/weighting factors used in the ULS calculations and checks. Two sets of parameters are available, each grouped under a tab

, one corresponding to the SSIM calculation and the other to the LEM. Some parameters are common to the two sets of parameters and can be modified in the SSIM tab and only viewed in the LEM tab.

The default values proposed are those resulting from one of the approaches (1, 2 or 3) of Eurocode 7 and its French application standard NF P94-282. It is however possible to modify them to adapt to application of other regulatory references.

The [Default values] button is used to reset the factors with the values corresponding to the approach chosen from the "Partial factors" drop-down list, which is also summarised in the title of the wizard window.

The [Unit values] button is used to assign a value of 1.0 to all factors. In this way, it is possible to run checks without applying any weighting.

The definitions of the various factors are presented below:

Actions and Effects of actions:

- **Soil – Water – Wall:** factors applied to the limit active soil pressure (γ_{pa}), water pressure (γ_{pw}) and weight of the wall (γ_W);
- **Loads applied on soil:** factors applied to overloads acting on the soil as a function of their nature (permanent γ_G / variable γ_Q);
- **Loads applied on wall:** factors applied to overloads applied directly to the wall as a function of its nature (permanent/variable) and their character (favourable/unfavourable). Several possible combinations: permanent favourable ($\gamma_{G,inf}$), permanent unfavourable ($\gamma_{G,sup}$) and variable unfavourable ($\gamma_{Q,sup}$);
- **Effect of actions** (γ_E): factor applied to the forces, loads and mobilised passive earth pressure.

Resistance parameters:

- $\gamma_{c'}$: applied to soil layers cohesion for drained behaviour;
- $\gamma_{\varphi'}$: applied to the tangent of the friction angle of the soil layers for drained behaviour;
- γ_{cu} : applied to soil layers cohesion for undrained behaviour;
- $\gamma_{\varphi u}$: applied to the tangent of the friction angle of the soil layers for undrained behaviour;

Resistances:

- $\gamma_{pb,D}$ and $\gamma_{pb,T}$: applied to the soil limit passive earth pressure as a function of the nature of the phase (permanent or transitory respectively);
- γ_{anc} : applied to the resistance of anchors;
- γ_{krz} : applied to the destabilising anchor force when checking the stability of the anchoring block.

The γ_{anc} and γ_{krz} factors apply exclusively for an SSIM type calculation.

Reference method for recalculation of k_a/k_p: to be chosen from the three methods available: Kérisel (corresponding to the Kérisel and Absi tables), Coulomb and Rankine.

Comments: Depending on the parameter applied to the tangent of the friction angle ($\gamma_{\varphi'}$, see B.3.1.2), the friction angle calculation value may differ from its characteristic value defined by the user. In this case, the values of k_a/k_p will be automatically recalculated by the calculation engine. The above option can be used to set the recalculation method for these parameters.

The following table summarises the set of default values proposed for the SSIM model, for each calculation approach:

Category	Partial factor	Symbol	Approach 1.1	1.2	2/2*([1])	3
Soil-Water-Wall	Limit active soil pressure	γ_{Pa}	1.35	1.00	1.00	1.00
	Water pressure	γ_{Pw}	1.35	1.00	1.00	1.00
	Weight of wall	γ_{w}	1.35	1.00	1.00	1.00
Load applied on soil	Permanent	γ_{G}	1.00	1.00	1.00	1.00
	Variable	γ_{Q}	1.11	1.30	1.11	1.30
Load applied on wall	Permanent favourable	$\gamma_{G,inf}$	1.00	1.00	1.00	1.00
	Permanent unfavourable	$\gamma_{G,sup}$	1.35	1.00	1.00	1.35
	Variable unfavourable	$\gamma_{Q,inf}$	1.50	1.30	1.11	1.50
Effects of actions		γ_{E}	1.00	1.00	1.35	1.00
Soil parameters	Cohesion (drained behaviour)	$\gamma_{c'}$	1.00	1.25	1.00	1.25
	Friction angle (drained behaviour)	$\gamma_{\varphi'}$	1.00	1.25	1.00	1.25
	Cohesion (undrained behaviour)	γ_{cu}	1.00	1.40	1.00	1.40
	Friction angle (undrained behaviour)	$\gamma_{\varphi u}$	1.00	1.40	1.00	1.40
Resistances	Limit passive soil pressure – Permanent phase	$\gamma_{pb,D}$	1.00	1.00	1.40	1.00
	Limit passive soil pressure – Transitory phase	$\gamma_{pb,T}$	1.00	1.00	1.10	1.00
	Resistance of anchors	γ_{anc}	1.10	1.10	1.00	1.00
	Destabilising anchor force	γ_{krz}	1.00	1.00	1.10	1.00

Table B 2: Default values of partial factor sets proposed in Eurocode 7

([1]) Model 2* is only valid for the SSIM method (see part C of the manual for more details and in particular for the values proposed for the LEM model).

B.3.2. Definition of soil layers

B.3.2.1. Soil characteristics definition dialogue box

This dialogue box is accessible by clicking the **Data** menu then **Soil layers**. For each wall, it is used to define the intrinsic parameters and the characteristics defining the soil-wall interaction (behaviour law).

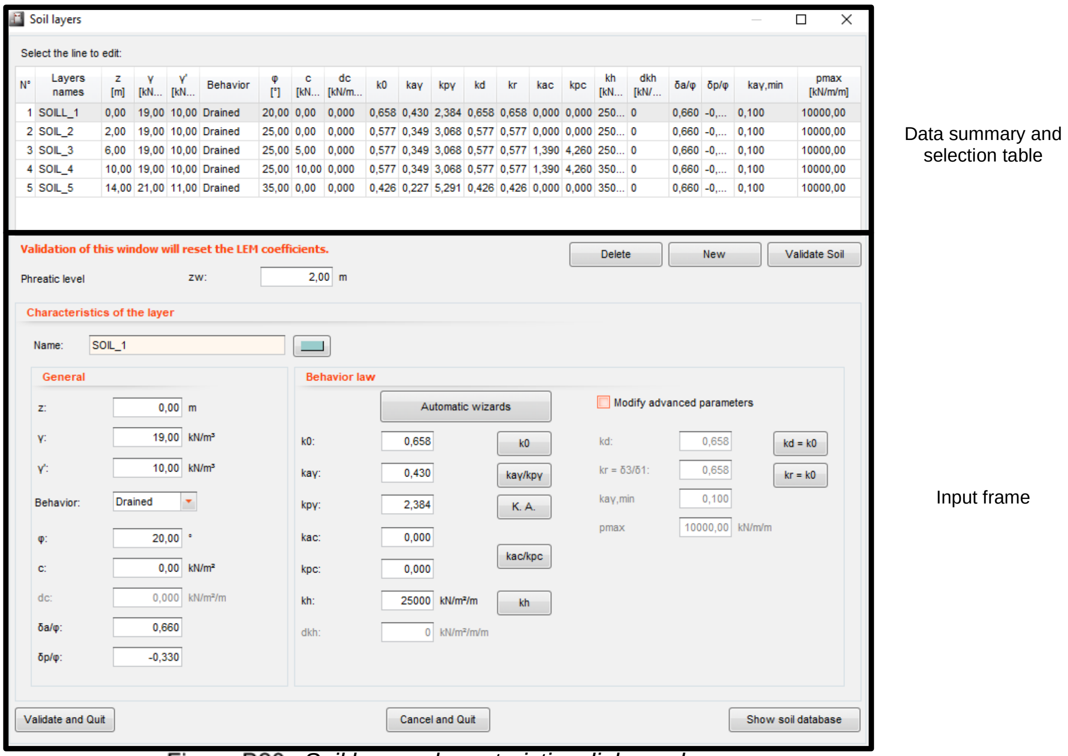


Figure B20 : *Soil layers characteristics dialogue box*

The dialogue box is divided into two parts. At the top, a summary table showing all the data and enabling a layer to be selected. At the bottom, an input frame for defining or modifying the characteristics of the layer selected in the summary table, and for accessing the Soils Database by clicking [Show soil database].

The soils database (DB) is used to keep a record of the soil layer and its characteristics. They can thus be reused to define a new soil layer. To save a soil layer, after validating the soil in the summary table, click [Show soil database], then the arrow pointing to the right. Conversely, if one wishes to use a layer already in the memory, click [Show soil database], then select the layer required by clicking it and then clicking the arrow pointing to the left. A layer can be removed from the memory by selecting it and then clicking the trash can icon under the list.

Once input of a layer is complete, click the summary table in the upper part to validate it or click the [Validate Soil] button and then [New] to begin input of a new layer or [Validate and Quit] to end input of all layers. The soil layers are automatically reorganised as a function of their upper level (z). A soil layer can be deleted by clicking [Delete].

In the input zone, it is first of all necessary to enter **z_w**: initial level of the top of the water table (m, ft). This level is common to all the soil layers which will be defined by the concerned wall.

In the other boxes one must then define the characteristics of the soil layers, beginning with the upper layer:

- Name of soil layer;
- Colour assigned to the soil layer: a simple click on the colour associated with the soil layer displays the colour selection dialogue box (see chapter B.3.2.5).

General Frame:

- **z** : level of head of layer (m, ft);
- γ : wet unit weight (characterising the soil situated above the groundwater table) (kN/m^3, kcf);
- γ' : buoyant unit weight (characterising the soil situated below the groundwater table) (kN/m^3, kcf);
- **Behaviour**: drained or undrained (the choice only impacts the safety factor on cohesion and internal friction angle)
- φ : internal friction angle (°);
- **c** : cohesion (kN/m², ksf);
- **dc** : variation in cohesion per unit depth in the layer – the reference being the initial head of the layer (kN/m²/m, ksf/ft);
- **δ_a/φ** : obliquity of limit active earth pressure stresses (ratio between angle of active pressures and angle of internal friction);
- **δ_p/φ** : obliquity of limit passive earth pressure stresses (ratio between angle of passive pressures and angle of internal friction).

Behaviour law:

- **k_0** : horizontal active earth pressure coefficient at rest;
- **$k_{a\gamma}$** : horizontal active earth pressure coefficient;
- **$k_{p\gamma}$** : horizontal passive earth pressure coefficient;
- **k_{ac}** : horizontal active earth pressure coefficient applied to cohesion;
- **k_{pc}** : horizontal passive earth pressure coefficient applied to cohesion;
- **k_h** : horizontal soil reaction coefficient (kN/m^2/m, ksf/ft);
- **dk_h** : variation in horizontal soil reaction coefficient per unit depth in the layer – the reference being the initial head of layer (kN/m^2/m/m, ksf/ft/ft);
- **k_d** : unloading ratio of soil;
- **k_r** : reloading ratio of soil;
- **$k_{a\gamma,min}$**: minimal active earth pressure coefficient (horizontal);
- **p_{max}** : limit pressure not to be exceeded (kN/m/m, kip/ft).

A tick box is used to activate the advanced parameters (**dc, dk_h, k_d, k_r, $k_{a\gamma,min}$** and **p_{max}**) so that they can be modified. When this box is not ticked, these parameters take the following default values:

- **dc = 0** (kN/m²/m, ksf/ft);
- **dk_h = 0** (kN/m^2/m/m, ksf/ft/ft);
- **$k_d = k_0$;**
- **$k_r = k_0$;**
- **$k_{a\gamma,min}$ = 0.10;**
- **$p_{max} = 10^4$** (kN/m/m, kip/ft).

Two additional buttons are accessible under the soil characteristics frame. The [Cancel and Quit] button cancels the modifications made and closes the dialogue box, while the [Validate and Quit] button saves the latest inputs before closing the window.

Caution: closing dialogue boxes by clicking the cross at the top-right of the window will close them without saving any modifications made (equivalent to clicking the [Cancel and Quit] button).

Wizards are available for determining the various coefficients and are accessible via the buttons in the dialogue box.

Clicking the [Automatic wizards] button enables the values of the k_0, $k_{a\gamma}$, $k_{p\gamma}$, k_d, k_r, k_{ac} and k_{pc} coefficients to be calculated in one go, according to the following choices:

- **k_0** : Jaky formula for a normally consolidated horizontal soil (OCR overconsolidation ratio = 1 and β "TN angle" = 0°);
- **$k_{a\gamma}$** : Kerisel and Absi wizard – Active earth pressure, weighted soil, no overload for a vertical wall and a horizontal soil (λ "obliquity of wall" = 0° and β "Ground level angle" = 0°);
- **$k_{p\gamma}$** : Kerisel and Absi wizard – Passive earth pressure, weighted cohesionless soil, no overload for a vertical wall and horizontal soil (λ "obliquity of wall" = 0° and β "Ground level angle" = 0°);
- **k_d = k_r = k_0**;
- If cohesion is nil, then: **k_{ac}** = **k_{pc}** = 0;
- If cohesion is not nil: **k_{ac}** and **k_{pc}** are obtained using the corresponding wizard (no value to be input, this wizard already knows everything)

The button located next to each coefficient can be used to access the corresponding wizard for a manual definition of the parameters of the behaviour law.

All the wizards are described in the following chapters.

These wizards are accessible via:

- Initial definition of soil layers;
- Definition of a bank or berm (fill) (see chapter B.5.2.2);
- Redefinition of soil layers (see chapter B.5.3);
- Definition of LEM coefficients (see chapter B.5.7.1);
- or, independently of the current project, via the **Wizards** menu.

CAUTION: WIZARDS ARE PROVIDED TO HELP THE USER, WHO HOWEVER REMAINS RESPONSIBLE FOR THEIR USE.

B.3.2.2. Wizards for determining active and passive earth pressures

Wizard $\mathbf{k_{a\gamma}/k_{p\gamma}}$ calculates the values of the active and passive earth pressures using one of the three methods proposed:

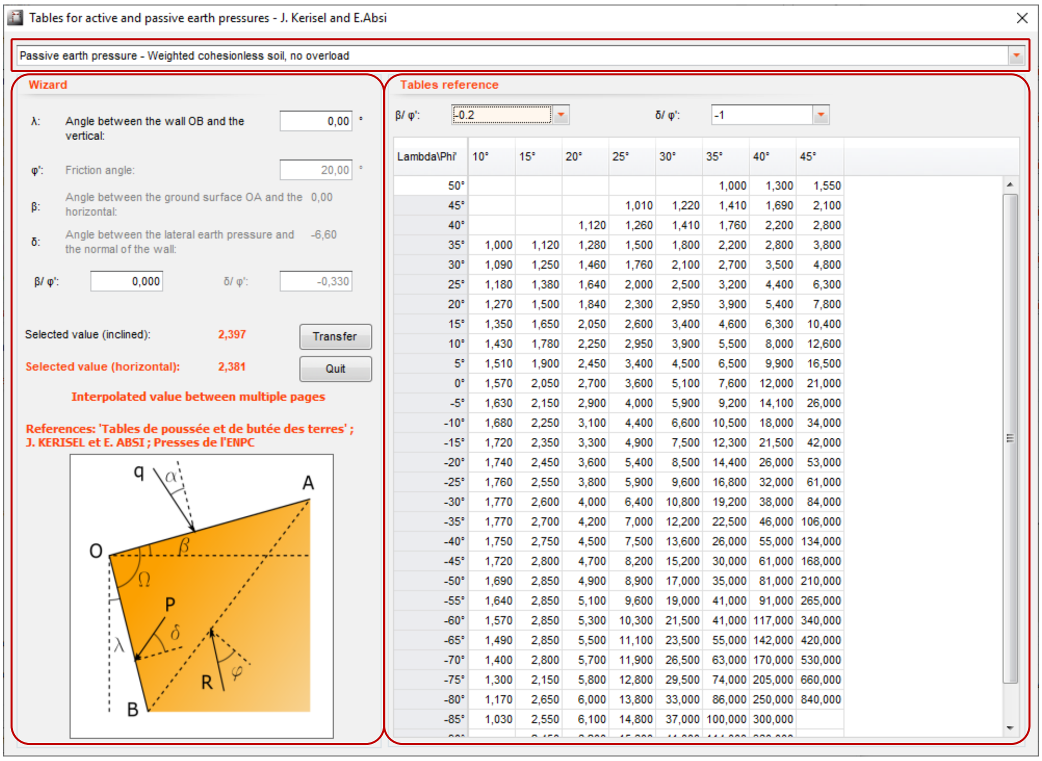
- reading the Kerisel & Absi tables
- the Coulomb sliding wedge method
- the Rankine formula

The theoretical bases used by these wizards are detailed in part C of the manual. This chapter simply describes how they are used.

a) <u>KERISEL and ABSI active and passive earth pressure tables</u>

This wizard takes the form of a dialogue box as illustrated below. It comprises a free consultation part (right-hand side) and a settings part to determine coefficients by interpolation (the actual wizard – left-hand side).

The values of the friction angle and those of the obliquities input in the soil layers characteristics definition box are automatically recovered.



Lambda\Phi'	10°	15°	20°	25°	30°	35°	40°	45°
50°						1,000	1,300	1,550
45°				1,010	1,220	1,410	1,690	2,100
40°			1,120	1,260	1,410	1,760	2,200	2,800
35°	1,000	1,120	1,280	1,500	1,800	2,200	2,800	3,800
30°	1,090	1,250	1,460	1,760	2,100	2,700	3,500	4,800
25°	1,180	1,380	1,640	2,000	2,500	3,200	4,400	6,300
20°	1,270	1,500	1,840	2,300	2,950	3,900	5,400	7,800
15°	1,350	1,650	2,050	2,600	3,400	4,600	6,300	10,400
10°	1,430	1,780	2,250	2,950	3,900	5,500	8,000	12,600
5°	1,510	1,900	2,450	3,400	4,500	6,500	9,900	16,500
0°	1,570	2,050	2,700	3,600	5,100	7,600	12,000	21,000
-5°	1,630	2,150	2,900	4,000	5,900	9,200	14,100	26,000
-10°	1,680	2,250	3,100	4,400	6,600	10,500	18,000	34,000
-15°	1,720	2,350	3,300	4,900	7,500	12,300	21,500	42,000
-20°	1,740	2,450	3,600	5,400	8,500	14,400	26,000	53,000
-25°	1,760	2,550	3,800	5,900	9,600	16,800	32,000	61,000
-30°	1,770	2,600	4,000	6,400	10,800	19,200	38,000	84,000
-35°	1,770	2,700	4,200	7,000	12,200	22,500	46,000	106,000
-40°	1,750	2,750	4,500	7,500	13,600	26,000	55,000	134,000
-45°	1,720	2,800	4,700	8,200	15,200	30,000	61,000	168,000
-50°	1,690	2,850	4,900	8,900	17,000	35,000	81,000	210,000
-55°	1,640	2,850	5,100	9,600	19,000	41,000	91,000	265,000
-60°	1,570	2,850	5,300	10,300	21,500	41,000	117,000	340,000
-65°	1,490	2,850	5,500	11,100	23,500	55,000	142,000	420,000
-70°	1,400	2,800	5,700	11,900	26,500	63,000	170,000	530,000
-75°	1,300	2,150	5,800	12,800	29,500	74,000	205,000	660,000
-80°	1,170	2,650	6,000	13,800	33,000	86,000	250,000	840,000
-85°	1,030	2,550	6,100	14,800	37,000	100,000	300,000	

Figure B21 *: Kerisel and Absi active and passive earth pressure tables*

The type of table to be used should be selected from the drop-down list at the top of the screen:

Passive earth pressure - Weighted cohesionless soil, no overload
Passive earth pressure - Weighted cohesionless soil, no overload
Active earth pressure - Weighted cohesionless soil, no overload
Weightless cohesionless soil, with overload

The contents of the "Tables reference" (right) is updated according to the type of tables selected.

In the "Wizard" frame, enter the data needed to determine the (active or passive earth pressure) coefficient in the input frame at the top-left of the window:

- **λ** : inclination of wall (i.e. angle between wall and vertical) - 0° by default (°);
- **β/φ** : angle of soil free surface normalised by **φ**;
- **α** : obliquity of overload on free surface (°);
- **Ω** : angle between free surface and wall (= π/2 + β - λ) (°).

The chosen value corresponding to the input data is displayed at the bottom of the interactive frame, plus the horizontal value which is that used in the calculations.

This value can then be transferred to the layer data currently being input, by using the [Transfer] button. To close the wizard, click [Quit].

<u>Note 1</u>: The transfer button only authorises values calculated with a zero wall inclination (λ=0) in order to comply with the reaction coefficients calculation method. The values calculated with a inclination other than zero (λ≠0) may be consulted but are not directly usable with the calculation method, which is why they cannot be transferred to the project.

<u>Note 2</u>: AMRetain performs linear interpolation for values which are not given in the tables.

CAUTION: WIZARDS ARE PROVIDED TO HELP THE USER, WHO HOWEVER REMAINS RESPONSIBLE FOR THEIR USE.

b) <u>COULOMB active and passive earth pressure formula</u>

This wizard takes the form of a dialogue box as illustrated below:

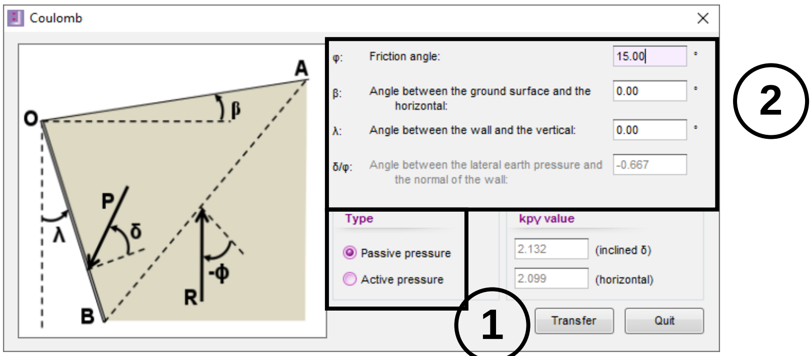


Figure B22 : *Calculation of active earth pressure coefficients using the Coulomb sliding wedge method*

The values of the friction angle and of the angles input into the soil layers characteristics definition box are retrieved automatically.

1) Select the type of calculation:
   - Active pressure;
   - Passive pressure.

2) Input the data needed for the calculation:
   - β : angle between the ground surface and the horizontal (°);
   - λ : angle between the wall and the vertical – 0° by default (°);

The calculated values (inclined and horizontal) are displayed at the bottom-right of the window. They may be transferred to the data of the layer currently being input by clicking the Transfer button. To close the wizard, click Quit.

Note 1: The transfer button only authorises values calculated with a zero wall inclination ($\lambda=0$) in order to comply with the reaction coefficients calculation method. The values calculated with an inclination other than zero ($\lambda\neq0$) may be consulted but are not directly usable with the calculation method, which is why they cannot be transferred to the project.

CAUTION: WIZARDS ARE PROVIDED TO HELP THE USER, WHO HOWEVER REMAINS RESPONSIBLE FOR THEIR USE.

c) RANKINE active and passive earth pressure formula

This wizard takes the form of a dialogue box as illustrated below:

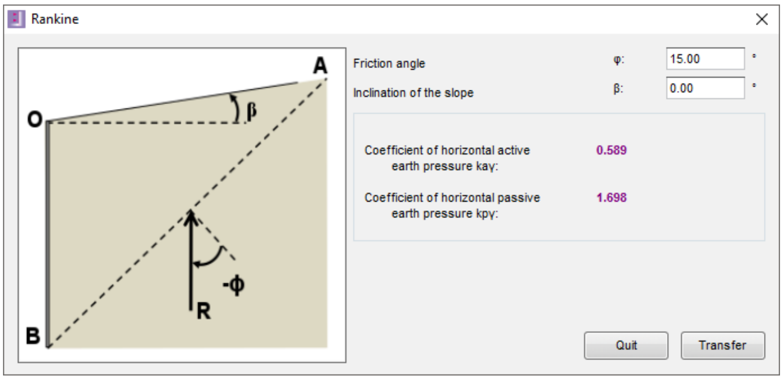


Figure B23 *: Calculation of earth pressure coefficients using the Rankine method*

Input of the friction angle φ and inclination of the slope β values is sufficient to calculate the active and passive earth pressure coefficients using the Rankine formula. Their horizontal projections are displayed in the lower part of the window.

Note: the wizard automatically retrieves the friction angle input in the soil layers characteristics definition box.

These values can then be transferred to the data for the layer currently being input by clicking the Transfer button. To close the wizard, click Quit.

CAUTION: WIZARDS ARE PROVIDED TO HELP THE USER, WHO HOWEVER REMAINS RESPONSIBLE FOR THEIR USE.

B.3.2.3. Wizard for determining coefficients k_{ac} and k_{pc}

This wizard proposes a calculation method to determine the active and passive earth pressure coefficients applied to the cohesion term.

The formulas used are given in part C of the manual. Only the use of the wizard is described below.

This wizard takes the form of a dialogue box illustrated below:

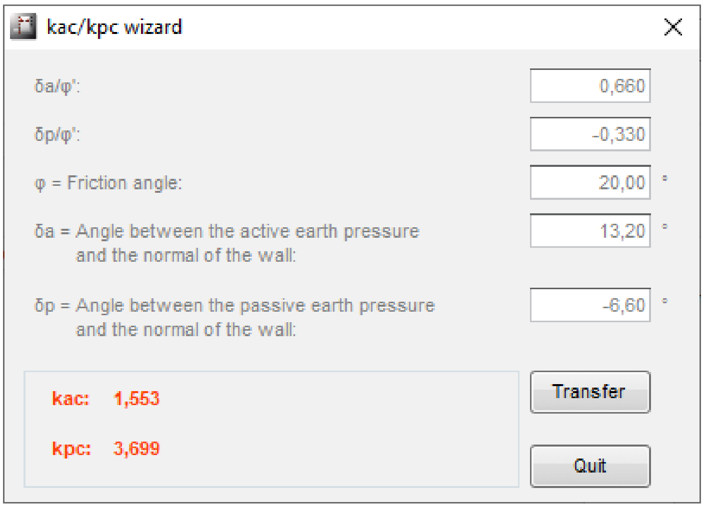


Figure B24 : *Calculation of coefficients k_{ac}/k_{pc}*

The wizard automatically retrieves the values input in the soil layers characteristics definition box:

- **δa/φ** : ratio between obliquity of active earth pressure stresses and friction angle;
- **δp/φ** : ratio between obliquity of passive earth pressure stresses and friction angle;
- **φ** : friction angle (°).

The values of k_{ac} and k_{pc} are displayed in the bottom-left of the window.

These values can then be transferred to the data of the layer currently being input by clicking the Transfer button. To close the wizard, click Quit.

CAUTION: WIZARDS ARE PROVIDED TO HELP THE USER, WHO HOWEVER REMAINS RESPONSIBLE FOR THEIR USE.

B.3.2.4. Wizards for determining the reaction coefficient

This wizard proposes three methods for determining the reaction coefficient: application of the Balay formula, application of the Schmitt formula and reading of the Chadeisson curves.

The theoretical bases used for these 3 methods are detailed in part C of the manual. Only the actual use of the wizard is described below.

The wizard takes the form of a single window, the upper part of which contains the choice of calculation method and a recapitulation of the values determined, the central part of which contains the parameters to be input for the calculation and, finally, the lower part of which contains the proposed value of k_h and the comments associated with the methods used.

Once the input parameters have been entered, the value of kh obtained can be transferred using the Transfer button.

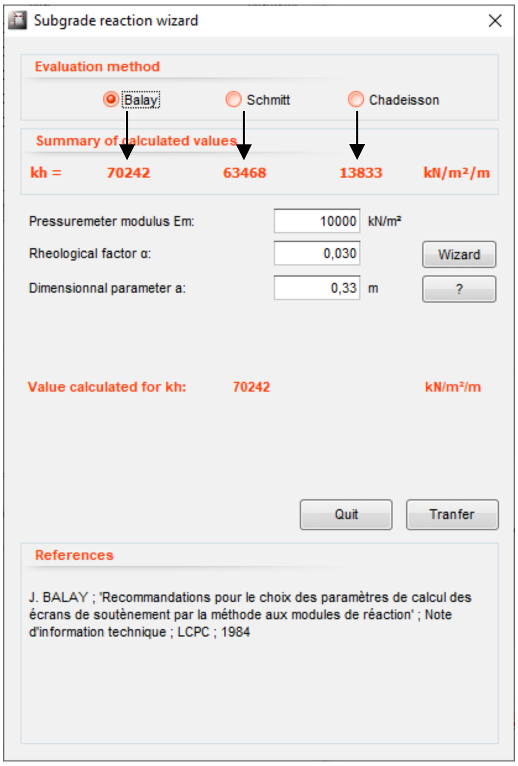


Figure B25 : *Calculation of subgrade reaction coefficient - Balay method selected*

a) BALAY formula

The following parameters must be input:

- **E_m:** pressuremeter strain modulus (kN/m², KsF) of the soil layer
- α: soil layer rheological coefficient

  Note: a wizard is provided for determining this coefficient (can be consulted simply by clicking the adjacent Wizard button). It is extracted from the Fascicule 62 (LCPC-SETRA).

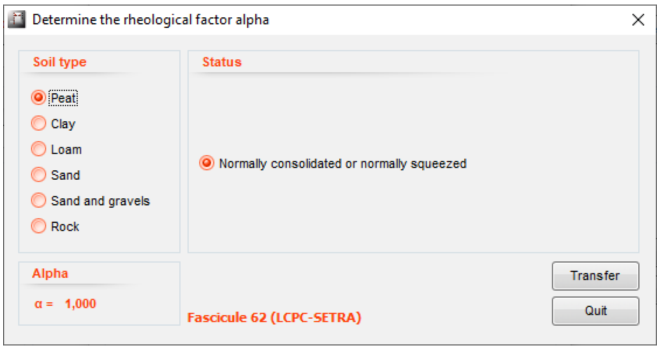


Figure B26 : *Determination of rheological parameter* α

- **a**: parameter to be defined as a function of wall embedment depth, the supported height and the relative position of the layer concerned with respect to the bottom of the excavation. The dimension of parameter "a" is a length. A help diagram illustrates the choice of this parameter (see Figure B27).

  Note: in certain special cases (same layer encountered on either side of bottom of excavation), the choice of parameter "a" requires differentiation between 2 layers with the same characteristics except for the value of k_h. This latter must be calculated for each side of the wall, allocating the appropriate value to parameter "a".

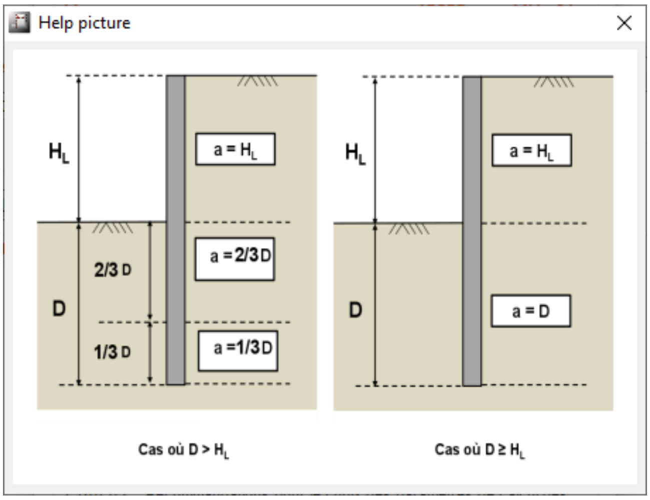


Figure B27 : *Help diagram for defining dimensional parameter a*

b) SCHMITT formula

Input parameter:

- **E_m**: pressuremeter strain modulus of the layer (kN/m², ksf);
- **α**: rheological coefficient of the layer. A wizard is available for determining this parameter by clicking Wizard >>;
- **Section**: if the EI product of the wall has already been input in the **Retaining Wall definition** window, the "Section" parameter gives direct access to the EI values for the various wall sections. If not, this parameter may be left blank;
- **EI**: average product of inertia of the wall (kN.m²/m, kip.ft²/ft).

The interest of this approach is that it takes account of the variation in the reaction coefficient with the stiffness of the wall: the stiffer the wall, the smaller the reaction coefficient, which is an accurate reflection of reality.

Figure B28 : *Calculation of reaction coefficient - Schmitt method selected*

c) CHADEISSON curves

The curves are read automatically after inputting the cohesion value and that of the friction angle. It is possible to check the value of k_h proposed by direct reading of the curves.

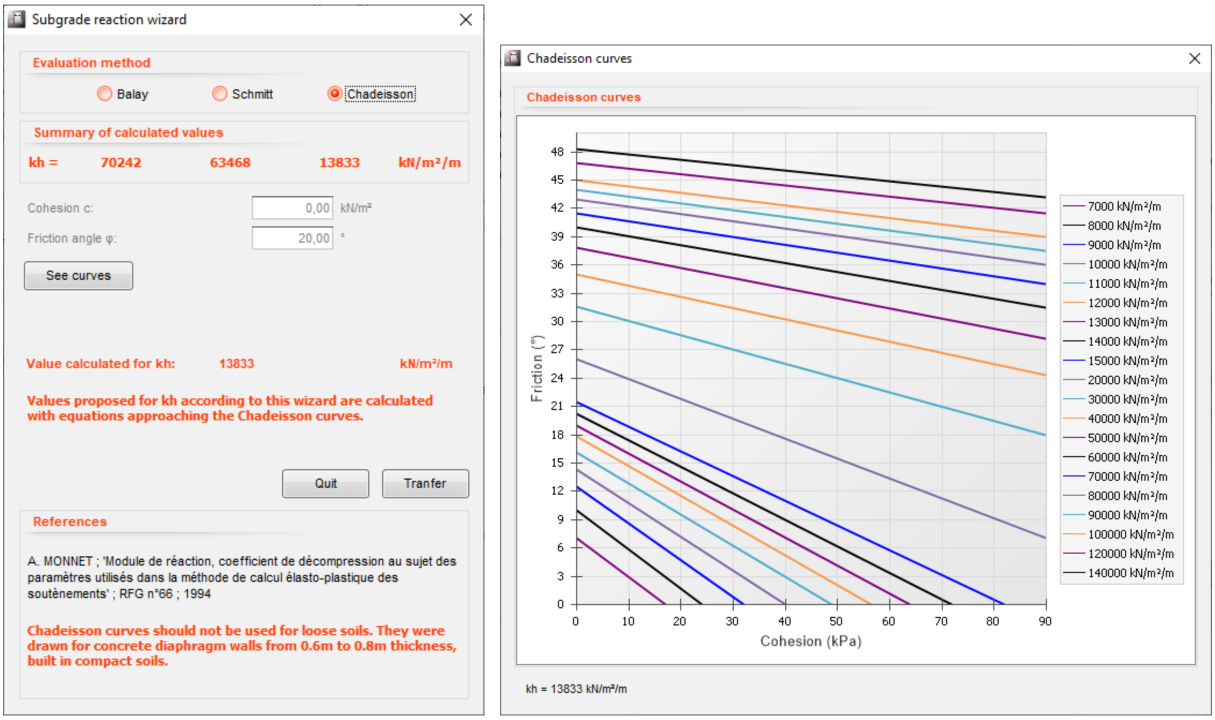


Figure B29 : *Determination of reaction coefficient from the Chadeisson curves*

The original curves were only approximately recreated. There may thus be a slight difference between what can be seen on the screen and what the user can do on paper.

B.3.2.5. Colour of layers

This wizard is accessible by opening the **Data** menu, then **Soil layers definition,** as well as in the **Fill** action. This action triggers opening of the soil layers definition dialogue box. Then click the layer colour to be modified in order to open the "Colours" wizard.

This enables a colour to be chosen other than that selected by default at creation of the soil layers. If the modifications are validated, the soil layers will appear with the new colours in the project cross-section.

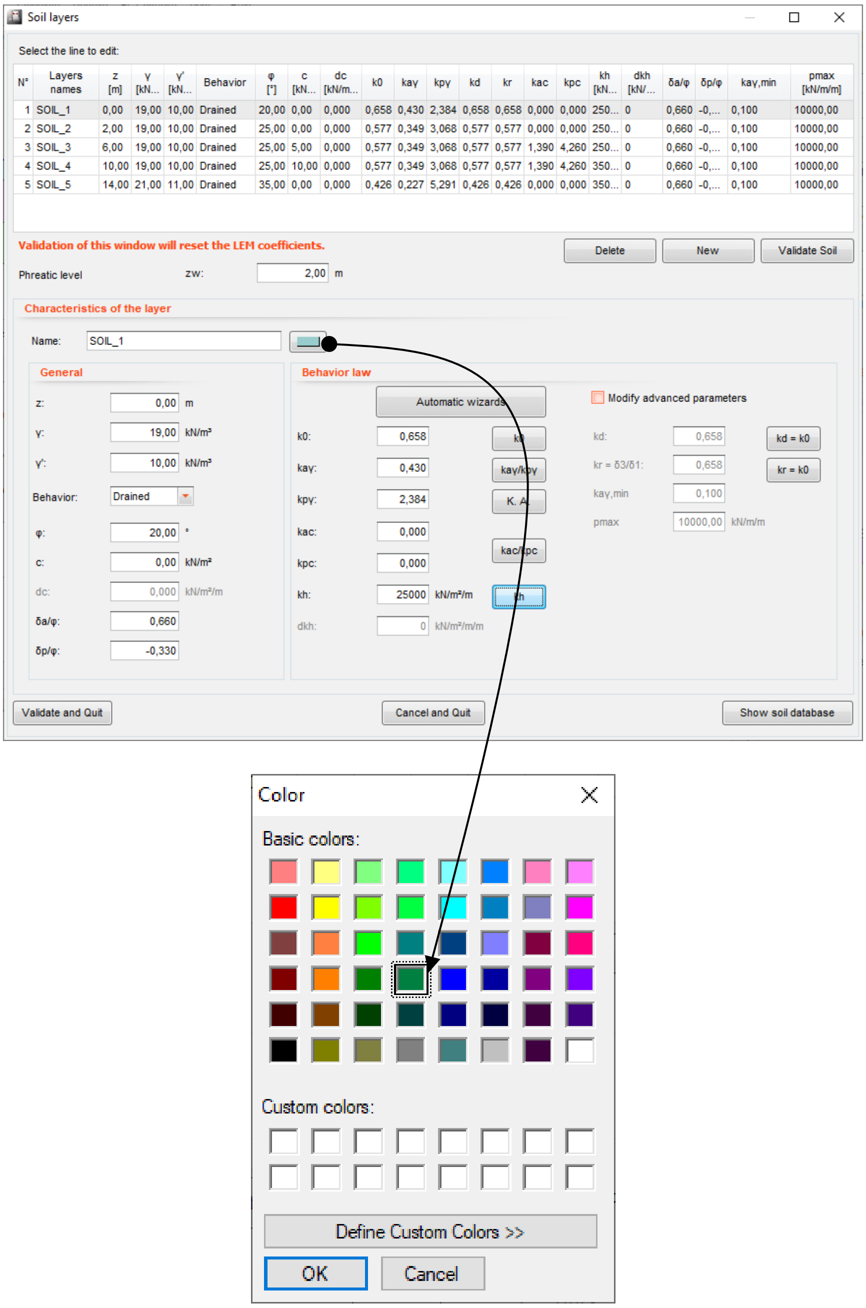


Figure B30 : *Choice of soil layer colours*

B.3.3. Retaining wall definition

This dialogue box is accessible by clicking the **Data** menu then **Retaining Wall** definition. It is used to define the wall characteristics needed for the calculation.

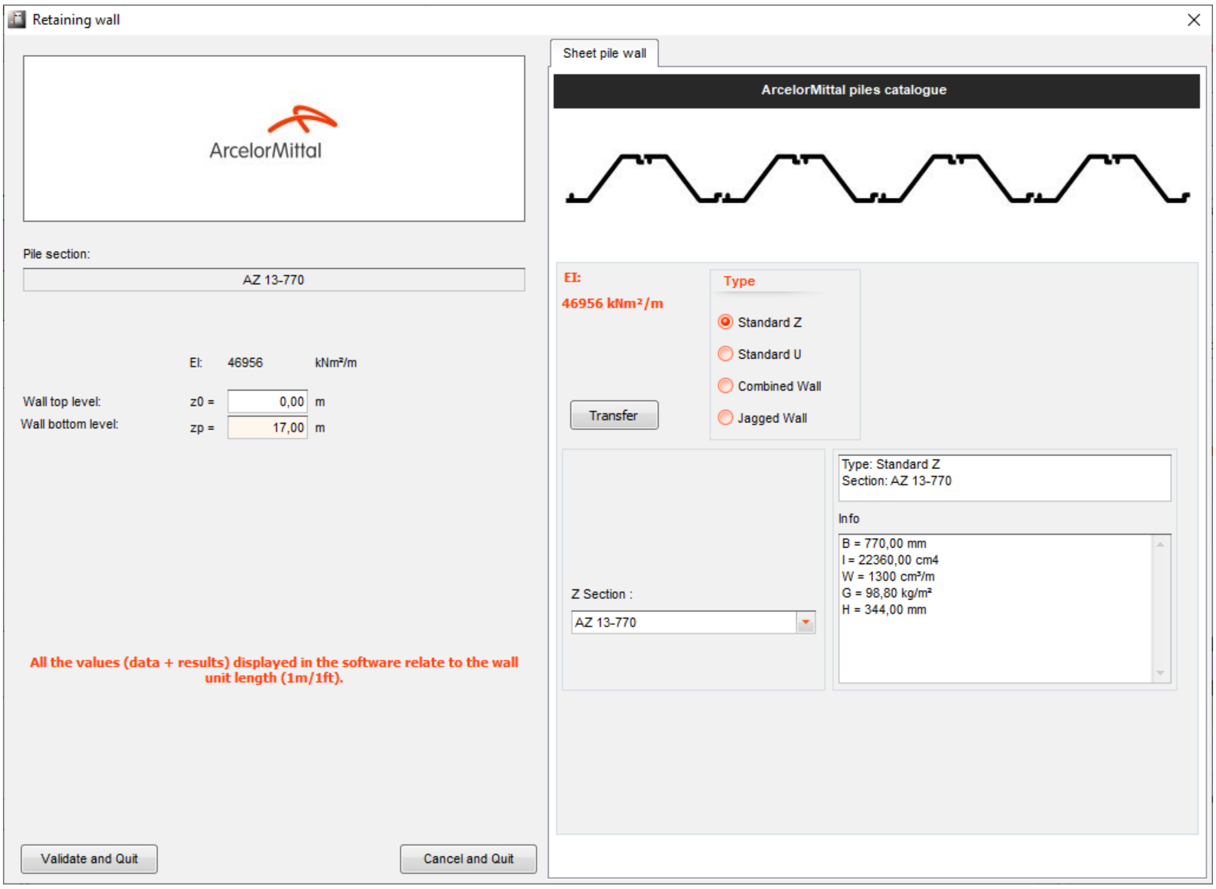


Figure B31 : *Retaining Wall definition:*
Plane wall (left) and circular wall (right)

Each wall is characterised by 3 parameters: Z0 (wall top level), Zp (wall bottom level) and EI (product of inertia of the wall).

To define Z0 and Zp, fill in the relevant values in the corresponding white edit boxes.

To define EI, you should select a sheet pile in the ArcelorMittal catalogue, displayed in the right part of the dialogue box. To do that, first select a sheet pile type (Standard Z, Standard U, Combined wall or Jagged wall).

Depending on this selection:

- **Standard Z**:

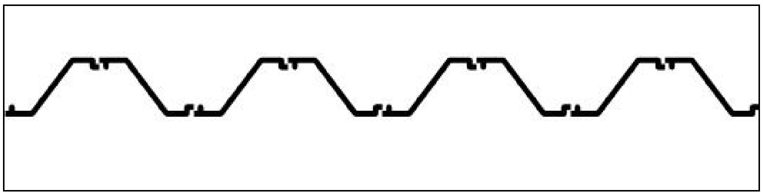


Figure B32 : *Typical picture of a « Standard Z » sheet pile*

Select the sheet pile reference in the list below, and click on the transfer arrow, which will copy the value of the product of inertia in the relevant data box (left side of the dialogue box). Click on Validate and Quit.

- **Standard U**:

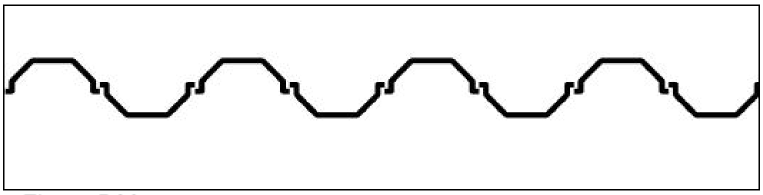


Figure B33 *: Typical picture of a « Standard U » sheet pile*

Select the sheet pile reference in the list below, and click on the transfer arrow, which will copy the value of the product of inertia in the relevant data box (left side of the dialogue box).

In the case of Standard U sheet piles, it is then possible to **activate a reduction coefficient betaD**, and to define betaD value (among the available values) which will be applied to EI value (and which you will be able to **modify during the staged construction** using a specific action, refer to section B.5.4.1).

The value of EI used in the calculations is then:

$$EI_{modified} = betaD*EI_{catalogue}$$

For instance, if the value 0.50 has been checked, then the product of inertia used in the calculation will be equal to 60% of the sheet pile catalogue value.

Figure B34 *: Definition of reduction factor betaD for a Standard U sheet pile*

Click on Validate and Quit.

- **Combined walls**:

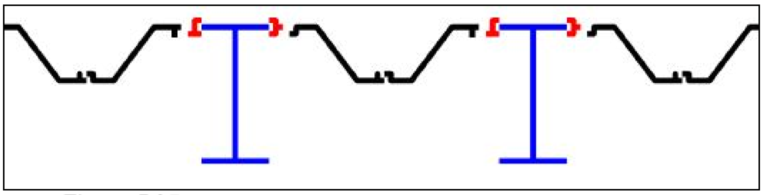


Figure B35 : *Typical picture of a « Combined wall »*

Select the combined wall type and reference, using the available lists. Then click on the transfer arrow, which will copy the value of the product of inertia in the relevant data box (left side of the dialogue box). Click on Validate and Quit.

- **Jagged walls**:

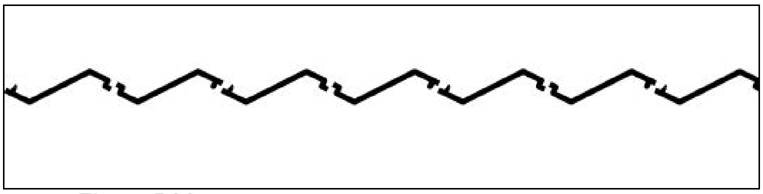


Figure B36 : *Typical picture of a « Jagged wall »*

Select the jagged wall type and reference, using the available lists. Then click on the transfer arrow, which will copy the value of the product of inertia in the relevant data box (left side of the dialogue box). Click on Validate and Quit.

Note: The ArcelorMittal sheet pile catalogue will be regularly updated and will thus change from time to time. The sheet pile types detailed here above may change, but the way to use the catalogue will remain the same.

It may happen that after one of these updates, some projects require sheet pile references that are not available anymore. In this case, AMRetain will display the following message:

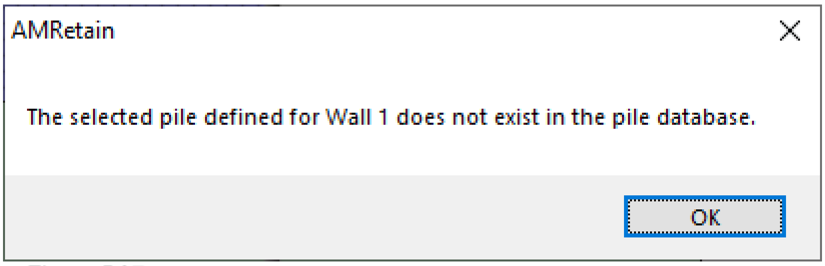


Figure B37 : *Message displayed when trying to use a sheet pile reference that is not available in the catalogue anymore*

It will then be necessary to select a new sheet pile reference in the updated catalogue, in order to be able to perform calculations again.

The frame in the bottom right part of the window enables to view for the selected sheet pile reference:

- **B:** Sheet pile width (mm or in)
- **I:** Sheet pile inertia (cm^4/m or in^4/ft)
- **W:** Sheet pile modulus (cm^3/m or in^3/ft)
- **G:** Sheet pile weight (kg/m^2 or lb/ft^2))
- **H:** Sheet pile height (mm or in)

The catalogue is available in the metric unit system only, but in the case of a project using the imperial system, all values are converted and displayed in the imperial units (in addition to metric values). The EI value will be converted into $KipFt^2$/Ft when clicking on the transfer button.

B.3.4. Input of data for double wall projects

In the case of double wall projects, the data to be input are the same as those described previously, but they must be input for each of the 2 walls. The additional parameters and particularities encountered when defining a double wall project are presented below.

B.3.4.1. Title and options (case of double wall)

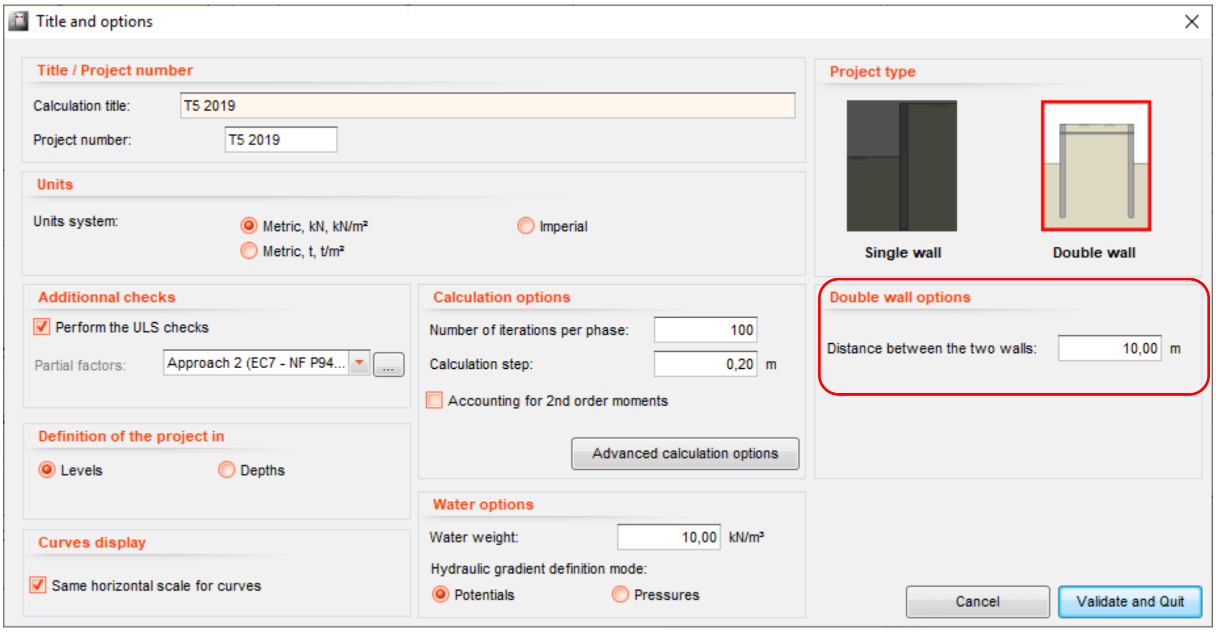


Figure B38 : *"Title and Options" dialogue box (double wall project)*

When choosing a double wall project type, an additional parameter needs to be filled out:

- Distance between the two walls (m, ft).

  It is important to note that this parameter is only used when defining the anchoring block, when ULS checks are requested. Its value has no influence on the other results.

Data input then refers to Wall 1 (left) and Wall 2 (right). See chapter B.1.2.2 for the conventions concerning these 2 walls and the choice of wall 1 and wall 2.

B.3.4.2. Definition of soil layers for a double wall

In the case of a double-wall project, the "Soil layers" definition dialogue box comprises two tabs, "Wall 1" and "Wall 2".

Input is exactly the same as for a single wall project (see § B.3.2).

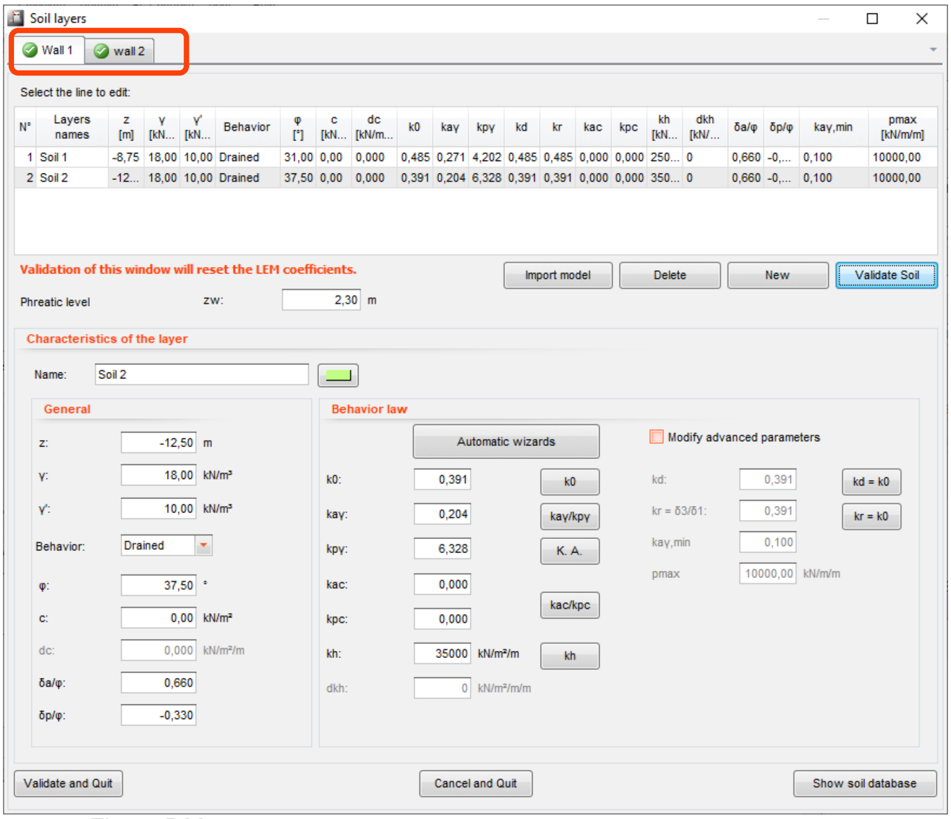


Figure B39 *: Soil layers characteristics dialogue box – Double wall project*

After entering the data for wall 1, it is possible to transfer the soil model from wall 1 to wall 2, by clicking the Import model button from the "Wall 2" tab.

B.3.4.3. Definition of characteristics of the two walls

The user must enter first all input the data for wall 1 and then those for wall 2.

Figure B40 : *Retaining wall definition window – Double wall project*

B.3.5. Definition of load cases

In AMRetain it is possible to create several load combinations in a single project. Unlike the first 3 windows described in chapters B.3.1 to B.3.3, the definition of the load cases is optional.

The definition of the load cases involves three steps:

1. Activate the calculation of load combinations: open the **Definition of load cases** window accessible from the Wizards menu and tick the box at the top of the window;
2. Define the load families for the project, giving them a name and specifying the weighting factor to be allocated to each combination. This is to be done in the upper part of the window;
3. Define the calculation combinations to be considered (combination 1, 2, etc.) in each calculation phase. This is to be done in the lower part of the window.

When defining the phasing, each overload (on the soil or wall) will have to be assigned to a load family.

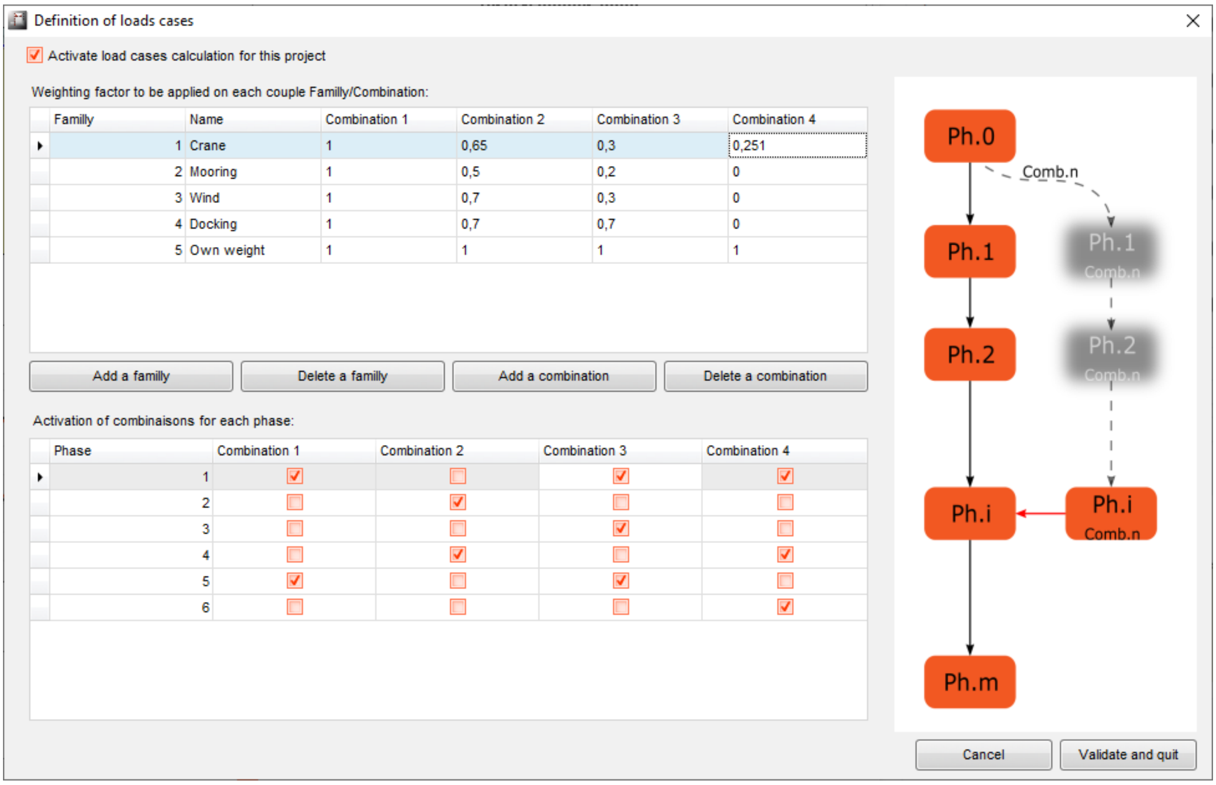


Figure B41 : *Window for defining families and load combinations*

The results of these load cases will appear in addition to those of the basic calculation. They can be accessed by choosing "Combinations" in the **Results** window and in the **EC7 Checks** window. This list of choices is accessible in all phases in which at least one combination was requested. If several combinations were considered in a given phase, a drop-down list can be used to navigate between them.

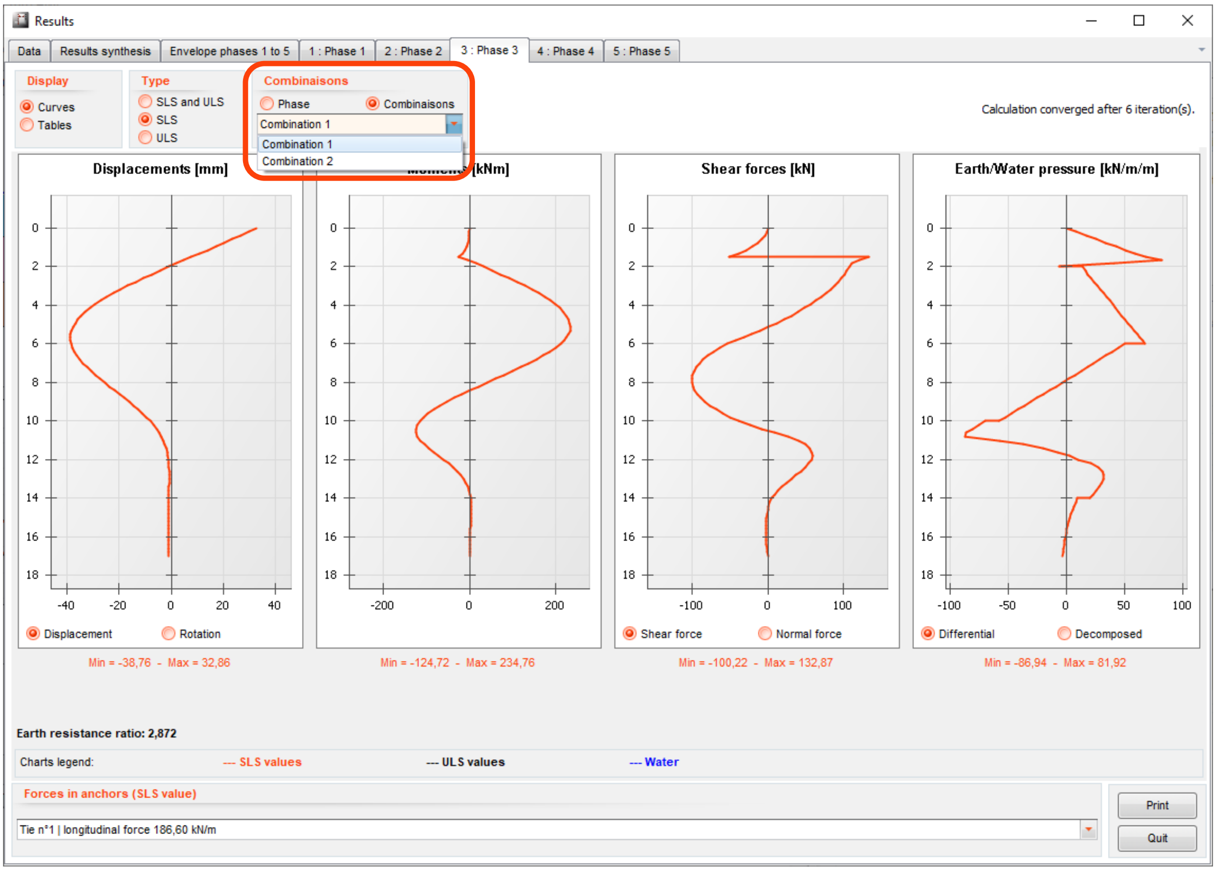


Figure B42 : *Results window giving access to the results per load combination*

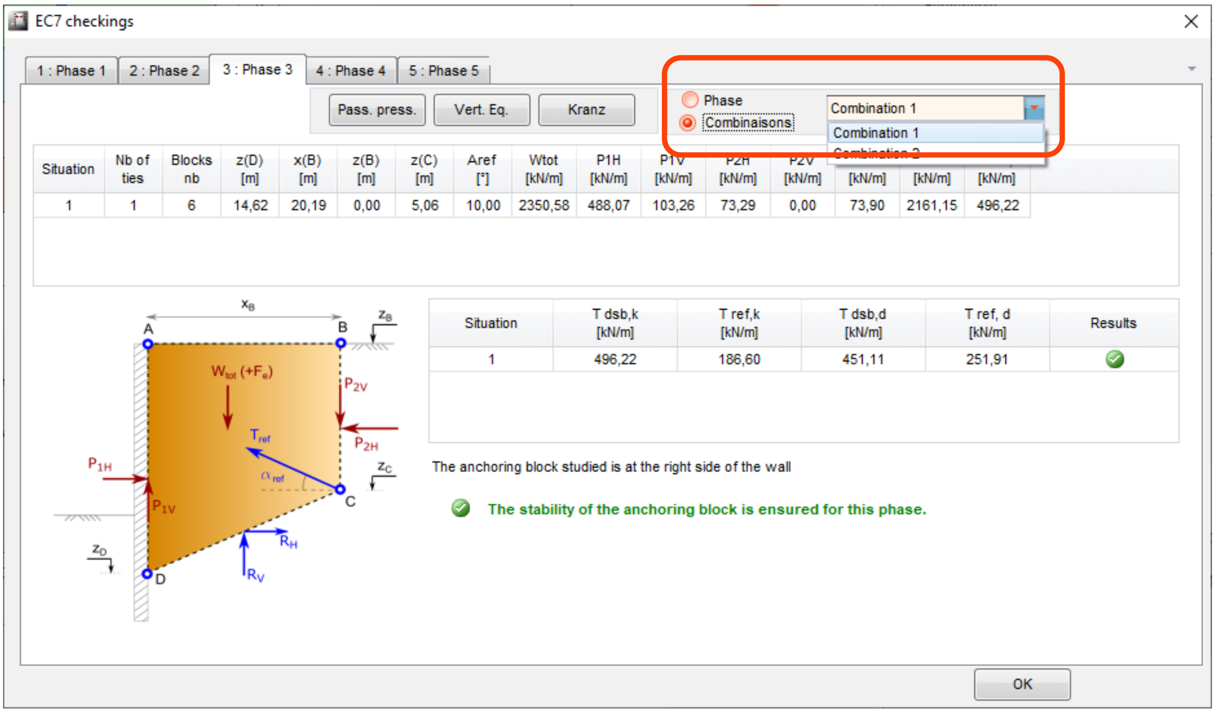


Figure B43 : *EC7 Checks window giving access to the results per load combination*

B.4. Definition of phasing

After inputting the soil and wall data, the calculation phasing must be defined, representing the project construction and service steps.

The choice of the kinematics of phasing may have a significant influence on the results, in particular owing to non-linearities as a result of soil plastification and changes in the stiffness of the wall and its anchors during the phasing.

Generally speaking, the phasing should be defined as close as possible to reality, breaking it down as much as possible and avoiding defining actions with opposite effects (fill followed by excavation for example) in a given phase, for a given side and wall.

This chapter gives a general description of the operations used to define the calculation phasing and the procedure for creating phasing for simple and double wall projects respectively. The actions that can be defined in a given phase are described in detail in chapter B.5.

B.4.1. Presentation

Phasing is managed via 3 zones:

- the phases management zone (create, delete, browse, etc.);
- the zone for choosing the actions to be applied in each phase;
- the zone for defining the parameters of each action.

The working of these various zones is explained in the following sub-chapters.

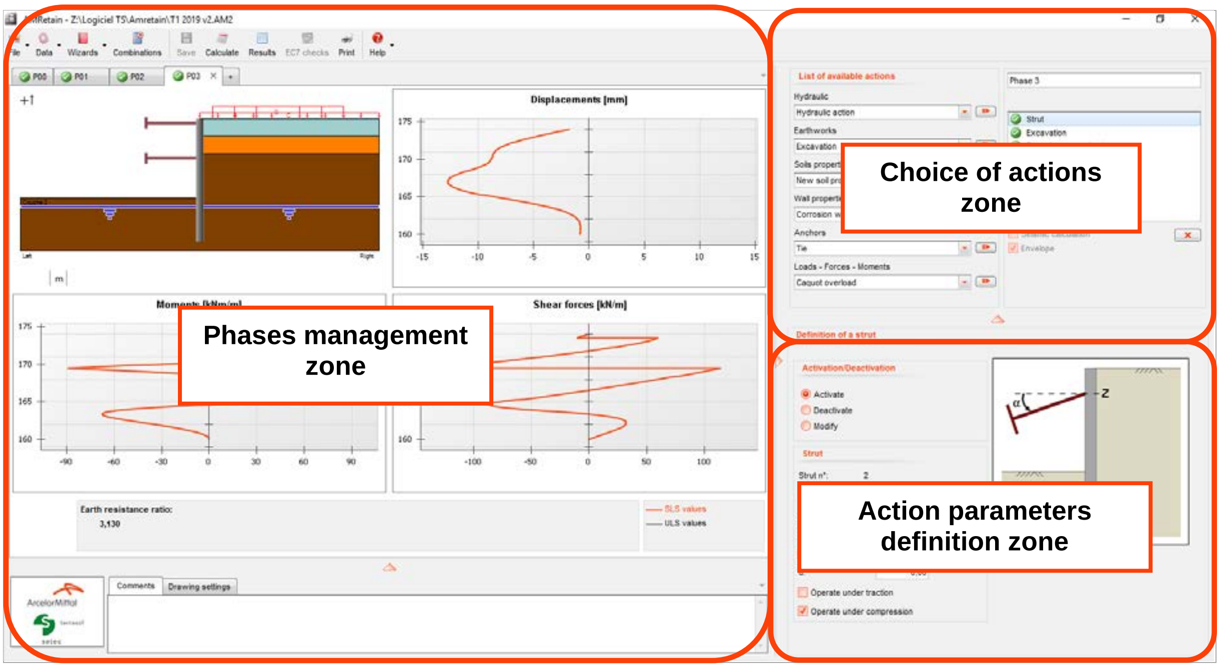


Figure B44 : *Main window – Phasing management*

B.4.2. Phases management frame

The following figure shows the phases management zone, situated on the left-hand side of the main window. It is used to create and control the calculation phases.

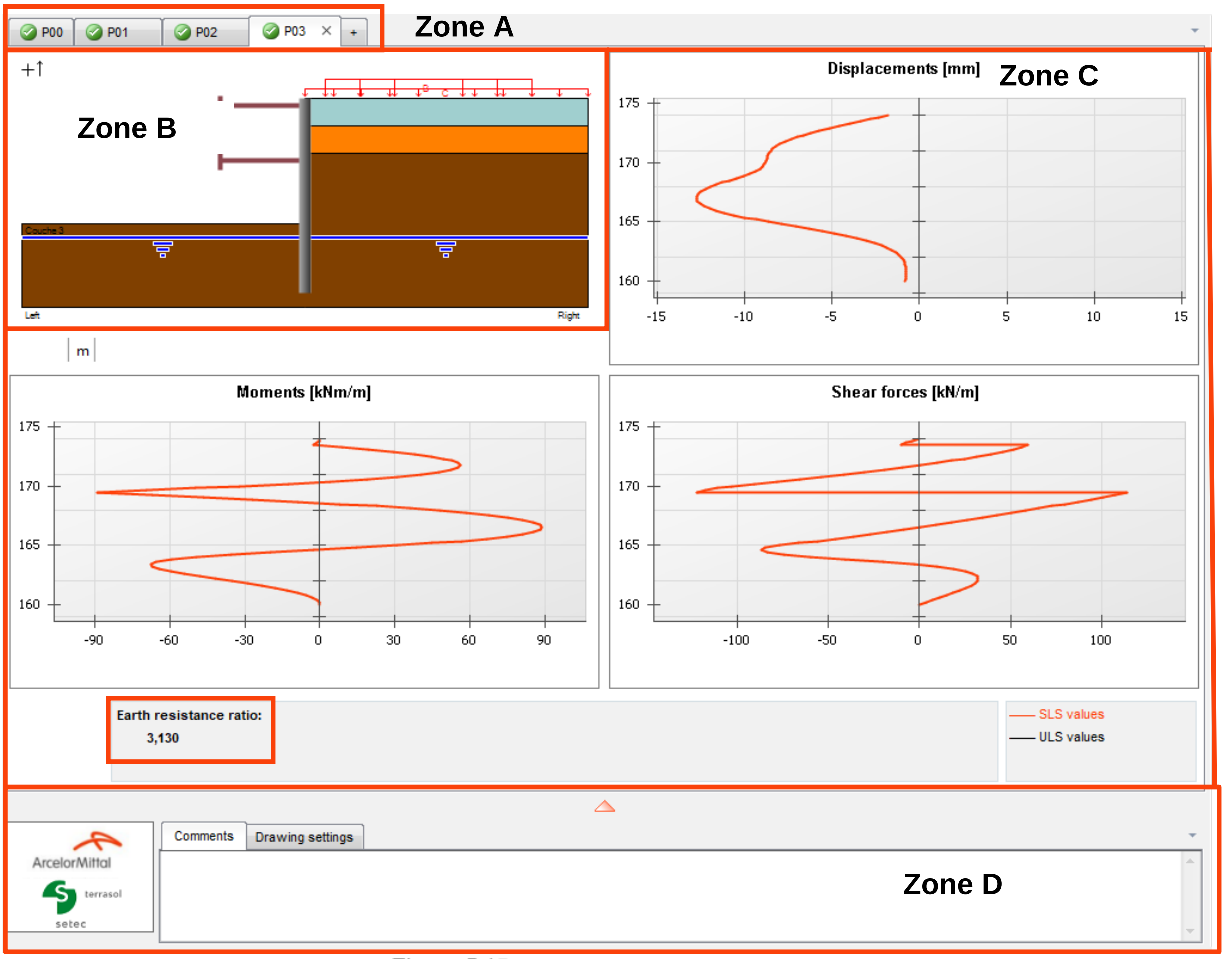


Figure B45 : *Phasing management zones*

Zone A presents the tabs corresponding to the calculation phases. It is possible to browse between the various phases of the project simply by clicking the tab of the phase one wishes to view.

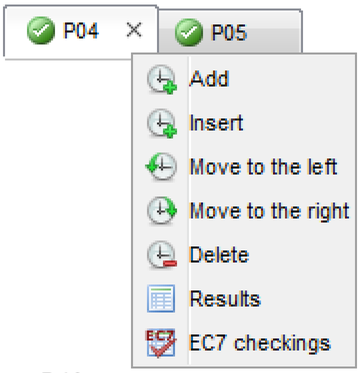


Figure B46 : *Phasing management menu*

A right click on the tab displays the following options :

- **Add**: adds a phase after the last phase;
- **Insert**: adds a phase to the left of the selected phase;
- **Move to the left**: shifts the selected phase to the left;
- **Move to the right**: shifts the selected phase to the right;
- **Delete**: deletes the selected phase, with a confirmation message;
- **Results**: opens the results window for the selected phase;
- **EC7 checks**: only accessible in projects for which the ULS checks are activated in the "Title and Options" menu. If this is the case, this button opens the EC7 checks for the selected phase.

Zone B is used to display the project cross-section corresponding to the current phase.

Zone C is used to display the results curves after starting the calculations. These are displacement curves, shear forces and bending moments diagrams concerning the wall for the current phase. The **earth resistance ratio(s)** on the excavation side are also displayed[1].

Zone D is reserved for drawings settings and comments. It is immediately below the phasing management frame and is used for:

- entering comments concerning the current phase. These are then recalled subsequently for information when printing the results.

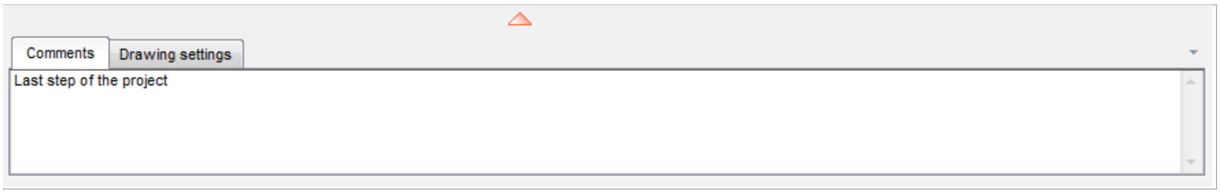
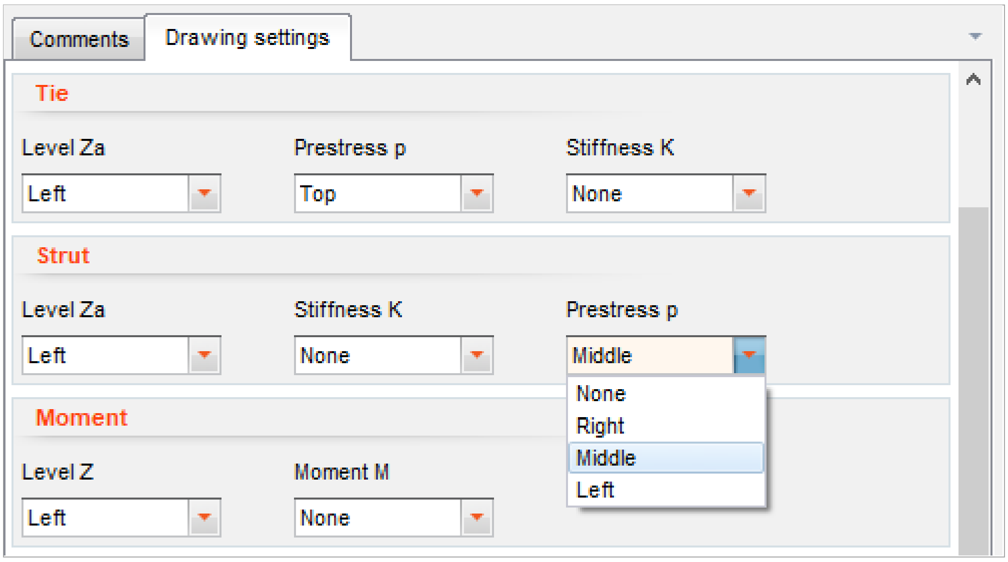


Figure B47 *: "Comments" tab*

- configuring the display, the project cross-section, the elevations of the soil layers and actions (groundwater, anchors, overloads, etc.), as well as for showing the names of the soil layers or the characteristics of the actions (stiffness of anchors, overload values, etc.).



[1] The earth resistance ratio does not appear in zone C if the ULS checks are activated. This parameter is however still available in the "Results synthesis" (see § B.6.2.3).

Figure B48 : *"Drawing settings" tab*

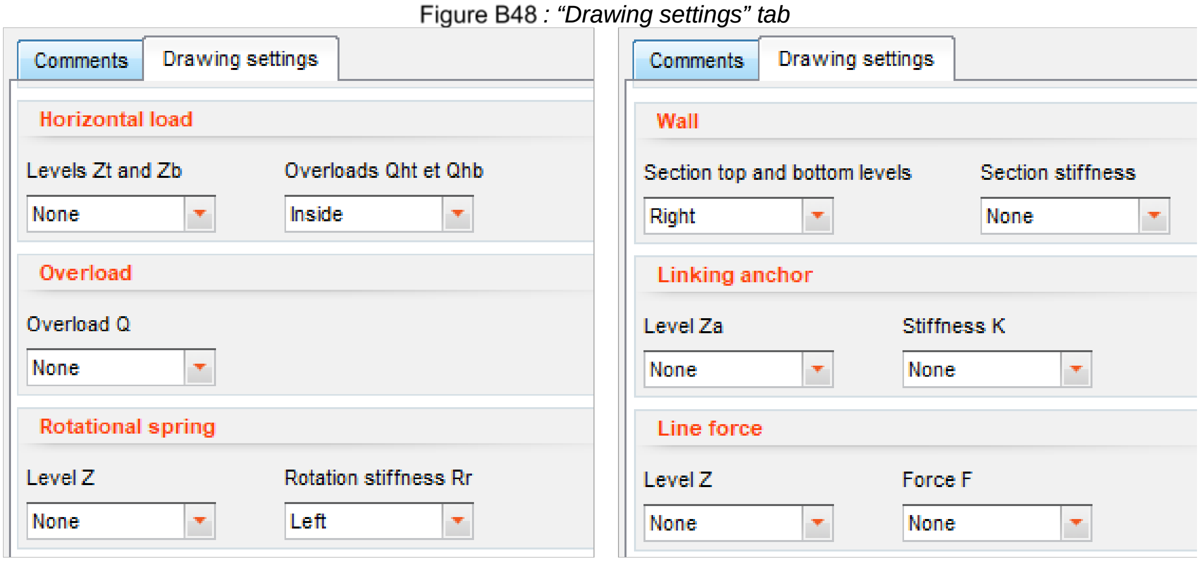


Figure B49 : *Drawing settings tab*
(examples of display settings for certain actions)

<u>Note 1</u>: the graphics can be enlarged to fill the entire phasing management frame by double-clicking on them. The mouse can be used to hover over the curves to display the value of the curve at the chosen point, in the form of a tooltip. In the case of a calculation with ULS check, two curves appear for the bending moments and the shear forces. The curve in pink/purple indicates the characteristic values (without weighting) and the black curve displays the design values (with weighting).

A right-click on these same graphics gives access to the context menu (see chapter B.2.3.9). A double-click returns the graphic to its original size.

<u>Note 2</u>: in **zone B**, the graphical representation of the soil layers, walls and actions follows a vertical scale but not a horizontal one. The coordinates system used is not orthonormal and the distance between the two walls is not at the same scale as the vertical coordinates. The length and inclination of the tie-rods and the spacing between the two walls (for a double wall project) coming from the graphical representation should not therefore be considered.

<u>Note 3</u>: the space given to the project cross-section, the graphical results, the comments and the settings in the main window may vary:

- clicking the arrow enables all the figures to occupy the entire window;
- clicking/dragging the arrow enables the user to split the window horizontally to about two-thirds;
- clicking the arrow:
  - displays the "Comments" or "Drawing settings" tab over the full height of the window, or
  - displays the definition of the action over the full height of the window
- click/dragging the arrow enables the user to split the window.

B.4.3. Actions selection frame

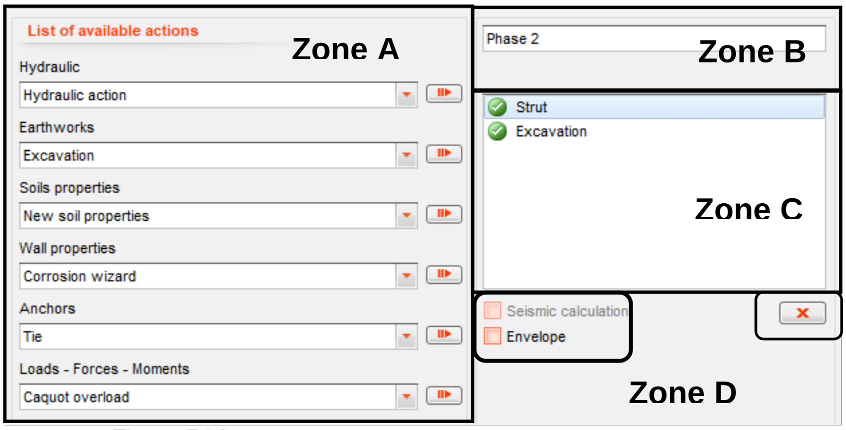


Figure B50 : *Actions selection frame for a calculation phase*

The choice of actions frame is displayed at the top-right of the main window. It can be used to apply the required actions in the selected calculation phase.

The title of the current phase is given in **zone B**. This title is recalled in the "Results" window to make it easier to read and interpret. It is possible to rename the selected phase by modifying the text input in this zone.

The actions in AMRetain on the whole define the wall support and loading conditions and their evolution during the construction phases. They can also be used to characterise the wall-soil and wall-anchors interactions.

These actions are classified by groups:

- **Hydraulic:** this group contains the hydraulic action used to define the groundwater levels and any gradients;
- **Earthworks:** contains the operations performed on the soil (excavation or fill) and offers the possibility of simulating bank or berm type geometries;
- **Soil properties:** this action is used to modify the inherent properties of the soil layers;
- **Wall properties:** this group contains 2 actions. Action "Modification of Beta D factor" allows modification of this factor. Action "Corrosion wizard" reduces the percentage of the inertia product of the wall.
- **Anchors:** comprises 3 anchor types (tie, strut, rotational spring) for single walls and 1 additional anchor types for double wall projects (linking anchor);
- **Loads, forces, moments**: comprises 2 types of overloads applicable to the soil (Caquot and Boussinesq), as well as 3 types of loads applicable directly to the wall (line force, linear moment and horizontal load).

Zone A contains drop-down menus corresponding to each group, for choosing the actions to be applied in the current phase.

The complete table of available actions and the detailed description of the parameters of each action are given in chapter B.5.

To apply an action, click inside the frame of the drop-down menu corresponding to the action group to be carried out.

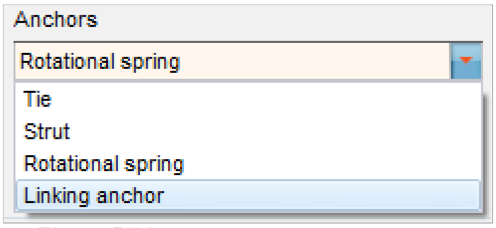


Figure B51 : *Selection of the Strut action*

Then click the transfer button to include it in the list of actions to be performed (**zone C**) during the current phase.

It then appears in the definition frame for the action selected under the choice of actions frame. The parameters needed to define the action are to be input in this frame.

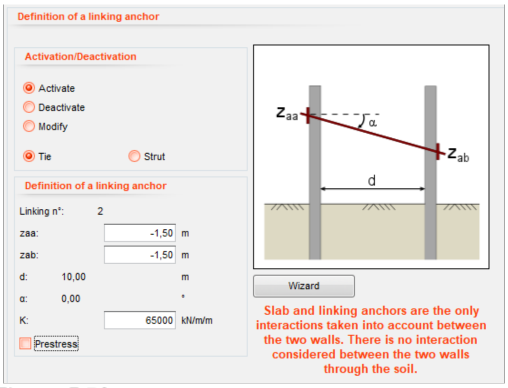


Figure B52 : *Definition of parameters of an action*

All the actions in a phase will appear in the form of a list classified in order of declaration in **zone C** situated under the name of the current phase.

Note 1: the ✕ button is used to delete the selected action from the list of actions for the current phase.

Note 2: the actions are marked:

- with a green tick when correctly defined;
- with a red cross when incomplete or not correctly defined.

A tooltip in the action definition frame and in the list of actions gives a certain amount of information about the reason for the input being considered invalid:

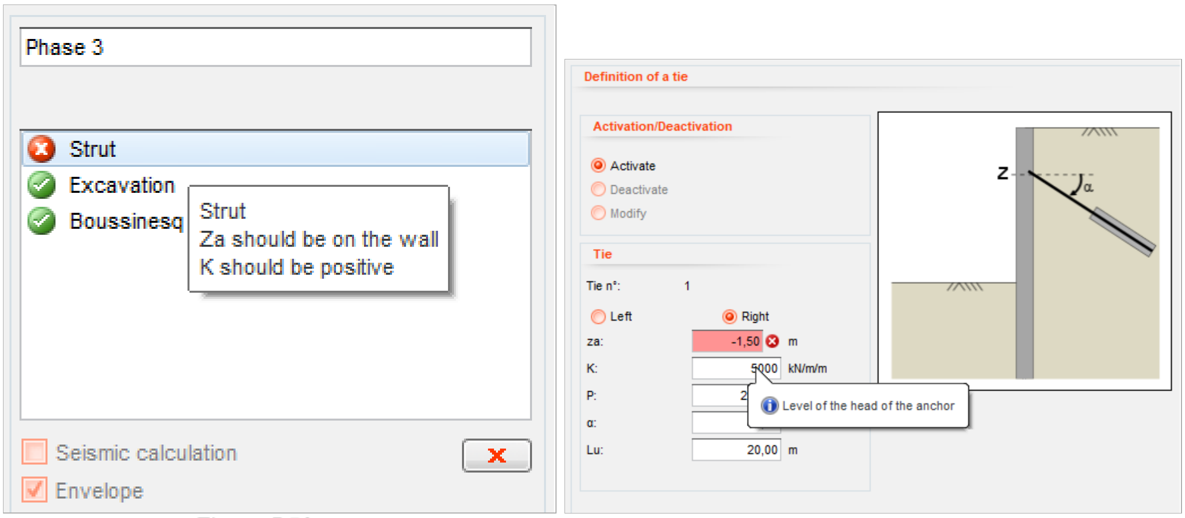


Figure B53 : *Information about the reason for input being considered invalid*

The mechanical properties of the actions are described in chapter B.5.

In the case of a project with ULS checks, two additional selections are needed to characterise the nature of the phase and the calculation model:

- **Transitory phase / Permanent phase**: this choice determines selection of the partial factor for the mobilisable passive earth pressure considered in the ULS passive earth pressure safety check (see § B.3.1.2);
- **Cantilever wall (LEM calculation):** this choice is only accessible for phases with no "active" support (element of "Anchors" group). It is activated by default in this case but can be deactivated by the user whenever they wish. If the box is ticked, the wall will be considered to be cantilever for the phase selected and the ULS checks will be made on the basis of a LEM calculation instead of a SSIM calculation (see part C of the manual). If the box is ticked, AMRetain will automatically create a **LEM coefficients** action (see § B.5.7.1).

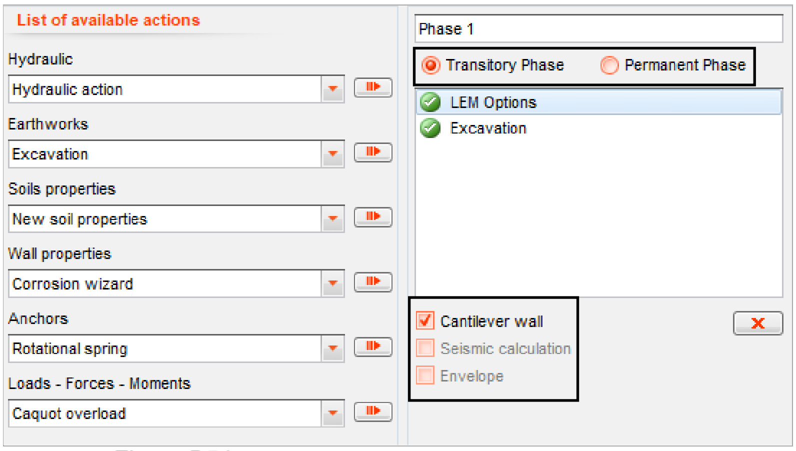


Figure B54 : *Choice of actions for a calculation phase*
(case of a project with ULS checks)

In any case (projects with or without ULS checks), the **"Seismic calculation"** and "**Envelope"** check boxes are available.

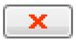
The **"Seismic calculation"** check box is used to reserve the phase in question for a calculation with earthquake. The particularity of such a phase is that:

- it is a dead end in that it does not modify the main phasing consisting of "non-seismic" phases;
- no action in the "choice of actions" frame can be added by the user. Conversely, the "Seismic calculation" option is deactivated and inaccessible in the phases containing at least one non-automatic action.

The "**Envelope"** check box is used to assemble the results curves from several successive phases. For example:

- If no "Envelope" box is ticked in a project, an envelope curves family will appear and collate the extreme displacement, shear force and bending moment values calculated on the basis of all the phases calculated.
- If a project contains 5 phases in addition to the initial phase and the "Envelope" box was ticked only in phase 3, two envelope curves (extreme displacement, shear force and bending moment values) will be represented for phases 1 to 3 and 4 to 5 respectively.

Note: The envelope box cannot be selected in the initial phase, nor in phase 1 (the results of phase 1 constitute their own envelope), nor in the last phase.

The  button deletes the selected action from the list of actions for the current phase. Caution, to simplify the operation, the action is deleted without requesting confirmation.

B.4.4. Actions definition frame

The actions definition frame appears at the bottom-right of the AMRetain interface (just below the choice of actions frame). It is used to define the selected action.

Figure B55 *: Actions definition frame (example of an excavation)*

Each action has its own actions definition frame. It generally consists of a left-hand part for inputting parameters defining the action and a right-hand part showing a schematic illustrating these parameters.

Figure B55 shows the definition frame for an excavation. The list of choices appears in pink/purple and the boxes to be filled out appear in white. This example illustrates excavation on the left-hand side to level 2.00 m.

All the definition frames are explained in chapter B.5 in the paragraphs dedicated to the corresponding actions.

B.4.5. Validation / Calculation / Results

An action is validated if its mandatory parameters have been duly filled out. It is then given a green tick in the list of actions.

The Calculate and Results buttons are accessible from the buttons bar.

- **Calculate**: starts the calculation;
- **Results**: opens the results window (deactivated if the project has not yet been calculated).
- **EC7 Checks**: opens the EC7 checks results. This button is only active if the ULS checks were requested in the project options and if the project has been calculated. These checks are also accessible from the results window, for each phase (see chapter B.6.4).

B.4.6. Definition of phasing for a "Single wall" type project

B.4.6.1. Projects without ULS checks

By default, AMRetain always creates a first calculation phase "P00" entitled "initial phase", as illustrated in the following figure:

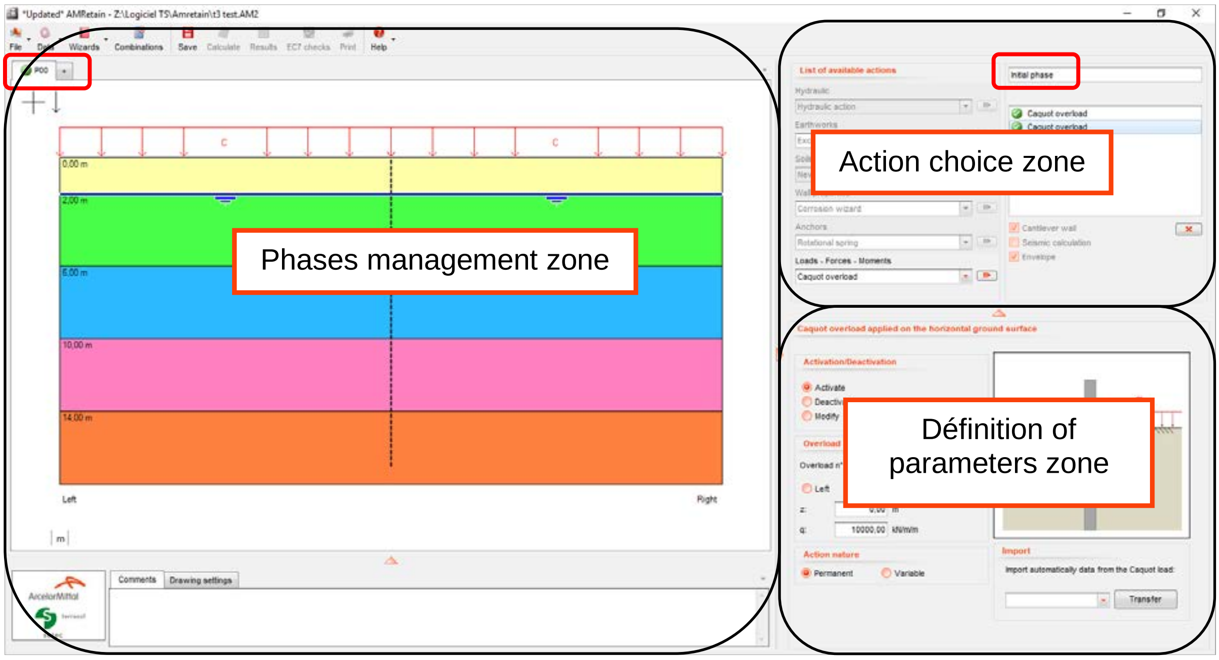


Figure B56 : *Initial phase*

The only actions available in the initial phase is "Caquot overload".

The working of the actions frame was described in chapter B.4.3 and details of the actions are given in §B.5. If an Caquot over load is defined in the initial phase, it will be represented on the project cross-section after validation.

Then, to create phase 1, click the + tab to the right of that of the initial phase, or use the context menu of the initial phase tab (right-click then "Add"). This action will create a new tab "P01" which by default will be named "Phase 1". The actions required for this phase 1 must be defined (as a function of your project). After each action creation in phase 1, the graphical representation of the project will be updated accordingly.

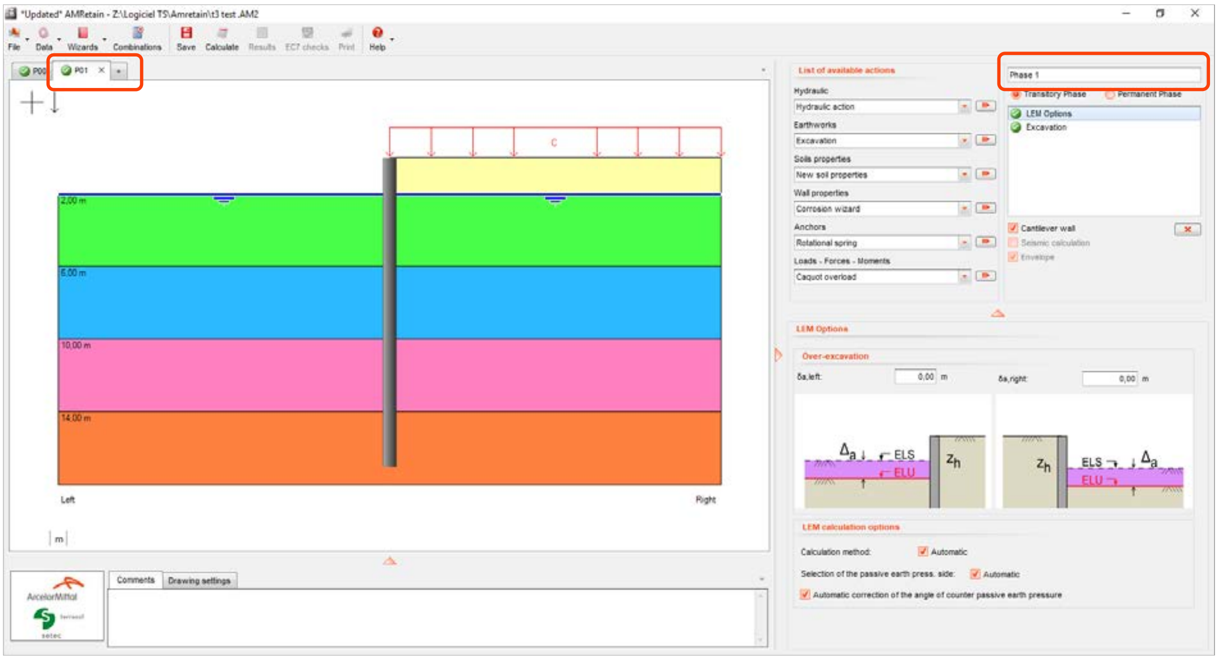


Figure B57 : *Creation and display of phase 1 of a project*

Then simply do the same for the following phases, until the phasing for the project concerned has been completed. Each time a new phase is added, the corresponding tab will appear after the existing tabs and will carry a name such as "PXX" where XX corresponds to the phase order in the project. By default, it will also be given a modifiable title such as "Phase XX".

The tabs in the phases management frame allow rapid browsing between the project calculation phases simply by clicking (during definition of phasing but also after calculation to view the results).

B.4.6.2. Projects with ULS checks

In the case of a project with ULS checks, AMRetain requires the input of additional data for definition of phases and actions.

Each phase must therefore be defined either as a **Transitory phase** or a **Permanent phase**.

For each phase, one must also state whether the wall is to be considered cantilever (LEM calculation) or anchored (SSIM calculation). The **Cantilever wall** option is automatically deactivated and inaccessible when an anchor is active in the phase in question, except for a tie without pre-stressing, which is not active in its installation phase.

In the phases for which the wall is considered to be cantilever, AMRetain automatically creates an **LEM options** action. This latter can be used to check over-excavations, the LEM calculation method used, the passive earth pressure elevation and, if necessary, the counter passive earth pressure parameters, its inclination angle in particular, for the current phase (see chapter B.5.7.1).

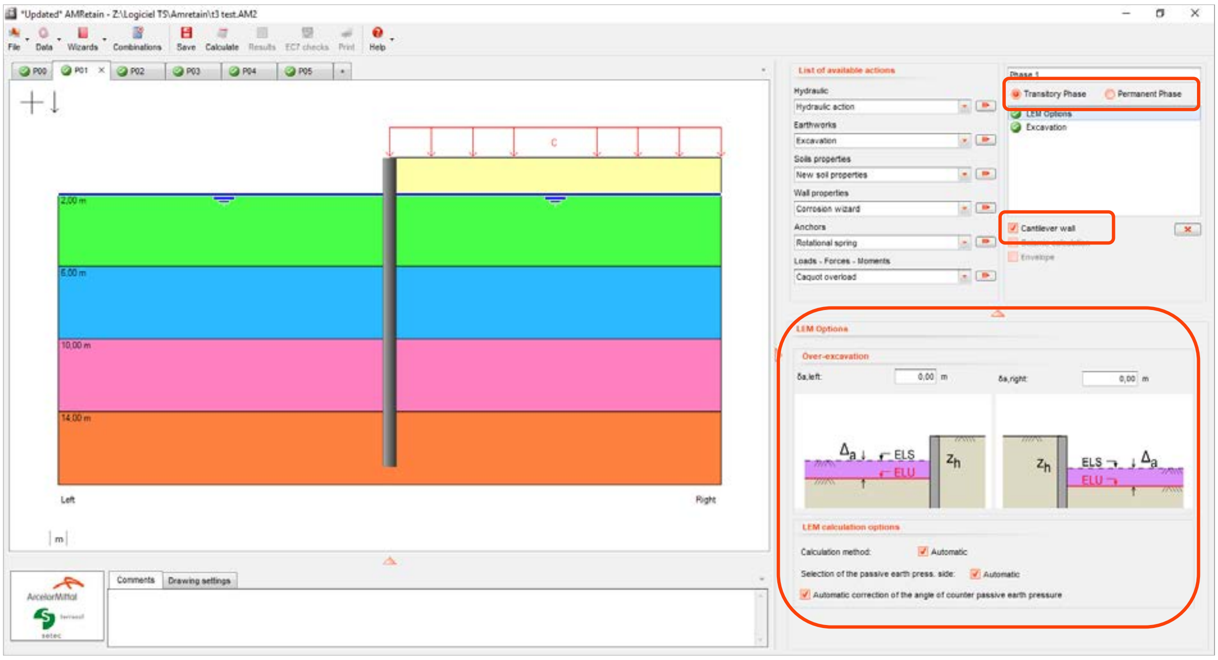


Figure B58 : *Example of additional data for projects with ULS checks if the wall is considered to be cantilever*

In the phases for which the wall is anchored, AMRetain automatically creates an **ULS options (SSIM)** action. This is used to check any over-excavations (see chapter B.5.7.1 and chapter B.5.7.2).

B.4.7. Definition of phasing for a "Double wall" type project

The phasing creation/management principle for a double wall project is the same as for a single wall project. The actions to be applied to each of the 2 walls will have to be defined.

Two buttons therefore appear at the top of the definition frame for each action, for allocation to wall 1 or wall 2. This concerns all the actions compatible with a single wall, the only exceptions being linking and slab anchors.

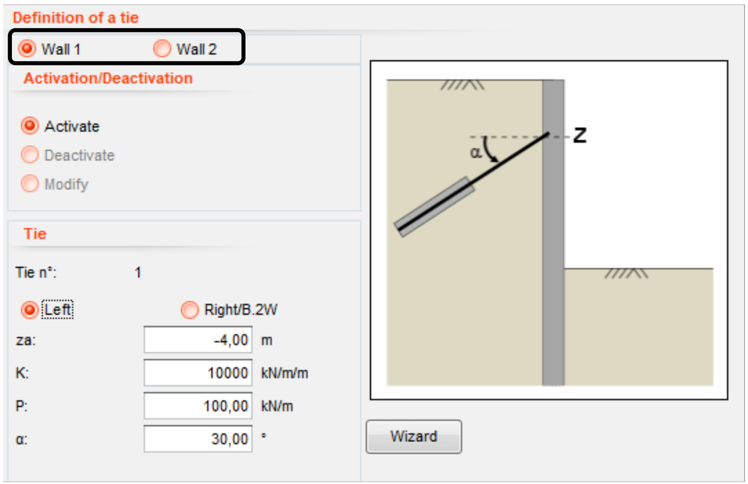


Figure B59 *: Double-wall project: choice of Wall 1 / Wall 2*

Moreover, the actions for the phase in progress carry the prefix of the wall to which they are linked:

- Wall 1: text in black;
- Wall 2: text in blue.

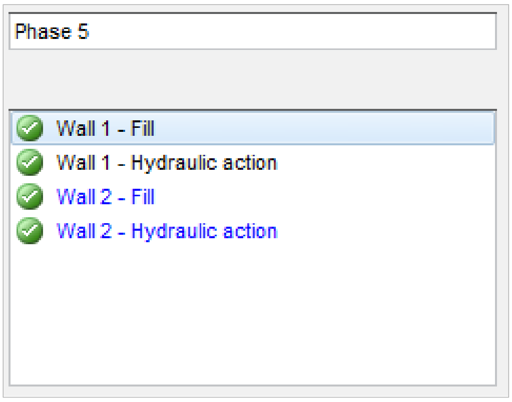


Figure B60 *: Double wall project: display of actions specific to each wall*

Finally, the two walls can be connected by one or more anchors, with no limit on their number. These latter may be either linking anchors (defined as ties or struts) or slabs. The interactions between the two walls are through these anchors only. AMRetain considers no interaction between the 2 walls via the soil medium separating them (see part C of the manual).

To find out more about the anchors, refer to chapters B.5.5.4.

B.5. Description of actions defined during phasing

AMRetain proposes a total of 17 actions, 3 of which are automatic, for simulating the construction phasing of a given project. The following table presents these actions by group:

Hydraulic	Hydraulic action
Earthworks	Excavation Fill
Soil properties	Redefinition of soil layers
Wall properties	Corrosion wizard Modification of Beta D factor (4)
Anchors	Tie Strut Rotational spring Linking anchor (2)
Loads, forces, moments	Caquot overload (1) Boussinesq overload Apply a line force Apply a moment Horizontal load on wall
Actions created automatically	LEM options (3) ULS options (SSIM) (3) Earthquake (Seismic calculation) (3)

(1) This action exists in the initial and other phases;
(2) This action is exclusively available for double wall type projects;
(3) This action is automatically created by AMRetain according to the status of the options detailed in § B.4.3. The user must always check the pre-defined parameters, or even modify and supplement them if such an action is present.
The remainder of the actions only exists in the standard phases, or in all the phases except for the initial phase.
(4) Only available for Standard U palplanche

Table B 3: Actions available for definition of phasing

An action is applied by means of the actions selection frame described in chapter B.4.3.

This chapter describes the actions in detail. Each sub-paragraph will comprise the principle of an action, possibly illustrated by a schematic or screenshot, followed by the designation of the corresponding input data.

B.5.1. Hydraulic action

This command is used to define the hydraulic conditions and if necessary correct the water pressures to take account either of a hydraulic gradient associated with the flow regime involved with groundwater drawdown, or the presence of impermeable passages or perched aquifers in the various layers.

It is important to note that definition of a hydraulic action has an impact both on the calculation of the horizontal water pressure on the wall and on that of the effective vertical stress in the soil (for more information, consult part C of the manual).

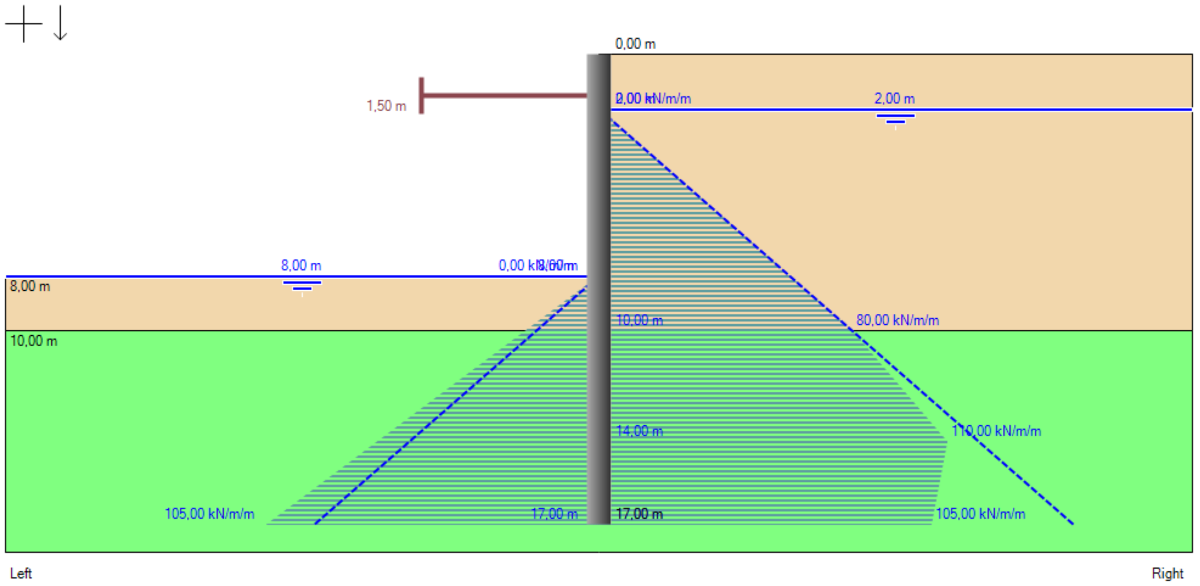


Figure B61 : *Example of definition of a hydraulic gradient*

Parameters to be filled out:

- Side concerned by the hydraulic action:

"Left or **Right"** for a single wall project;

"**Left** or **Right/E.2R"** (wall 1) or "**Left/E.2R** or **Right"** (wall 2) for a double wall project;

- **z_w**: level (elevation or depth) of the hydrostatic water table.

It is also possible to impose a pressure or potential diagram, for example to define a hydraulic gradient. To do this, the corresponding box must be ticked and the following filled out point by point:

- **Level** (elevation or depth) of the diagram point;
- **Hydraulic Potential** or **Pressure** (according to the option chosen in the "Title and options" window) to be considered for this point.

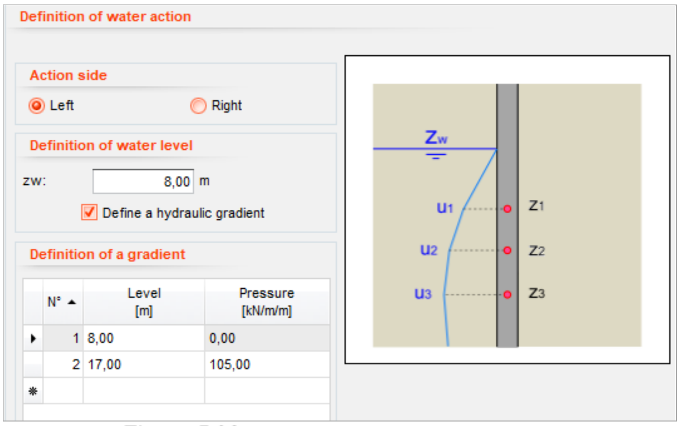


Figure B62 : *Water action definition frame*

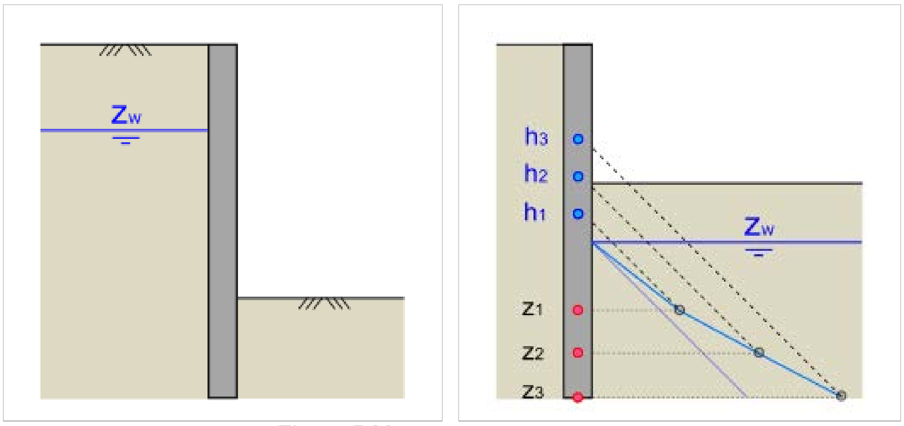


Figure B63 : *Hydraulic conditions:*
phreatic level (left) and hydraulic gradient (right)

B.5.2. "Earthworks" actions

B.5.2.1. Excavation

This action is used to define an excavation on one side of the wall. The excavation level is by default horizontal. An additional option allows definition of an excavation in the form of a bank or berm.

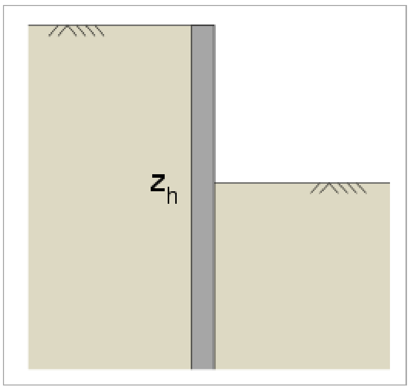


Figure B64 : *Definition of an excavation*

Parameters to be input:

- Side concerned by the excavation:

"Left or **Right"** for a single wall project;

"**Left** or **Right/E.2R"** (wall 1) or "**Left/E.2R** or **Right"** (wall 2) for a double wall project;

- $\mathbf{z_h}$: excavation level (elevation or depth) (m or ft).

It is also possible to define an excavation in the form of a bank or berm. The additional parameters to be input are:

- **"Bank** or **Berm**" according to the geometry to be defined;
- $\mathbf{z_t}$: level of head of bank or berm (m or ft);
- **a**: distance between top of bank or berm and wall > 0 (m or ft);
- **b**: distance between base of bank or berm and wall > 0 (m or ft);
- $\boldsymbol{\alpha_e}$: multiplication factor (initially set at 1.00) used to correct the Boussinesq overloads (see § B.5.6.2 and part C of the manual).
- **β :** slope of the berm of bank (°)

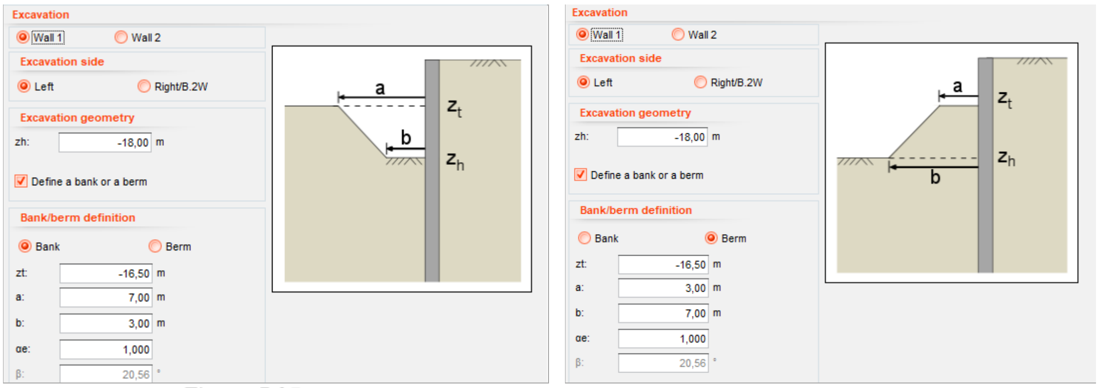


Figure B65 *: Definition of an excavation in the form of a bank (left) or berm (right)*

A few recommendations concerning the "excavation" action:

This action cancels the Caquot or Boussinesq type overloads on the soil on the side concerned by the excavation. To maintain them, they have to be redefined.

AMRetain does not verify the stability of the bank or berm. This type of verification is the responsibility of the user and must be done beforehand using an appropriate model (for example with Talren v5).

A horizontal excavation action systematically cancels out the geometric effects linked to the existence of a bank or berm, regardless of the side of the earthworks.

The level z_h of a new excavation must be below that of the previous level. In the case of a bank or berm, the z_t level must also meet this condition.

The lower level of a fill (z_b) will by default be considered to be equal to the level in contact with the wall previously. If a bank or berm already existed, the level z_b will be equal to its upper level, that is $z_b = z_{t0}$.

	Former geometry	Subsequent action	
		Excavation	Fill
Project defined in levels	Bank between [z_{h0}, z_{t0}]	$z_t \leq z_{t0}$ $z_h \leq z_{h0}$	$z_t \geq z_{h0}$ $z_h \geq z_{h0}$
	Berm between [z_{h0}, z_{t0}]	$z_t \leq z_{t0}$ $z_h \leq z_{h0}$	$z_t \geq z_{t0}$ $z_h \geq z_{t0}$
Project defined in depths	Bank between [z_{h0}, z_{t0}]	$z_t \geq z_{t0}$ $z_h \geq z_{h0}$	$z_t \leq z_{h0}$ $z_h \leq z_{h0}$
	Berm between [z_{h0}, z_{t0}]	$z_t \geq z_{t0}$ $z_h \geq z_{h0}$	$z_t \leq z_{t0}$ $z_h \leq z_{t0}$

Table B 4: Criteria for defining excavation and fill levels after a bank or berm ground level geometry

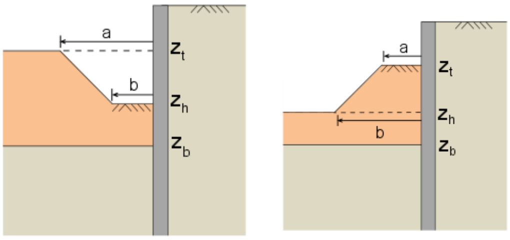


Figure B66 *: Help diagrams for a fill action after a bank left) or berm (right) type geometry*

B.5.2.2. Fill

This function is used for a fill with a base resting on the existing soil. The upper surface of the fill is by default horizontal, but a bank or berm type geometry can be defined using the appropriate option

The parameters to be input are:

- **Name of layer** constituting the fill;
- Colour of fill on the cross-section (choice from a colour pallet);
- Side concerned by the fill: **"Left** or **Right"** for a single wall; "**Left** or **Right/E.2R"** (wall 1) or "**Left/E.2R** or **Right"** (wall 2) for a double wall project;
- $\mathbf{z_t}$: level of top of fill (m or ft);
- $\mathbf{z_b}$**:** level of base of fill (m or ft) automatically pre-defined by the interface.

If the definition of a bank or berm is activated, the following additional parameters must be defined:

- **"Bank** or **Berm"** type of geometry to be defined;
- $\mathbf{z_h}$: level of base of bank or berm (m or ft);
- **a:** distance between top of bank or berm and wall > 0 (m or ft);
- **b:** distance between base of bank or berm and wall > 0 (m or ft);
- α_e: multiplication factor (initially set at 1.00) used to correct the Boussinesq overloads (see § B.5.6.2 and part C of the manual).

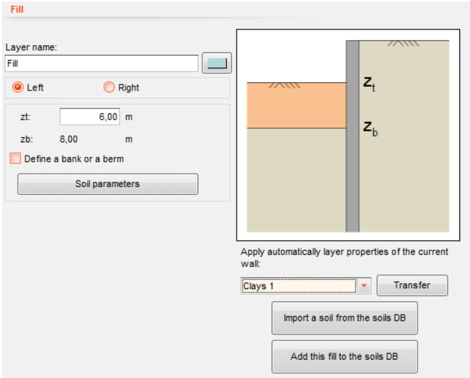


Figure B67 : *Fill definition zone*

It is possible:

- to input or modify the parameters of a fill by clicking the [Soil parameters] button;
- to import existing soil characteristics into the current project, by selecting from the drop-down list under the help diagram and clicking the [Transfer] button;
- to import existing soil characteristics into the database by clicking the [Import a soil from the soils DB] button;
- to save a fill in the soils database by clicking the [Add this fill to the soils DB] button.

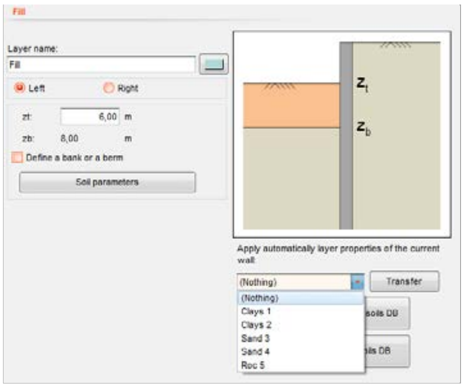


Figure B68 : *Previously defined soil layer properties can be imported*

Figure B69 *: Fill soil definition window*

The parameters to be input are as follows:

- γ and **γ'**: wet and buoyant unit weights (kN/m^3 or kcf);
- **Behaviour**: displays the drained or undrained behaviour of the soil;
- φ: internal friction angle (°);
- **c** and **dc**: cohesion and its variation until depth (kN/m^2 and kN/m^2/m or ksf and ksf/ft);
- δ_a/φ and δ_p/φ: angle of limit active and passive earth pressures;
- k_i: initial active earth pressure coefficient;
- $k_{a\gamma}$, $k_{p\gamma}$, k_{ac} and k_{pc}: active and passive earth pressure coefficients;
- k_h and dk_h: horizontal reaction coefficient and its variation with depth (kN/m^2/m and kN/m^2/m/m or ksf/ft and ksf/ft/ft);
- k_d and k_r: unloading and reloading ratios;
- $k_{a\gamma,min}$ and p_{max}: allowable minimum active pressure coefficient and maximum pressure.

Tick the "**Modify advanced** parameters" box to modify **dc**, dk_h, k_d, k_r, $k_{a\gamma,min}$ and p_{max}.

The wizards present in this window correspond to the same wizards available in the soil layers definition window.

A few recommendations concerning the "Fill" action:

AMRetain does not verify the stability of the bank or berm. This type of verification is the responsibility of the user and must be done beforehand using an appropriate model (for example with Talren v5).

Part C of the manual details how a fill is taken into account, in particular regarding the installation phase.
The k_i coefficient is commonly taken within the range [k_a, k_0]: the use of k_0 generally corresponds to the case of compacted fill, while the use of k_a is to be preferred for fills put into place using gravity alone.

It is possible to create several successive fills with different characteristics on the same side of the wall (in successive phases).

This action cancels the Caquot or Boussinesq type overloads on the soil on the side concerned by the fill. To maintain them, they have to be redefined.

The lower level of a fill (z_b) will by default be considered to be equal to the level in contact with the wall previously. If a bank or berm already existed, the level z_b will be equal to its upper level, that is $z_b = z_{t0}$.

Table B3 summarises the application of these rules.

B.5.3. Soil Characteristics

The "Redefinition of soil layers*" action is used to modify the characteristics of a soil layer during phasing. The parameters of this layer can be modified on the left, right or both sides of the wall.*

The following data are to be input:

- **"Wall 1"** or "**Wall 2"** only for a double wall project;
- "**Left**", "**Right**" or "**Left and right**";
- **Name of soil layer** to be modified: can be selected with the mouse from the drop-down list;
- New parameters: input window accessible via the [Soil parameters] button.

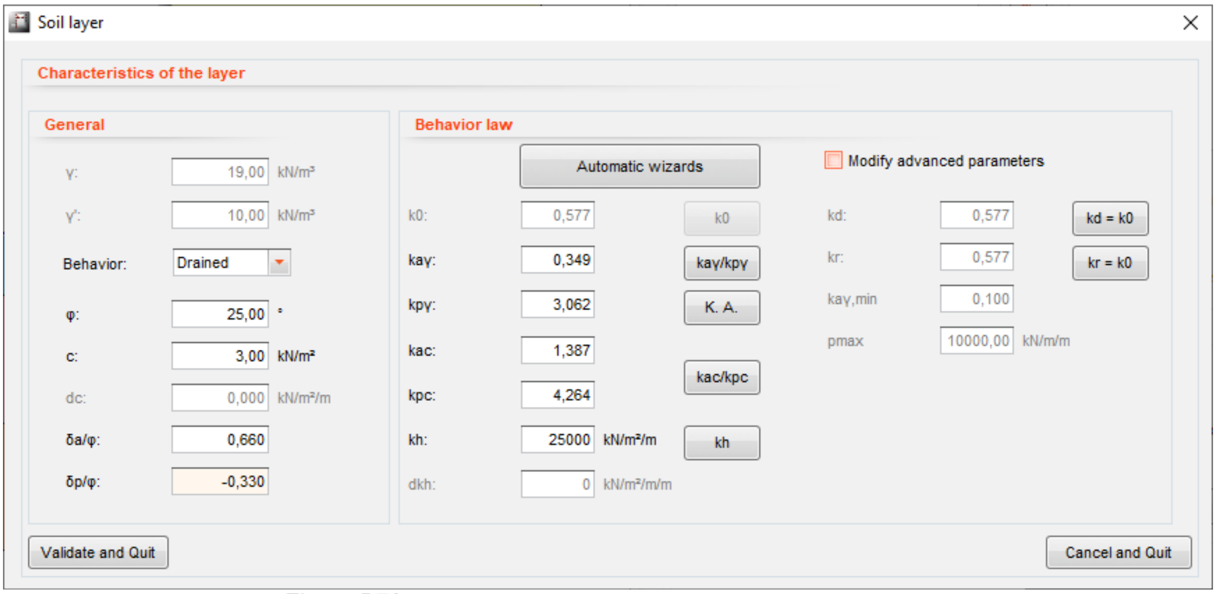


Figure B70 *: Window for redefining a soil layer during phasing*

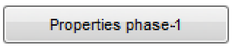
The modifiable parameters are:

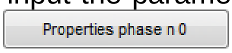
- **Behaviour**: drained or undrained (the choice only impacts the safety factor on cohesion and internal friction angle)
- **φ:** internal friction angle (°);
- **c** and **dc**: cohesion and its variation with depth (kN/m^2 and kN/m^2/m or ksf and ksf/ft);
- **δ_a/φ** and **δ_p/φ**: angle of limit active and passive earth pressure stresses;
- **$k_{a\gamma}$**, **$k_{p\gamma}$**, **k_{ac}** and **k_{pc}**: active and passive earth pressure coefficients;
- **k_h** and **dk_h**: horizontal reaction coefficient and its variation with depth (kN/m^2/m and kN/m^2/m/m or ksf/ft and ksf/ft/ft);
- **k_d** and **k_r**: unloading and reloading ratios;
- **$k_{a\gamma,min}$** and **p_{max}**: allowable minimum active earth pressure coefficient and maximum pressure.

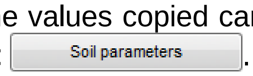
Tick the "**Modify advanced parameters"** box allows to modify **dc**, **dk_h**, **k_d**, **k_r**, **$k_{a\gamma,min}$** and **p_{max}**. The non-modifiable parameters γ, γ' and **k_0**, are shown for information.

This action can be used to modify one or more soil layer parameters independently of each other. The wizards in the soil layers definition window are also available in this window.

Modification of the parameters applies to the layer chosen in the current phase. To modify the parameters of another layer, one must add another "**Soil layers redefinition"** action to the list of actions of the same phase, choose the other layer to be modified and input the new parameters. This procedure is to be repeated as many times as necessary.

In the new parameters definition frame for a soil layer, the 

button is used to automatically input the parameters by recovering all of those defined in the previous phase. Similarly, the 

button can be used to import the initial parameters of the soil layer in question. The values copied can then be modified by consulting the soil parameters input wizard window: 

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B.5.4. Characteristics of the wall

B.5.4.1. Modification of Beta D factor

This action is available only for « Standard U » sheet pile walls and when the option **Apply reduction coefficient betaD** has been checked in the initial definition of the wall (section B.3.3).

This action enables to change in a given phase the value of the betaD coefficient, and thus the EI value for the wall. This EI value is calculated by applying the new betaD value (to be chosen by the user among the available values in the range [0.3; 1]:

$$EI_{modified} = BetaD*EI_{catalogue}$$

For instance, if the value 0.60 has been checked, then the modified EI value will be equal to 60% of the ArcelorMittal catalogue EI value.

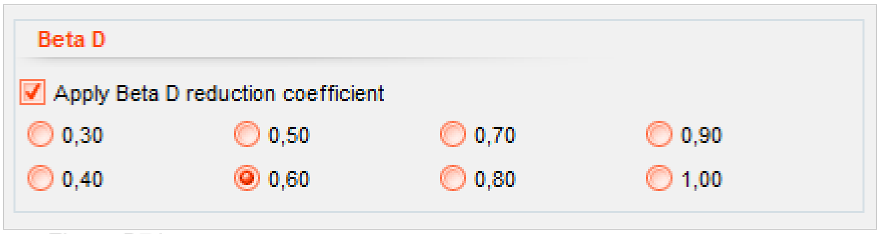


Figure B71 : *Modification of betaD coefficient (Standard U sheet piles only)*

The previous EI value will be replaced with the new one in the equations and this change will thus have an influence on the wall displacements.

B.5.4.2. Corrosion wizard action

This action reduces the percentage of the inertia product of the wall in order to consider the effect of corrosion.

$$EI_{modifié} = \%EI * EI_{catalogue}$$

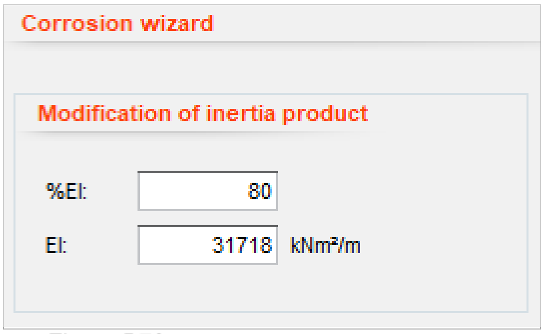


Figure B72 : *Modification of inertia product*

B.5.5. Anchors and supports

The anchors, except for active anchors, work in one of the two modes defined in "Advanced calculation options" (in the "Title and Options" window). These modes are considered as follows:

- Activation as of the installation phase: in this case, the anchor stiffness is **always** taken into account as of the installation phase;
- Activation in two stages if pre-stressing is active: the stiffness is only taken into account as of the phase following installation, **provided that the anchor is initially pre-stressed.** If this is not the case, the anchor works as in the first mode.

B.5.5.1. Tie

This action is used to activate, modify or deactivate a layer of bedded ties. For simplification purposes, we will refer to "layer of ties" as "tie" in the documentation and in the interface. By convention, the force in a tie is positive in traction.

In AMRetain, the characteristics of a layer of ties are given per unit length of wall.

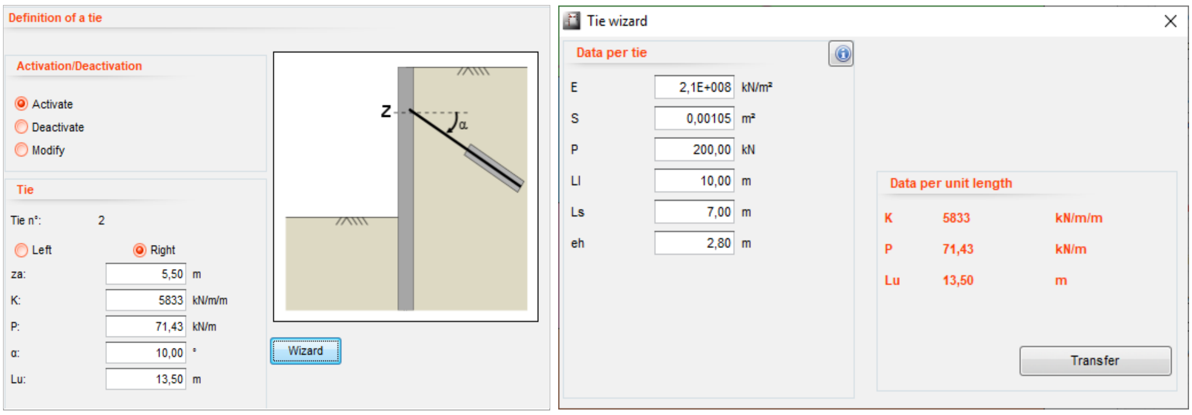


Figure B73 : *Definition of a tie and corresponding wizard*

When installing a tie (installation phase), only the pre-stressing is taken into account in the calculation. The stiffness of the tie is activated as of the following phase.

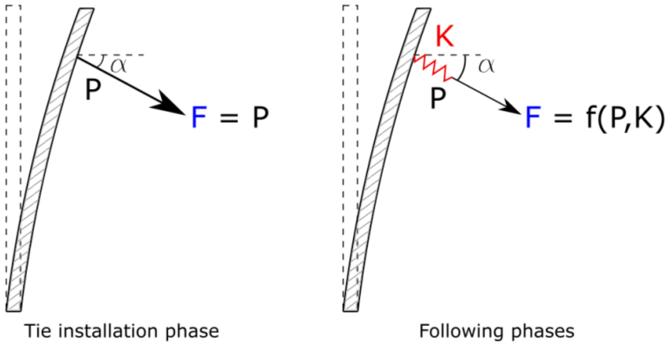


Figure B74 : *Behaviour of a tie with pre-stressing*

The parameters needed to define a tie are:

- Choice of wall: "**Wall 1"** or "**Wall 2"** for a double wall project;
- Choice of **"Activate":** chosen by default when defining a new tie;
- Choice of side: **"Left"** or "**Right"** for a single wall project, "**Left"** or "**Right/E.2R"** (wall 1) or "**Left/E.2R"** or "**Right"** (wall 2) for a double wall project;
- $\mathbf{z_a}$: level of application (m or ft);
- **K**: axial stiffness (kN/m/m or kip/ft);
- **P**: pre-stressing counted in positive traction (kN/m or kip/ft);
- α: angle of tie with respect to the horizontal, counted as positive if the angle is downwards (°);
- $\mathbf{L_u}$: useful length of tie (in m or ft) usually taken as equal to the distance, along the axis of the tie, between the anchor head and the point corresponding to the middle of the bedding (also see the anchoring block check in part C of the manual for validation of the value of L_u to be considered and in part D for examples of its definition). This parameter is only required if the ULS checks are activated;
- $\mathbf{L_s}$**:** length of the grouted embedment (in m or ft). It is to be filled out if the "consideration of the grouted embedment length" option was chosen in the "Anchoring block check" grouped in the "Advanced calculation options" (see Part D of the manual for examples of definition of L_s);

The [Wizard >>] button gives access to the **Tie Wizard** (right-hand part of the above figure). It is used to calculate the stiffness of the tie and the pre-stressing force per unit length, on the basis of the formulas given in the technical manual (Part C of the manual).

The data to be input into the tie wizard are as follows:

- **eh**: spacing of ties (distance between axis) (m);
- **E**: Young's modulus (kN/m²);
- **S**: calculation cross-section (m²);
- **P**: pre-stressing (kN);
- **Ll**: free length (m);
- **Ls**: grouted length.

After entering the input data, the values of K, P and Lu (for the ULS calculations only) are calculated per unit length. Click the [Transfer] button to transfer the values to the project.

A help diagram is available by clicking the button:

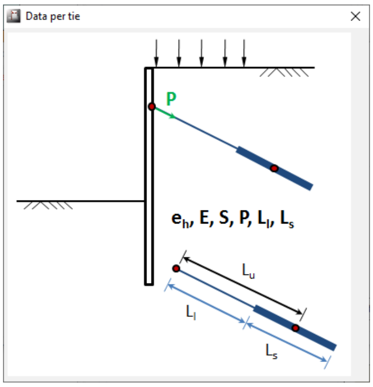


Figure B75 : *Tie wizard help - schematic*

This "Data per tie" figure clarifies the meaning of the wizard input parameters.

To **modify a tie** that was previously defined, select "**Modify**". The modifiable values are as follows:

- **K**: axial stiffness per unit length (kN/m/m or kip/ft);
- **P**: pre-stressing (kN/m or kip/ft);
- **F**$_{adm,tr}$: allowable traction force (kN or kip).

The following figure illustrates the appearance of a drop-down list containing the ties active in the phase in question. Each tie is identified by:

- its identification number;
- its application level;
- its stiffness;
- its pre-stressing;
- its inclination angle.

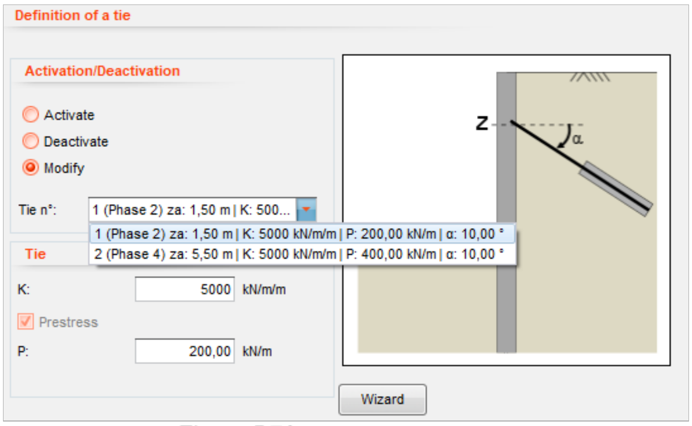


Figure B76 : *Modification of a tie*

To **deactivate a tie** previously defined, select **"Deactivate".** The following figure shows the drop-down list available containing all the ties that the user can deactivate. Each tie is identifiable by the following:

- its declaration number;
- its application level;
- its stiffness;
- its pre-stressing;
- its inclination angle.

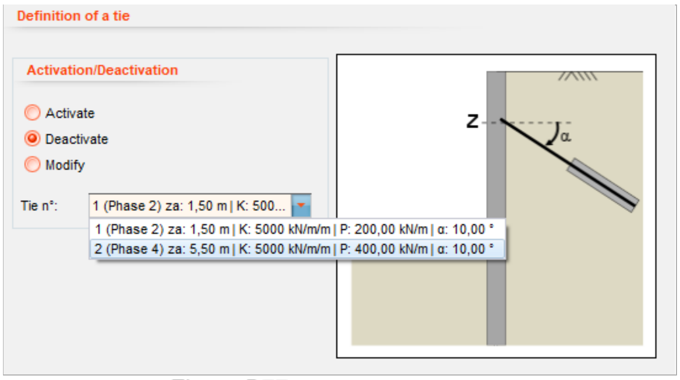


Figure B77 : *Deactivation of a tie*

B.5.5.2. Strut

This action is used to activate, modify or deactivate a layer of struts. For simplification purposes, we will refer to "layer of struts" as "strut" in the documentation and in the interface. By convention, the force in a strut is positive in compression.

The parameters to be input to define a strut are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default when defining a new strut;
- **"Left"** or "**Right"** for a single wall project, "**Left"** or "**Right/E.2R"** (wall 1) or "**Left/E.2R"** or "**Right"** (wall 2) for a double wall project;
- **z_a**: application level (m or ft);
- **K**: axial stiffness (kN/m/m or kip/ft);
- **P**: pre-stressing counted positively in compression (kN/m or kip/ft);
- α: inclination angle of strut with respect to the horizontal considered to be positive if the angle is downwards;
- **Operate under traction:** if ticked, the strut can operate under traction;
- **Operate under compression:** if ticked, the strut can operate under compression;

It should be recalled that the calculation is made for a unit length of wall.

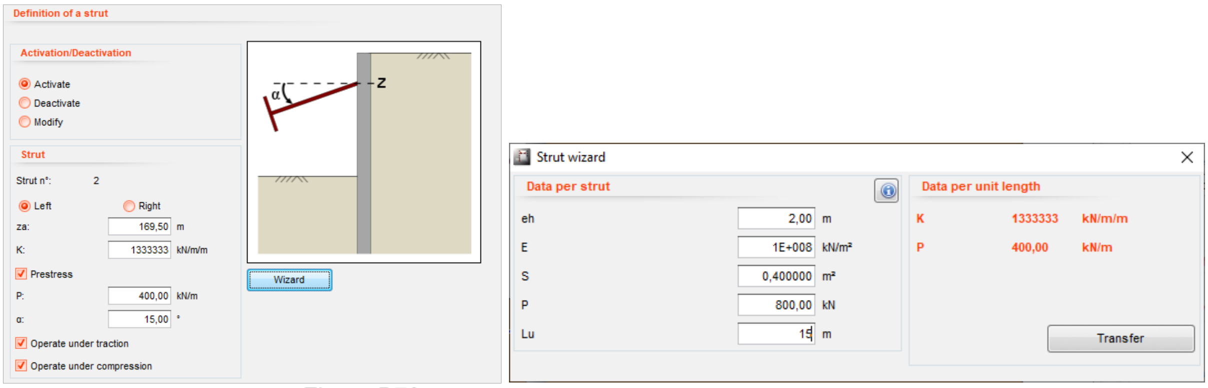


Figure B78 : *Definition of a strut and corresponding wizard*

The Wizard >> button gives access to the **Strut wizard** (see above figure). This is used to calculate the stiffness of the strut and its pre-stressing, if any, per unit length, using the formulas given in the technical manual (Part C of the manual). It also includes a tool for evaluating the equivalent stiffness of a diagonal strut.

The input data to be entered into the strut wizard are as follows:

- eh: spacing of struts (m);
- E: Young's modulus (kN/m²);
- S: cross-section (m²);
- P: pre-stressing (kN);
- L_u: useful length (m);

Once the values have been input, AMRetain displays the values selected for K, P and $F_{,adm\ cp}$ or $\sigma_{,adm\ cp}$, in the right-hand part of the window.

Four help diagrams can be obtained by clicking the [i] buttons:

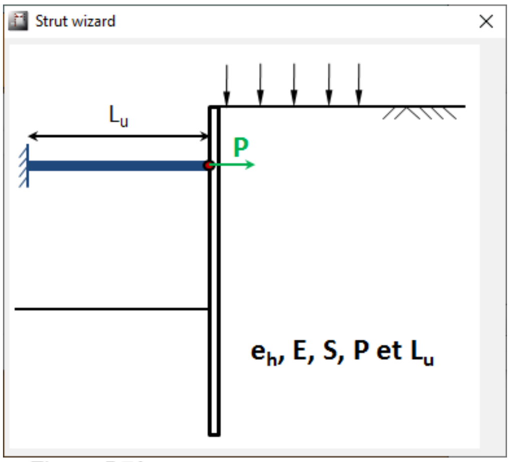


Figure B79 : *Strut wizard help - Schematics*

To **modify a strut** previously defined, select "**Modify**". The modifiable values are:

- **K**: stiffness per unit length (kN/m/m or kip/ft);
- **P:** pre-stressing (kN/m or kip/lf);

The following figure shows the appearance of a drop-down list with all the existing and modifiable struts, each identified by its characteristics:

- its declaration number;
- its application level;
- its stiffness;
- its pre-stressing;
- its inclination angle.

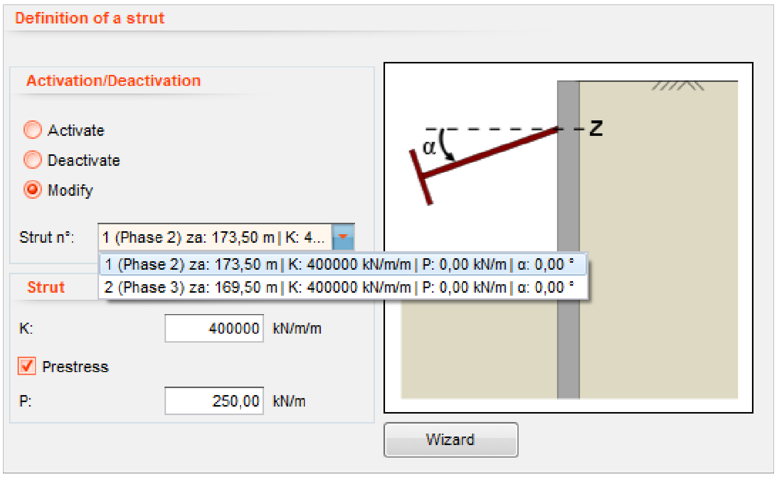


Figure B80 : *Modification of a strut*

To **deactivate a strut** previously defined, select **"Deactivate**". The strut deactivation frame illustrated in the following figure then appears. From the drop-down list select the strut to be modified, identified by the following:

- its declaration number;
- its application level;
- its stiffness;
- its pre-stressing;
- its inclination angle.

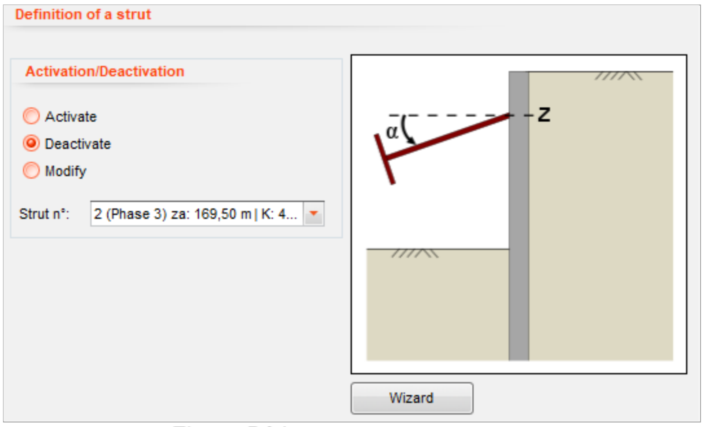


Figure B81 : *Deactivation of a strut*

B.5.5.3. Rotational spring

Rotation spring corresponds to an anchor which opposes the rotation of the wall. This command is used to activate, modify or deactivate this type of anchor. By convention, the moment induced in a rotational spring is positive clockwise.

The parameters to be defined are as follows:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** choice by default to define a new rotational spring;
- **z_a**: application level (m or ft);
- **R_r**: rotational stiffness (kNm/rad/m or kip.ft/rad/ft);

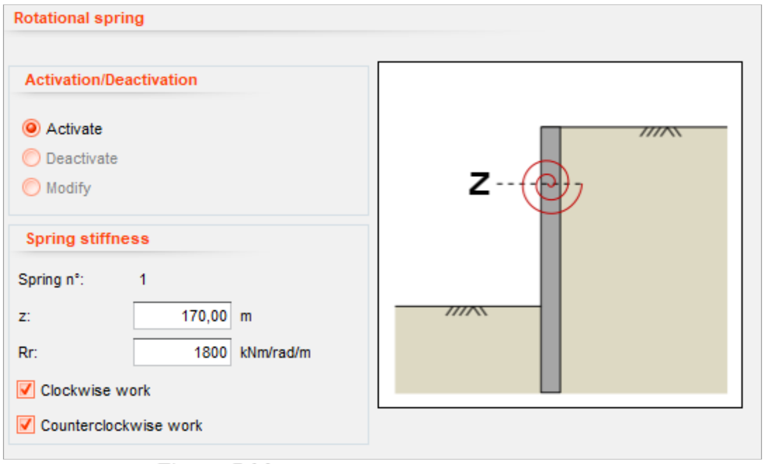


Figure B82 : *Definition of a rotational spring*

To **modify a rotational spring** previously defined, select "**Modify**". The modifiable values are:

- **R_r**: rotational stiffness (kNm/rad/m or kip.ft/rad/ft);

The following figure shows the drop-down list consisting of the rotational springs previously defined and which are modifiable. Each of them is identified by the following:

- its declaration number;
- its application phase;
- its stiffness.

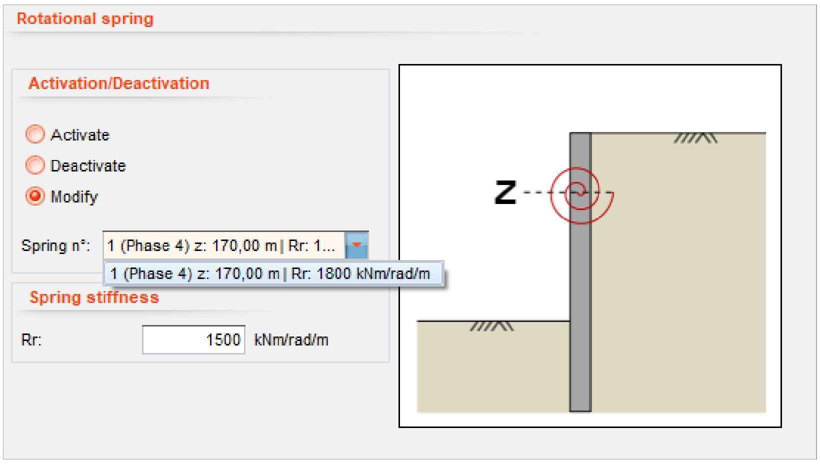


Figure B83 : *Modification of a rotational spring*

To **deactivate a rotational spring** previously defined, select **"Deactivate"**. The deactivation frame illustrated in the following figure then appears. From the drop-down list select the rotational spring to be deactivated, identified by the following:

- its declaration number;
- its application level;
- its stiffness;
- its initial moment.

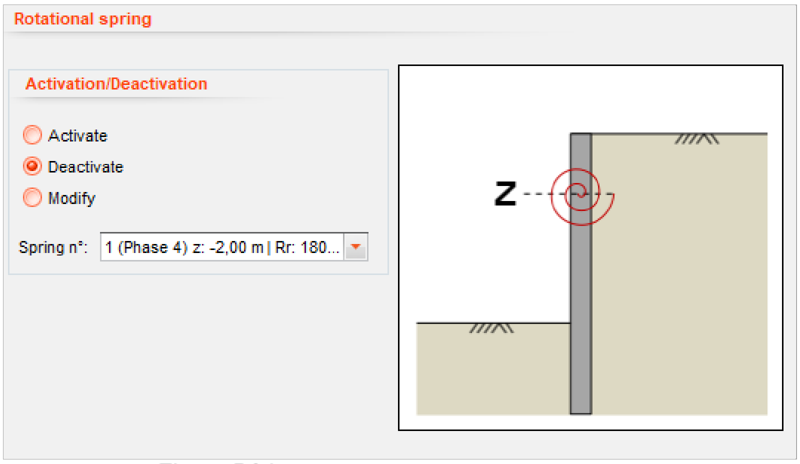


Figure B84 : *Deactivation of a rotational spring*

B.5.5.4. Linking anchor

This action is only available for a double wall project and can be used to activate, modify or deactivate a linking anchor joining the two walls.

The parameters to be input to define a linking anchor are:

- **Activate**: chosen by default to define a new strut;
- **Tie** or **Strut:** choice of type of anchor. By convention, the force in a tie is positive in traction, that in a strut is positive in compression;
- $\mathbf{z_{aa}}$: anchor level on wall 1 (m or ft);
- $\mathbf{z_{ab}}$**:** anchor level on wall 2 (m or ft);
- **d**: distance between the two walls. This value is recovered directly from the "Title and Options" tab, where it was filled out as a project parameter. It is recalled for information (m or ft);
- α: this value is not to be defined by the user and is automatically calculated as a function of the distance d and anchor levels z_{a1} and z_{a2};
- **K**: axial stiffness per unit length (kN/m/m or kip/ft);
- **P**: pre-stressing per unit length (kN/m or kip/ft).

It should be recalled that the calculation is made for a unit length of wall.

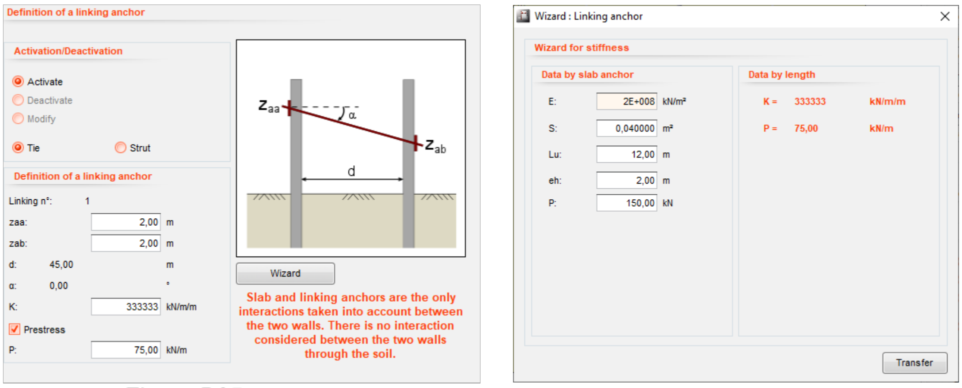


Figure B85 *: Definition of a linking anchor and corresponding wizard*

The [Wizard >>] button gives access to the **Linking anchor wizard**. This latter can be used to calculate the stiffness of the connecting anchor and its pre-stressing, if any, per unit length, using the formulas indicated in the technical manual (see Part C of the manual).

To **modify a linking anchor** previously defined, select **"Modify"**. The modifiable values are:

- K: stiffness (kN/m/m or kip/ft);
- P: pre-stressing (kN/m or kip/ft);

The following figure shows the drop-down list consisting of the linking anchors previously defined and which are modifiable. Each linking anchor is identified by the following:

- its declaration number and its installation phase;
- its anchor levels (z_{a1} and z_{a2});
- its stiffness.

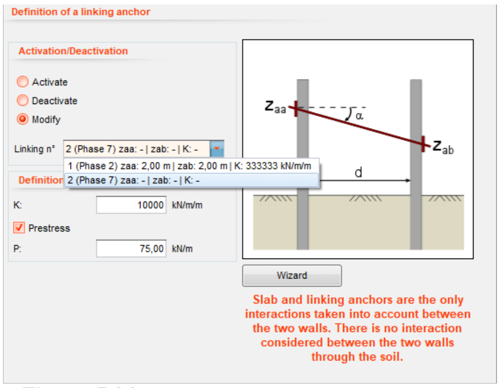


Figure B86 : *Modification of a linking anchor*

To **deactivate a linking anchor** previously defined, select "**Deactivate**". The following figure shows the drop-down list containing the linking anchors previously defined. Each linking anchor is identified by the following:

- its declaration number;
- its anchor levels (z_{a1} and z_{a2});
- its stiffness.

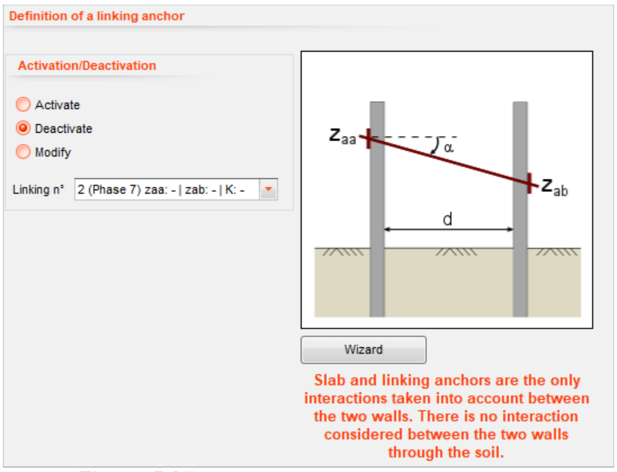


Figure B87 : *Deactivation of a linking anchor*

B.5.6. Soil and wall loading

B.5.6.1. Caquot overload

This action is used to apply a semi-infinite vertical overload to the soil situated on one side of the wall (details of how this type of overload is taken into account in the calculations are given in part C of the manual).

The parameters to be input to define a Caquot overload are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default to define a new overload;
- Overload application side:
  - **"Left"** or "**Right"** for a single wall project
  - **"Left"** or "**Right/E.2R"** (wall 1) or "**Left/E.2R"** or "**Right"** (wall 2) for a double wall project;
- **z**: overload application level (m or ft);

- **q**: overload amplitude (kN/m/m or kip/ft).
- **Action nature**: if ULS checks were requested, the nature of the overload must also be defined, by specifying whether it is **permanent** or **variable**. This choice determines the value of the partial factor to be applied to the overload (see § B.3.1.2).
- **Family**: if the load cases calculation was activated (see §B.3.5), the overload must be allocated to a loads family using the drop-down list containing all the previously defined families.

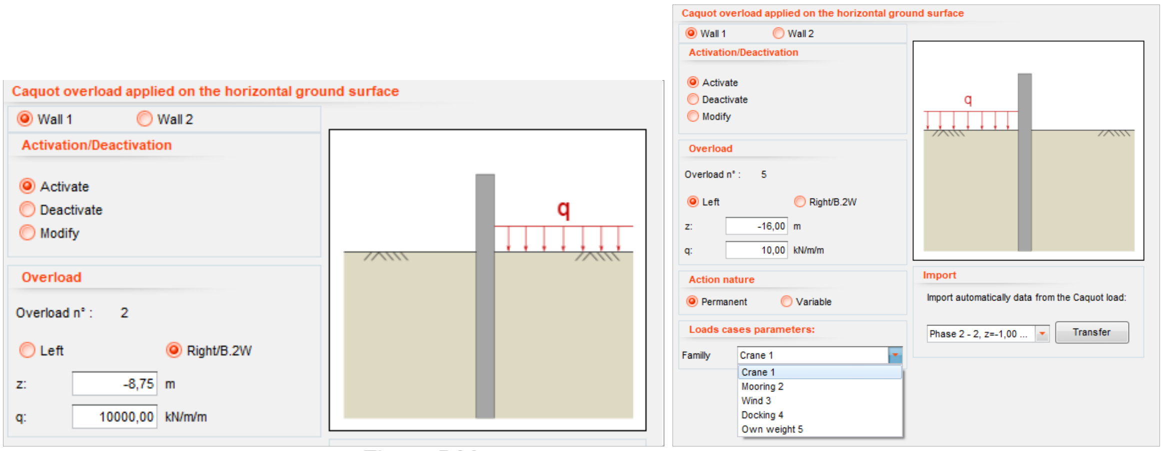


Figure B88 *: Definition of Caquot overload*

It is also possible to automatically import the properties of a previously defined Caquot overload into the project: select the overload to be imported from the drop-down list and then click the Transfer button.

The "Excavation" and "Fill" actions cancel out the Caquot overloads previously defined on the same side of the wall.

To **modify a Caquot overload** previously defined, select "**Modify"**. The modifiable values are:

- **q**: overload amplitude (kN/m/m or kip/ft);
- **Action nature**: if ULS checks are requested.

The following figure shows the drop-down list containing the previously defined Caquot overloads which are still present. Each Caquot overload is identified by the following:

- its definition phase and its declaration number;
- its application level;
- its amplitude.

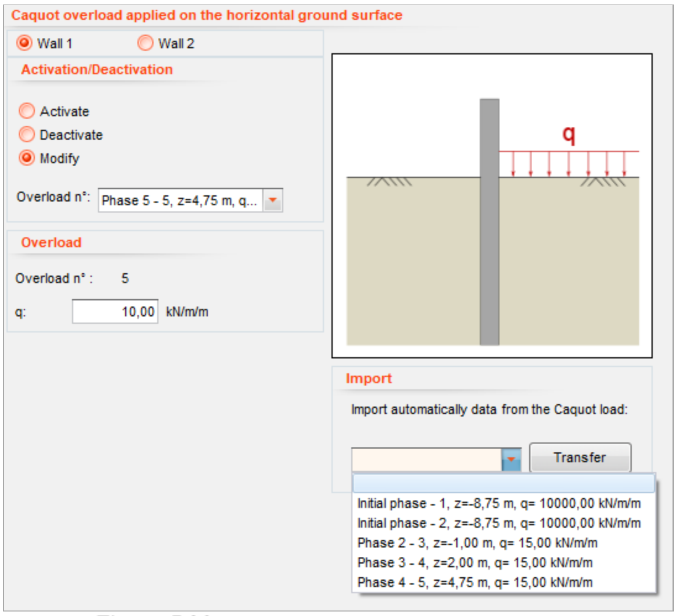


Figure B89 : *Modification of a Caquot overload*

To deactivate a previously defined **Caquot overload**, select "**Deactivate**". The following figure shows the drop-down list containing the previously defined Caquot overloads which are still present. Each Caquot overload is identified by the following:

- its definition phase and its declaration number;
- its application level;
- its amplitude.

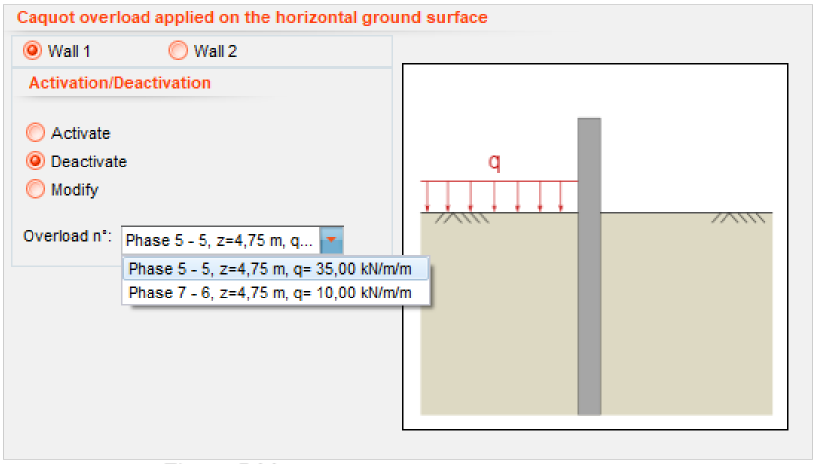


Figure B90 : *Deactivation of a Caquot overload*

B.5.6.2. Boussinesq overload

This action is used to apply a localised vertical Boussinesq type overload to a limited width in the soil on one side of the wall (part C of the manual details how Boussinesq overloads are taken into account in the calculations).

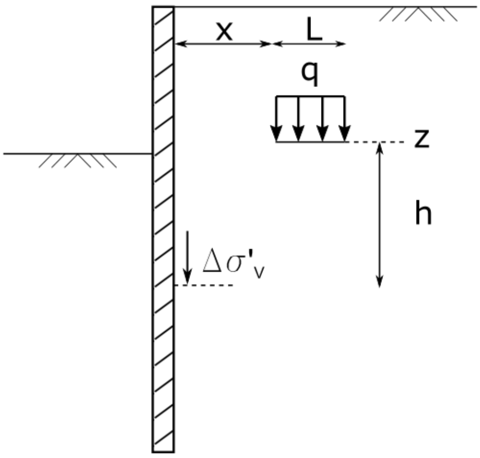


Figure B91 : *Schematic of a Boussinesq overload*

The parameters to be input to define a Boussinesq overload are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default to define a new overload;
- Side of application of the Boussinesq overload:
  - o **"Left"** or "**Right"** for a single wall project,
  - o **"Left"** or "**Right/E.2R"** (wall 1) or "**Left/E.2R"** or "**Right"** (wall 2) for a double wall project;
- **z**: level of application of the overload (m or ft);
- **x**: distance from the wall > 0 (m or ft);
- **L**: width of application > 0 (m or ft);
- **q**: overload amplitude (kN/m/m or kip/ft);
- $\boldsymbol{\alpha_e}$: multiplication coefficient used to correct the Boussinesq overload (taking account of the wall effect) The [αe = (x+2)/(x+1)] button gives this coefficient the value derived from the following formula:

  $\alpha_e = (x + 2) / (x + 1)$
- **Action nature**: if ULS checks were requested, the nature of the overload must also be defined by specifying whether it is **permanent** or **variable**. This choice determines the value of the partial factor to be applied to the overload (see § B.3.1.2).
- **Family**: if the load cases calculation has been activated (see §B.3.5), the overload must be allocated to a loads family using the drop-down list containing all the previously defined families.

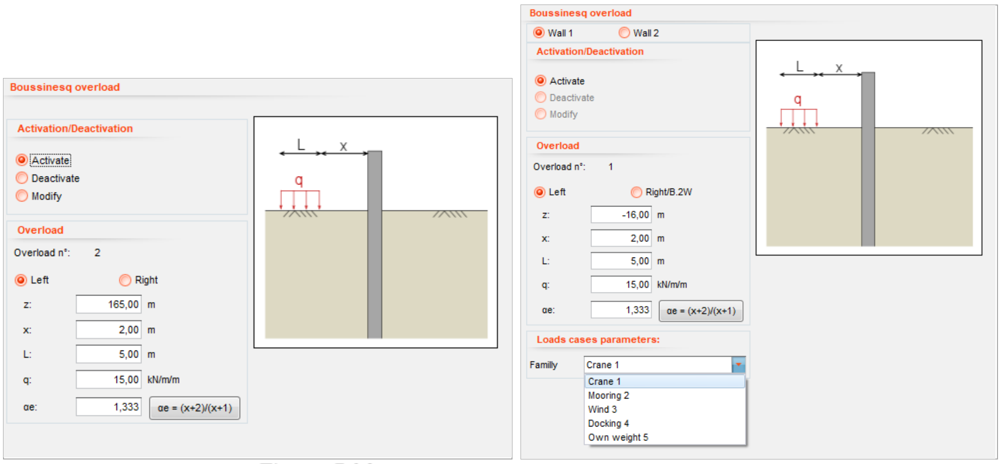


Figure B92 *: Definition of Boussinesq overload*

The "Excavation" and "Fill" actions cancel the previously defined Boussinesq overloads on the same side of the wall.

To **modify a Boussinesq overload** previously defined, select "**Modify"**. The modifiable values are:

- **q**: overload amplitude (kN/m^2 or KsF);
- **Action nature**: if ULS checks were requested.

The following figure shows the drop-down list containing the previously defined Boussinesq overloads which are still present. Each Boussinesq overload is identified by the following:

- its declaration number and its definition phase;
- its application level;
- its amplitude.

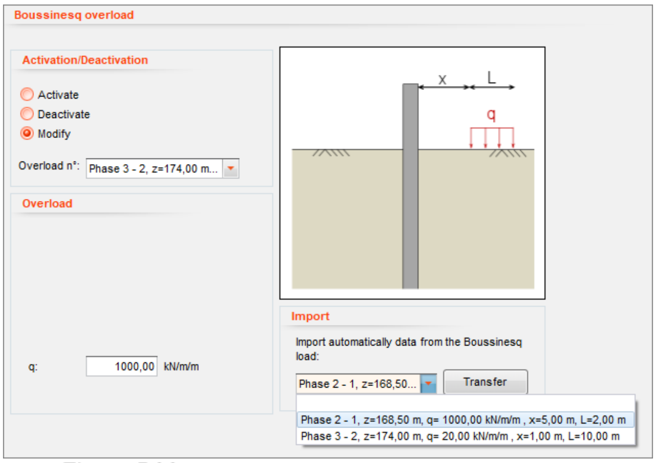


Figure B93 *: Modification of a Boussinesq overload*

To deactivate a previously defined **Boussinesq overload,** select "**Deactivate"**. The following figure shows the drop-down list containing the previously defined Boussinesq overloads which are still present. Each Boussinesq overload is identified by the following:

- its declaration number and its definition phase;
- its application level;
- its amplitude.

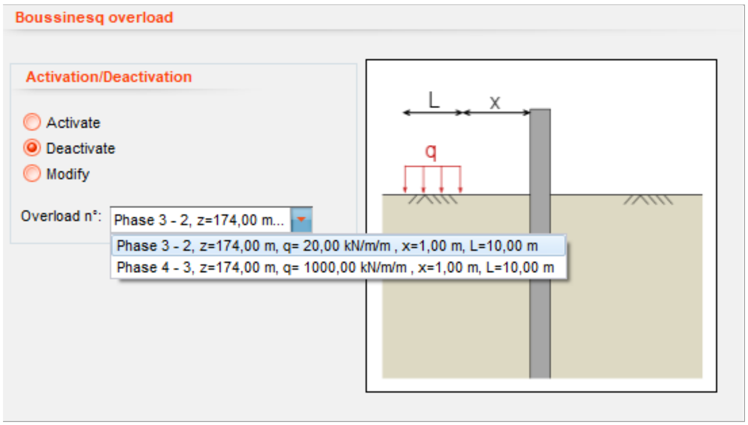


Figure B94 : *Deactivation of a Boussinesq overload*

B.5.6.3. Line force

This action is used to manage (activate, modify or deactivate) the line forces applied directly to the wall.

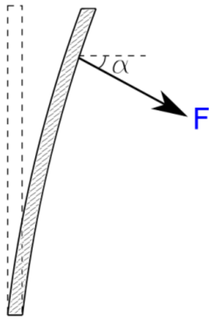


Figure B95 : *Line force schematic*

The parameters needed for definition of a line force are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default to define a new force;
- **z**: level of application (m or ft);
- **F**: amplitude of the force (kN/m or kip/ft);
- α: angle of the force with respect to the horizontal, counted positively clockwise (°);
- **Action nature**: if ULS checks were requested, the nature of the force must also be defined, specifying whether it is **permanent** or **variable** on the one hand, and **favourable** or **unfavourable** on the other. These choices will affect the value of the partial factor to be applied to the load value (see § B.3.1.2 of the manual).
- **Family**: if the load cases calculation was activated (see §B.3.5), the overload must be allocated to a loads family using the drop-down list containing all the previously defined families.

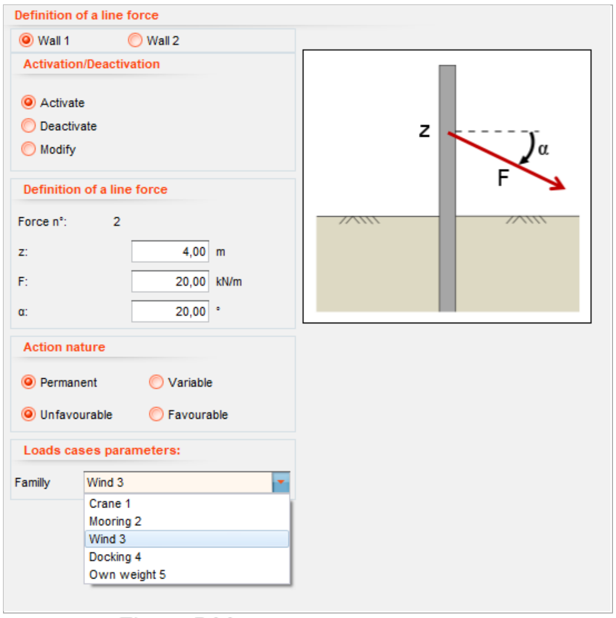


Figure B96 : *Definition of a line force*

To **modify a line force** previously defined, select **"Modify"**. The following figure shows the drop-down list containing the previously defined line forces which are still present. Each line force is identified by the following:

- its declaration number;
- its application level;
- its amplitude;
- its angle.

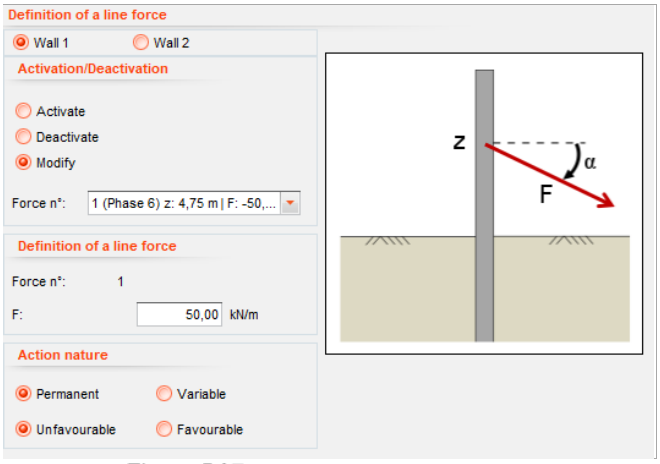


Figure B97 : *Modification of a line force*

The modifiable values are:

- **F**: force amplitude (kN/m or kip/ft);
- **Action nature**: if ULS checks are requested.

To deactivate a previously defined **line force**, select "**Deactivate"**. The following figure shows the drop-down list containing the previously defined line forces which are still present. Each line force is identified by the following:

- its declaration number and its definition phase;
- its application level;
- its amplitude;
- its angle.

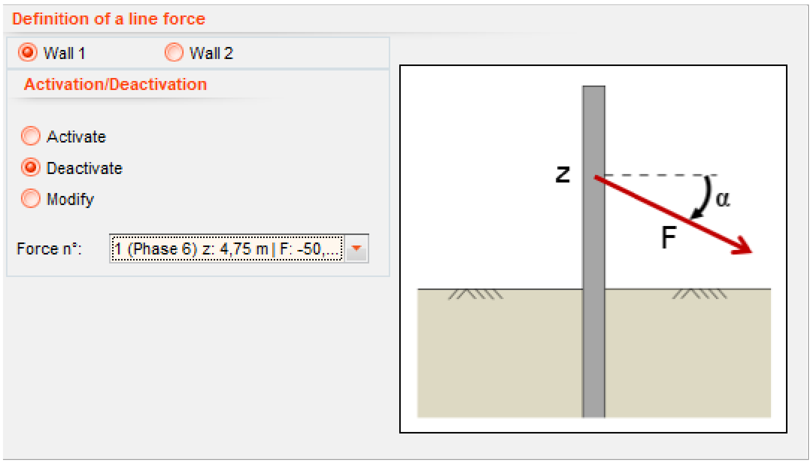


Figure B98 : *Deactivation of a line force*

B.5.6.4. Moment

This action is used to manage (activate, modify or deactivate) the linear moments applied directly to the wall.

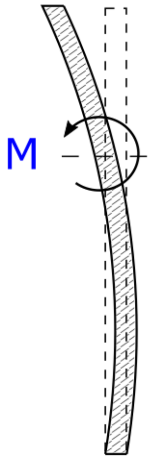


Figure B99 : *Moment schematic*

The parameters to be input to define a moment are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default to define a new moment;
- **z:** level of application (m or ft);
- **M:** amplitude of moment (kNm/m or kip/ft);
- **Action nature:** if ULS checks were requested, the nature of the load must also be defined, specifying whether it is **permanent** or **variable** on the one hand and **favourable** or **unfavourable** on the other. These choices will affect the value of the partial factor to be applied to the load value (see § B.3.1.2 of the manual).
- **Family**: if the load cases calculation was activated (see §B.3.5), the overload must be allocated to a loads family using the drop-down list containing all the previously defined families.

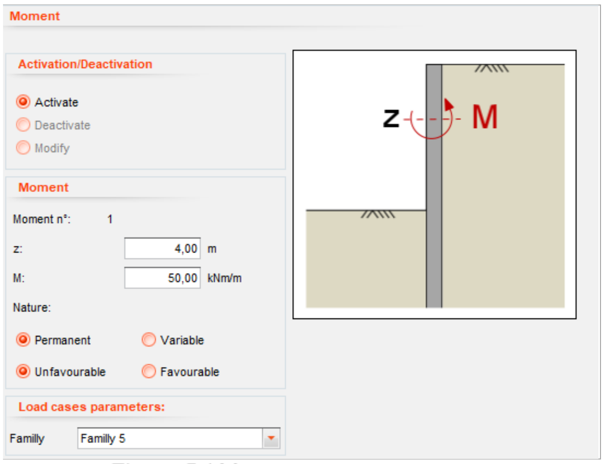


Figure B100 *: Definition of a moment*

To **modify a moment** previously defined, select "**Modify"**. The following figure shows the drop-down list containing the previously defined moments which are still present. Each moment is identified by the following:

- its declaration number and the definition phase;
- its application level;
- its amplitude;
- its angle.

The modifiable values are:

- **M**: moment amplitude (kNm/m or kip.ft/ft);
- **Action nature**: if ULS checks were requested, the nature of the load must also be defined, specifying whether it is **permanent** or **variable** on the one hand and **favourable** or **unfavourable** on the other. These choices will affect the value of the partial factor to be applied to the load value (see § B.3.1.2 of the manual).

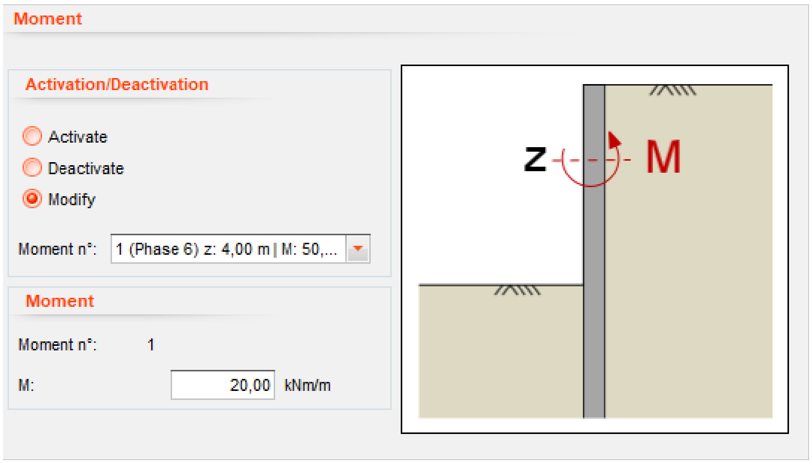


Figure B101 : *Modification of a moment*

To **Deactivate a moment** previously defined, select "**Deactivate"**. The following figure shows the drop-down list containing the previously defined moments which are still present. Each moment is identified by the following:

- its declaration number and its definition phase;
- its application level;
- its amplitude.

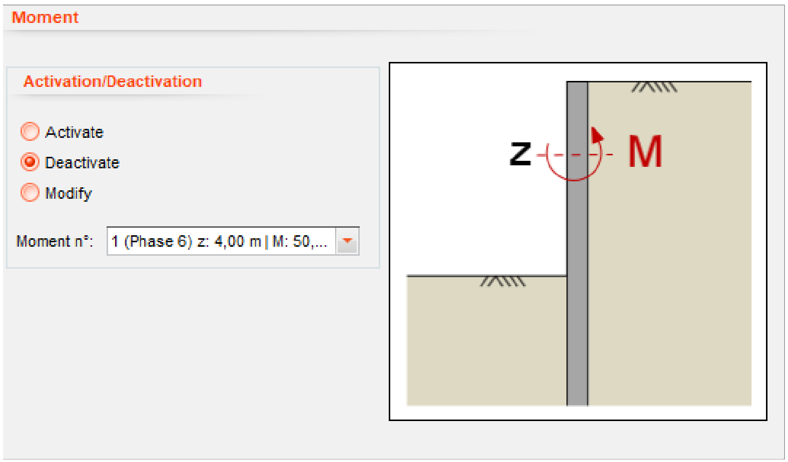


Figure B102 : *Deactivation of a moment*

B.5.6.5. Horizontal load

This command is used to manage (activate, modify or deactivate) the horizontal loads applied directly to the wall.

The parameters to be input to define this type of load are:

- **"Wall 1"** or "**Wall 2"** for a double wall project;
- **Activate:** chosen by default to define a new load;
- **z_t**: upper level of load (m or ft);
- **z_b**: lower level of load (m or ft);
- α: angle of the load with respect to the horizontal, counted positively clockwise (°).
- **q_{ht}**: load amplitude at level z_t (kN/m/m or kip/ft);
- **q_{hb}**: load amplitude at level z_b (kN/m/m or kip/ft).
- **Action nature:** if ULS checks were requested, the nature of the load must also be defined, specifying whether it is **permanent** or **variable** on the one hand and **favourable** or **unfavourable** on the other. These choices will affect the value of the partial factor to be applied to the load value (see § B.3.1.2 of the manual).
- **Family**: if the load cases calculation was activated (see §B.3.5), the overload must be allocated to a loads family using the drop-down list comprising all the previously defined families.

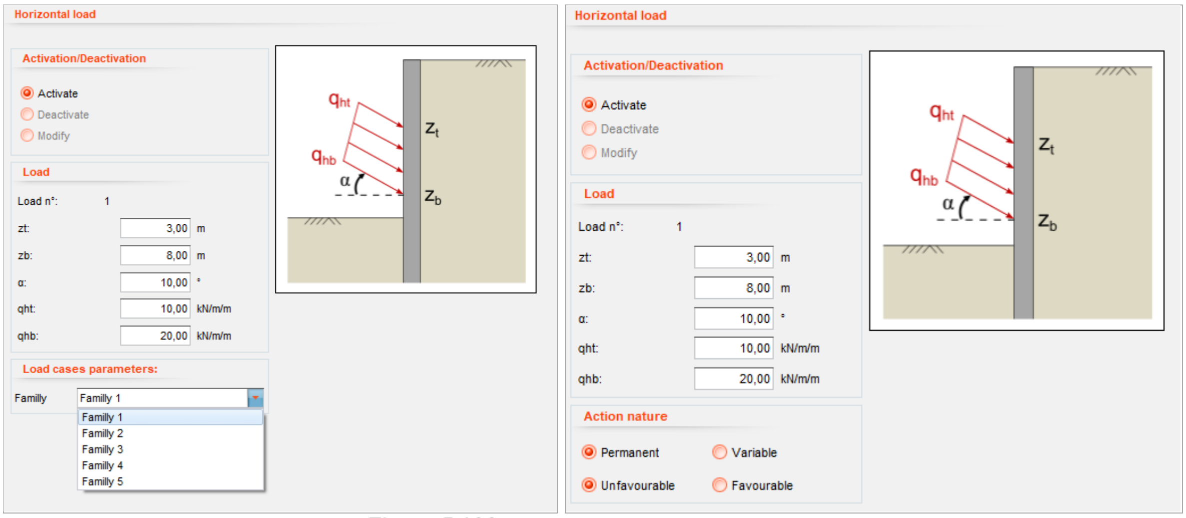


Figure B103 *: Definition of a horizontal load*

The overload value between **q_{ht}** and **q_{hb}** is obtained by linear interpolation between levels **z_t** and **z_b.**

To **modify a horizontal load** previously defined, select "**Modify"**. The modifiable values are:

- **q_{ht}**: load amplitude at level z_t (kN/m/m or kip/ft);
- **q_{hb}**: load amplitude at level z_b (kN/m/m or kip/ft).
- **Action nature:** if ULS checks were requested, the nature of the load must also be defined, specifying whether it is **permanent** or **variable** on the one hand and **favourable** or **unfavourable** on the other. These choices will affect the value of the partial factor to be applied to the load value (see § B.3.1.2 of the manual).

The following figure shows the drop-down list containing the previously defined horizontal loads which are still present. Each horizontal load is identified by the following:

- its declaration number and its definition phase;
- its application levels (top and bottom);
- its amplitude at levels z_t and z_b;
- its angle.

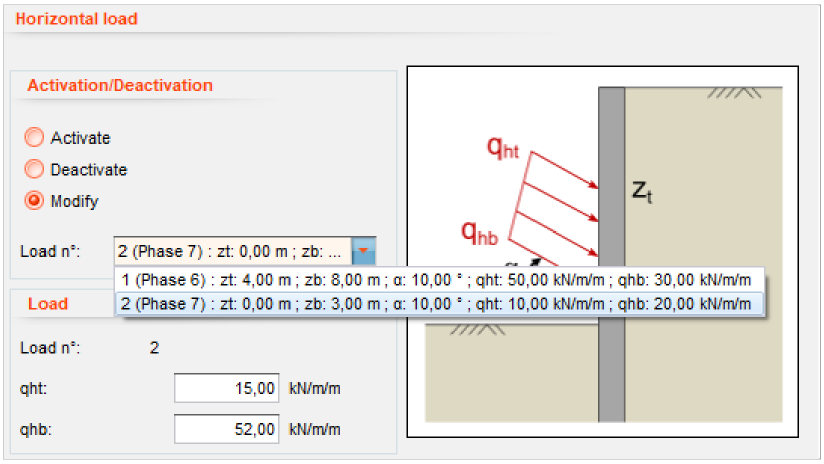


Figure B104 : *Modification of a horizontal load*

To deactivate a previously defined **horizontal load**, select "**Deactivate**". The following figure shows the drop-down list containing the previously defined horizontal loads which are still present. Each horizontal load is identified by the following:

- its declaration number and its definition phase;
- its application levels (top and bottom);
- its angle;
- its amplitude at levels z_t and z_b.

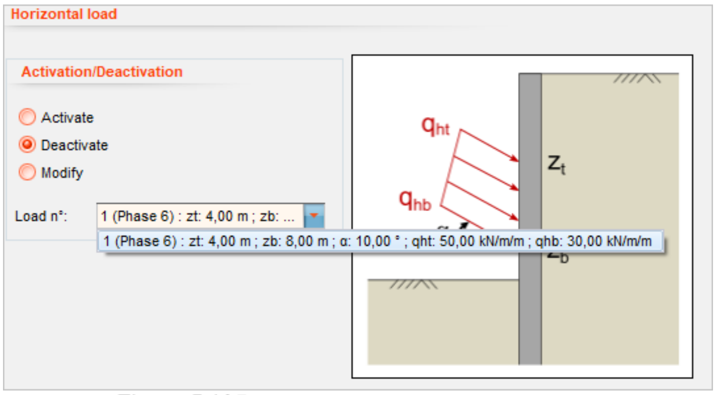


Figure B105 : *Deactivation of a horizontal load*

B.5.7. Automatic actions

B.5.7.1. LEM Options (Limit Equilibrium Method)

This action is used to check the available options in the ULS checks frame for the phases during which the wall is defined as cantilever (LEM calculation), in other words, the phases for which the "**Cantilever wall**" box is ticked.

This command comprises 2 sections:

- **Over-excavation:** definition of the over-excavations to be taken into account in the ULS checks;
- **LEM calculation options:** configuration of the options used in the LEM calculation.

The parameters of this automatic action are as follows:

- **Δa_{left}:** over-excavation value on the left side of the wall to be taken into account in the ULS checks (LEM);
- **Δa_{right}**: over-excavation value on the right side of the wall to be taken into account in the ULS checks (LEM).

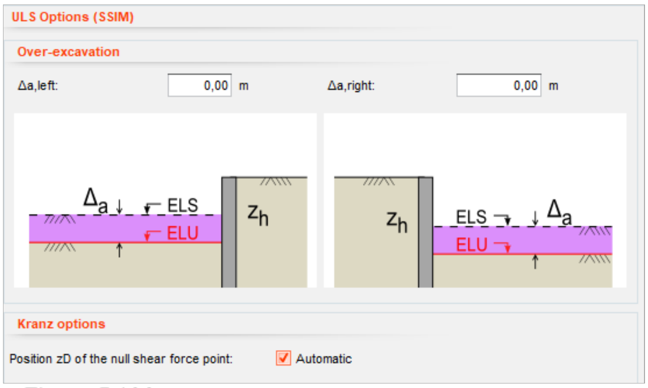


Figure B106 *: Modification of over-excavation parameters*

- **Calculation method:** calculation method used for the LEM checks. The "Automatic" choice is selected by default. In this case, method D is used. If you uncheck this option, you can choose to apply method F or method D for this phase (see Part C of the manual for details about these two calculation methods). When method D is selected, an additional option can be used to define the design embedment depths.

Three choices are then available for the base of the embedment depth considered in the LEM calculation:

  - **Wall base:** the base of the embedment depth considered corresponds to the base of the wall (default option);
  - **Level z_c – 0.2 x f_0**: the embedment depth base considered corresponds to the point on the wall $z_{base} = z_c - 0.2 \times f_0$ and is automatically evaluated by the calculation engine once z_c and f_0 have been calculated;
  - **Personalized**: the base of the embedment depth considered is set by the user.

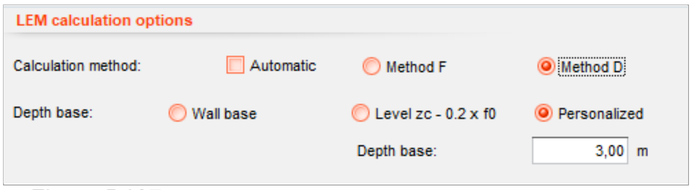


Figure B107 *: Modification of calculation method parameters*

- **Selection of passive earth pressure side**: passive earth pressure side considered during the checks performed for this phase. The "Automatic" box is selected for this option by default. In this case, the side with the lowest passive earth pressures ratio in the SSIM calculation is chosen. If you deselect this option, you can force the choice of passive earth pressure side considered (see Part C of the manual).

Figure B108 *: Modification of passive earth pressure side*

- **Automatic correction of counter passive earth pressure angles:** allows automatic correction of the counter passive earth pressure angles when evaluating the checks for this phase (see Part C of the manual + Part D/Tutorial 3).

  When the user deactivates this option, a table containing the soil layers present in the current phase appears. This table enables the user to define personalized counter passive earth pressure parameters.

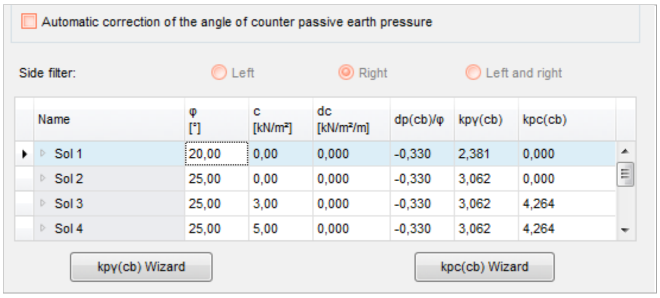


Figure B109 *: Modification of characteristics of counter passive earth pressure for a LEM calculation*

By default, for each soil layer, the counter passive earth pressure parameters ($\delta_{p(cb)}/\varphi$, $k_{p\gamma(cb)}$ and $k_{pc(cb)}$) are considered to be equal to those of the passive earth pressure (values of δ_p/φ, $k_{p\gamma}$ and k_{pc}).

In order to be able to simultaneously check the vertical and horizontal forces with compatible pressures, the user may need to modify the angle of the counter passive earth pressure $\delta_{p(cb)}/\varphi$ (see Example 3 in part D of the manual).

These parameters are used for ULS (LEM) verification calculations as described in part C of the manual.

B.5.7.2. ELU Options (SSIM)

This command is used to check the options available for ULS checks for the phases during which the wall is considered to be anchored (SSIM calculation), in other words, the phases for which the "**Cantilever wall"** box is not ticked.

This command comprises 2 sections:

- **Over-excavation:** definition of over-excavations to be taken into account in the ULS checks;
- **Anchoring block check :** options used for the anchoring block check.

The parameters of this command are as follows:

- **Δa_{left}**: over-excavation value on the left side of the wall to be taken into account during the ULS (SSIM) checks;
- **Δa_{right}**: over-excavation value on the right side of the wall to be taken into account during the ULS (SSIM) checks.

Figure B110 *: Modification of over-excavation parameters*

- **Position z_D of the null shear force point**: used to choose how the z_D point used during the anchoring block check is set (see Part C of the manual). The “Automatic” option is selected by default, in which case the calculation engine considers the shear force point to be the lowest point between the base of the wall and the bottom of the excavation. If this option is deselected, it is possible to impose the level considered for the z_D point.

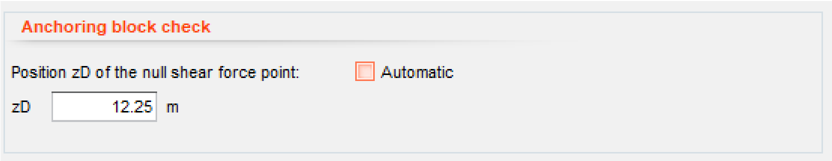


Figure B111 : *Position of the zD null shear force point*

B.5.8. Earthquake (seismic calculation)

This action is used to define the characteristics of a seismic calculation with respect to a phase for which the **"Seismic calculation"** box was ticked.

It should be noted that this option is only available in the phases for which the user has not yet inserted actions. Conversely, activation of this option deactivates the possibility of creating new actions in the current phase. The phase is then considered to be an "orphan". This means that the initial state reference for a phase without earthquake defined after a phase with earthquake will be the last phase without earthquake previously defined and not the seismic calculation phase. The following diagram explains the phasing when phases with earthquake are present.

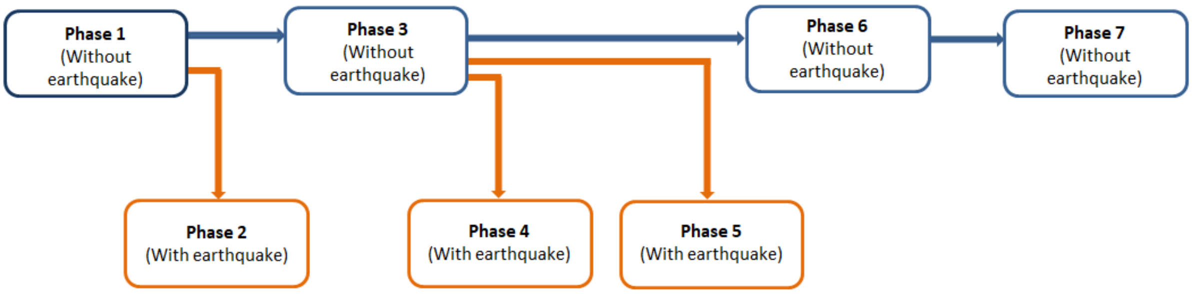


Figure B112 : *Calculation phasing with processing of phases with earthquake*

This command comprises 2 sections:

- **Acceleration parameters:** characteristics of the earthquake;
  - **k_h:** horizontal seismic coefficient;
  - **k_v:** vertical seismic coefficient;
  - **XP:** passive earth pressure limitation factor (≤1).
- **Soil parameters:** soil behaviour during seismic calculation. For each soil layer:
  - γ: wet unit weight (kN/m^3, kcf);
  - γ_d: dry unit weight (kN/m^3, kcf);
  - **Water behaviour left** and **right**: used to choose an open behaviour (highly permeable soil) or closed behaviour (low permeability soil) for the soil layer selected on each side of the wall.

The calculation of seismic effects is carried out using the “pseudo-static” method. The AMRetain calculation engine uses the above parameters for the following operations:

- Correction of limit active/passive earth pressure diagrams on each side of the wall taking account of seismic action;
- Correction of hydraulic profiles on each side of the wall at the levels where the groundwater is free and/or those where the soil was declared as an “open” medium.
- Application of a force of inertia associated with the mass of the wall.

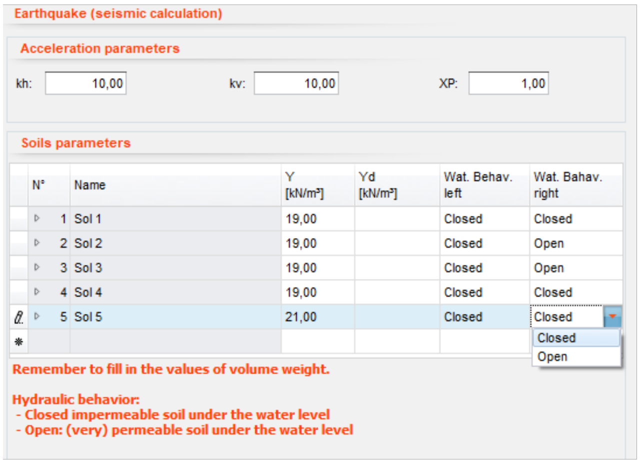


Figure B113 *: Seismic calculation*

The mathematical description of the calculation method used is detailed in part C of the manual.

B.6. Calculations and results

The calculations carried out by AMRetain are performed for a unit length of wall, so most of the data and results are relative to this unit length. The unit /m (per linear metre) or /ft (per linear foot) is explicitly recalled in the results provided.

B.6.1. General presentation

B.6.1.1. Calculation

Click the **Calculate** button on the buttons bar to start the calculations for all the calculation phases and ULS checks, if requested.

The calculations can be made at any time (in initial phase, during phasing, or in the final phase) provided that the soil, wall and action data have been correctly filled out.

B.6.1.2. Calculations flowchart

The available results depend on the type of calculation performed. The following calculation flowchart explains the results obtained for the various types of available calculation. Part C of the manual gives detailed explanations about the various types of calculation mentioned in this flowchart.

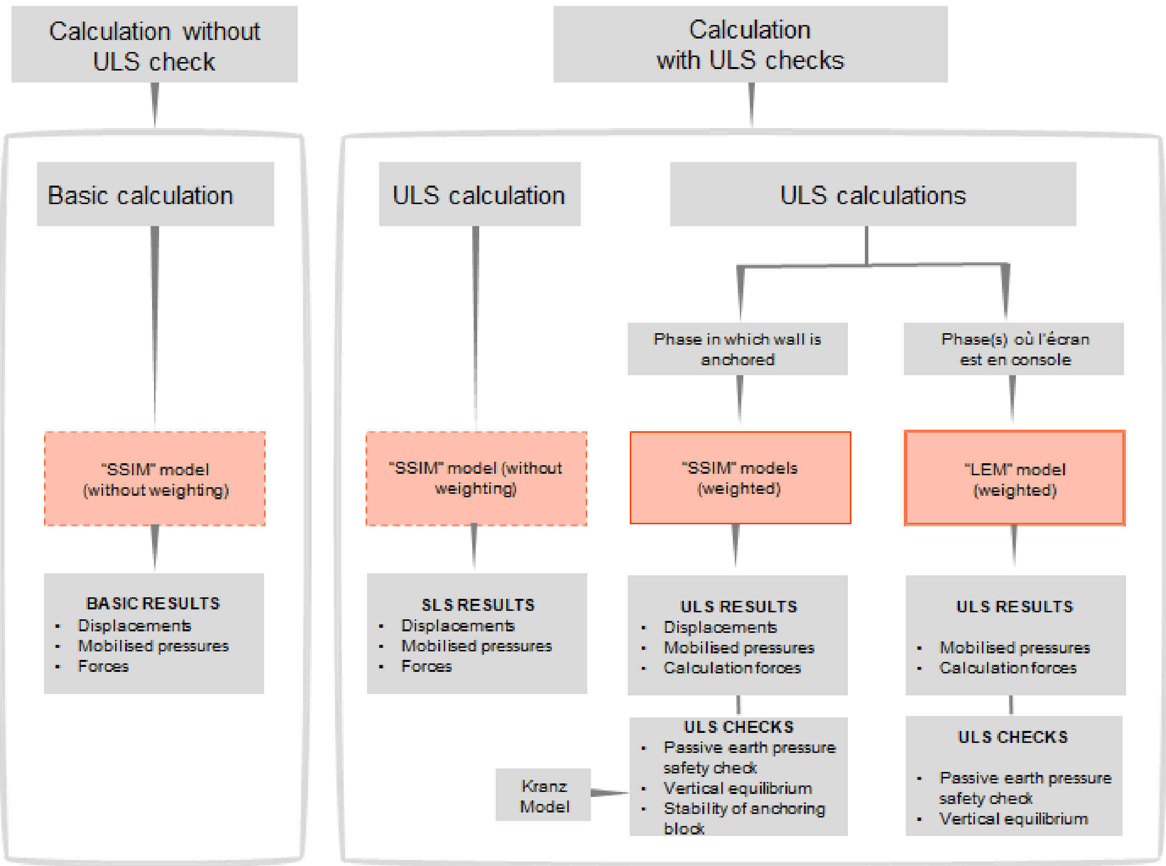


Figure B114 : *Calculation flowchart and results obtained for each type of calculation*

B.6.1.3. Results for a calculation without ULS checks

All the phases are processed using the "basic" SSIM calculation without weighting on the soil characteristics and overloads.

The results obtained include: wall displacements, bending moments, shear forces, mobilised pressures and support reactions.

Chapter B.6.2 gives a detailed presentation of the results of the "basic" SSIM calculation.

B.6.1.4. Calculation with ULS checks

For each phase, two calculations are performed:

- **A "SLS" calculation:** calculation based on an SSIM model carried out without weighting on the characteristics of soils and overloads. The results of this calculation are strictly identical to those of a calculation "without ULS checks": displacements, bending moments, shear forces, mobilised pressures and support reactions.

  See chapter B.6.2.5 for a detailed presentation of the SLS results as displayed in AMRetain (the presentation of these results is very similar to that of the basic SSIM calculation results.

- **A "ULS" calculation:** calculation based on a weighted SSIM model supplemented by a LEM calculation for those phases in which the wall is considered to be cantilever.

  The available results are as follows:

  - Bending moments and shear forces calculation values;
  - Mobilised pressures calculation values;
  - Forces in supports calculation values.

  See chapter B.6.3 for a detailed presentation of the ULS results (SSIM) as displayed in AMRetain.

  The results of the following ULS checks are also available:

  - Verification of passive earth pressure safety check;
  - Verification of vertical equilibrium;
  - Verification of stability of anchoring block for phases in which wall is anchored.

  See chapter B.6.4 for a detailed presentation of the verification results as displayed in AMRetain.

B.6.2. Calculation without ULS checks

B.6.2.1. Results available in the AMRetain main window

After the end of the calculations, some of the results are displayed in graphic form in the main window in the context of management of the current phase: displacements, bending moments and shear forces.

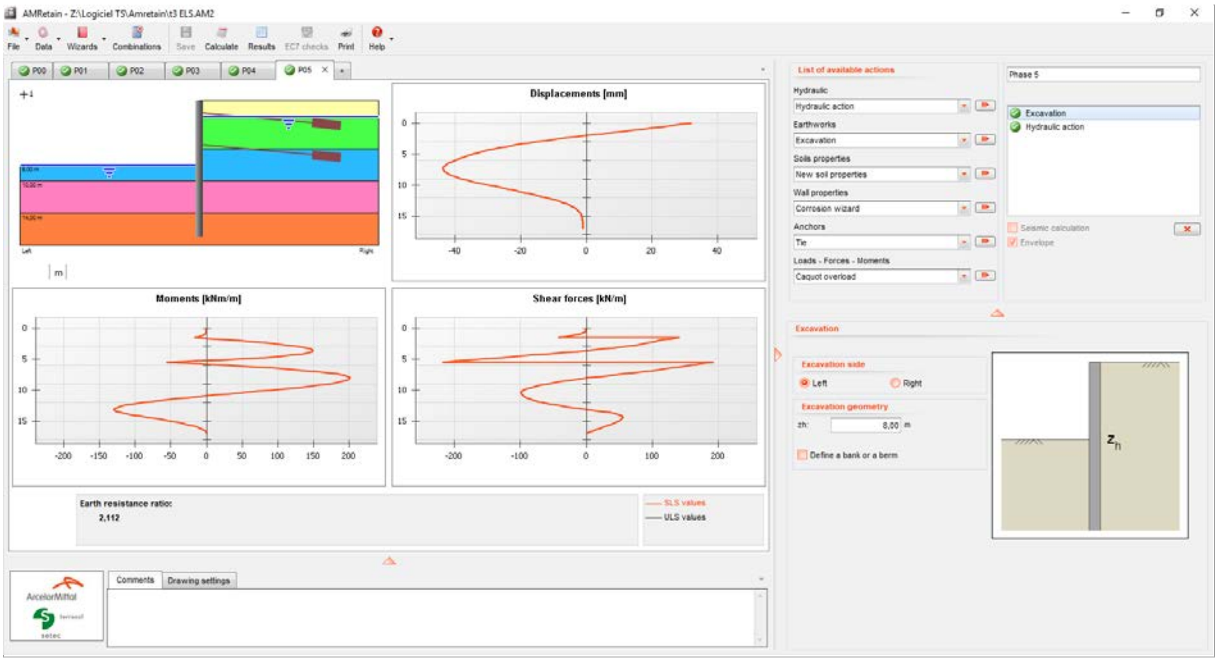


Figure B115 *: Display of SSIM results (without ULS checks) in the main window*

The (mobilisable passive earth pressure/mobilised passive earth pressure) ratio is also displayed in the main window.

A warning message appears in the phasing management frame if the calculation reaches the maximum number of iterations per phase. For reasons of consistency, this message also appears for all the phases following a phase in which the calculation did not converge.

The calculation stop a max iteration!!!

Try to refine the calculation step, or to increase the iterations number per phase. If the problem persists, we advise you to check your project data and look for possible instability causes.

It is of course possible to access more detailed results by opening the results window: this is a specific window which follows the same operating principle as the phasing management frame, using tabs. For this, click the "**Results"** button on the buttons bar.

B.6.2.2. Results window / "Data" tab

When the results window appears, it opens by default on the first tab, which is a recapitulation of the general project data:

Results

Data | Results synthesis | Envelope phases 1 to 5 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5

GENERAL SETTINGS	
Units system:	Metric, kN, kN...
Weight density of water:	10,00 kN/m³
Number of iterations:	100
Calculation step:	0,20 m
Taking account of anchors buc...	No
Project definition:	Depths

SOIL PARAMETERS (character...

Layer	z	zw	γ	γ'	φ	c	dc	k0	kaγ	kpγ	kd	kr	kac	kpc	kh	dkh	δa/φ	δp/φ
	m	m	kN/m³	kN/m³	°	kN/m²	kN/m²/m								kN/m²/m	kN/m²/...		
Sol 1	0,00	2,00	19,00	10,00	20,00	0,00	0,000	0,658	0,431	2,381	0,658	0,658	0,000	0,000	25000	0	0,660	-0,330
Sol 2	2,00	2,00	19,00	10,00	25,00	0,00	0,000	0,577	0,349	3,062	0,577	0,577	0,000	0,000	25000	0	0,660	-0,330
Sol 3	6,00	2,00	19,00	10,00	25,00	3,00	0,000	0,577	0,349	3,062	0,577	0,577	1,387	4,264	25000	0	0,660	-0,330
Sol 4	10,00	2,00	19,00	10,00	25,00	5,00	0,000	0,577	0,349	3,062	0,577	0,577	1,387	4,264	35000	0	0,660	-0,330
Sol 5	14,00	2,00	21,00	11,00	35,00	0,00	0,000	0,426	0,227	5,276	0,426	0,426	0,000	0,000	35000	0	0,660	-0,330

WALL PROPERTIES

z0	0,00 m			
Section	z,base	EI	Rc	W
	m	kNm²/m	kN/m³	kN/m/m
1	17,00	60228	0	1,04

Figure B116 *: Results window: "Data" tab*

For a single wall project, this tab groups together all the soil and wall characteristics data along with the chosen calculation options and the actions performed in the initial phase (e.g. reduced pressure).

B.6.2.3. Results window / "Results synthesis" tab

The "Results synthesis" tab, which follows that dedicated to data, gives a summary table of the extreme values obtained for the main types of results, for each calculation phase and overall for the phasing as a whole (last line of table).

Results

Data | Results synthesis | Envelope phases 1 to 5 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k tie n°1 [kN/m]	F,k tie n°2 [kN/m]
1	-12,34	-12,34	-35,65	46,88	-19,50	5,858	-	-
2	10,35	10,35	83,72	45,76	146,07	5,885	200,00	-
3	32,86	-38,76	234,76	82,87	132,87	2,872	186,60	-
4	32,00	-34,59	207,47	76,68	-211,05	3,030	187,20	400,00
5	31,89	-43,73	200,93	105,99	-217,28	2,112	185,07	415,76
Extrema	32,86	-43,73	234,76	105,99	-217,28	2,112	200,00	415,76

Figure B117 *: Display of results synthesis table*
(single wall, without ULS checks)

The types of results for which these extreme values are given are as follows:

- **Displacement at head** of wall (in mm or in);
- **Maximum displacement** obtained along the wall (in mm or in);
- **Maximum bending moment** obtained along the wall (in kNm/m or kip.ft/ft);
- **Maximum shear force** obtained along the wall (in kN/m or kip/ft);
- **Maximum arch pressure** obtained along the wall, only for walls defined as being circular (in kN/m);
- **Maximum normal force** obtained along the wall (in kN/m);
- **Earth pressures ratio:** (mobilisable passive earth pressure / mobilised passive earth pressure) ratio. It should be noted that unlike the other columns, the extreme value presented in the last row for the passive earth pressures ratio is the minimum value encountered on all the phases (and not the maximum value, as is the case for the other columns);
- **Characteristic force ties:** forces taken up by the anchors for each phase (variable unit).

B.6.2.4. Results window/ "Envelope" tab(s)

The tab(s) which follow "Results synthesis" in the results window is (are) devoted to the envelope displacements, bending moments and shear forces.

- If no "intermediate" envelope was requested at definition of phasing, a single "Envelope" tab is available. It corresponds to the envelopes calculated for the entire phasing defined.
- If intermediate envelopes were requested at definition of phasing, several envelope tabs are created and correspond to the breakdown imposed by the user with the ticked boxes.

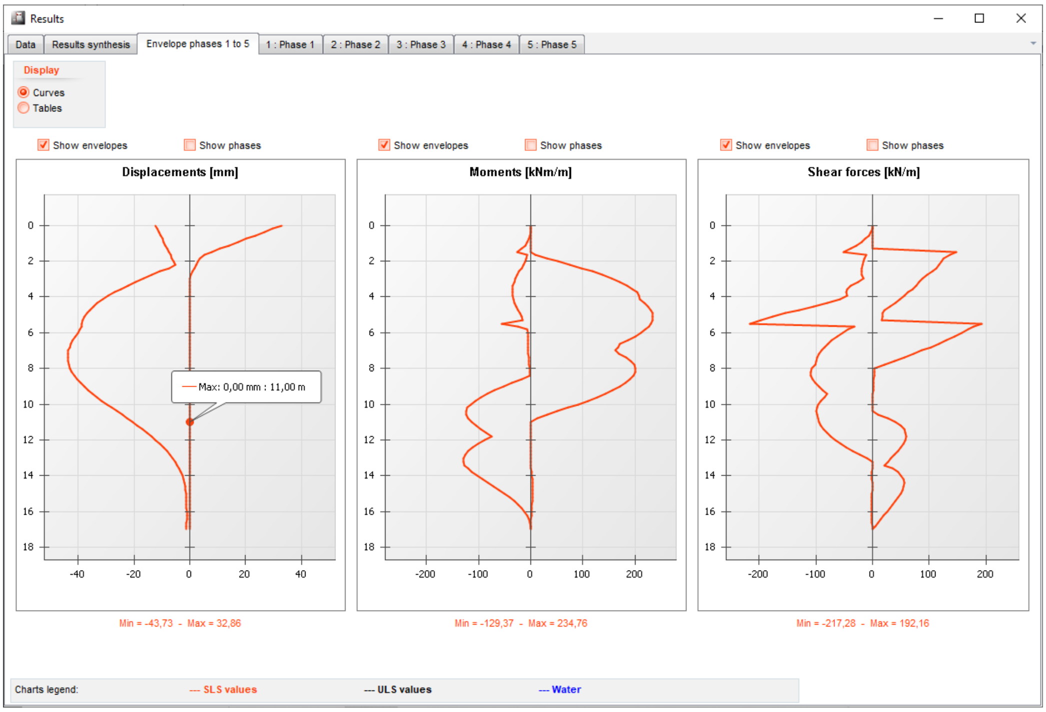


Figure B118 : *Display of envelopes for phases 1 to 5*

In each "Envelope" tab, it is possible to switch to "Curves" or "Table" display mode from the selection list.

Two buttons appear in each tab in the results window. The Print button is used to open the print dialogue box and the Quit button is used to close the results window.

B.6.2.5. Results per phase: graphical representation

The following tabs correspond to the phases defined in the project. They give the curves ("Curves" option checked by default): displacements, bending moments, shear forces, rotations, arch pressures, normal force and soil and water pressures.

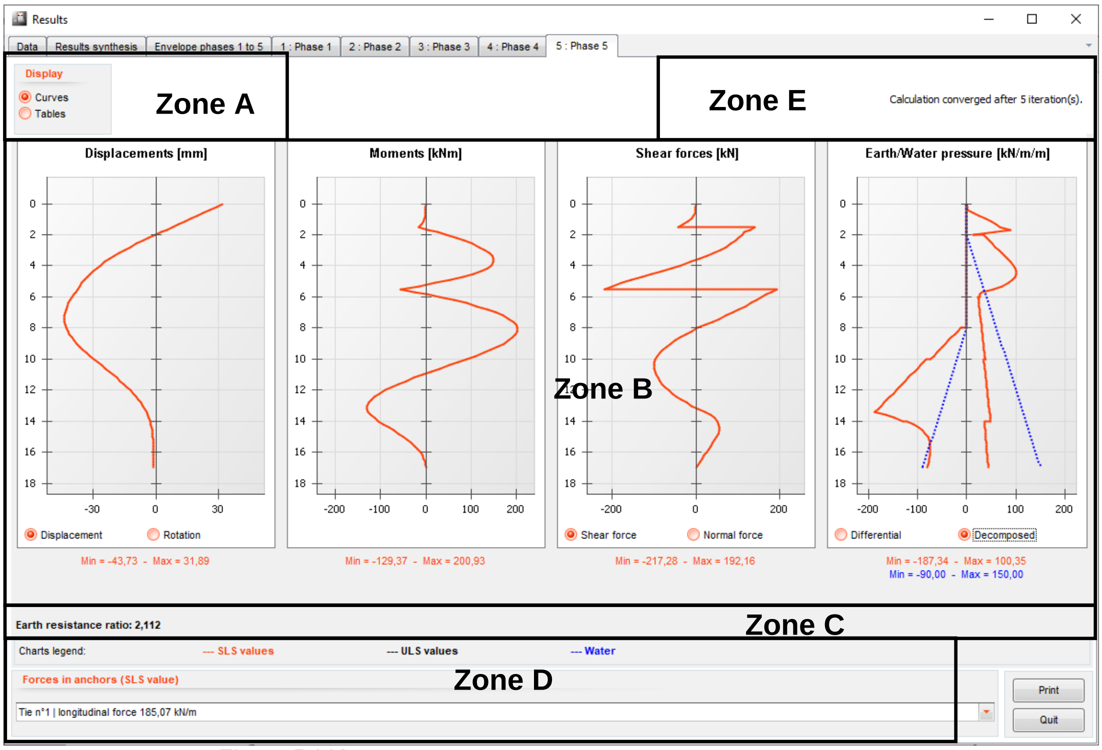
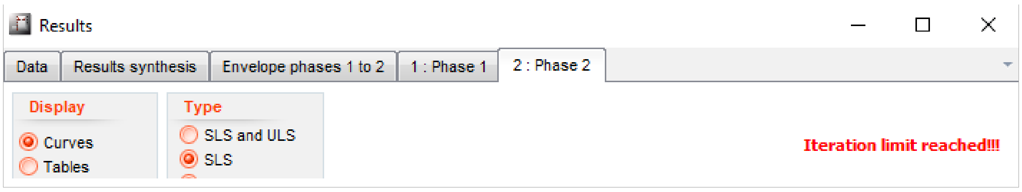


Figure B119 : *Display of results of a phase in the form of curves (single wall, without ULS checks)*

Each "phase" tab comprises **five zones**:

- **Zone A:** choice of type of display (curves or tables).
- **Zone B:** devoted to the display of the actual results:
- **Zone C**: reserved for display of the (mobilisable passive earth pressure / mobilised passive earth pressure) ratio.
- **Zone D**: contains a drop-down list giving the forces in the anchors active in the phase concerned.

  Zone E: devoted to information or warning messages, such as that regarding calculation convergence. If this was not reached after the maximum number of iterations set in the data (see chapter B.3.1), the calculation stops (to avoid an infinite loop) and a message appears to alert the user.



In zone B, the following curves are displayed:

- curve of wall **displacements** / **rotations**;
- curve of wall **bending moment**;
- curve of calculated wall shear force / axial force;
- curve of **earth and water pressures**: in the case of a "decomposed" display, the solid purple line curves correspond to the earth pressures and the dotted blue lines to the water pressures. The curves corresponding to the negative values are those of the pressures which apply to the left-hand side of the wall. Conversely, those which correspond to the positive values are the pressure values which apply to the right-hand side of the wall. It is also possible to request display of the differential pressure calculated by adding the earth pressures on either side of the wall and the water pressures.

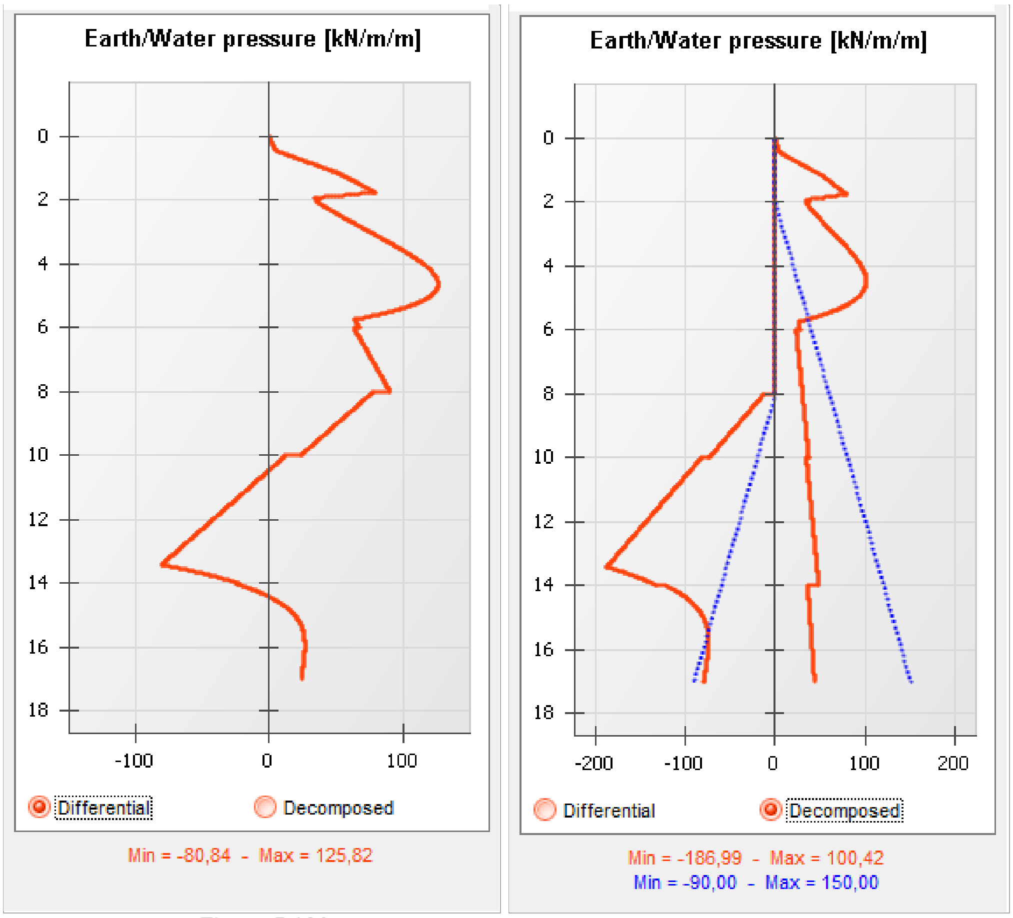
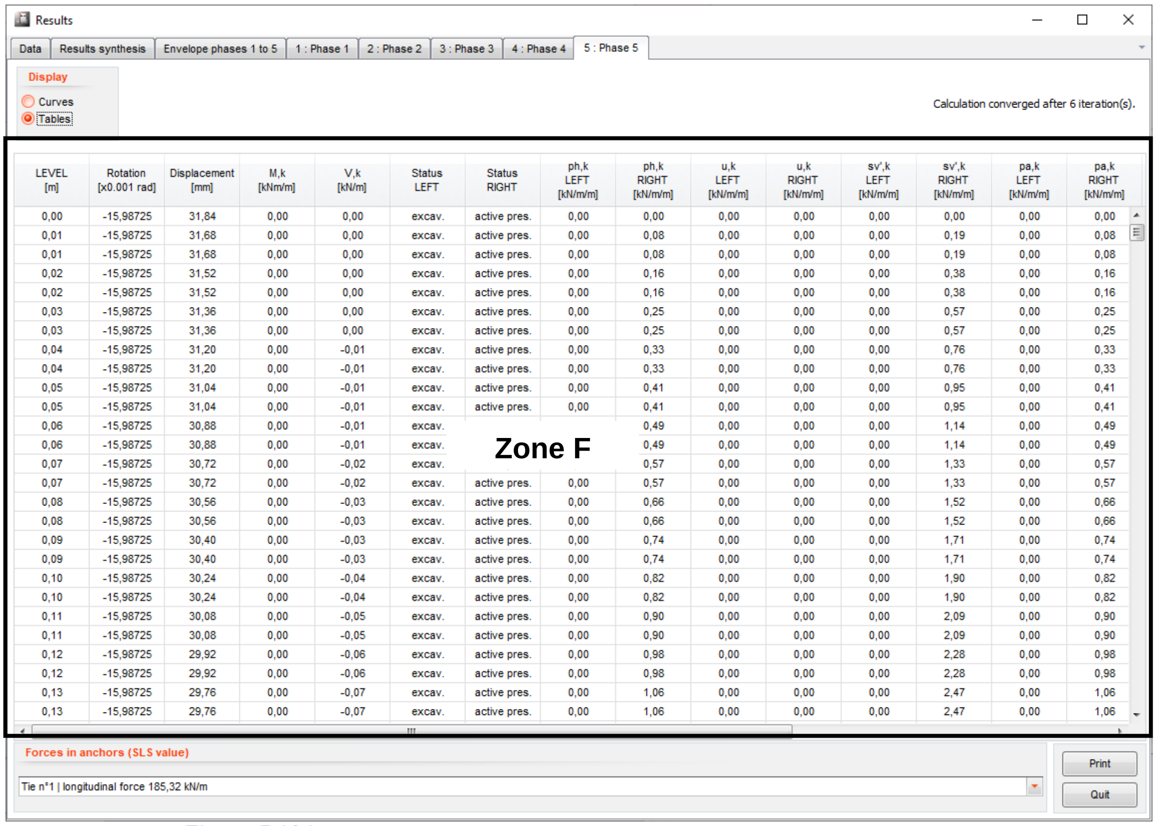


Figure B120 *: Example of differential pressure display (left) and decomposed pressures display (right)*

The minimum and maximum values of each of the curves appear under each of the curves.

B.6.2.6. Results per phase: tables of values

It is possible to switch to a display in the form of results tables, by selecting the "Tables" option.



LEVEL [m]	Rotation [x0.001 rad]	Displacement [mm]	M,k [kNm/m]	V,k [kN/m]	Status LEFT	Status RIGHT	ph,k LEFT [kN/m/m]	ph,k RIGHT [kN/m/m]	u,k LEFT [kN/m/m]	u,k RIGHT [kN/m/m]	sv',k LEFT [kN/m/m]	sv',k RIGHT [kN/m/m]	pa,k LEFT [kN/m/m]	pa,k RIGHT [kN/m/m]
0,00	-15,98725	31,84	0,00	0,00	excav.	active pres.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,01	-15,98725	31,68	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19	0,00	0,08
0,01	-15,98725	31,68	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19	0,00	0,08
0,02	-15,98725	31,52	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38	0,00	0,16
0,02	-15,98725	31,52	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38	0,00	0,16
0,03	-15,98725	31,36	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57	0,00	0,25
0,03	-15,98725	31,36	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57	0,00	0,25
0,04	-15,98725	31,20	0,00	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76	0,00	0,33
0,04	-15,98725	31,20	0,00	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76	0,00	0,33
0,05	-15,98725	31,04	0,00	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95	0,00	0,41
0,05	-15,98725	31,04	0,00	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95	0,00	0,41
0,06	-15,98725	30,88	0,00	-0,01	excav.			0,49	0,00	0,00	0,00	1,14	0,00	0,49
0,06	-15,98725	30,88	0,00	-0,01	excav.			0,49	0,00	0,00	0,00	1,14	0,00	0,49
0,07	-15,98725	30,72	0,00	-0,02	excav.			0,57	0,00	0,00	0,00	1,33	0,00	0,57
0,07	-15,98725	30,72	0,00	-0,02	excav.	active pres.	0,00	0,57	0,00	0,00	0,00	1,33	0,00	0,57
0,08	-15,98725	30,56	0,00	-0,03	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52	0,00	0,66
0,08	-15,98725	30,56	0,00	-0,03	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52	0,00	0,66
0,09	-15,98725	30,40	0,00	-0,03	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71	0,00	0,74
0,09	-15,98725	30,40	0,00	-0,03	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71	0,00	0,74
0,10	-15,98725	30,24	0,00	-0,04	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90	0,00	0,82
0,10	-15,98725	30,24	0,00	-0,04	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90	0,00	0,82
0,11	-15,98725	30,08	0,00	-0,05	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09	0,00	0,90
0,11	-15,98725	30,08	0,00	-0,05	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09	0,00	0,90
0,12	-15,98725	29,92	0,00	-0,06	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28	0,00	0,98
0,12	-15,98725	29,92	0,00	-0,06	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28	0,00	0,98
0,13	-15,98725	29,76	0,00	-0,07	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47	0,00	1,06
0,13	-15,98725	29,76	0,00	-0,07	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47	0,00	1,06

Figure B121 *: Display of results of a calculation phase in the form of a table*

Each column recalls the physical value in the title, the application side (left or right) and the usual units defined for the project.

The columns are described below:

- **Depth or level** (m, ft): elevation/depth of calculation points for wall elements. The calculation step input in the "Title and options" window is a maximum spacing value between two successive points. AMRetain adjusts this spacing when necessary as a function of the soil interfaces and anchors (1 point for anchors and 2 points for soil layer interfaces).
- **Rotation** (rad): rotation (or distortion) of wall at calculation point.
- **Displacement** (mm, in): lateral displacement of wall at calculation point.
- **M_k** (kNm/m, kip.ft/ft): characteristic value of bending moment in wall.
- **V_k** (kN/m, kip/ft): characteristic value of shear force in wall.
- **Status**: gives the status of the soil at the nodes, with the following notation:
  - Excavation: the soil is excavated in front of the left or right hand side of the wall;
  - Unsticking: the soil and wall are no longer in contact (negative pressure replaced by minimum pressure, more details in part C of the manual);
  - Active earth pressure: the soil in contact with the wall is in active earth pressure state;
  - Elastic: the soil in contact with the wall is in elastic phase;
  - Passive earth pressure: the soil in contact with the wall is in passive earth pressure state.
- **$p_{h,k}$** (kN/m/m, kip/ft): characteristic value of the mobilised effective horizontal pressure;

- **u_k** (kN/m/m, kip/ft): characteristic value of the water pressure calculated as a function of the unit volume of water at the node considered;
- **$\sigma'_{v,k}$** (kN/m/m, kip/ft): characteristic value of the effective vertical stress at the point considered;
- **$p_{a,k}$** (kN/m/m, kip/ft): characteristic value of the effective active earth pressure (mobilisable active earth pressure);
- **$p_{b,k}$** (kN/m/m, kip/ft): characteristic value of the effective passive earth pressure (mobilisable passive earth pressure);
- **p_k** (kN/m/m, kip/ft): characteristic value of the differential pressure, calculated as follows:

$$p_k = p_{h,k}^{right} - p_{h,k}^{left} + u_{,k}^{right} - u_{,k}^{left}$$

- **$F_{v,k}$** (kN/m, kip): characteristic value of the of the arch pressure;
- **$N_{,k}$** (kN/m, kip/ft): characteristic value of the normal force;
- **$p_{0,k}$** (kN/m/m, kip/ft): initial pressure value.

B.6.3. Calculation with ULS checks (main results)

In the case of single walls with ULS checks, AMRetain is used to display the SLS results on the one hand and the ULS results on the other.

For each ULS result, the "k" index shows that this is a characteristic value while the "d" index shows that this is a "design" value.

B.6.3.1. Main window

In the main window, only the ULS calculation results are displayed. The display of the results differs according to whether or not the wall is anchored in the phase considered.

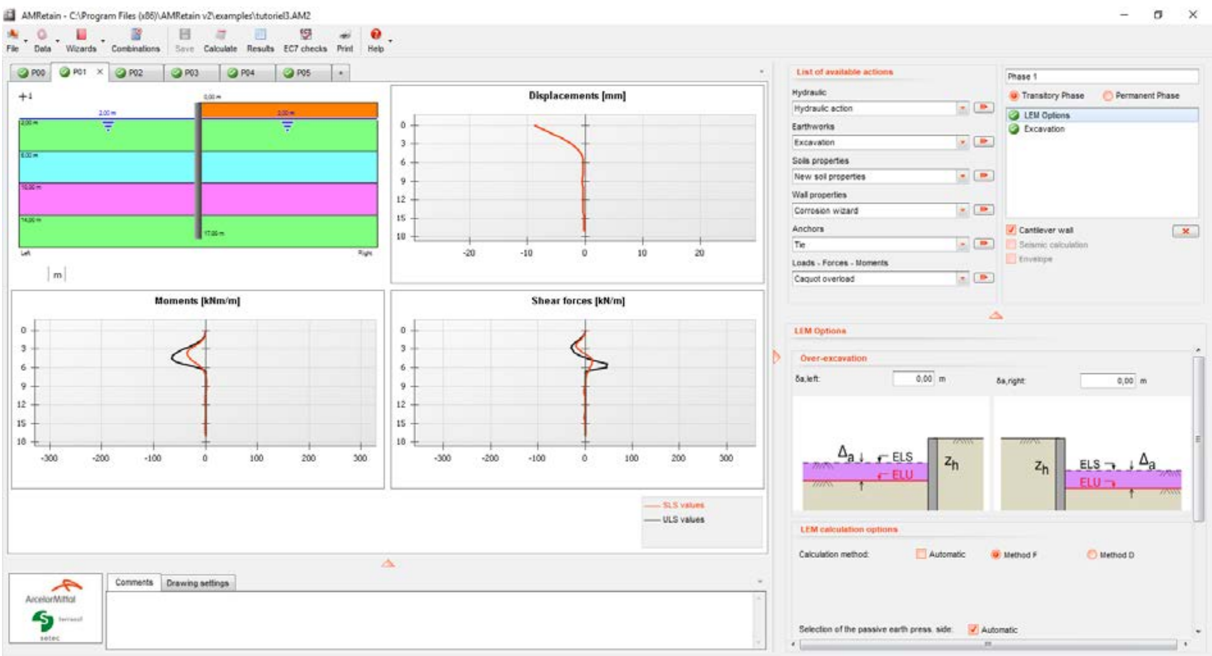


Figure B122 *: ULS results of a phase in which the wall is cantilever (LEM calculation) – The displacements are not displayed*

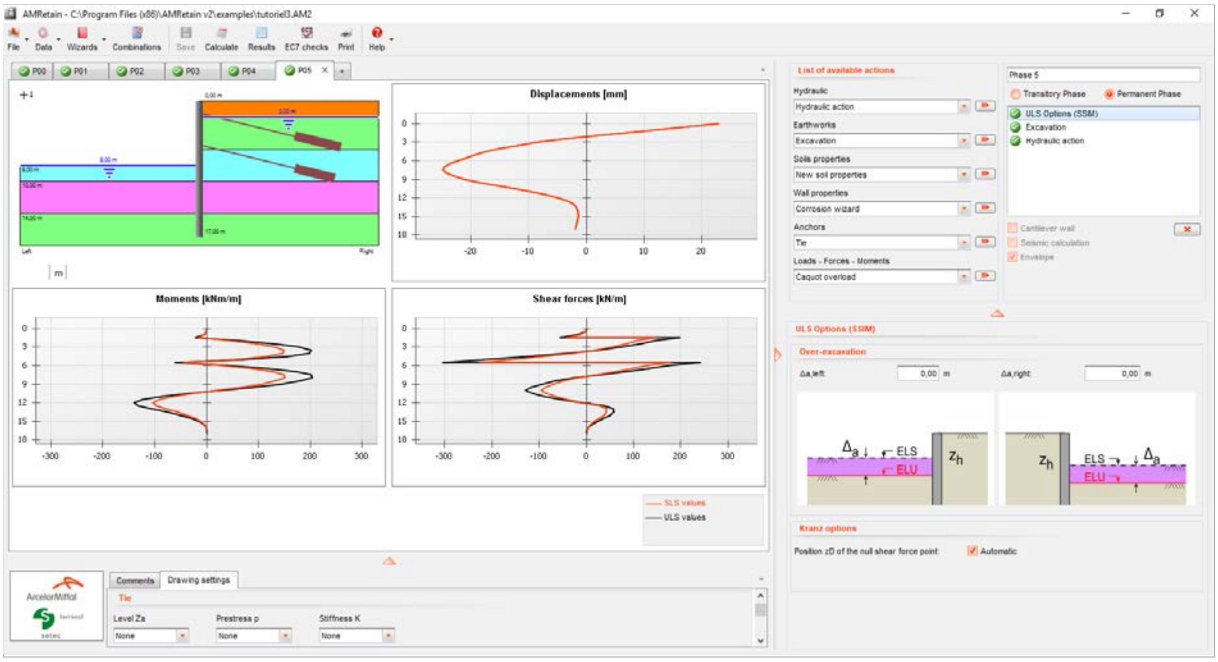


Figure B123 : *ULS results of a phase in which the wall is anchored (SSIM calculation)*

In the upper part of the window, AMRetain enables the user to switch between the SLS results and ULS results at any moment (whether for the "phases", "results synthesis" or "envelopes" tabs).

In addition, when the display requested is that of the ULS results, 3 additional buttons appear and give access to the results of the ULS checks (see Part C of the manual).

B.6.3.2. SLS results per phase

The results of a SLS calculation are the same as those of a basic SSIM calculation.
The contents of chapters B.6.2.2 to B.6.2.5 therefore remain valid.

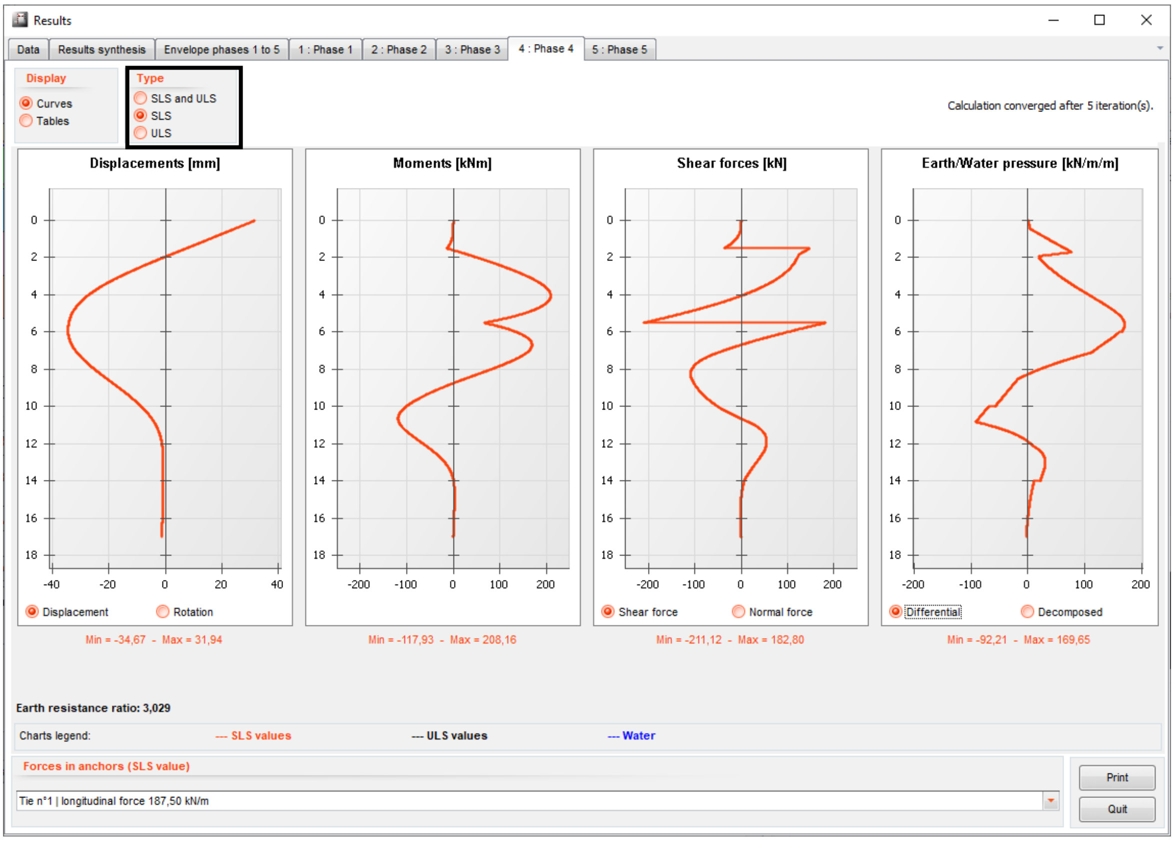


Figure B124 : *Display of SLS results in the results window*

B.6.3.3. ULS results per phase: LEM calculation (cantilever wall)

In this case, the LEM calculation performed gives the following results on the curves and in the tables (see Figure B125 and Figure B126):

- only the design values (d index) of the bending moments and shear forces are available,
- the results in terms of displacements are not displayed (neither on the curves nor in the tables), because this is a limit equilibrium calculation.

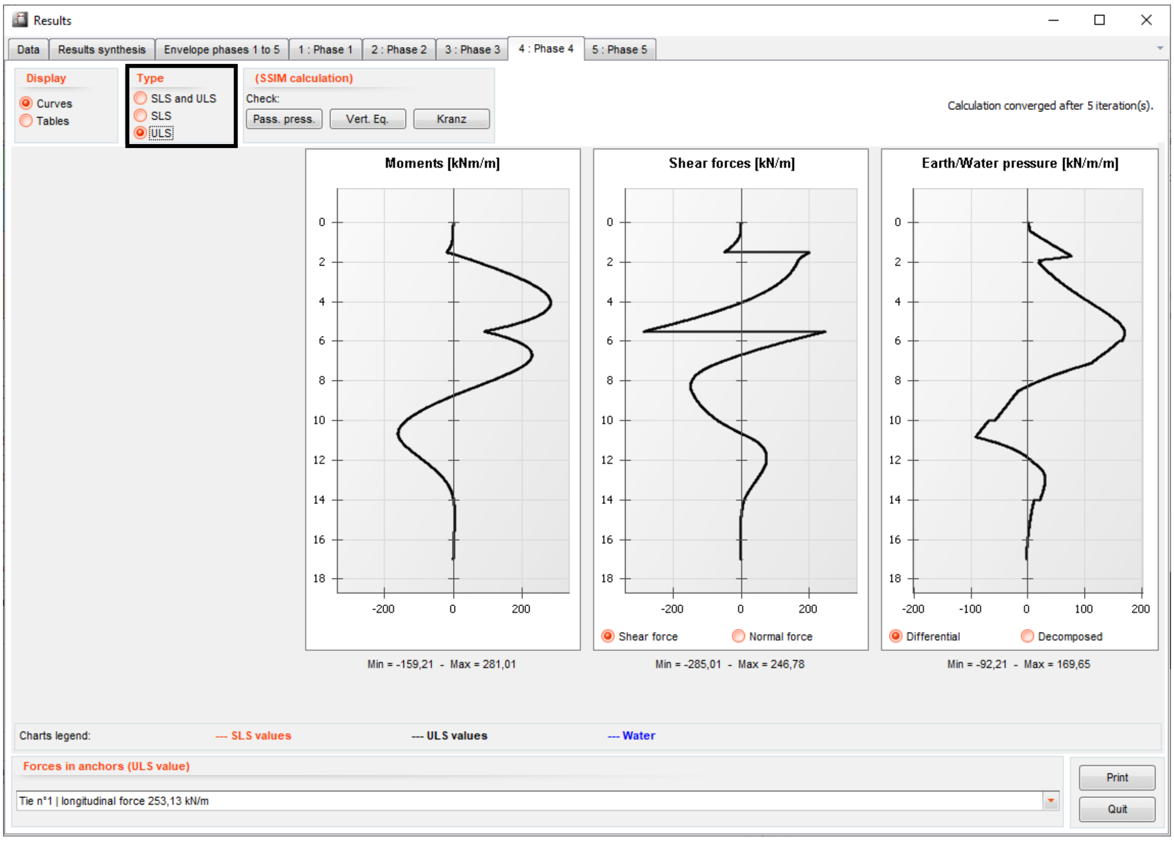
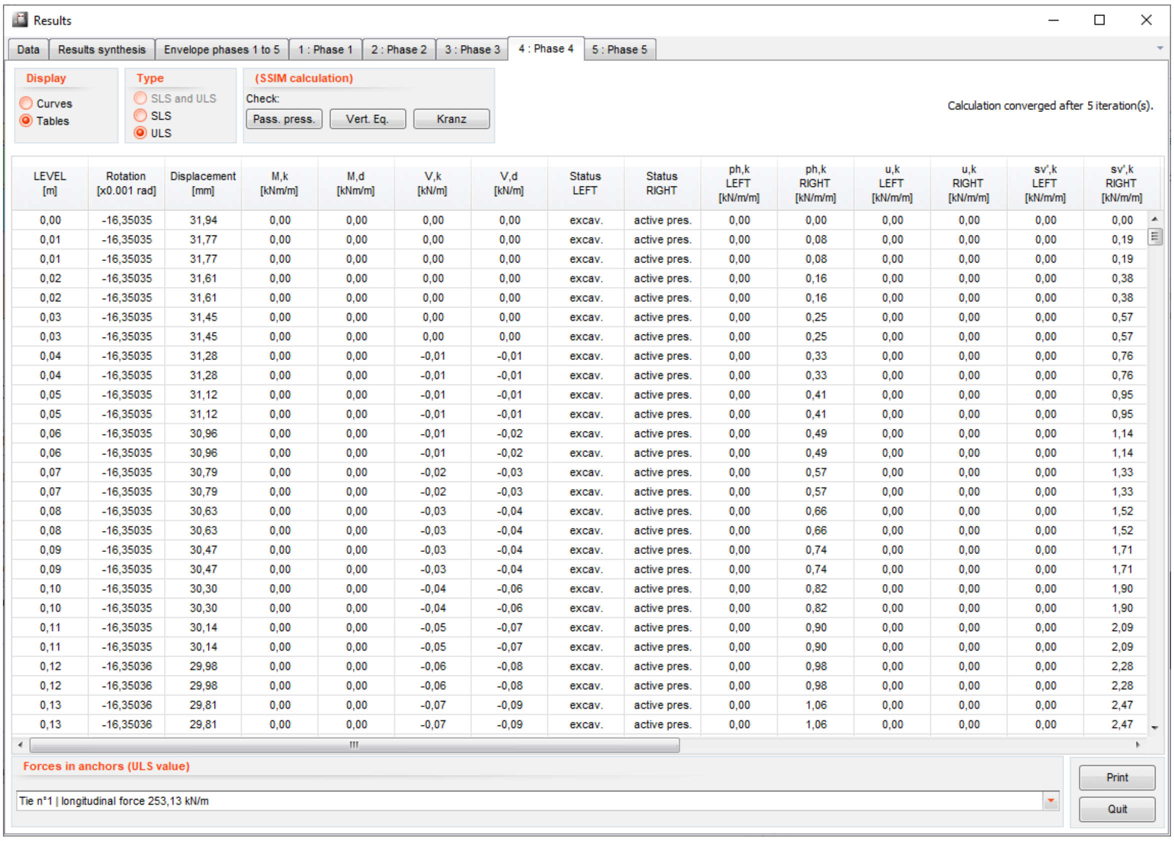


Figure B125 : *Results window – ULS results (LEM) - Curves*

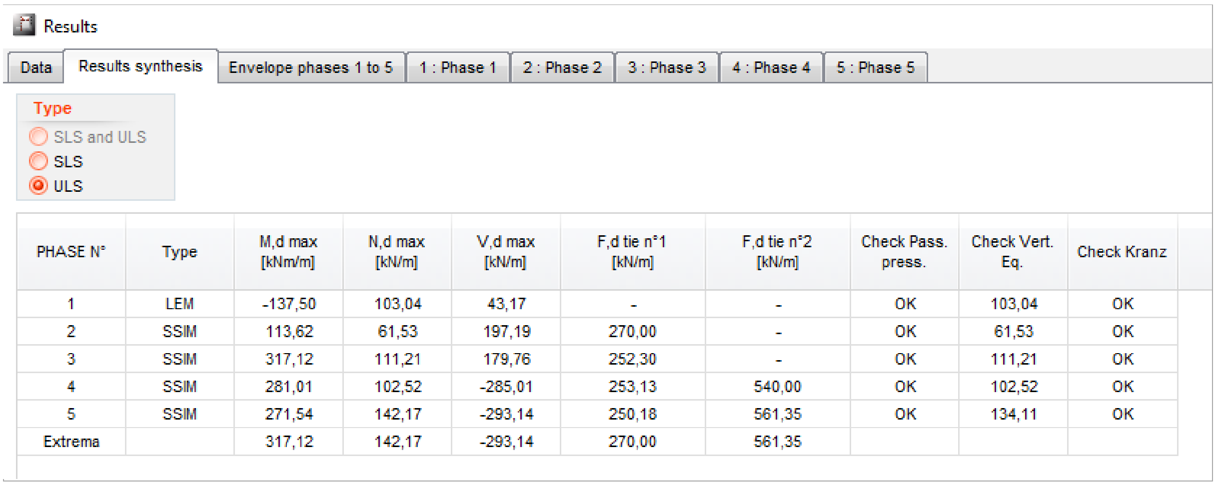


LEVEL [m]	Rotation [x0.001 rad]	Displacement [mm]	M,k [kNm/m]	M,d [kNm/m]	V,k [kN/m]	V,d [kN/m]	Status LEFT	Status RIGHT	ph,k LEFT [kN/m/m]	ph,k RIGHT [kN/m/m]	u,k LEFT [kN/m/m]	u,k RIGHT [kN/m/m]	sv',k LEFT [kN/m/m]	sv',k RIGHT [kN/m/m]
0,00	-16,35035	31,94	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,00	0,00	0,00	0,00	0,00
0,01	-16,35035	31,77	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19
0,01	-16,35035	31,77	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19
0,02	-16,35035	31,61	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38
0,02	-16,35035	31,61	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38
0,03	-16,35035	31,45	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57
0,03	-16,35035	31,45	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57
0,04	-16,35035	31,28	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76
0,04	-16,35035	31,28	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76
0,05	-16,35035	31,12	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95
0,05	-16,35035	31,12	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95
0,06	-16,35035	30,96	0,00	0,00	-0,01	-0,02	excav.	active pres.	0,00	0,49	0,00	0,00	0,00	1,14
0,06	-16,35035	30,96	0,00	0,00	-0,01	-0,02	excav.	active pres.	0,00	0,49	0,00	0,00	0,00	1,14
0,07	-16,35035	30,79	0,00	0,00	-0,02	-0,03	excav.	active pres.	0,00	0,57	0,00	0,00	0,00	1,33
0,07	-16,35035	30,79	0,00	0,00	-0,02	-0,03	excav.	active pres.	0,00	0,57	0,00	0,00	0,00	1,33
0,08	-16,35035	30,63	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52
0,08	-16,35035	30,63	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52
0,09	-16,35035	30,47	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71
0,09	-16,35035	30,47	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71
0,10	-16,35035	30,30	0,00	0,00	-0,04	-0,06	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90
0,10	-16,35035	30,30	0,00	0,00	-0,04	-0,06	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90
0,11	-16,35035	30,14	0,00	0,00	-0,05	-0,07	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09
0,11	-16,35035	30,14	0,00	0,00	-0,05	-0,07	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09
0,12	-16,35036	29,98	0,00	0,00	-0,06	-0,08	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28
0,12	-16,35036	29,98	0,00	0,00	-0,06	-0,08	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28
0,13	-16,35036	29,81	0,00	0,00	-0,07	-0,09	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47
0,13	-16,35036	29,81	0,00	0,00	-0,07	-0,09	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47

Figure B126 : *Results window – ULS results (LEM) - Tables*

In addition, extra columns appear in the **Results synthesis** tab (see Figure B127):

- **Type:** indicates the type of calculation performed (LEM or SSIM);
- **Check pass. press.:** indicates the passive earth pressure safety check results;
- **Check Vert Eq.:** indicates the vertical resultant calculated when checking vertical equilibrium (positive value if the vertical forces resultant is directed downwards).



PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	F,d tie n°1 [kN/m]	F,d tie n°2 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-137,50	103,04	43,17	-	-	OK	103,04	OK
2	SSIM	113,62	61,53	197,19	270,00	-	OK	61,53	OK
3	SSIM	317,12	111,21	179,76	252,30	-	OK	111,21	OK
4	SSIM	281,01	102,52	-285,01	253,13	540,00	OK	102,52	OK
5	SSIM	271,54	142,17	-293,14	250,18	561,35	OK	134,11	OK
Extrema		317,12	142,17	-293,14	270,00	561,35			

Figure B127 *: Results window – ULS results synthesis for cantilever phases only*

B.6.3.4. ULS results per phase: SSIM calculation (anchored wall)

In this case, the SSIM calculation gives the following results:

- the curves and tables presenting the results in characteristic values (k index) and in design values (d index) (Figure B128 and Figure B129);
- a key is given under the curves to distinguish between the results in characteristic values (orange curves) and the results in design values (black curves).

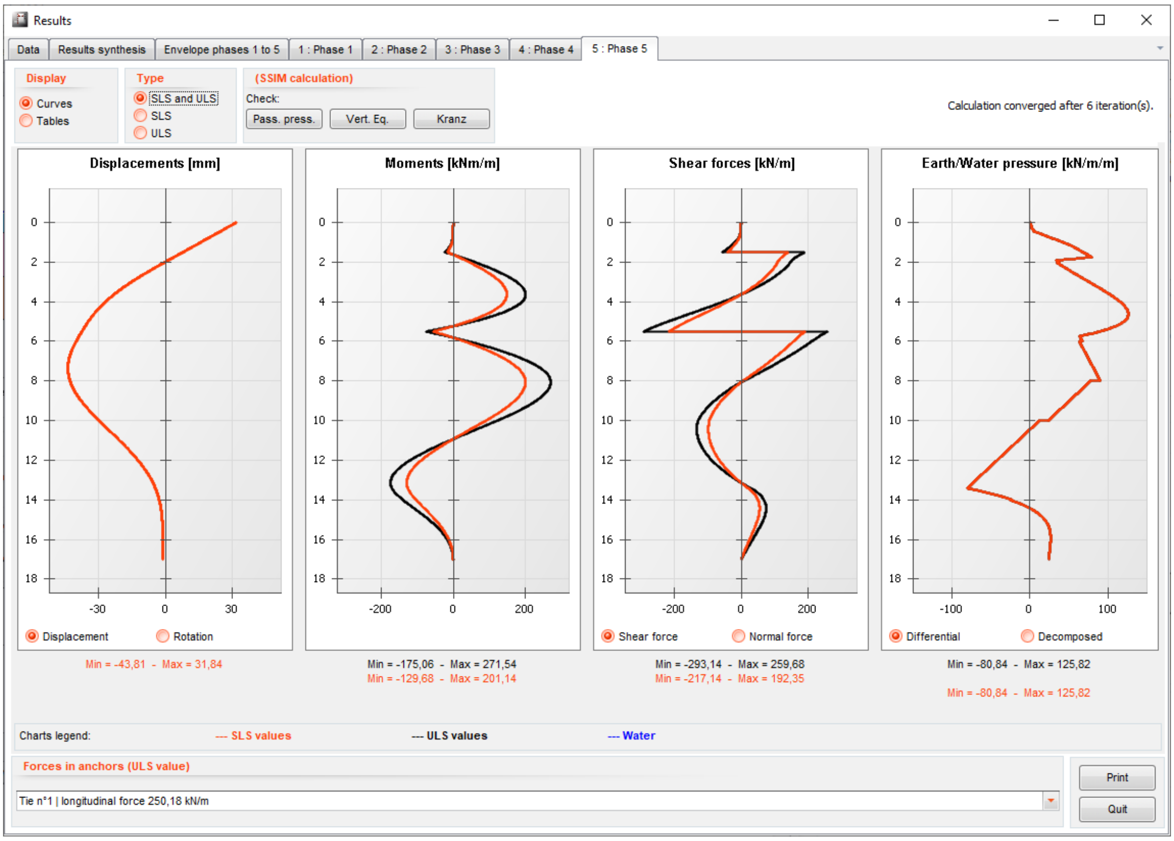
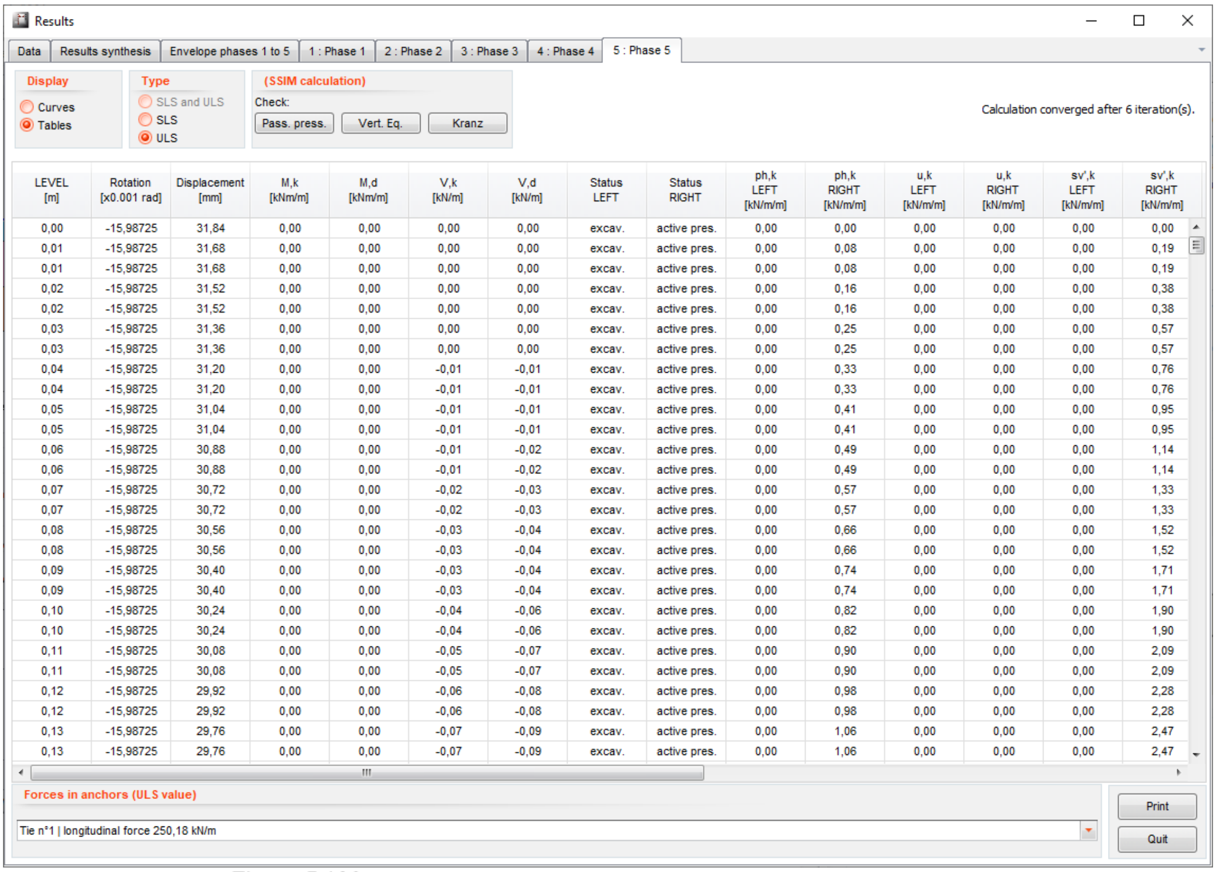


Figure B128 : *Results window – ULS results (SSIM calculation) - Curves*



LEVEL [m]	Rotation [x0.001 rad]	Displacement [mm]	M,k [kNm/m]	M,d [kNm/m]	V,k [kN/m]	V,d [kN/m]	Status LEFT	Status RIGHT	ph,k LEFT [kN/m/m]	ph,k RIGHT [kN/m/m]	u,k LEFT [kN/m/m]	u,k RIGHT [kN/m/m]	sv',k LEFT [kN/m/m]	sv',k RIGHT [kN/m/m]
0,00	-15,98725	31,84	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,00	0,00	0,00	0,00	0,00
0,01	-15,98725	31,68	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19
0,01	-15,98725	31,68	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,08	0,00	0,00	0,00	0,19
0,02	-15,98725	31,52	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38
0,02	-15,98725	31,52	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,16	0,00	0,00	0,00	0,38
0,03	-15,98725	31,36	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57
0,03	-15,98725	31,36	0,00	0,00	0,00	0,00	excav.	active pres.	0,00	0,25	0,00	0,00	0,00	0,57
0,04	-15,98725	31,20	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76
0,04	-15,98725	31,20	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,33	0,00	0,00	0,00	0,76
0,05	-15,98725	31,04	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95
0,05	-15,98725	31,04	0,00	0,00	-0,01	-0,01	excav.	active pres.	0,00	0,41	0,00	0,00	0,00	0,95
0,06	-15,98725	30,88	0,00	0,00	-0,01	-0,02	excav.	active pres.	0,00	0,49	0,00	0,00	0,00	1,14
0,06	-15,98725	30,88	0,00	0,00	-0,01	-0,02	excav.	active pres.	0,00	0,49	0,00	0,00	0,00	1,14
0,07	-15,98725	30,72	0,00	0,00	-0,02	-0,03	excav.	active pres.	0,00	0,57	0,00	0,00	0,00	1,33
0,07	-15,98725	30,72	0,00	0,00	-0,02	-0,03	excav.	active pres.	0,00	0,57	0,00	0,00	0,00	1,33
0,08	-15,98725	30,56	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52
0,08	-15,98725	30,56	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,66	0,00	0,00	0,00	1,52
0,09	-15,98725	30,40	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71
0,09	-15,98725	30,40	0,00	0,00	-0,03	-0,04	excav.	active pres.	0,00	0,74	0,00	0,00	0,00	1,71
0,10	-15,98725	30,24	0,00	0,00	-0,04	-0,06	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90
0,10	-15,98725	30,24	0,00	0,00	-0,04	-0,06	excav.	active pres.	0,00	0,82	0,00	0,00	0,00	1,90
0,11	-15,98725	30,08	0,00	0,00	-0,05	-0,07	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09
0,11	-15,98725	30,08	0,00	0,00	-0,05	-0,07	excav.	active pres.	0,00	0,90	0,00	0,00	0,00	2,09
0,12	-15,98725	29,92	0,00	0,00	-0,06	-0,08	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28
0,12	-15,98725	29,92	0,00	0,00	-0,06	-0,08	excav.	active pres.	0,00	0,98	0,00	0,00	0,00	2,28
0,13	-15,98725	29,76	0,00	0,00	-0,07	-0,09	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47
0,13	-15,98725	29,76	0,00	0,00	-0,07	-0,09	excav.	active pres.	0,00	1,06	0,00	0,00	0,00	2,47

Figure B129 : *Results window – ULS results (SSIM calculation) - Tables*

Additional columns also appear in the **Results synthesis** tab (see B.6.2.3):

- **Type:** indicates the type of calculation performed (LEM or SSIM);
- **Pass. Press. Check:** indicates the result of the passive earth pressure safety check;
- **Vert. Eq. Check:** indicates the resultant calculated during the vertical check (positive value if the vertical forces resultant is directed downwards);
- **Kranz or Jelinek Check:** indicates the result of the anchoring block check.

Results

Data | Results synthesis | Envelope phases 1 to 5 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5

Type
- SLS and ULS
- SLS
- ULS

PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	F,d tie n°1 [kN/m]	F,d tie n°2 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-65.44	16.17	47.73	-	-	OK	14.52	OK
2	SSIM	113.45	54.36	197.10	270.00	-	OK	54.36	OK
3	SSIM	276.57	100.28	185.70	258.42	-	OK	100.28	OK
4	SSIM	253.43	100.23	-294.66	259.22	540.00	OK	98.44	OK
5	SSIM	203.79	128.64	-303.39	257.41	553.14	OK	116.74	OK
Extrema		276.57	128.64	-303.39	270.00	553.14			

Figure B130 : *Results window – ULS results summary for a project with cantilever and anchored phases*

B.6.4. ULS checks

When the ULS checks have been activated for a project, AMRetain provides the results of three types of ULS checks performed for each phase defined in the project.

These results are displayed in a specific window, which can be accessed in two ways:

- By clicking directly on the "EC7 checks button.
- By clicking one of the [Pass. press.] [Vert. Eq.] [Kranz] buttons from the detailed results presentation window (when the ULS results are displayed).

The specific ELU checks results window (Figure B131) then opens and by default is positioned on the phase currently selected before the results display request: either the phase displayed in the main window in the case of access by the EC7 button, or the phase displayed in the results window in the case of access from one of the [Pass. press.] [Vert. Eq.] [Kranz] buttons.

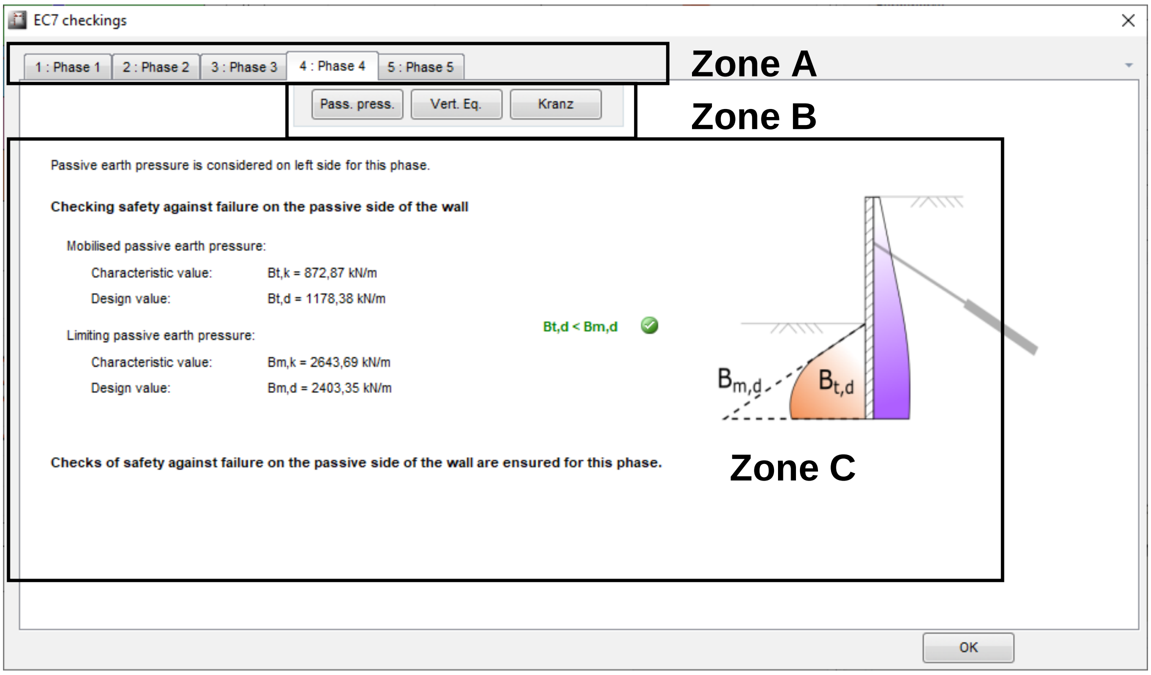


Figure B131 *: ULS checks results display window*

The check results display window contains 3 zones:

- **Zone A:** corresponds to the tabs used to select the phase for which the checks are displayed.
- **Zone B:** corresponds to the tabs used to select the ULS check for which one wishes to display the results:
  - o The passive earth pressure safety check;
  - o The vertical equilibrium check;
  - o The check on the stability of the anchoring block (only available if at least one anchor is active in the selected phase).
- **Zone C:** requested results display zone.

The following sub-chapters specify the various results displayed for each type of check. These results and their notations refer to part C of the manual for details of the calculation methods applied (in accordance with French standard NF P94-282).

B.6.4.1. Passive earth pressure safety check

B.6.4.1.1. Case of an anchored wall (SSIM calculation)

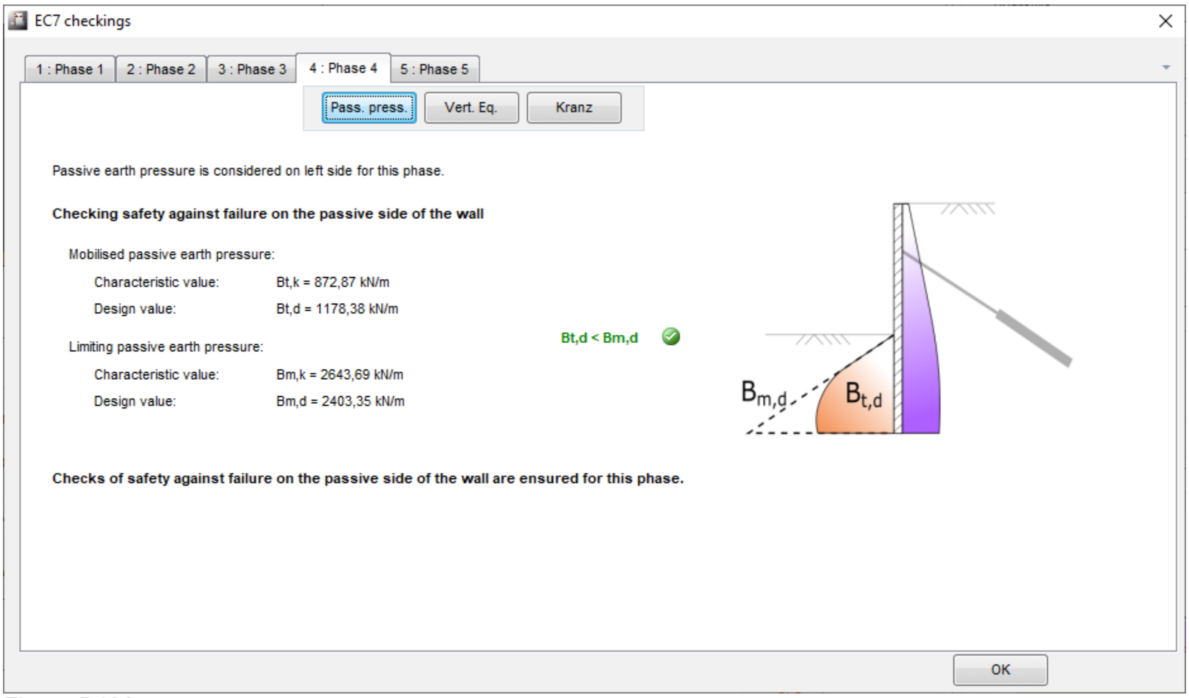


Figure B132 *: ULS check – Results of passive earth pressure safety check – Anchored phase (SSIM calculation)*

In the case of an anchored wall, the passive earth pressure safety check is based on the evaluation of the following parameters:

- **$B_{t,k}$:** characteristic value of mobilised passive earth pressure resultant (in kN or kp);
- **$B_{t,d}$:** calculation value of mobilised passive earth pressure resultant (in kN or kip);
- **$B_{m,k}$:** characteristic value of mobilisable passive earth pressure resultant (in kN or kip);
- **$B_{m,d}$:** calculation value of mobilisable passive earth pressure resultant (in kN or kip).

AMRetain compares the value of $B_{t,d}$ with that of $B_{m,d}$ and an indicator shows the result of the check for the selected phase: green circle if the mobilised passive earth pressure $B_{t,d}$ is less than the mobilisable passive earth pressure $B_{m,d}$, or red one otherwise.

For more details on this check, refer to part C of the manual.

B.6.4.1.2. Case of a cantilever wall (LEM calculation)

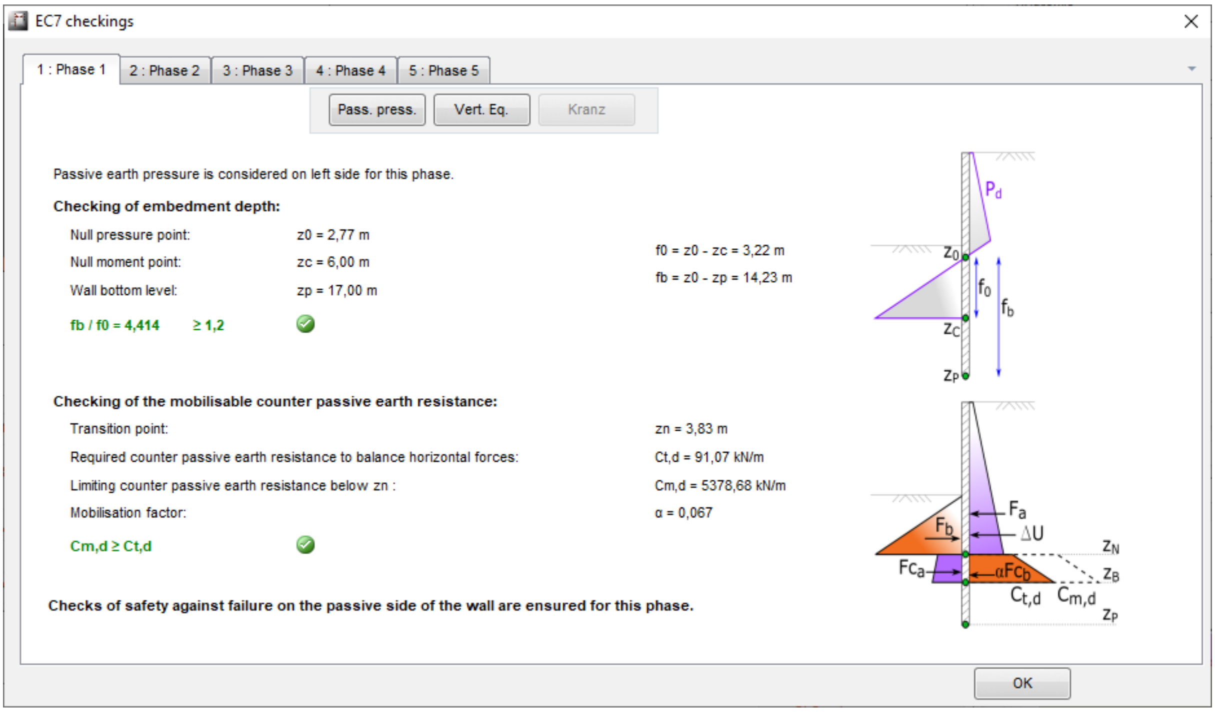


Figure B133 : *ULS check – Results of passive earth pressure safety check – Cantilever phase (LEM calculation)*

In the case of an anchored wall, the passive earth pressure safety check is based on a LEM type calculation (limit equilibrium model) which involves the following intermediate parameters:

- **z_0:** elevation/depth of null differential pressure point (in m or ft);
- **z_c:** elevation/depth of null moment point (in m or ft);
- **z_p:** elevation/depth of base of wall (in m or ft);
- **f_0:** "available" wall embedment depth under z_0 (in m or ft);
- **f_b:** minimum embedment depth, under z_0, needed to obtain equilibrium of moments (in m or ft);
- **f_0/f_b:** ratio between the two previously calculated embedment depths (no units);
- Embedment depth height verification indicator: this indicator is green if the verification is positive (available embedment depth greater than minimum embedment depth with a safety coefficient greater than 1.2); it is red otherwise.
- **z_n** (only if method D was chosen; otherwise point z_n is implicitly the same as point z_c)**:** elevation/depth of transition point (in m or ft);
- **$C_{t,d}$:** value of calculation of resultant of counter passive earth pressure necessary for equilibrium of the horizontal forces (in kN/m or kip/ft);
- **$C_{m,d}$:** value of calculation of resultant of counter passive earth pressure mobilisable under the transition point (in kN/m or kip/ft);
- **α:** mobilisation factor (function of ratio $C_{t,d}$ / $C_{m,d}$, see Part C);
- **Counter passive earth pressure verification indicator:** this indicator is green if the verification is positive (value of α is 1 or less); it is red otherwise.

For more details on this verification, please refer to part C of the manual.

B.6.4.2. Verification of vertical equilibrium of wall

B.6.4.2.1. Case of anchored wall (SSIM calculation)

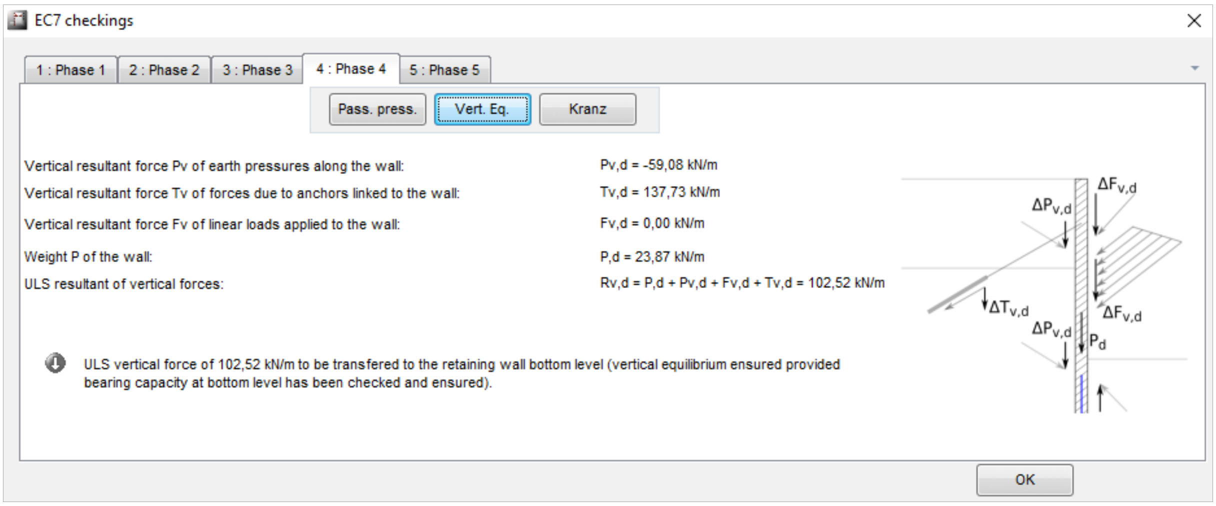


Figure B134 *: ULS check– Vertical equilibrium results – Anchored wall (SSIM calculation)*

In the case of an anchored wall, the vertical equilibrium check involves the following parameters:

- **$P_{v,d}$:** calculation value of vertical resultant of earth pressures over the height of the wall (in kN/m or kip/ft);
- **$T_{v,d}$:** calculation value of vertical resultant of forces due to anchors connected to the wall (in kN/m or kip/ft);
- **$F_{v,d}$:** calculation value of vertical resultant of linear overloads applied over the height of the wall (in kN/m or kip/ft);
- **P_d:** calculation value of own weight of wall (in kN/m or kip/ft);
- **$R_{v,d}$:** calculation value of resultant of vertical forces at ULS (in kN/m or kip/ft). A symbol at the bottom of the window indicates if this resultant is directed upwards or downwards.

The verification of vertical equilibrium of the wall is considered to be satisfactory when the resultant of the vertical forces is positive, it is then by convention directed "downwards".

To the left of the conclusion, a grey icon with a down arrow tells the user that the resultant of the vertical forces is positive and directed "downwards".

If not, a red icon with an upwards arrow informs the user that the resultant of the vertical forces is negative and directed "upwards". The concluding sentence in this case will also be written in red.

The user must check that the wall base bearing is guaranteed taking account of the value obtained for $R_{v,d}$.

For more details concerning this verification, please refer to part C of the manual.

B.6.4.2.2. Case of a cantilever wall (LEM calculation)

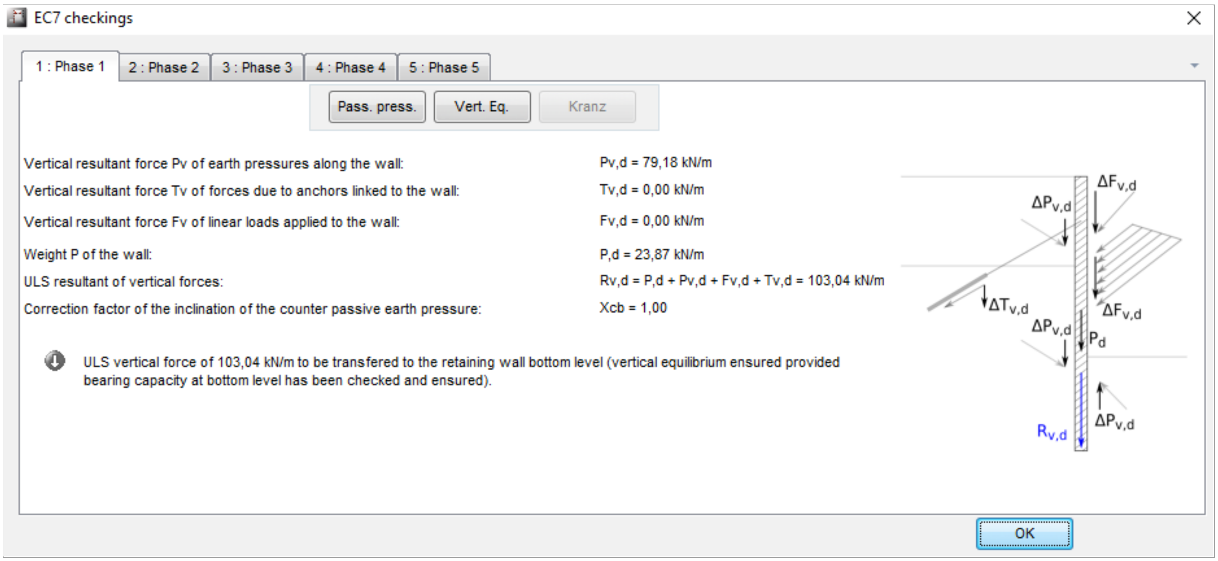


Figure B135 : *ULS check– Vertical equilibrium results – Cantilever wall (LEM calculation)*

For the phases in which the wall is considered to be cantilever, the vertical equilibrium check involves the following parameters:

- $\mathbf{P_{v,d}}$: calculation value of vertical resultant of earth pressures over the height of the wall (in kN/m or kip/ft);
- $\mathbf{T_{v,d}}$: calculation value of vertical resultant of forces due to anchors connected to the wall (in kN/m or kip/ft);
- $\mathbf{F_{v,d}}$: calculation value of vertical resultant of linear overloads applied to the height of the wall (in kN/m or kip/ft);
- $\mathbf{P_d}$: calculation value of own weight of wall (in kN/m or kip/ft);
- $\mathbf{R_{v,d}}$: calculation value of resultant of vertical forces (in kN/m or kip/ft). A symbol at the bottom of the window indicates whether this resultant is directed upwards or downwards.
- $\mathbf{X_{cb}}$: counter passive earth pressures angle correction factor. This factor, determined automatically by AMRetain, acts on the angle of the passive earth pressure initially defined to correct the angle of the counter passive earth pressure, such as to obtain a vertical resultant ($R_{v,d}$) that is directed downwards:

$$(\delta/\varphi)_{\text{counter-passive earth pressure}} = X_{cb} \times (\delta/\varphi)_{\text{passive earth pressure}}$$

The verification of vertical equilibrium is considered to be satisfactory when the resultant of the vertical forces is positive, it then being directed "downwards" by convention. To the left of the conclusion, a grey icon with a down arrow informs the user that the resultant of the vertical forces is positive and directed "downwards". Otherwise, the icon is red with an up arrow informing the user that the resultant of the vertical forces is negative and directed "upwards". The concluding sentence in this case will also be written in red.

The user shall ensure that the wall base bearing is guaranteed taking account of the value obtained for $R_{v,d}$. For more details concerning this check, please refer to part C of the manual.

B.6.4.3. Verification of stability of the anchoring block

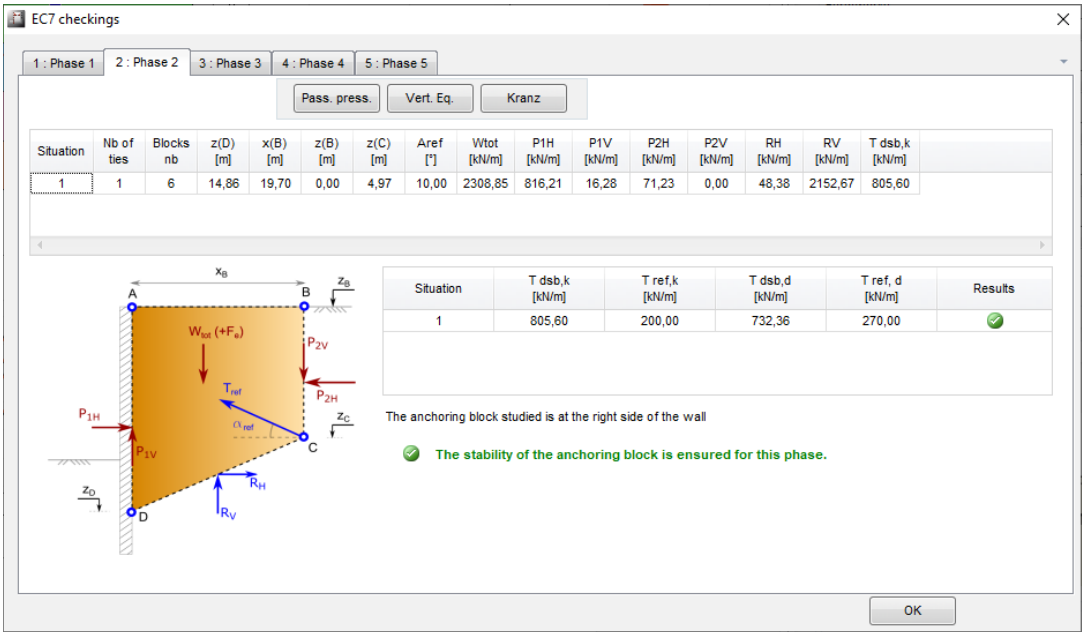


Figure B136 : *ULS checks – Anchoring block check (Kranz method)*

The check on the anchoring block stability (Kranz or Jelinek) is only available for the phases in which at least one tie has been defined.

The first table gives the intermediate calculation results:

- **Situation:** situation number (the situation number corresponds to the number of active anchors in the phase concerned);
- **Spiral angle:** angle at pole of spiral (°);
- **Nb of ties:** number of ties considered in each situation;
- **Blocks nb:** number of blocks defined during discretisation of the anchoring block (as a function of the number of layers intersected along the base of the anchoring block);
- **z(D):** elevation/depth of null shear force point (in m or ft);
- **x(B):** distance between vertical projection of point C and the head of the wall (in m or ft);
- **z(B):** elevation/depth of soil (in m or ft);
- **z(C):** elevation/depth of effective anchor point of tie (in m or ft), corresponding to the useful length L_u defined for the anchor;
- **A_{ref}:** angle of anchor with respect to the horizontal (in °);
- **W_{tot}:** total weight of block for the situation considered (in kN/m or kip/ft);
- **P_{1H}:** horizontal component of wall reaction on the anchoring block (in kN/m or kip/ft);
- **P_{1V}:** vertical component of wall reaction on the anchoring block (in kN/m or kip/ft);
- **P_{2H}:** horizontal component of the active earth pressure force exerted upstream of the anchoring block (in kN/m or kip/ft);
- **P_{2V}:** vertical component of the active earth pressure force exerted upstream of the anchoring block (in kN/m or kip/ft);
- **R_H:** horizontal component of the soil reaction under the anchoring block (in kN/m or kip/ft);
- **R_V:** vertical component of the soil reaction under the anchoring block (in kN/m or kip/ft);
- **$T_{dsb,k}$:** characteristic value of the destabilising anchor force (in kN/m or kip/ft).

The second table gives the results of the check:

- **$T_{dsb,k}$:** characteristic value of the destabilising anchor force (in kN/m or kip/ft), this value is identical to that of the last column in the previous table;
- **$T_{ref,k}$:** characteristic value of reference anchor force resulting from the ULS SSIM calculation (in kN/m or kip/ft);
- **$T_{dsb,d}$:** calculation value of destabilising anchor force (in kN/m or kip/ft);
- **$T_{ref,d}$:** calculation value of reference anchor force (in kN/m or kip/ft).
- **"OK"** (or "**non OK"**): for each situation, the last column shows whether the check is satisfactory, that is if $T_{ref,d}$ is less than $T_{dsb,d}$.

In the lower part of the window, an indicator specifies whether the check is satisfactory for all the situations studied (the check is only satisfactory overall if it is satisfactory for each calculation situation): if this is the case, the indicator is a green circle ✅.

For more details concerning this check, please refer to part C of the manual.

B.6.5. Double wall project

B.6.5.1. Main results

For each wall, the results presented are the same as for a single wall project without ULS checks.

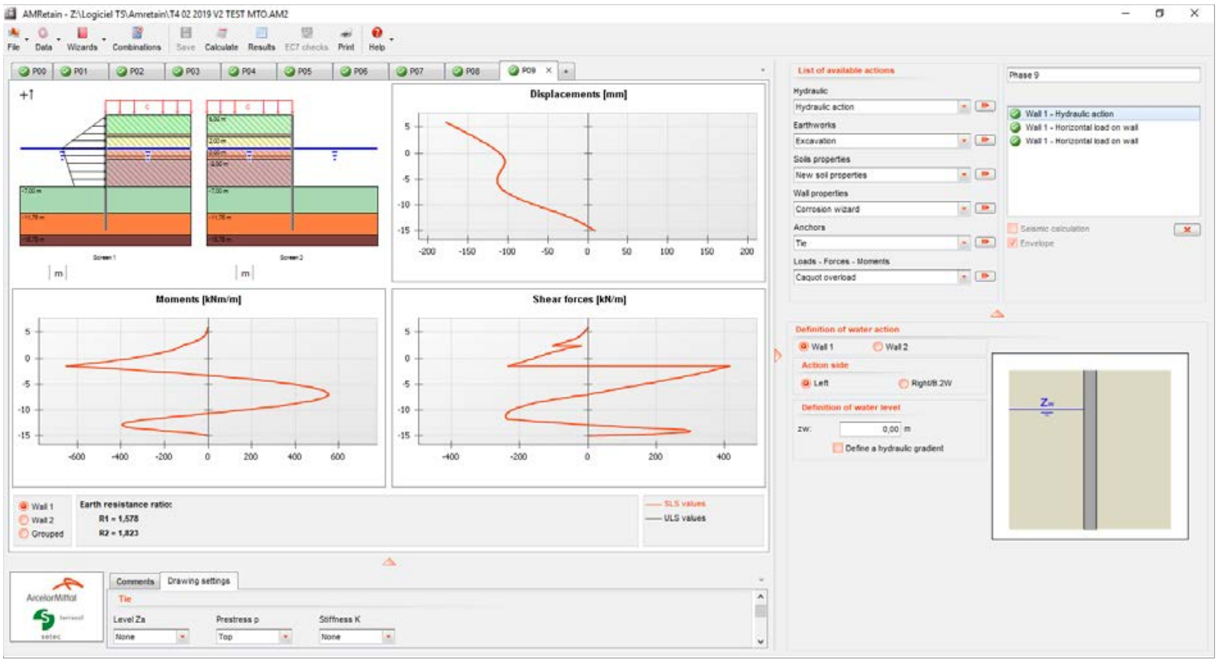


Figure B137 *: Main window – Results of a double wall project*

It is also possible to choose simultaneous (superposed) display of the results curves of both walls, by clicking the "**Grouped**" choice (in the list of choices under the moments curve). In this case, the curves on the active screen appear in thick purple, while those of the other wall appear in thin purple. The passive earth pressures ratio obtained is also displayed for each wall (see Figure B138).

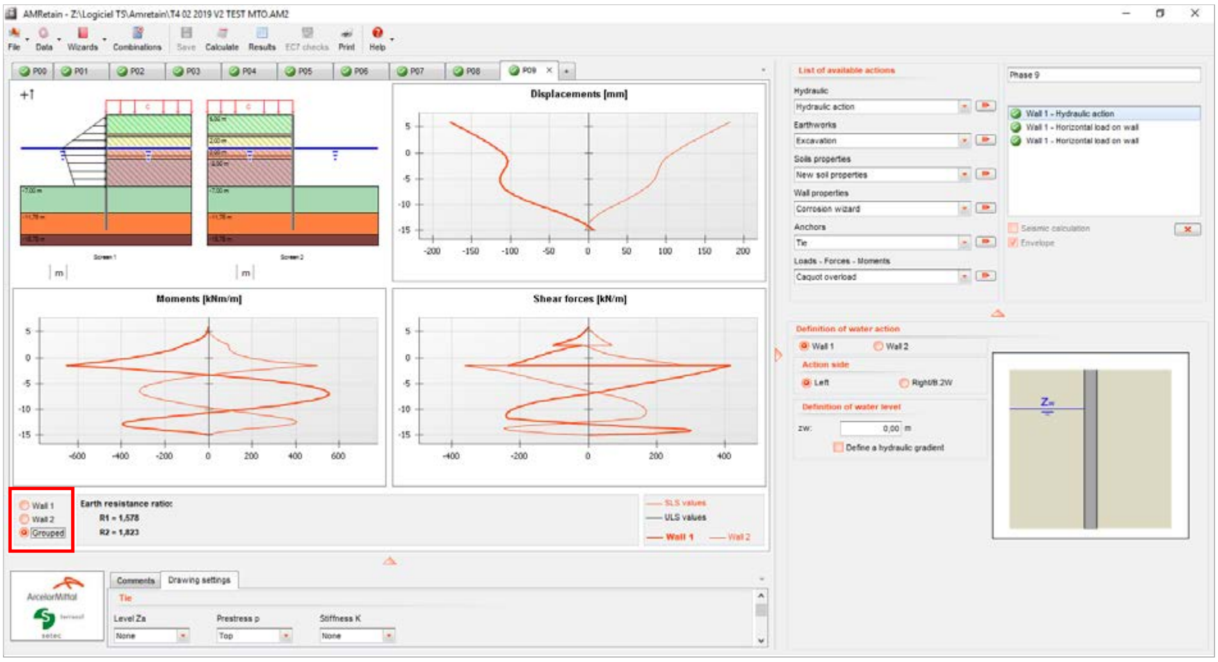


Figure B138 : *Main window – Results of a double wall project*

As with the single wall projects, the detailed results are accessible via the "Results" button.

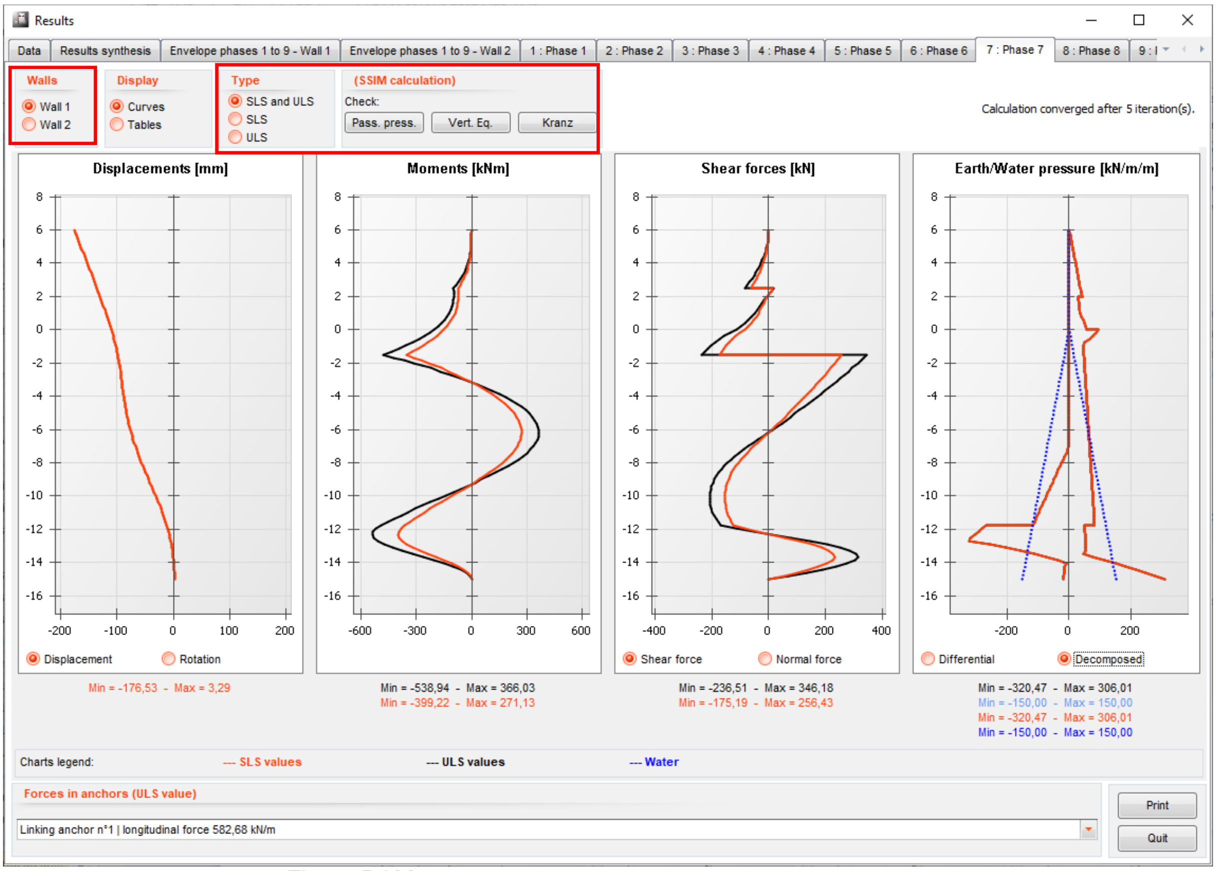


Figure B139 : *Results window – Case of a double wall project*

The results given for each wall are as specified in chapter B.6.2 (results of a single wall calculation without ULS checks).

At any moment it is possible to go from the results of one wall to those of the other via the selection buttons in the results window (Data, Phases, Results Synthesis and Envelopes). This remark is valid for any tab of the results window.

B.6.5.2. ULS checks

AMRetain is used to carry out ULS checks for double wall type projects if the "ULS checks" box was activated in the "Title and Options" window.

The passive earth pressure safety checks for each wall are performed and their presentation is comparable to that of a single wall.

The use of the anchoring block check is broadened by allowing validation of the distance between walls, while verifying the stability of everything between the two walls on the basis of the forces behind each wall. For more details, please refer to part C of the manual.

B.7. Printing

This is accessible by the shortcut buttons present in the various Print windows or by the **File Menu**, then **Print**.

B.7.1. Single wall type projects without ULS checks

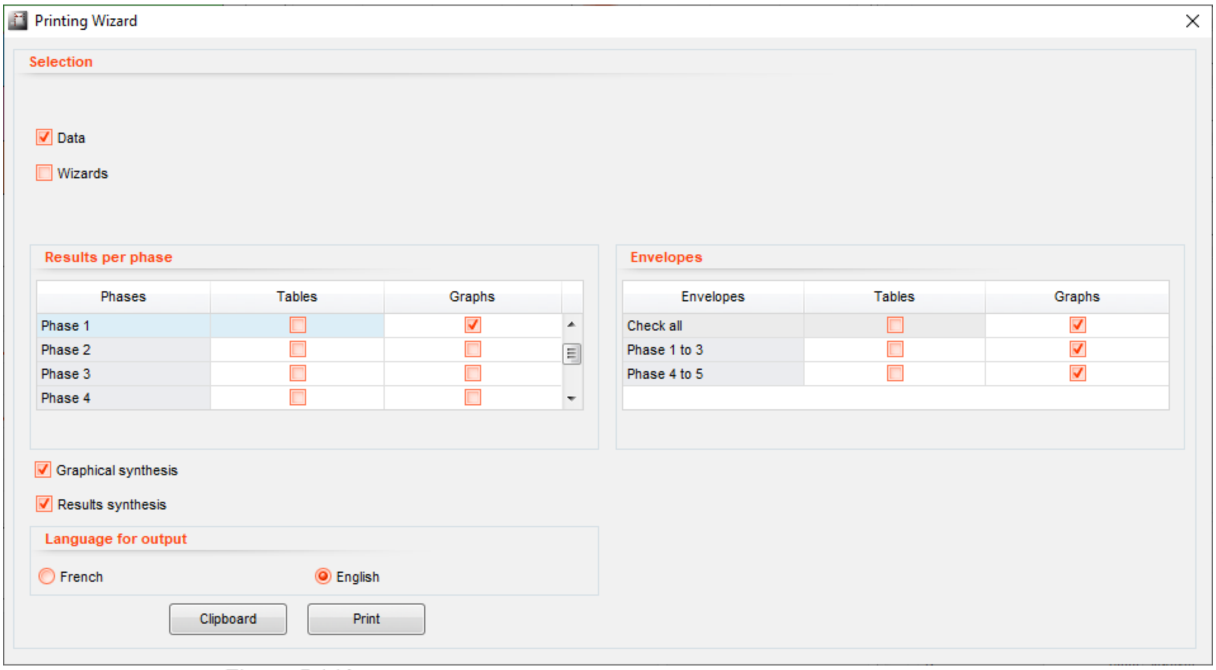


Figure B140 : *Printing wizard for a single wall project without ULS checks*

By a simple click, the print dialogue box is used to select the items to be printed:

- **Data:** prints the first tab in the results window containing the reminder of the soil characteristics, the retaining wall and the selected options.
- **Wizards**: prints the wizards input data and the results obtained.
- **Graphical synthesis**: prints the synthesis of the project phasing. This synthesis includes the project cross-section for each phase and the parameters of the various actions defined.
- **Results per phase**: used to print the results of all the calculation phases (**Check all**) or only those selected. it is possible to print the results tables (left-hand column) and/or the Graphs (right-hand column).
- **Envelops**: prints the calculated envelopes in table and/or graphic format.
- **Results synthesis**: prints the synthesis table of the results obtained.

These "printouts" can be:

- Either copied to the clipboard for subsequent inclusion in another document;
- Or sent to a printer.

The choice is made by clicking the appropriate button at the bottom of the printing wizard window, once the elements to be printed have been selected.

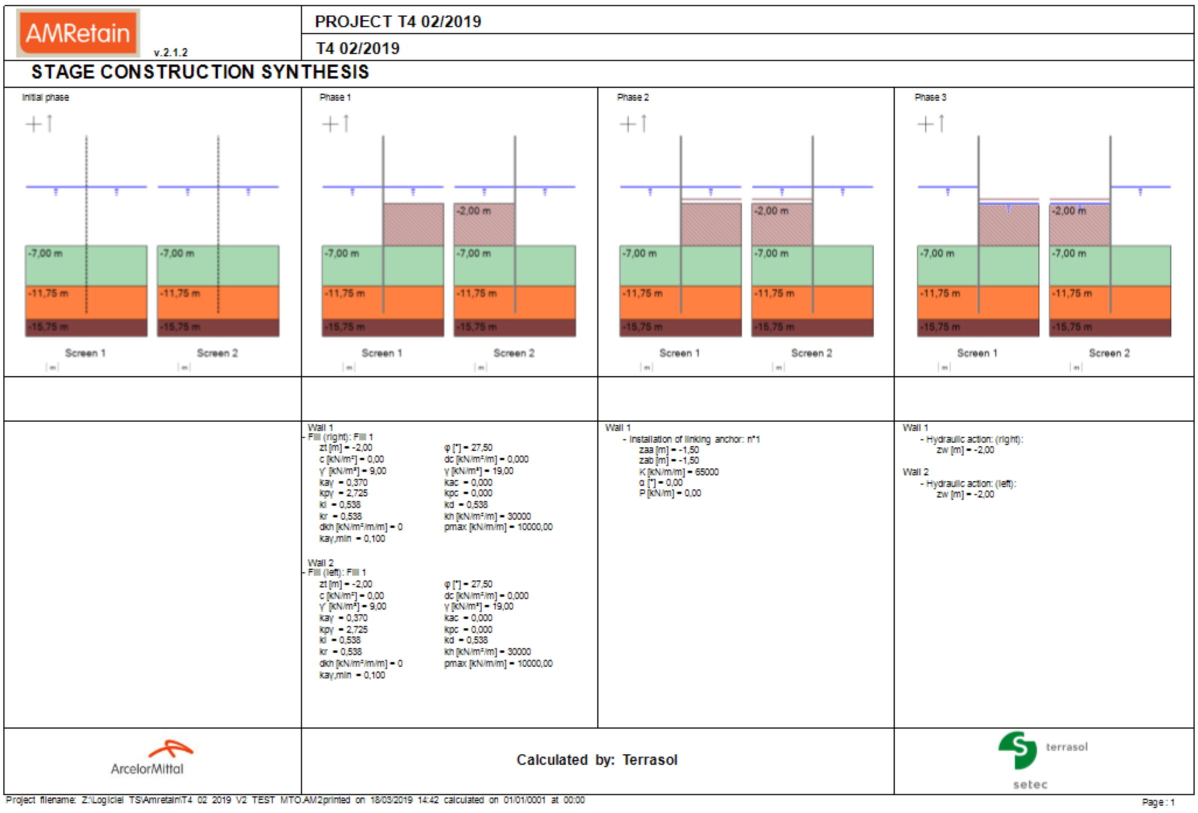


Figure B141 *: Example of printing of graphical synthesis of phasing*

B.7.2. Single wall type projects with ULS checks

When printing the calculation results for a single wall project with ULS checks, the type of results to be printed must be chosen:

- **SLS results**: these are results produced by the "standard" SSIM calculation without weighting.
- **ULS results**: these are results produced by the calculation with weighting (LEM or SSIM depending on the phases) performed in the context of the ULS checks.

The choice between these two types of results is by means of the selection made at the top of the printing wizard window.

SLS results

If the "SLS" option is selected in the printing wizard (see following figure), the available printing options are the same as for a single wall calculation without ULS checks (see chapter B.7.1).

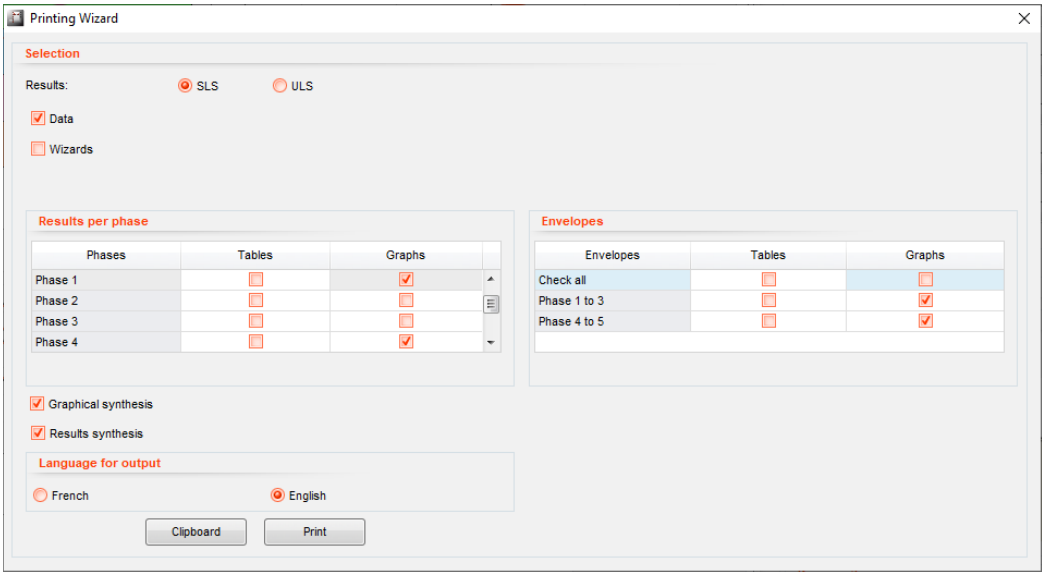


Figure B142 : *Printing wizard for a single wall project with ULS checks, with selection of SLS results for printing*

Note: as these are the SLS results, only the characteristic values (K index) of the unweighted calculation results will be printed.

ULS results

If the "ULS" option was selected in the printing wizard (see figure below), the available printing options correspond to the results available for a calculation with ULS checks.

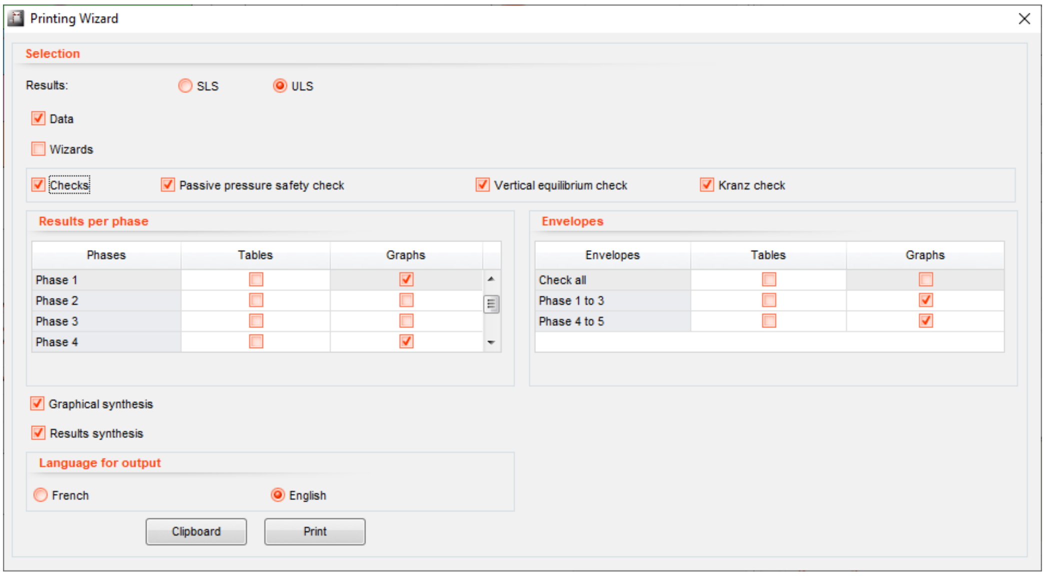


Figure B143 : *Printing wizard for a single wall project with ULS checks, with selection of ULS results for printing*

The printing options are as follows:

- **Data:** prints the first tab in the results window containing the reminder of the soil characteristics, the wall and the selected options (same as previously).
- **Wizards**: prints the wizards input data and the results obtained.
- **Graphical synthesis**: prints the synthesis of the phases (same as previously).
- **Results per phase**: used to print the results of all the calculation phases (**Check all**) or only those selected. It is possible to print the results tables (left-hand column) and/or the graphs (right-hand column).
- **Checks**: prints the results of the ULS checks performed for each phase (check on passive earth pressure safety, check on vertical equilibrium and check on stability of anchoring block in the case of a project including one or more ties).
- **Detailed anchoring block check**: prints the details of the calculations performed (in addition to the synthesis results already printed if the **Checks** box above is ticked).
- **Results synthesis**: prints the synthesis of results obtained for displacements, bending moments, shear forces and forces in the anchors.

Note: as these results are ULS, the characteristic values (k index) and design values (d index) of the results will be printed for the phases in which the walls are anchored (SSIM calculation). For those phases in which the wall is assumed to be cantilever (LEM calculation), only the design values (d index) of the results will be printed (see Part C of the manual).

B.7.3. Double wall type projects

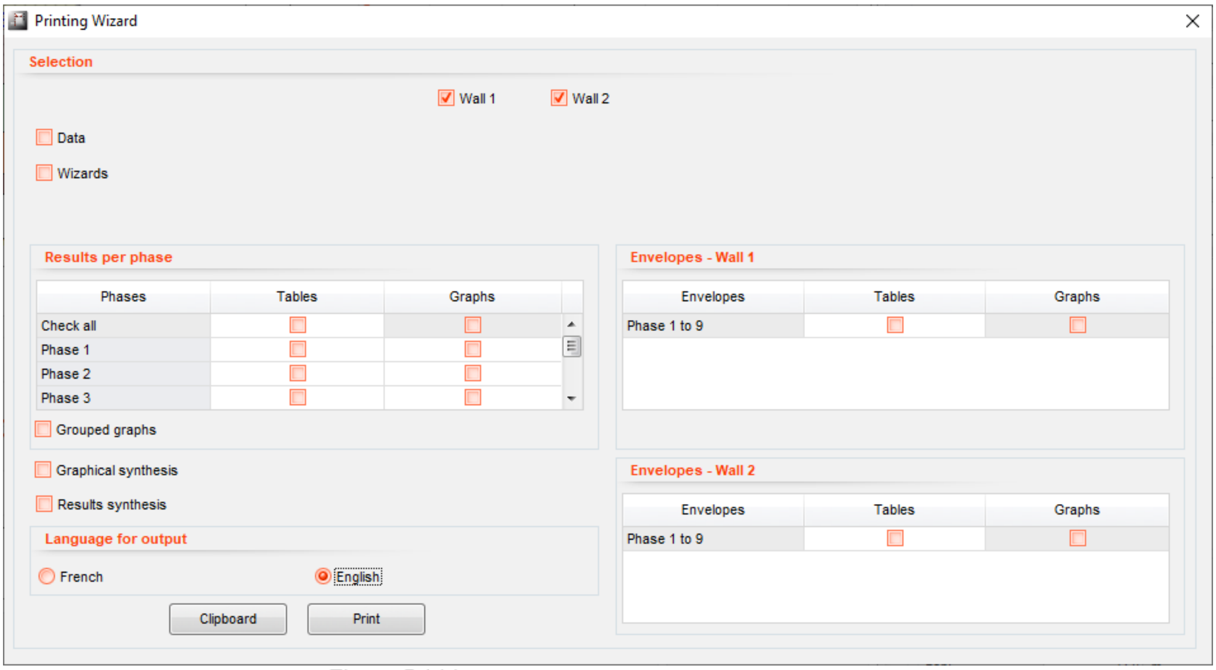


Figure B144 : *Printing wizard for a double wall project*

The printing options available for double wall projects are on the whole the same as for single walls without ULS checks, but they are doubled, to enable the user to choose whether to print the results for wall 1 and/or for wall 2. By default, the wizard proposes printing the results for both walls.

In addition, for the results per phases and the envelopes in graph format, it is possible to superpose the results of the 2 walls on the same graphs, by ticking the "**Grouped graphs"** box.

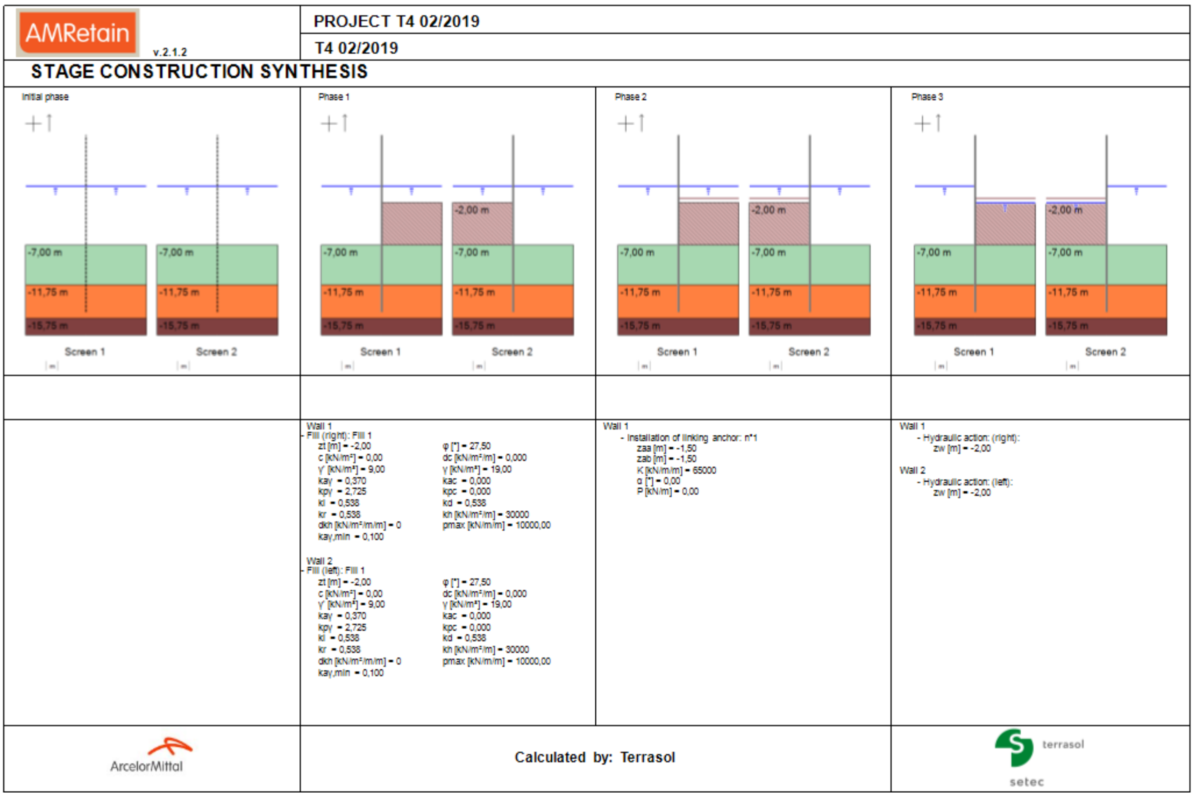


Figure B145 *: Extract of printout of a phasing graphical synthesis for a double wall project*

AMRetain

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C.1. Introduction and main principles

C.1.1. Calculations and application field

AMRetain is intended to study the behaviour of retaining walls (internal efforts and deformations) subjected to a series of construction stages.

The calculation method used consists in the subgrade reaction calculation method (type SSIM-K[1] according to the application standards of the Eurocode 7 designated by SSIM in this document for simplification purposes). It is based on the model of a beam supported by elastic-plastic springs.

AMRetain enables the analysis of two types of projects:

- « Simple wall » projects: comprising one single plane retaining wall;

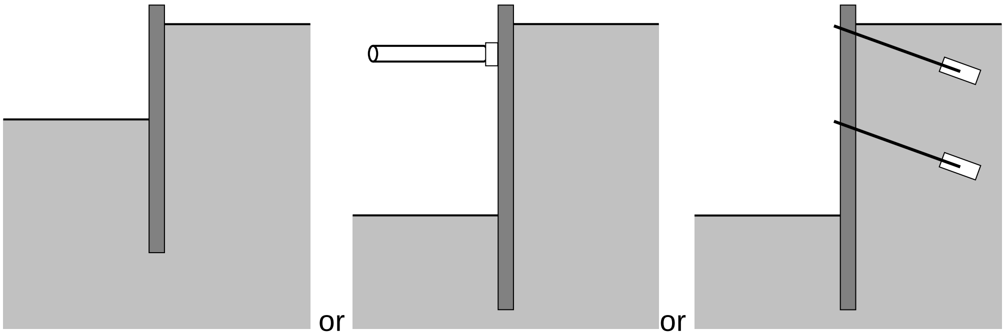


Figure C1: Examples of « simple wall » projects

- « Double-wall » projects: comprising two plane walls, linked to each other (or not) by one or more linking anchor layers.

  Note: in this manual, the term "double walls" designates projects with either 2 walls with approximately the same length (cofferdams for instance), or a main wall anchored on a smaller rear wall.

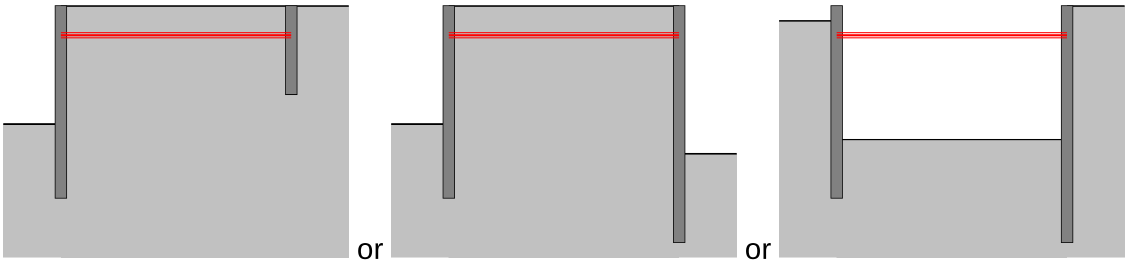


Figure C2: Examples of « double-wall » projects

The series of construction stages includes the initial stage of the wall(s) installation which is followed by different phases, each one corresponding to a set of actions, such as the implementation of struts or anchors, the modification of the water or soil level, the application of overloads or the implementation of link anchors (in the case of a double-wall project).

The SSIM calculation is presented and detailed in sections C.1.2.1 and C.2.

Moreover, in addition to the SSIM calculation, AMRetain performs 3 types of ULS checks according to the recommendations of the Eurocode 7 (cf chapters C.1.2.2 and C.4), particularly the implementation of the limit equilibrium method (LEM) for cantilever walls.

[1] SSIM-K : Model of soil-structure interaction based on the subgrade reaction method.

The global articulation between these calculation types and checks is displayed in an diagram in chapter C.1.2.3.

C.1.2. Introduction to the calculating methods and suggested verifications

C.1.2.1. Basic calculation method SSIM

The SSIM method associates a beam model representing the wall and elastic-plastic springs representing of the soil-wall interaction. The anchoring elements are modelled with equivalent elastic-plastic springs.

In AMRetain, the model is equated with an overall matrix formulation associating both walls. In this formulation, liaison elements like struts or anchors produce a coupling between the freedom degrees of both walls.

C.1.2.2. ULS checks according to Eurocode 7

Eurocode 7 (completed by its application standards) fixes the list of verifications (ULS) to carry out considering the principle risks related to retaining structures:

- Verification of the passive earh pressure (1);
- Verification of the retaining wall resistance and of its supports (2);
- Verification of the vertical equilibrium of the wall (3);
- Verification of the hydraulic stability (4);
- Verification of the stability of the anchoring block (5);
- Verification of overall stability (6);

AMRetain carries out checks (1), (3) and (5) for each stage according to standard NF P 94-282 (Eucorode 7). It also provides the necessary elements to carry out check (2). Checks (4) and (6) require specific calculation programs.

In AMRetain v2, these checks can be done according to one of the three approaches of the Eurocode 7 (see §C.4.1 for a detailed description of these approaches and their implementation within AMRetain v2).

C.1.2.3. Articulation of different calculation methods

In the case of a calculation led without ULS checks, all phases are processed using the « basic » model, which is a displacements model based on the subgrade reaction coefficients method (SSIM-K, designated in this document by SSIM only), and performed without weighting factors on soil properties nor surcharges. The results obtained include wall displacements, mobilised pressures as well as shear forces and bending moments (V, M).

In the case of calculations carried out along with ULS checks, wo calculations are executed for each stage:

- « SLS » calculation method based on the SSIM model without weighting on soil and surcharge properties. This calculations results are strictly identical to those of a calculation “without ULS verifications”: displacements, mobilised pressures and forces (V, M) ;

- « ULS » calculation method which model varies depending on whether the wall is anchored or not in the considered stage: SSIM model for the case of an anchored wall, LEM model for a cantilever wall. The result of ULS calculations is completed with the following mechanisms analysis:
  - Verification of passive earh pressure;
  - Verification of vertical equilibrium of the wall;
  - Verification of stability of the anchoring block;

The figure hereunder summarises the general diagram of calculations performed by AMRetain and their articulation.

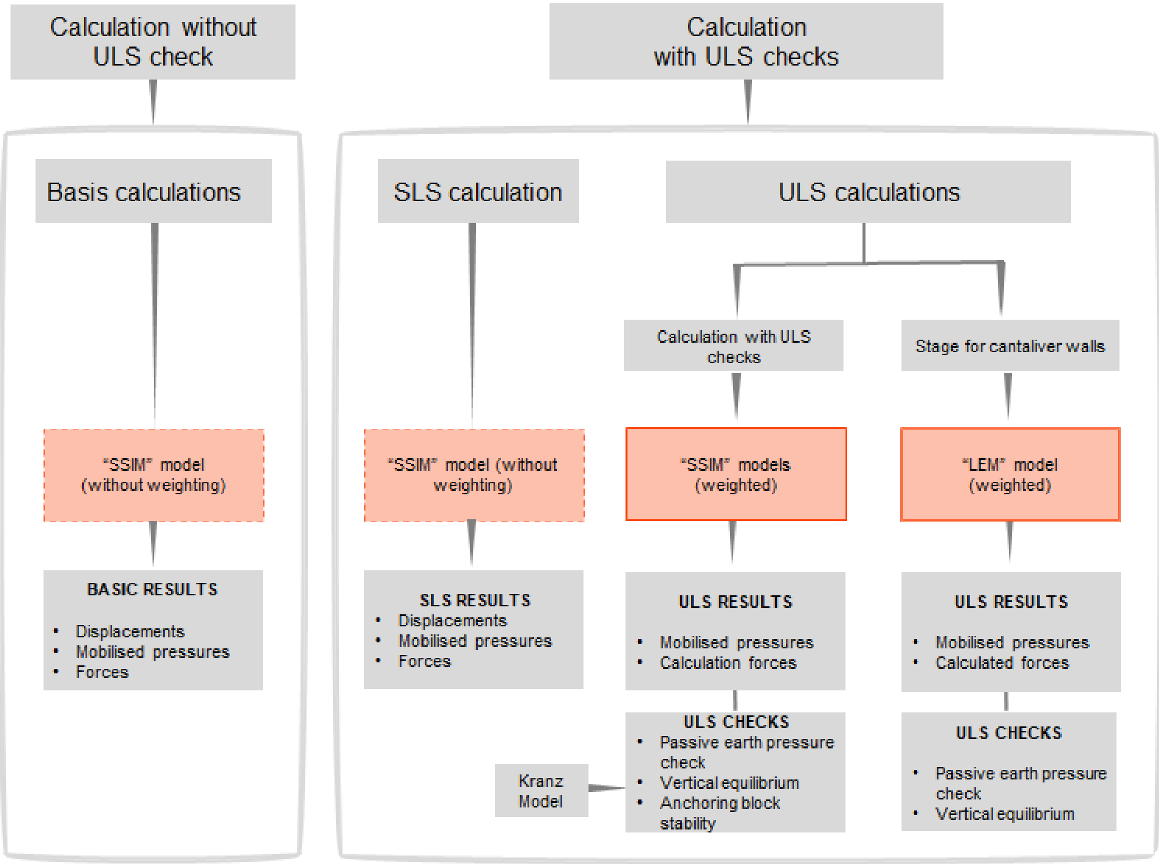


Figure C3: Calculation diagram

C.1.3. Sign convention

For each wall, the part left to the wall is called the left side; the part right to the wall is called the right side. Wall displacements and forces are positive when directed to the right (cf. Figure C4:).

Note: the « main » excavation can be either located on the left or on the right side without distinction.

The z-coordinates are either positive upwards when using the **levels**, either positive downwards when using **depths**. This option is defined in the **Menu Data**, **Titles and Options**.

As for the external forces applied onto the wall, the forces (represented by F on the figure hereunder) are positive when oriented from left to right and moments (represented by M in the figure hereunder) are positive when anti-clockwise.

Support forces are considered positive:

- In traction in the case of an anchor (grouted or linking);
- In compression in the case of a strut (single or linking).

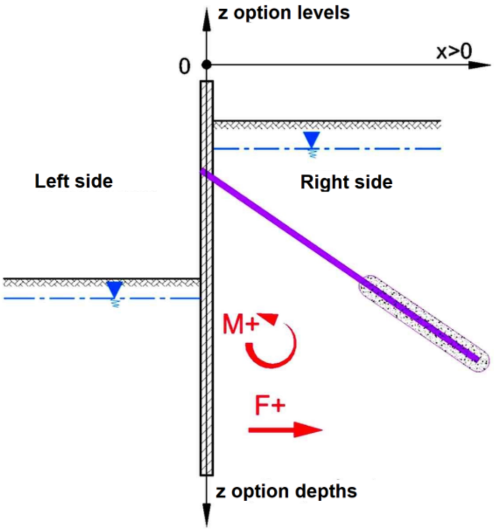


Figure C4: Sign conventions for external loads

In addition, the figure hereunder presents the sign conventions used within AMRetain for the internal forces (M, V and N). The axial force N is considered positive in compression.

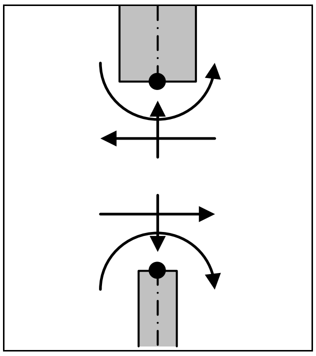


Figure C5: Sign convention for inner efforts

C.2. Theoretical aspects

C.2.1. Equation

C.2.1.1. Wall behaviour

Each wall « i » is represented by a linear elastic beam with a homogeneous section. We consider the hypothesis of a thin beam to allow neglecting the deformations caused by the shearing force.

The behaviour of the beam in bending mode, representative of wall « i », can be described with the following general equation:

$$\frac{d^2}{dz^2}\left(EI_i \frac{d^2 w_i}{dz^2}\right) + Rc_i.w_i = q_i^{ext} - \left(r_i^d - r_i^g\right) - r_i^a \quad (1)$$

In which:

- w_i bending (transversal displacement) of the wall « i » (positive towards the right);
- EI_i product of inertia of wall « i »;
- Rc_i cylindrical rigidity of wall « i »;
- r_i^d density of soil horizontal reaction on the right side of wall « i »;
- r_i^g density of soil horizontal reaction on the left side of wall « i »;
- r_i^a density of the horizontal reaction of anchors connected to wall « i »;
- q_i^{ext} horizontal density of external loads on wall « i ».

C.2.1.2. Soil/wall interaction law

The soil / wall interaction law is described, for each side and each wall, with a curve of classical active and passive earth pressure characterised by 4 parameters:

- k_h: horizontal subgrade reaction coefficient of the wall (or surface unit stiffness);
- p_a: limit horizontal active earth pressure (or active pressure) ;
- p_b: limit horizontal passive earth pressure (or passive pressure) ;
- p_0: horizontal reference pressure (also named « initial » pressure or "at rest pressure").

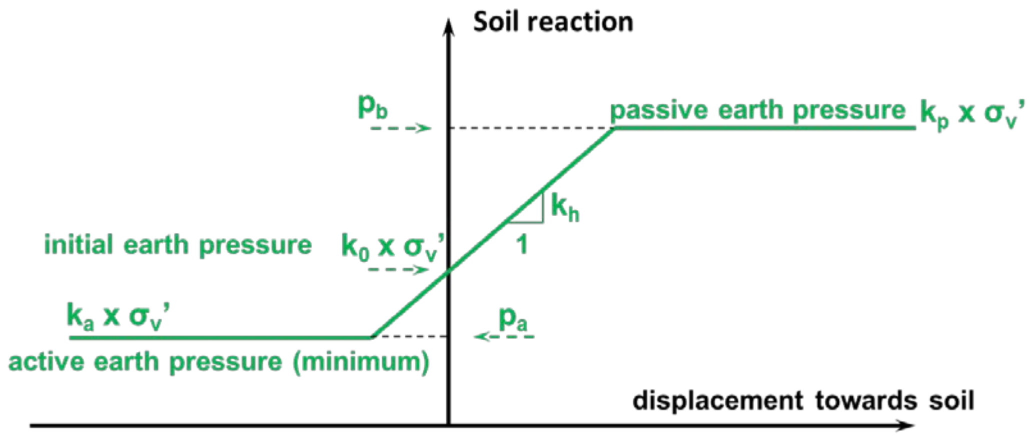


Figure C6: Soil/wall interaction law

According to the notations of the above figure, the lateral reaction of the soil on one side of the wall can be expressed as follows:

$$\begin{cases} r_i^d = +\alpha.w + \beta \\ r_i^g = -\alpha.w + \beta \end{cases} \qquad (2)$$

In which:

- Elastic stage: $\alpha = k_h$ $\beta = p_0$
- Limit state of active earth pressure: $\alpha = 0$ $\beta = p_a$
- Limit state of passive earth pressure: $\alpha = 0$ $\beta = p_b$

By default, the values of $p_a/p_b/p_0$ are automatically determined by AMRetain according to the soil characteristics and the effective vertical stress σ_v' for a given stage, wall and side (see §C.3.1).

C.2.1.3. Pore pressure

A non-zero pore-water pressure u(z) (hydrostatic or flow conditions) (cf. §C.3.1.3):

- Modifies the state of effective stress which is directly dependant on the mobilization of the soil reaction law ($p_a/p_b/p_0$ are functions of σ_v');
- Mobilizes horizontal pressure directly on the wall equal to u(z), that adds up to the external load's density on the wall $q^{ext}(z)$.

C.2.1.4. Anchors

Isolated anchors (struts, ties, circular walings, rotational springs and surface struts) should follow an elastoplastic reaction law like in the hereunder diagram.

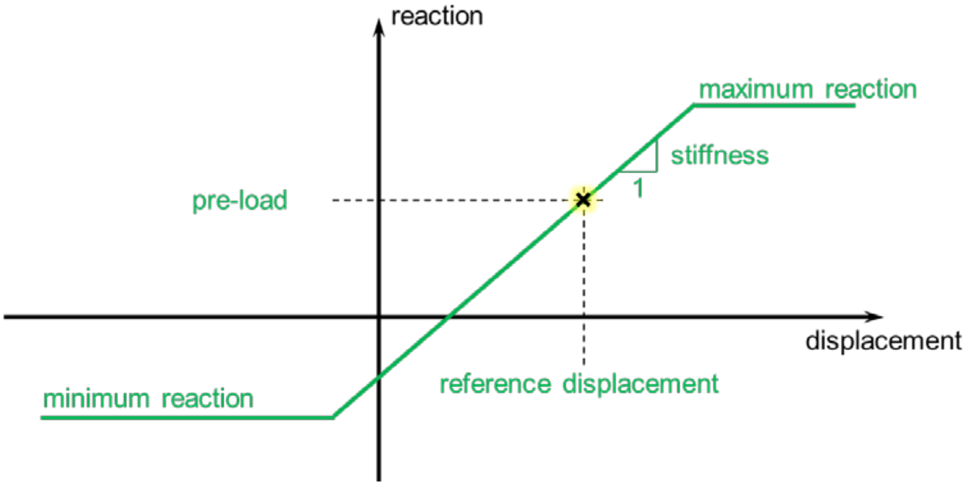


Figure C7: Mobilization law of anchor reaction

The anchor reaction mobilization law can also be expressed with the following equation:

$$r_i^a = k_i^a.w + p_i^a \qquad (3)$$

C.2.1.5. Resolution

The resolution of the equations system (1) + (2) + (3) can be conducted digitally by discretizing the representative beam of screen "i" in elements with two nodes and four degrees of freedom (two displacements and two rotations).

This discretization allows to express the elastic-plastic equilibrium of the wall in the form of a matrix system of size 2(n+1) x 2 (n + 1), where n is the total number of elements:

$$\left(\mathbf{K}_i^e + \mathbf{K}_i^s + \mathbf{K}_i^a\right).\mathbf{w}_i = \mathbf{F}_i^{ext} - \mathbf{P}_i^s - \mathbf{P}_i^a \qquad (4)$$

In which, for the « i »:

- $\mathbf{w}_i$: equivalent displacement vector constituted by the displacements and rotations of each mesh node;

- $\mathbf{F}_i^{ext}$: load vector of external loading (+ water pressure);
- $\mathbf{P}_i^s$: reaction vector of the constant part (β) of the soil reaction;
- $\mathbf{P}_i^a$: reaction vector of the constant part (p^a) of the anchor reaction;

- $\mathbf{K}_i^e$: wall stiffness matrix (in bending mode and cylindrical) ;
- $\mathbf{K}_i^s$: soil stiffness matrix (elastic part α for each level) ;
- $\mathbf{K}_i^a$: anchor stiffness matrix (elastic part k^a for each level) ;

The resolution of this equation provides the displacements and the reactions for each point of each mesh element.

C.2.2. Linking anchors

We now examine the case of a double-wall with one or more linking anchor of type ties/ struts (single or surface struts). These elements follow a reaction law similar to the one of the "non-linking" anchors (cf. § C.2.1.4).

The particularity of a linking anchor resides in the fact that its reaction is a function of the relative displacement between both walls (and not of the absolute displacement).

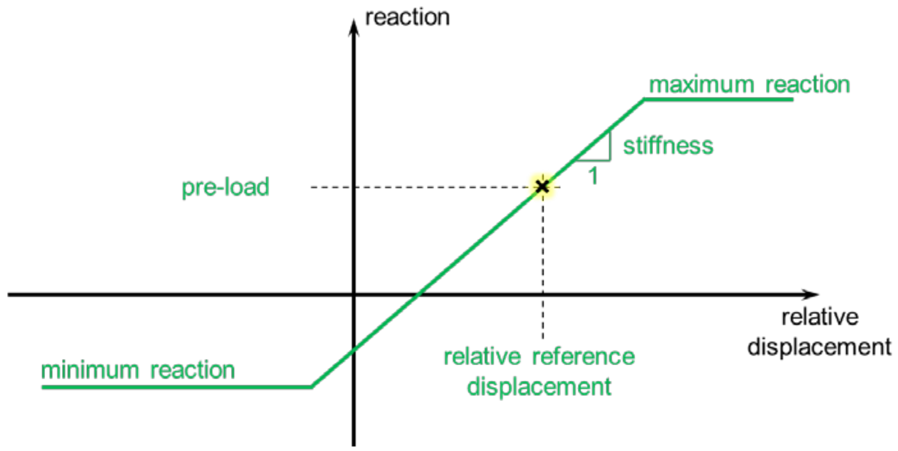


Figure C8: Mobilization law of the linking anchor reaction

Using the matrix formulation for each wall, the balance of the two walls in interaction can be determined with a unique matrix system:

$$\begin{pmatrix} \mathbf{K}_1^e + \mathbf{K}_1^s + \mathbf{K}_1^a + \mathbf{K}^L & -\mathbf{K}^L \\ -\mathbf{K}^L & \mathbf{K}_2^e + \mathbf{K}_2^s + \mathbf{K}_2^a + \mathbf{K}^L \end{pmatrix} . \begin{pmatrix} \mathbf{w}_1 \\ \mathbf{w}_2 \end{pmatrix} = \begin{pmatrix} \mathbf{F}_1^{ext} - \mathbf{P}_1^s - \mathbf{P}_1^a - \mathbf{P}^L \\ \mathbf{F}_2^{ext} - \mathbf{P}_2^s - \mathbf{P}_2^a + \mathbf{P}^L \end{pmatrix}$$

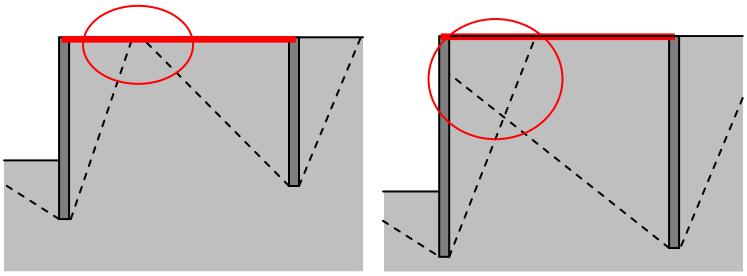
In which:

- $\mathbf{K}^L$: stiffness matrix of linking anchors (elastic part);
- $\mathbf{P}^L$: vector of the constant part of the linking anchors reaction.

For the model to be valid, it is assumed that the linking anchors if they exist are the only interaction between the two walls. AMRetain does not take into account any interaction between the two walls through the soil situated between them. In particular, AMRetain does not explicitly carry out overlapping verifications (figures herebelow) for:

- o Active/ passive earth pressure corners in the case of double wall project;
- o Passive earth pressure corners in the case of an excavation with struts.

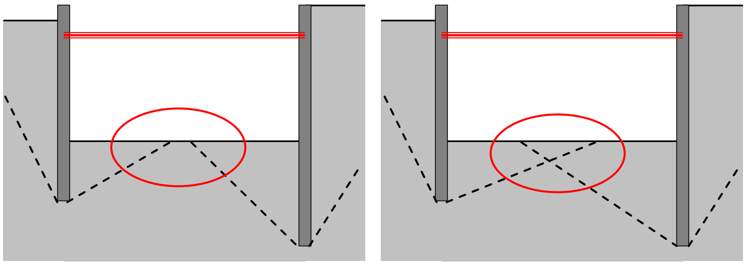
These interactions have to be verified by the user with other means. Nevertheless, in the case of a double wall project (head wall anchored to an anchor wall using anchors), the stability verification of the foundation block with a Kranz model (that AMRetain does automatically if ULS calculations are requested) implicitly suggests that there is enough distance between both walls not to consider any interaction between both walls through the anchoring block between both walls.



Case of non-interaction of active/passive pressure corners

Case of interaction of active/passive pressure corners together and with one of the walls

Figure C9: Case of a double wall with interaction between corners of active/passive pressure



Case of non-interaction betwee passive pressure corners

Case of interaction of active pressure corners

Figure C10: Case of an excavation with struts and interaction between passive pressure corners

C.2.3. Stress calculations

In AMRetain, internal effort calculations for each wall are performed by the integration of the reactions calculated in the preceding stage.

- Shearing force $V_i(z) = \int_0^z \left[q_i^{ext}(t) - r_i^d(t) + r_i^g(t) - r_i^a(t) - Rc_i(t).w_i(t)\right]dt + V_i(0)$
- Bending moment $M_i(z) = -\int_0^z V_i(t)dt + M_i(0)$ (+reaction of the joints)
- Orthoradial pressure $N_i^{\theta\theta}(z) = -Rc_i(z).w_i(z).R_i(z)$ (positive in compression)

Where R_i (z) indicates the radius of the excavation at z level in the case of a circular wall ($Rc_i \neq 0$).

AMRetain also calculates a vertical axial force $N_i^{zz}(z)$ taking into account the “surface” weight of the wall, the vertical component of the external load and support efforts, as well as the vertical projection of earth pressure pv. The latter is estimated from the horizontal earth pressure ph with the following equation:

$$p_v = \begin{cases} \tan\delta_a p_a \left(\dfrac{p_0 - p_h}{p_0 - p_a}\right) & \text{if } p_a \le p_h \le p_0 \\ \tan\delta_b p_b \left(\dfrac{p_h - p_0}{p_b - p_0}\right) & \text{if } p_0 \le p_h \le p_b \end{cases}$$

Where, δ_a and δ_b are the values of the inclination of the active and passive earth pressures to horizontal.

C.2.4. Effects of 2nd order

It is possible to consider second-order effects on the wall. This consists in considering the displacements and complementary forces (moments and shear) brought by the additional vertical axial force $\Delta_{ad}N$ (z). The latter is calculated by considering the vertical components of linear loads and forces in the anchors. Mathematically, this is equivalent to the application of an additional lateral load of density $\Delta q_{ad}(z)$:

$$\Delta q_{ad} = \Delta N_{ad} \frac{d^2 w}{dz^2}$$

These effects are considered iteratively until convergence of the term $\Delta q_{ad}(z)$. At the end of the calculation, the evaluation of additional internal efforts (ΔM_{ad}, ΔV_{ad}) due to the 2nd order effects is conducted using the following equation:

$$\frac{d\Delta\Delta_{ad}}{dz} = \Delta N_{ad} \frac{dw}{dz} \qquad \Delta V_{ad} = -\Delta N_{ad} \frac{dw}{dz}$$

C.2.5. Phasing management

C.2.5.1. Soil / wall interaction

C.2.5.1.1. Effect of a change in the effective vertical stress

The modification of the effective vertical stress in the ground σ_v' in a given phase, under the effect of an excavation ($\Delta\sigma_v' < 0$), of a backfilling ($\Delta\sigma_v' > 0$) or of the application of an overload on the ground ($\Delta\sigma_v' > 0$) results in the following double effect:

- Modification of the value of the pressure p_i with zero displacement using recompression k_r and decompression k_d coefficients:
  - $\Delta p_i = k_r.\Delta\sigma'_v$ si $\Delta\sigma'_v > 0$
  - $\Delta p_i = k_d.\Delta\sigma'_v$ si $\Delta\sigma'_v < 0$
- The update of both plastic earth pressures (active/passive) using the coefficients of passive/active pressure defined by the user for each layer:
  - $\Delta p_a = k_a.\Delta\sigma'_v$
  - $\Delta p_b = k_p.\Delta\sigma'_v$

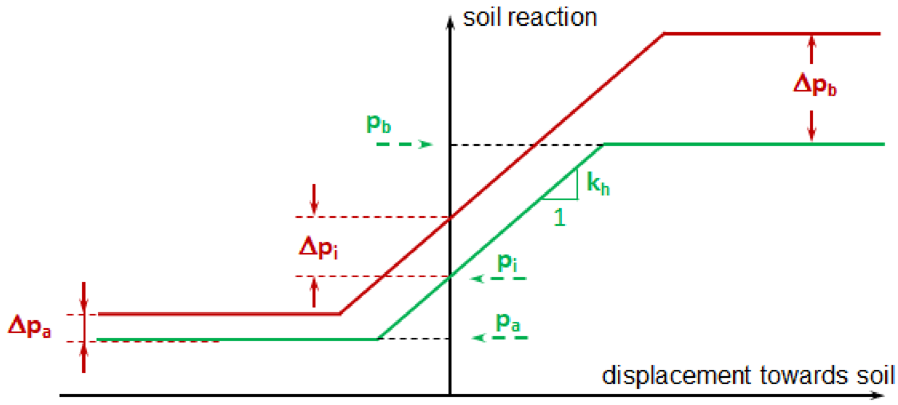


Figure C11: Effect of a modification in the effective vertical stress

C.2.5.1.2. Effect of plastification

Soil plastification in a phase has the effect, in the next phase, of horizontally shifting the soil/wall interaction curve with a residual displacement δ_r. This leads to a "fictitious" modification of the initial pressure p_i. Therefore, its value can no longer be directly connected to the vertical stress state.

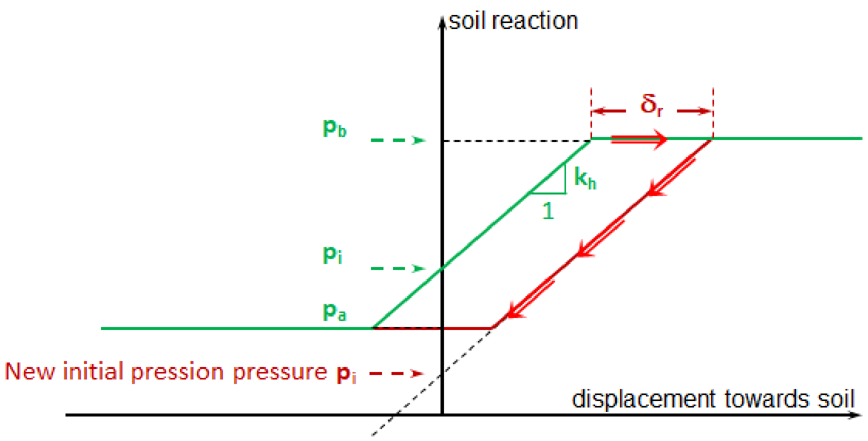


Figure C12: Effect of soil plastification – notion of residual displacement

Special case of deplastification: the line of return is unchanged and so the initial pressure is also unchanged.

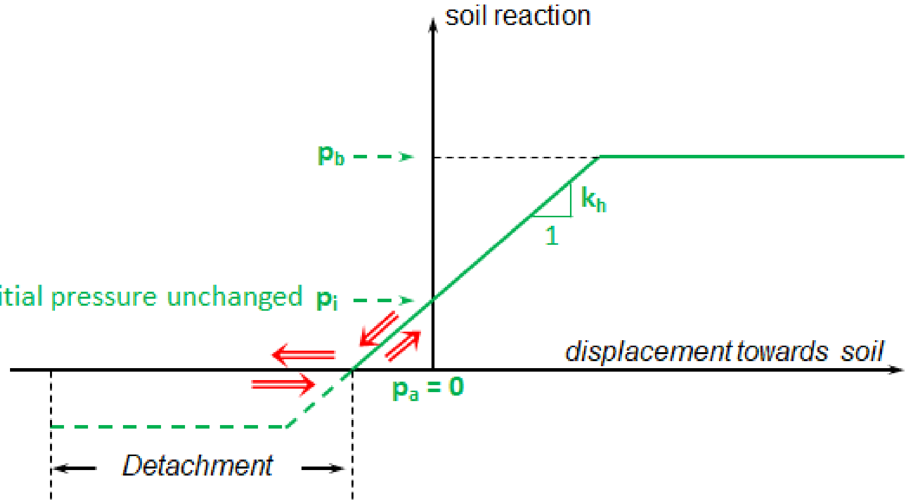


Figure C13: Particular case of soil detachment

C.2.5.1.3. Modification of the reaction coefficient

The modification of the reaction coefficient leads to a rotation of the elastic part around the point of balance achieved in the previous phase, which implies a modification of the initial apparent pressure (figure below).

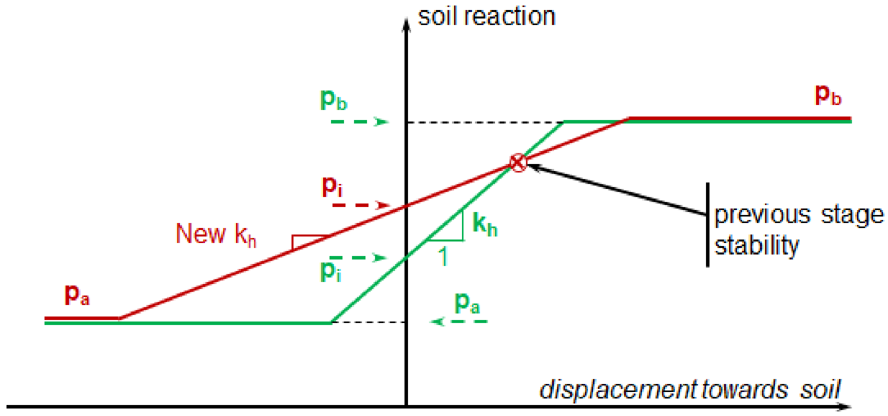


Figure C14: Effect of a change in the coefficient of soil reaction

As suggested in the figure above, the modification of the reaction coefficient does not have an impact on the previous equilibrium and no displacement is generated if there is no additional load.

C.2.5.2. Anchors

C.2.5.2.1. Creep

The modification of an anchor stiffness during phasing is treated differently depending on whether it is reduced (creep) or increased with respect to its initial value. Reducing the stiffness of an anchor (creep) leads to a regeneration of the interaction law around the reference point, thus leading to an additional displacement in the absence of any other action during the study stage.

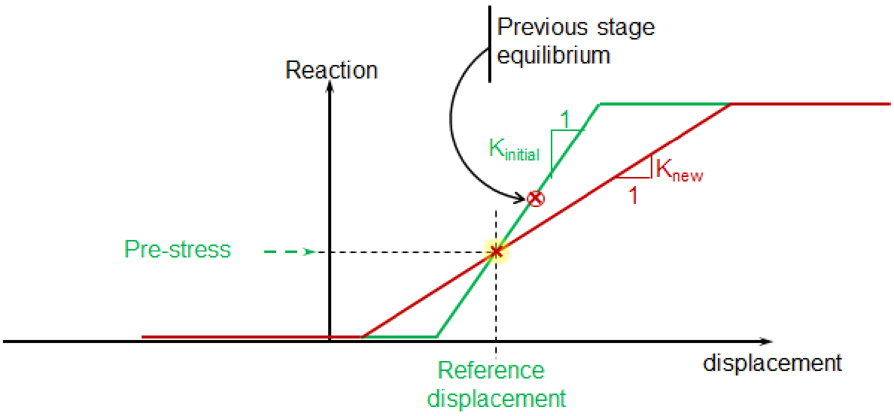


Figure C15: Creep of the anchors - modification of the mobilization law

C.2.5.2.2. Stiffening

A stiffness increment is treated by applying a rotation of the reaction law around the equilibrium point achieved in the previous phase (and not around the reference point as in the case of a creep). As a result, the previous equilibrium is not modified and no movement is generated in the absence of any other load.

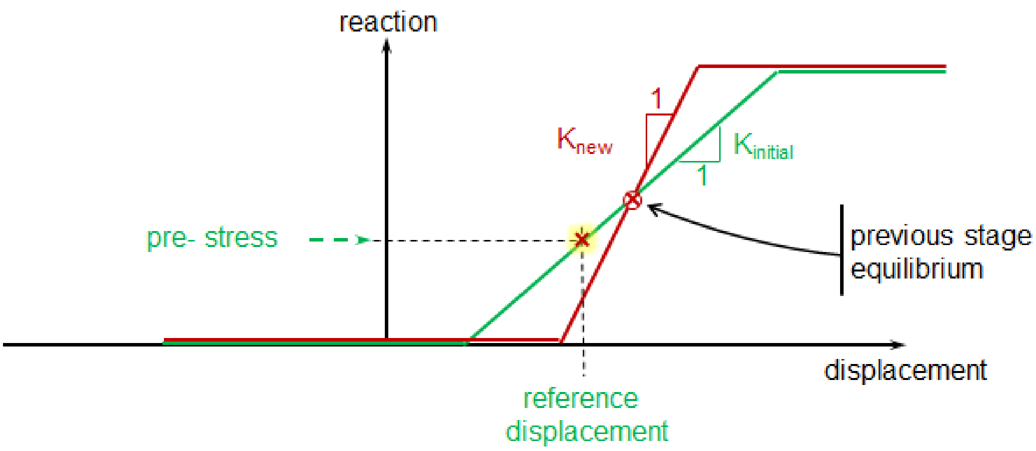


Figure C16:Increase of anchor stiffness

C.2.5.2.3. *Modification of pre-loading*

The modification of the pre-stress during phasing is treated as a vertical shift of the mobilization curve equal to the difference between the new pre-loading and the original one (figure below).

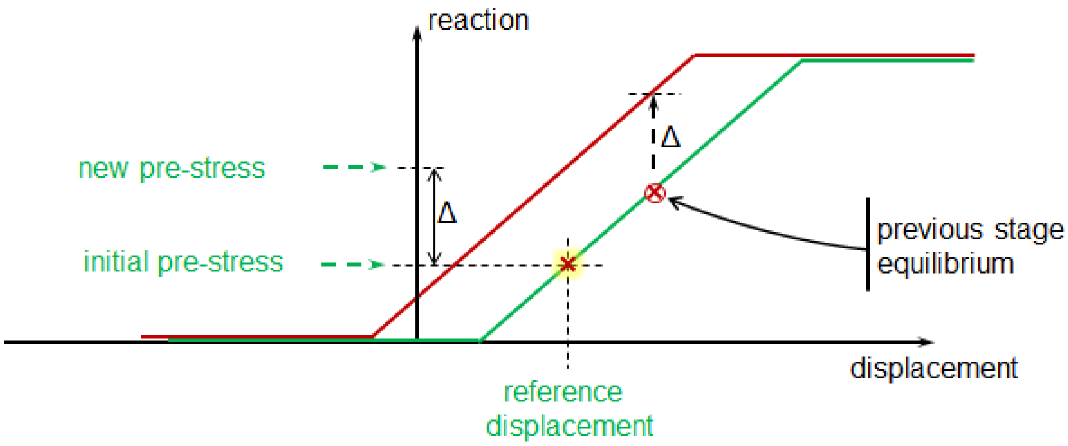


Figure C17: Effect of a change in preload during phasing

C.2.5.2.4. *Detachment*

The anchors working "unilaterally" follow a reaction curve that includes a 'minimum' level. The detachment/re-examination process is schematized in the figure below.

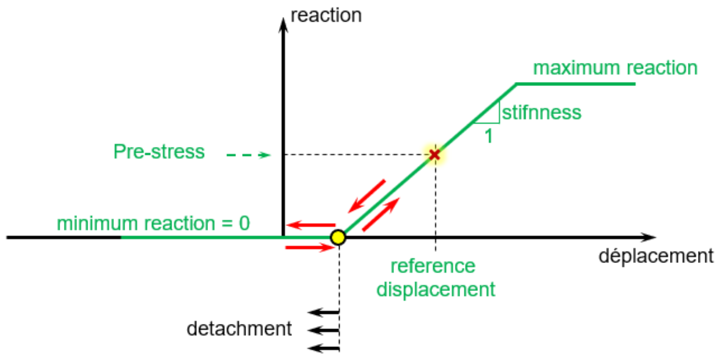


Figure C18: Process of detachement/repasting for an anchor working unilateraly

C.2.5.2.5. Plastification

In the general case, plastification management during phasing is conducted in a similar way to the law of soil/wall interaction, by updating the law of mobilization at each stage taking into account the accumulation of irreversible displacements.

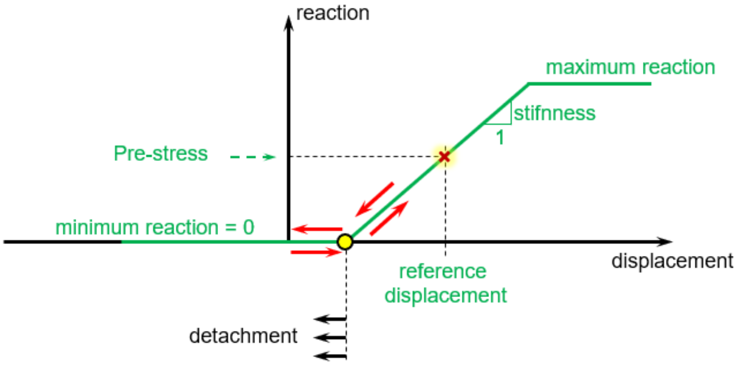


Figure C19: Plastification of the anchors during phasing - general principle diagram

C.3. Implementation

C.3.1. Ground and water pressure

C.3.1.1. At-rest earth pressure

The (horizontal) pressure for zero displacement uses, in the initial state of the ground, the notion of active earth pressure at rest characterized by the active earth pressure at rest coefficient, k_0, assigned to the considered soil layer, in which case:

$$p_i = p_0 = k_0.\sigma'_{v0}$$

The value of k_0 is a function of the intergranular friction angle of the soil, of the initial ground's slope as well as of the over-consolidation state (cf. §C.5.1.1). The effective vertical stress, at rest, is evaluated as follows:

$$\sigma'_{v0} = \int_0^{z_w} \gamma dz + \int_{z_w}^{z} \gamma' dz$$

In which:

γ	total soil unit weight above water table
γ'	submerged soil unit weight below water table
z_w	preatic level

As stated in the § C.2.5.1.1, the modification of this pressure under the effect of a vertical stress increment uses the notion of decompression/recompression coefficients (k_r and k_d) according to the following equation:

- $\Delta p_i = k_r.\Delta\sigma'_v$ if $\Delta\sigma'_v > 0$
- $\Delta p_i = k_d.\Delta\sigma'_v$ if $\Delta\sigma'_v < 0$

The definition of these coefficients is detailed in §C.5.1.2.

C.3.1.2. Pressure limit

The limits of active/passive earth pressures are linked to the effective vertical stress σ_v' (at the level of the wall) through the coefficients of active/passive pressure:

- Limit active earth pressure: $p_a = \max\left(k_{a\gamma}.\sigma'_v - k_{ac}.c \,;\, k_{a\min}.\sigma'_v\right)$
- Limit passive earth pressure: $p_b = \min\left(k_{p\gamma}.\sigma'_v + k_{pc}.c \,;\, p_{\max}\right)$

In which:

$k_{a\gamma}$	coefficient of active earth pressure (cf. §0)
k_{ac}	coefficient of active pressure related to cohesion (cf. §0)
$k_{a\min}$	coefficient of minimum active pressure, by default equal to 0.10 (NF P 94-282)
$k_{p\gamma}$	coefficient of passive earth pressure (cf. §0)
k_{pc}	coefficient of passive earth pressure related to cohesion (cf. §0)
$p_{\max}$	ultimate soil pressure (applicable value for a discontinued wall)
c	soil cohesion

C.3.1.3. Pore pressure

C.3.1.3.1. Hydrostatic system

In hydrostatic state, the pore-water pressure on the screen is evaluated as follows:

$$u_w^0(z) = \gamma_w (z - z_w)$$

Where γ_w designates the unit weight of the water.

C.3.1.3.2. Hydraulic gradient

The presence of a hydraulic gradient (upward flow) means there is a hydraulic state different from the hydrostatic one. Such state can be characterized with a pore pressure diagram defined according to the following equation:

$$u_w(z) = \gamma_w [z - h_w(z)]$$

Where $h_w(z)$[2] designates the hydraulic potential at depth z.
The presence of a hydraulic gradient also implies the effective vertical stress will be modified according to the following relationship:

$$\sigma'_v = \sigma'_{v0} - \Delta\sigma(u) \text{ In which } \Delta\sigma(u) = u_w - u_w^0 = [z_w - h_w(z)].\gamma_w$$

An « ascendant » hydraulic gradient ($u_w \geq u_w^0$) reduces the effective stress, and therefore, the available resistance (reduction of the limit of the passive earth pressure).

C.3.1.4. Backfill

Activation of a fill during phasing has the effect of initializing a new soil layer above the ground below the fill with:

- Under the embankment, an increase in vertical stresses due to the weight of the embankment
- On the height of the embankment, the initialization of a soil pressure mobilization law according to the following principles:
  - During the backfill placement phase, the backfill acts as a horizontal pressure imposed on the wall equal to $p_i = k_i.\sigma'_v$;
  - From the phase following the placement of the backfill, it behaves like a soil layer with a mobilization law characterized by an initial pressure equal to p_i, a reaction coefficient k_h and limit pressures of active/passive p_a and p_b (calculated according to the principles described in §C.3.1.2).

The coefficient ki can be chosen according to the following principles:

- $k_i = k_0$ to represent a state of stress close to that of a soil at rest;
- $k_i > k_0$ to account for a compaction of the soil constituting the backfill;
- $k_i = k_a$ to simulate the mobilization of an active limit state (ignoring the effect of cohesion).

[2] In the case of an hydraulic system, we have: $h_w(z) = Cte = z_w$

C.3.2. Soil overload

C.3.2.1. Caquot

It consists in a semi-infinite load on one side of the wall, at a depth z_0. Its application induces an increment of uniform horizontal stress below z_0:

$$\Delta\sigma_v(z) = q \quad \text{for} \quad z \geq z_0$$

C.3.2.2. Boussinesq overload

C.3.2.2.1. General case

It consists in a localized vertical overload, of length l and density S, applied at a depth z_0 and at a distance x from the wall. Its application induces an increment of the horizontal stress at the wall level estimated by integrating the Boussinesq solution (initially established for the case of semi-infinite homogenous soil):

$$\Delta\sigma_h = \alpha_e \frac{S}{\pi}\left(\text{atg}\left(\frac{hl}{x(x+l)+h^2} \right) + \frac{xh}{x^2+h^2} - \frac{(x+l)h}{(x+l)^2+h^2} \right) \quad \text{where} \quad h = z - z_0$$

The factor α_e designates an amplifier factor that takes into account the « mirror effect » implicitly induced by the presence of the retaining wall (by construction, this effect is not included in the Boussinesq solution). The value α_e can be approximately calculated using the following formula (NF P 94 282):

$$\alpha_e \approx \frac{x+2}{x+1}$$

In AMRetain, this horizontal stress increment is « transformed » in an equivalent increment of the vertical stress through the following association:

$$\Delta\sigma_v = \frac{1}{0{,}5}\Delta\sigma_h$$

On the base of this vertical stress increment (equivalent), the modification of the initial levels of active and passive pressure, is made according to the equation described in §C.2.5.1.1.

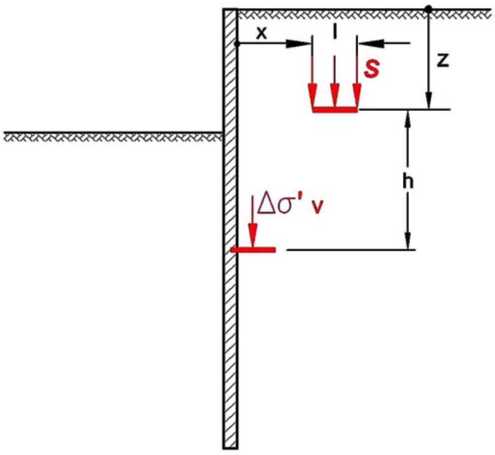


Figure C20: Simulation of an overload on the ground with the Boussinesq model

C.3.2.2.2. Case of an overload defined in the initial stage

For the overloads defined in the common calculation stages, the stress increment is only considered on the side where the overload is applied (wall effect). In the initial stage, when the wall isn't implemented yet, there is stress continuity from one side of the wall to the other and the increment that results from a declared overload in the initial stage is considered (initially) on both sides of the wall.

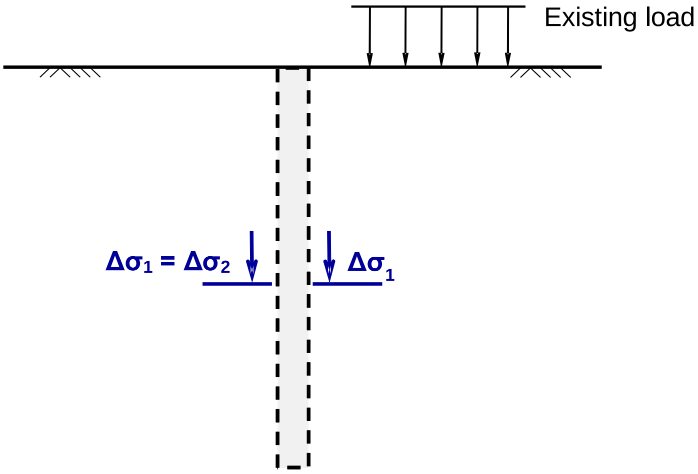


Figure C21: Treatment of a « Boussinesq » overload defined in the initial stage

Therefore, a Boussinesq overload defined in the initial stage (representative for example of an existingt building) requires the following adaptations (applied automatically by the computation engine):

- increment of the identical horizontal and vertical equivalent stresses on both sides of the wall;
- absence of the mirror effect ($\alpha_e = 1$).

These adaptations apply for the Boussinesq overloads and for the actions that depend on it (initial pressure related to the effects of the embankment and platform – cf. § C.3.3).

C.3.3. Slope and berm

The simulation of slope and berm effects can be conducted with three different approaches.

C.3.3.1. Method of equivalent overloads

In the case of a slope, this method consists in assimilating the slope's weight to a superposition of Boussinesq overloads of equivalent density S(x) as shown in the figure herebelow. Active/passive pressure levels (initial and limit) are updated following the same steps as the ones described in §C.2.5.1.1 and §C.3.2.2.

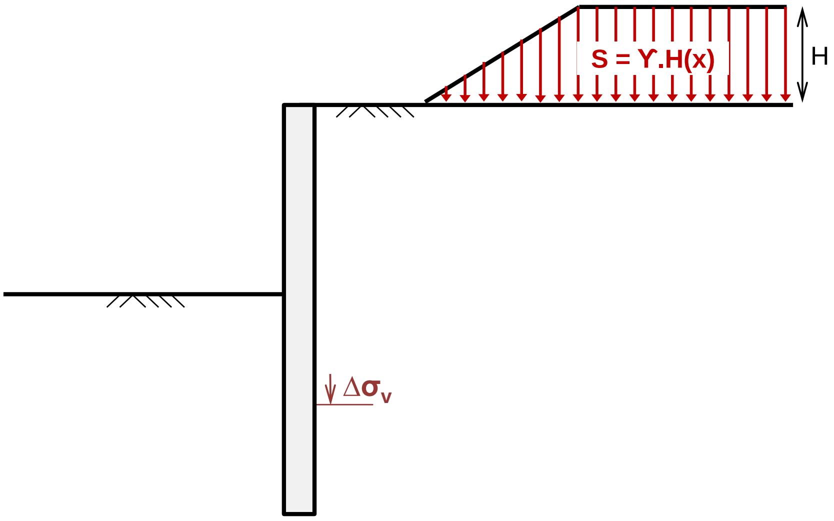


Figure C22: Simulation of the effect of a slope through Boussinesq equivalent overloads

In the case of a berm, this method consists in assimilating the berm to a fictitious horizontal layer whose weight is corrected by superposition of negative semi-infinite overloads applied at different levels on the height of the berm, as in the figure below.

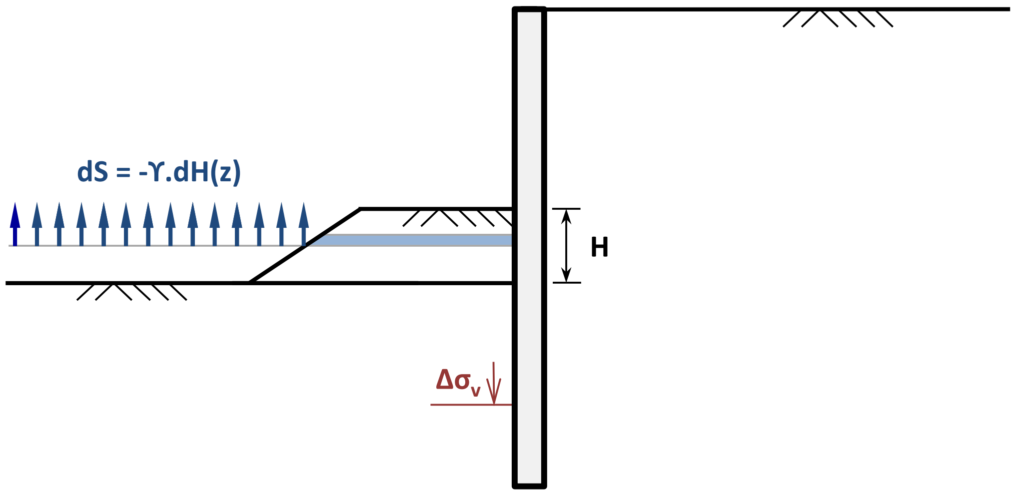


Figure C23:Figure C1 : Simulation of the effect of a berm through equivalent Boussinesq overloads

The update of active/passive pressure levels (initial and limit) follows the same process as described in §C.2.5.1.1 and §C.3.2.2.

Attention is drawn on the fact that such an approach is likely to lead in some cases to overly optimistic results (cf. NF P 94 282).

C.3.3.2. Models complying with NF P 94-282

The application of the model below aims exclusively to control the diagrams of active/passive pressure limits in relation to the recommendations of standard NF P 94 282. The "initial" (or at rest) active pressure is, in any case, evaluated with the equivalent overloads method described previously.

C.3.3.2.1. Case of a slope

The standard NF P 94 282 recommends carrying out the evaluation of the effects of a slope in compliance with the Houy model as shown in the figure below.

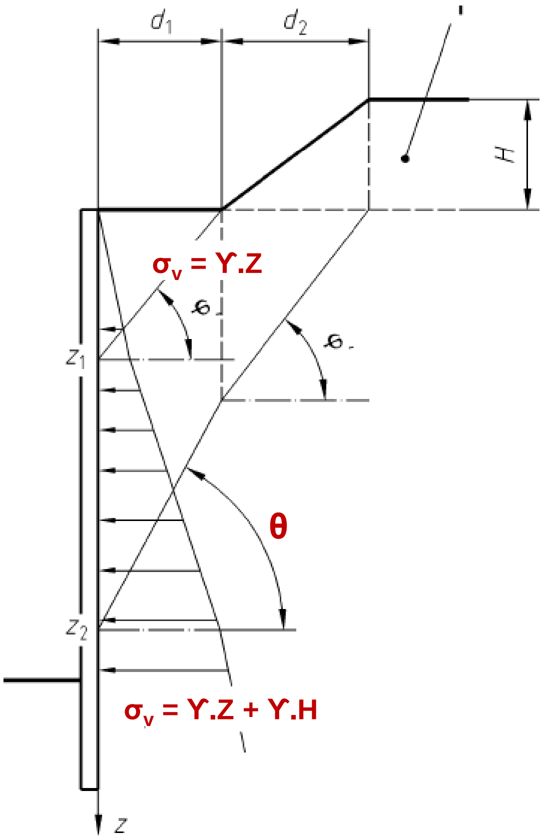


Figure C24: Effect of a slope according to the Houy model

According to the notations of the figure above:

- for $z \leq z_1$ slopes not taken into account
- for $z \geq z_2$ effect equivalent to a Caquot equivalent overload
- for $z_1 \leq z \leq z_2$ linear interpolation of active/passive pressure diagrams

The value of θ is taken to be equal to:

- $\theta = \frac{\pi}{4} + \frac{\varphi}{2}$ for the evaluation of the active pressure limit;
- $\theta = \frac{\pi}{4} - \frac{\varphi}{2}$ for the evaluation of the passive pressure limit;

The case of a multilayer requires a suitable reprocessing of the model, which is automatically managed by AMRetain (scheme incorporating a variable friction angle by layer).

C.3.3.2.2. Case of a berm

Houy's model principle previously described can be extended to the case of a berm as presented in figure below.

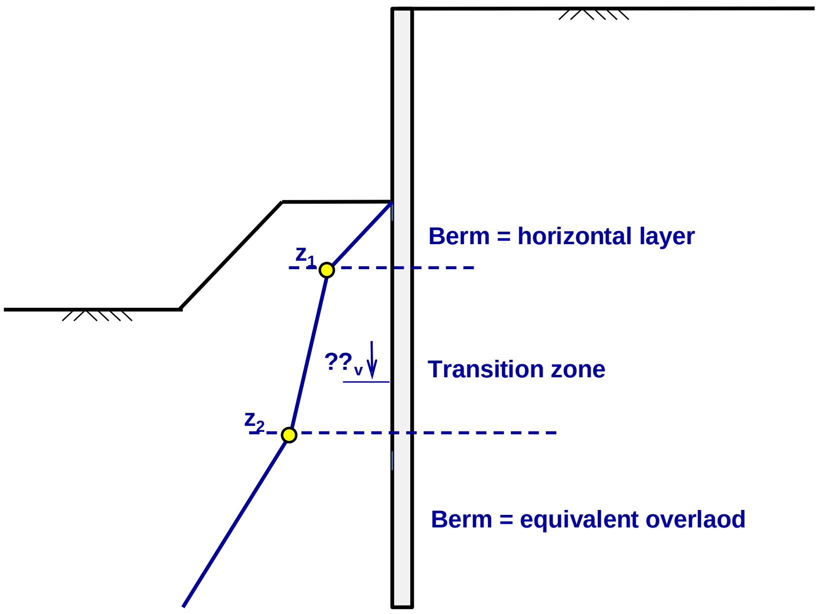


Figure C25: Effect of a berm according to the generalized Houy model

There are three areas:

- for $z \leq z_1$ — the effect of the berm is the effect of a horizontal layer
- for $z \geq z_2$ — effect equivalent to the effect of an equivalent overload
- for $z_1 \leq z \leq z_2$ — linear interpolation of active/passive pressure diagrams

Furthermore, the standard NF P 94-282 recommends, in the absence of an advanced approach, to control the limit of the passive pressure at height H of a berm by ensuring that it does not exceed the resulting shear force mobilisable at the base of the berm, according to the notations of the figure hereunder:

$$B_{max} = \frac{1}{2} k_p \gamma H^2 + k_{pc} c.H \leq W.\tan(\varphi) + c.L_r$$

It is implicitly assumed that the failure mechanism of the passive pressure is a horizontal plan which is developed preferentially at the base of the berm. Note that AMRetain applies this verification at all points at the full height of the berm.

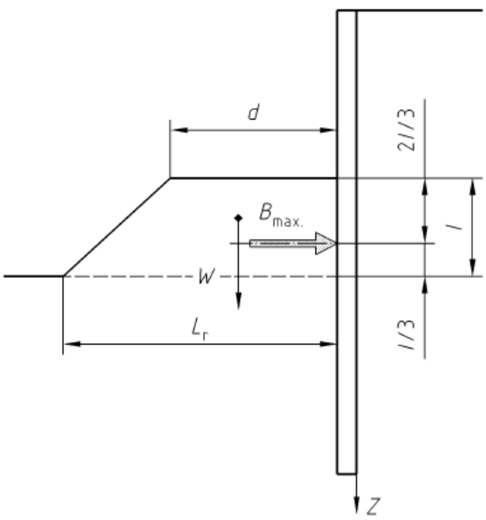


Figure C26: "Banquette approach" to control the limit passive earth pressure over the entire height of a berm

C.3.4. Treatment of load combinations

The treatment of complex projects with a large number of load cases requires an automated management study of different combinations depending on the regulatory framework applicable to the project. This concerns all applications where the wall communicates with civil engineering works (directly or indirectly through the foundation block). This also concerns the harbour structures with a high number of combinations to study and is too laborious for manual processing.

The phasing diagram usually considered for civil engineering calculations consists of treating load combinations through orphan complementary stages issued from the studied stage (stage 1 by combination). The validity of such pattern implicitly assumes “elastic linear” behaviour and the lack of any 'irreversible' displacements of the system, which is not the case of a retaining structure: in this case it is essential to ensure the consistency of the elastoplastic calculation for a given load combination. This justifies the use of the stage principle, shown below, which consists in generating a "full" phasing diagram in parallel to each of the combinations studied. Then, the interface only operates the stages for which the combination has been requested.

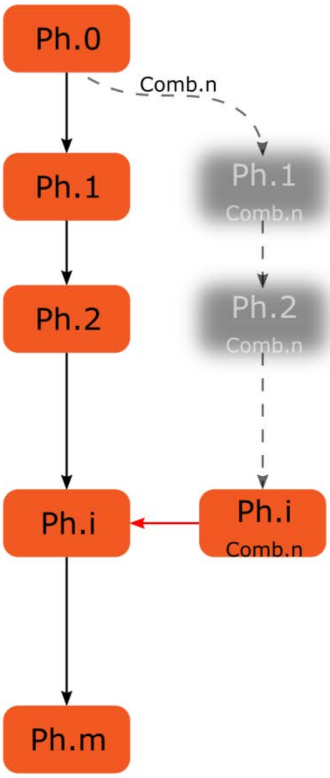


Figure C27: Phasing principle for the treatment of a load combination

Note that for ULS calculations, the defined weighting s of load combinations are added to the specific ones that belong to the calculation approach of ULS checks:

- ULS Calculation without load combinations $S_{calculation} = \gamma_Q.S$
- ULS calculation with load combinations $S_{calculation} = \psi_{combination}.\gamma_Q.S$

C.3.5. Taking into account seismic conditions

C.3.5.1. Principle

The seismic effects in AMRetain are simulated using a pseudo-static approach, whose principles are the following (see figure below):

- Re-evaluation of limit levels of active pressure (p_a) and of passive pressure (p_b) on each side of the screen, taking into account the inertia forces in the soil;
- Reassessment of the water pressure on the wall taking into account hydrodynamic effects in the levels where the watertable is considered to be 'free' under earthquake conditions ('open' soil with or without earthquake);
- Taking into account the inertia forces $F_H = k_H P_{wall}$ x and $F_V = k_V$ x P_{wall} associated with the dead weight of the wall P_{wall};
- Revaluation of anchor stiffness;
- Zero modifications in the elastic level (k_h) and in the initial pressure p_i.

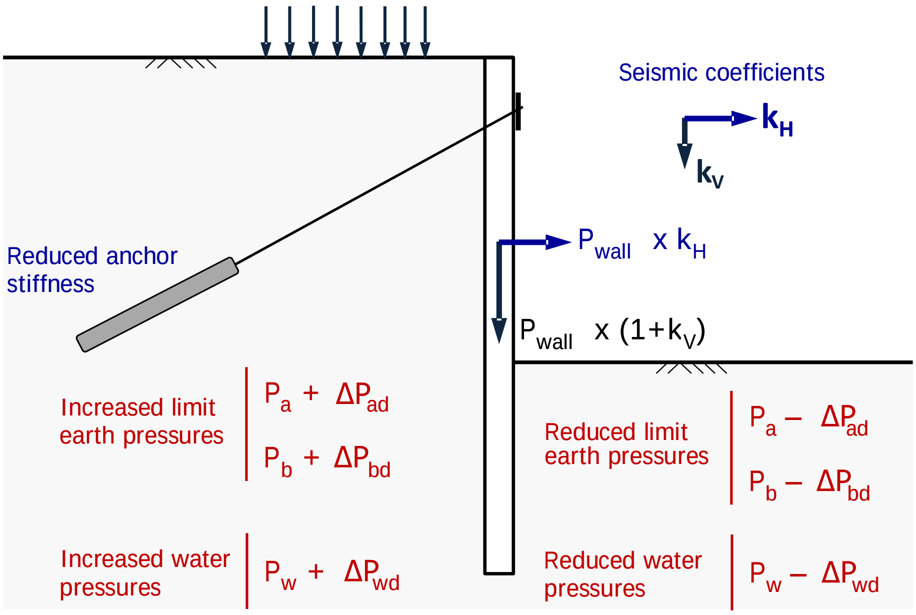


Figure C28:Taking into account seismic conditions – principles of the implemented method in AMRetain v2

C.3.5.2. Behaviour modes under seismic conditions

The implementation of the pseudo-static method for the calculation of the retaining structures under seismic conditions differentiates, in the framework of Eurocode 8 - part 5, three types (or modes) of soil behaviour under seismic stress: dry soil, 'open' soil and 'closed' soil. For each type of behaviour, the table below details the soil characteristics to take into account for the seismic calculations.

Case	Type of soil	Shear behaviour	Shear parameters	Soil weight
A	Sands and gravels above water table	Friction	Friction angle	$\gamma^* = \gamma$
B	Soil « open» below watertable = very permeable under seism	Friction	Friction angle	$\gamma^* = \gamma'$
C	Soil « closed» below watertable = « waterproof» under seism	Cohesion	Undrained cohesion	$\gamma^* = \gamma'$

Table C1: Types of behaviour under seismic conditions

C.3.5.3. Seismic coefficients

The implementation of the pseudo-static method is based on the concept of seismic coefficients defined as follows:

$$k_H = \frac{1}{r}\frac{a_N}{g} \qquad\qquad k_V = \pm\frac{1}{2}k_H$$

Where a_N refers to nominal seismic acceleration, which is a function of the seismicity zone, of the soil classification and of the type of structure.

The parameter 'r' is a dimensionless factor bigger than/or equal to 1, which is a function of the sensitivity of the stucture whose displacements have been studied. A value of r = 1 must be considered for a structure sensitive to displacements.

The concept of seismic coefficients allows to introduce the concept of equivalent seismic inclination Θ whose value depends on the type of behaviour according to the notations of the previous table:

- o Case A (sands and gravels above water table) $\tan\theta = \frac{k_H}{1 \pm k_V}$
- o Case B (open soil below water table) $\tan\theta = \frac{\gamma_d}{\gamma'}.\frac{k_H}{1 \pm k_V}$
- o Case C (closed soil below water table) $\tan\theta = \frac{\gamma}{\gamma'}.\frac{k_H}{1 \pm k_V}$

In which
- o γ total soil weight above water table;
- o γ' submerged soil weight below water table;
- o γ_d soil weight below water table (not submerged).

C.3.5.4. Increment of the active dynamic pressure (limit)

Seismic effects imply a reduction of the shear strength available and therefore an increase of the level of the ultimate active earth pressure through a "dynamic" increment Δp_{ad}, as schematized in the figure below.

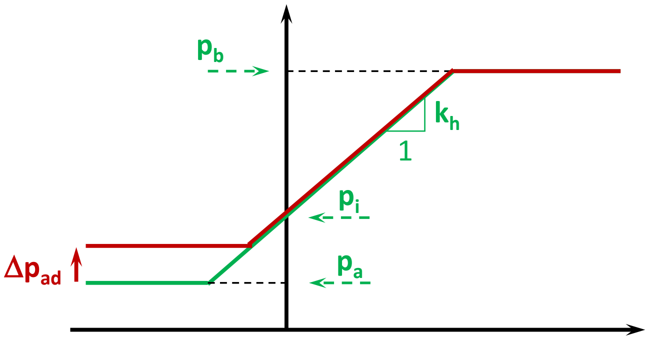


Figure C29: Taking into account a dynamic increment of the active earth pressure limit

The evaluation of this dynamic increment is conducted using a generalized form of the Mononobe-Okabe method (1924), extended to the case of a soil with a non-zero cohesion. This model consists in the generalization of the Coulomb active pressure corner by integrating to the forces equilibrium those related to the effects of inertia, which influence the mass of the block, as shown in the figure below: P refers to the « stabilizing » reaction of the wall at the limit equilibrium state (resulting in the limit of the active earth pressure).

The method simply explores the failure plan mechanisms forming an angle α with respect to the wall. For each value of α, the vertical and horizontal forces components at limit equilibrium limit leads to a system with two equations and two unknown values (R_f and P), which allows to estimate the value of P(α). Then, we calculate the value of α when P is at its maximum.

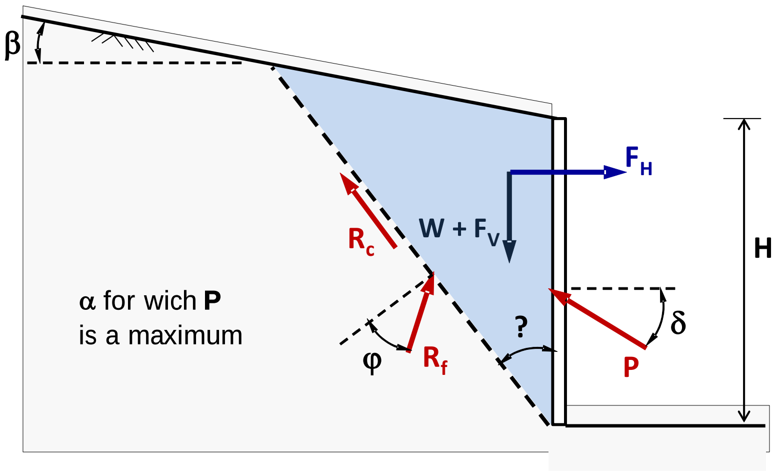


Figure C30: Mononobe-Okabe model for a non-zero cohesion soil – active pressure mechanism

The implementation of this model allows to establish the equation that results from the dynamic active pressure limit:

$$P_{ad} = K_{ad}\left[\frac{1}{2}\gamma^*(1 \pm k_V)H^2\right] - K_{acd}[cH]$$

The coefficients of the dynamic active pressure K_{ad} and K_{acd} are functions of four parameters:

$$\begin{cases} K_{ad} = f_1(\varphi, \delta, \theta, \lambda) \\ K_{acd} = f_2(\varphi, \delta, \theta, \lambda) \end{cases} \quad \text{where} \quad \lambda = \frac{\gamma H}{2c}$$

Functions f_1 and f_2 are obtained through digital integration. The figure below shows the case of a horizontal active earth pressure (δ = 0).

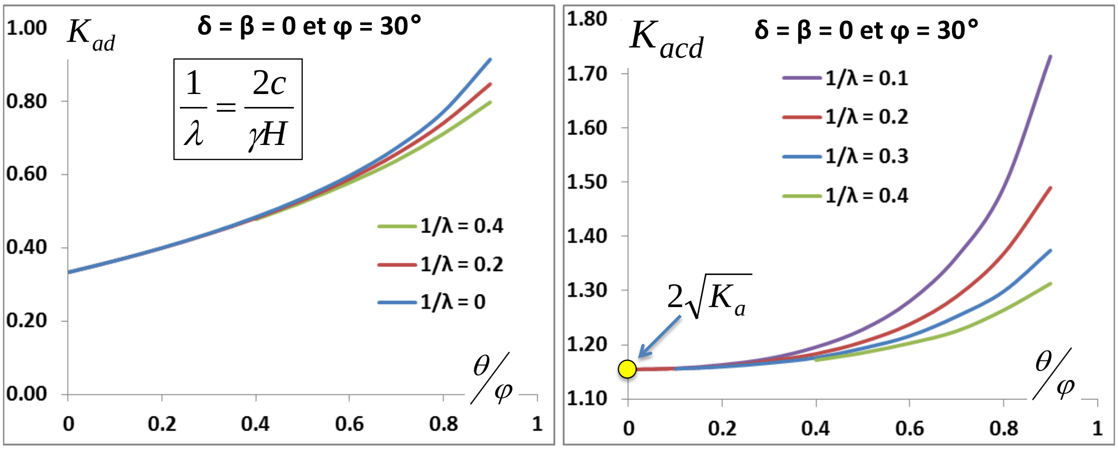


Figure C31: Mononobe-Okabe Model for a non-zero cohesion - soil coefficients of dynamic active pressure

On the basis of the variation of P_{ad} with depth, we can estimate by differentiation, a dynamic active pressure density p_{ad} between depths z_{i-1} and z_i from the top of the wall:

$$p_{ad}(z_{i-1} \le z \le z_i) = \frac{P_{ad}(H = z_i) - P_{ad}(H = z_{i-1})}{z_i - z_{i-1}}$$

We can then deduce the 'dynamic' increment to be considered on the 'static' active pressure limit:

$$\Delta p_{ad} = p_{ad}(k_H, k_V) - p_{ad}(k_H = 0, k_V = 0)$$

The limit active pressure taken into account in the calculation can also be expressed as:

$$p_a\big|_{statique+dynamique} = p_a\big|_{statique} + \Delta p_{ad}$$

C.3.5.5. Increment of the (limit) dynamic passive pressure

Seismic effects imply a reduction in shear resistance and therefore a decrease in the level of the limit passive pressure through a "dynamic" increment Δp_{bd}, as schematized in figure below.

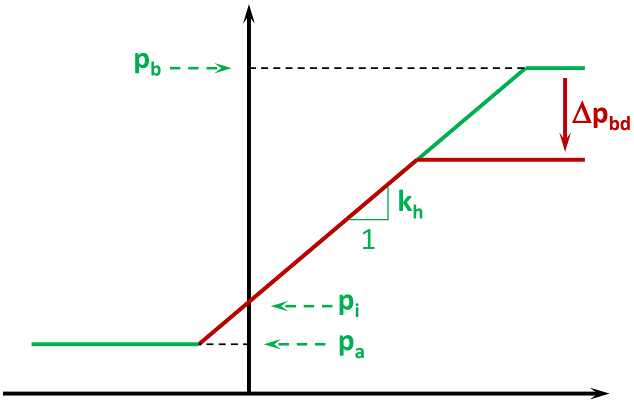


Figure C32: Taking into account a dynamic increment on the level of passive pressure limit

The evaluation of this dynamic increment is conducted using a generalized form of the Mononobe-Okabe method (1924), extended to the case of a soil with a non-zero cohesion. This model consists in the generalization of the Coulomb active pressure corner by integrating to the forces equilibrium those related to the effects of inertia, which influence the mass of the corner, as shown in the figure below: P refers to the « destabilizing » reaction of the wall at the limit equilibrium state (resulting in the limit of the passive earth pressure).

This method simply explores the failure plan mechanisms forming an angle α with respect to the wall. For each value of α, the vertical and horizontal forces components at limit equilibrium limit leads to a system to two equations and two unknown values (R_f and P), which allows to estimate the value of P(α). Then, we calculate the value of α when P is at its minimum.

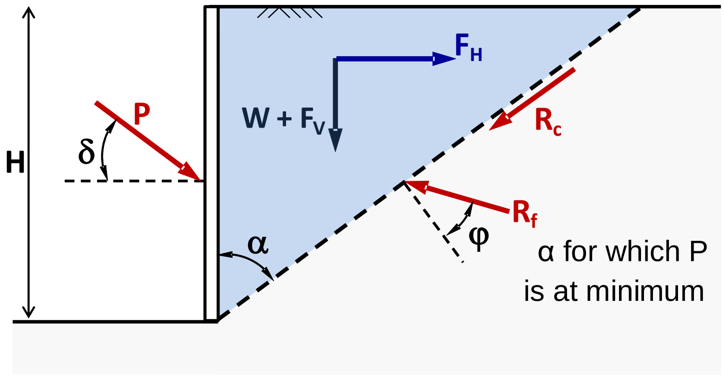


Figure C33: Mononobe-Okabe model for a non-zero cohesion soil – passive pressure mechanism

This method allows to establish the equation that results from the limit dynamic passive pressure:

$$P_{bd} = K_{pd}\left[\frac{1}{2}\gamma^{*}(1 \pm k_V)H^2\right] + K_{pcd}[cH]$$

The coefficients of dynamic passive pressure K_{pd} et K_{pcd} are functions of four parameters:

$$\begin{cases} K_{pd} = g_1(\varphi, \delta, \theta, \lambda) \\ K_{pcd} = g_2(\varphi, \delta, \theta, \lambda) \end{cases} \quad \text{where } \lambda = \frac{\gamma H}{2c}$$

The functions g_1 and g_2 are obtained by digital integration.

On the basis of the variation of P_{bd} with depth, estimated by differentiating a density of dynamic passive pressure p_{bd} between depths z_{i-1} and z_i from the top of the wall:

$$p_{bd}(z_{i-1} \le z \le z_i) = \frac{P_{bd}(H = z_i) - P_{bd}(H = z_{i-1})}{z_i - z_{i-1}}$$

We can then deduce the 'dynamic' increment to be considered on the limit "static" passive pressure:

$$\Delta p_{bd} = p_{bd}(k_H = 0, k_V = 0) - p_{bd}(k_H, k_V)$$

The limit passive pressure taken into account in the calculation is:

$$p_b|_{statique+dynamique} = XP.(p_b|_{statique} - \Delta p_{bd})$$

Where XP is a multiplying factor (less than/or equal to 1.00) that aims at reducing the passive pressure taken into account in the calculation for structures that are sensitive to displacements (for sensitive industrial facilities XP is usually between 0.33 and 0.50).

C.3.5.6. Hydrodynamic effects

The hydrodynamic effects, which are likely to develop in the levels where the water is considered to be earthquake "free" (soil absence or 'open' soil), are simulated using the Westergaard method as shown in the figure below.

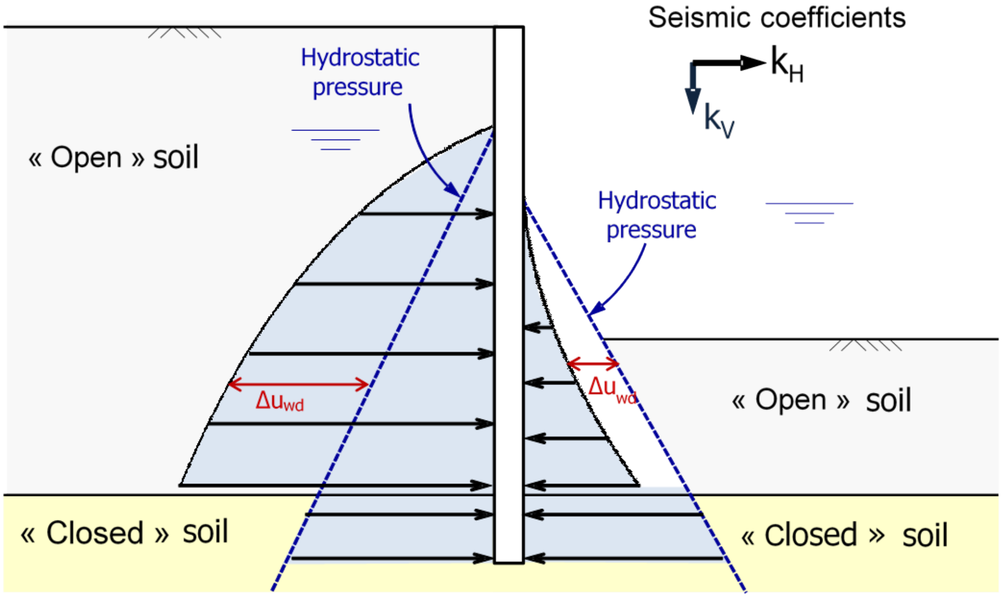


Figure C34: Principle of the Westergaard method as implemented in AMRetain

Taking into account seismic conditions implies a 'static' water pressure modification of the dynamic increment, such as (in the 'open' soil layers the watertable):

$$u_w \big|_{static+dynamic} = u_w \big|_{static} \pm \Delta u_{wd}$$

In which:

$$\Delta u_{wd}(z) = \frac{7}{8} k_H \gamma_w \sqrt{Hz}$$

Where:

- o Z designates the depth of the calculation point below the water table;
- o H designates the height of the watertable from the base of the wall.

C.3.5.7. Modification of anchors stiffness

The seismic effects induce a modification of the anchors' visible stiffness, according to the following equation:

$$K_{dynamic} = \frac{1}{1+1{,}5|k_H|} \left(\frac{\cos(\alpha \pm \theta)}{\cos\alpha} \right)^2 .K_{static}$$

Where α refers to the inclination of the anchor from the horizontal axes.

C.4. ULS checks

C.4.1. Calculation approaches

C.4.1.1. Weighting principle

The weighting system of AMRetain is applied on moments (variable and permanent), moment effects (calculation results), strength parameters (shear characteristics), as well as on strenght (passive pressure and anchors). Three calculation approaches are proposed (1, 2 and 3) according to Eurocode 7 and its application standard NF P 94-282.

C.4.1.1.1. Action weighting

Moment weighting is applied according to the following equation:

$$A_d = \gamma_A . A_k$$

In AMRetain, this concerns the following parameters:

- « Active » soil pressure — weighting of active pressure limit coefficients
- Water pressure — weighting of differential water pressure
- Soil overloads — weighting of the value of overloads characteristics
- Wall overloads — weighting of the value overloads characteristics

C.4.1.1.2. Weighting of moment effects

The weighting of the moment effects is applied according to the following equation:

$$E_d = \gamma_E . E_k$$

In AMRetain, this applies to the "results" of the calculation and aims to evaluate calculation values of loads on the wall, the anchors and on the soil:

- Loads on the wall — weighting of efforts diagram (N, V, M)
- Anchorage forces — weighting of reactions of struts and anchors
- Mobilized passive pressure — weighting of the mobilized passive pressure

The value of the partial coefficient γ_E is identical for all action effects.

C.4.1.1.3. Weighting of shear parameters

The weighting of shear parameters is applied according to the following equation:

$$\tan\varphi_d = \frac{\tan\varphi_k}{\gamma_M} \qquad c_d = \frac{c_k}{\gamma_M}$$

In AMRetain, this implies a reassessment of the (limit) active/passive pressure coefficients on the basis of the calculation value of shear parameters. It is worth noting that the pressure at rest (k0) coefficients and the reaction coefficient remain unaltered.

C.4.1.1.4. Strength weighting

The weighting of the resistances is applied according to the following equation:

$$R_d = \frac{R_k}{\gamma_R}$$

In AMRetain, this concerns the following parameters:

- Soil limit passive pressure — weighting of passive pressure (post-treatment)
- Anchorage structure — weighting of the elastic limit of anchors
- Anchor block — weighting of the disruptive strain issued from Kranz

C.4.1.2. Approach 2/2* - NF P 94 282

According to the Eurocode 7 application standard in France (NF P 94-282), the approach 2/2* offers partial coefficients which differ according to the calculation method used (SSIM or LEM) for the wall equilibrium:

- SSIM: weighting (post-processing) of the effects of moments and strength;
- LEM: weighting (at the source) of moments and strength;

In both cases, no weighting is applied to strength parameters.

The table below shows the partial coefficients proposed by default in AMRetain when this approach is used.

		Approach 2/2*	SSIM method	LEM method
Actions (γ_A)	Limit active soil pressure		1.00	1.35
	Water pressure		1.00	1.35
	Wall weight		1.00	1.35
	Loads applied on soil	Permanent	1.00	1.00
		Variable	1.11	1.11
	Loads applied on wall	Permanent favorable	1.00	1.00
		Permanent unfavorable	1.00	1.35
		Variable unfavorable	1.11	1.50
Effect of actions (γ_E)	Wall loads Anchor loads Mobilized passive pressure		1.35	1.00
Strength parameters (γ_M)	Friction angle	Drained behaviour	1.00	1.00
	Cohesion (effective)	Drained behaviour		
	Friction angle	Undrained behaviour	1.00	1.00
	Cohesion	Undrained behaviour		
Resistances (γ_R)	Mobilisable passive pressure	Permanent stage	1.40	1.40
		Transitory stage	1.10	1.10
	Support strength	Elastic limit	1.00	-
	Anchor block (Kranz)	Disruptive strain	1.10	-

*Table C2: Partial coefficients applied with approach 2/2 **

C.4.1.3. Approach 3

Approach 3 offers by default identical partial coefficients between SSIM and LEM methods.

Unlike approach 2/2*, this approach is characterized by the weighting application at the source on the strength parameters (c and φ), which requires a reassessment by the computation engine of the active/passive pressure coefficients considered in the ULS calculations:

$$k_{a,d} = k_a\left(\frac{\tan\varphi_k}{\gamma_M}\right) \qquad k_{p,d} = k_p\left(\frac{\tan\varphi_k}{\gamma_M}\right)$$

Then, except for the transitory overloads (weighted by 1.30), weighting isn't applied on actions (nonstructural initial permanent loads), on moment effects or on strength.

It should be noted that this approach doesn't allow (by default) to differentiate any security level between transitory and permanent stages.

The table below shows the partial coefficients proposed by default in AMRetain when this approach is used.

		Approach 3	SSIM method	LEM method
Actions (γ_A)	Limit active soil pressure		1.00	1.00
	Water pressure		1.00	1.00
	Wall weight		1.00	1.00
	Loads applied on soil	Permanent	1.00	1.00
		Variable	1.30	1.30
	Loads applied on wall	Permanent favorable	1.00	1.00
		Permanent unfavorable	1.35	1.35
		Variable unfavorable	1.50	1.50
Effect of actions (γ_E)	Wall loads Anchor loads Mobilized passive pressure		1.00	1.00
Strength parameters (γ_M)	Friction angle Cohesion (effective)	Drained behaviour Drained behaviour	1.25	1.25
	Friction angle Cohesion	Undrained behaviour Undrained behaviour	1.40	1.40
Resistances (γ_R)	Passive pressure mobilized	Permanent stage	1.00	1.00
		Transitory stage	1.00	1.00
	Support strength	Elastic limit	1.00	-
	Anchor block (Kranz)	Disruptive strain	1.00	-

Table C3: Partial coefficients applied with approach 3

C.4.1.4. Approches 1.1/1.2

Approach 1 has two "variations":

- a possible variant 1.1 similar to approach 2 (moment weighting, no weighting of the strength parameters);
- a possible variant 1.2 similar to approach 3 (weighting of strength, no weighting of moments);

In countries where this approach applies (for example in England), it is advised to examine successively the two existant variants and retain the one leading to the worst-case scenario design.

The tables below show the partial coefficients proposed by default in AMRetain when this approach is used.

	Approach 1.1		SSIM method	LEM method
Actions (γ_A)	Limit active soil pressure		1.35	1.35
	Water pressure		1.35	1.35
	Wall weight		1.35	1.35
	Loads applied on soil	Permanent	1.00	1.00
		Variable	1.11	1.11
	Loads applied on wall	Permanent favorable	1.00	1.00
		Permanent unfavorable	1.35	1.35
		Variable unfavorable	1.50	1.50
Effect of actions (γ_E)	Wall loads Anchor loads Mobilized passive pressure		1.00	1.00
Strength parameters (γ_M)	Friction angle	Drained behaviour	1.00	1.00
	Cohesion (effective)	Drained behaviour		
	Friction angle	Undrained behaviour	1.00	1.00
	Cohesion	Undrained behaviour		
Resistances (γ_R)	Passive pressure mobilized	Permanent stage	1.00	1.00
		Transitory stage	1.00	1.00
	Support strength	Elastic limit	1.10	-
	Anchor block (Kranz)	Disruptive strain	1.00	-

Table C4: Partial coefficients applied with approach 1.1

	Approach 1.2		SSIM method	LEM method
Actions (γ_A)	Limit active soil pressure		1.00	1.00
	Water pressure		1.00	1.00
	Wall weight		1.00	1.00
	Loads applied on soil	Permanent	1.00	1.00
		Variable	1.30	1.30
	Loads applied on wall	Permanent favorable	1.00	1.00
		Permanent unfavorable	1.00	1.00
		Variable unfavorable	1.30	1.30
Effect of actions (γ_E)	Wall loads Anchor loads Mobilized passive pressure		1.00	1.00
Strength parameters (γ_M)	Friction angle	Drained behaviour	1.25	1.25
	Cohesion (effective)	Drained behaviour		
	Friction angle	Undrained behaviour	1.40	1.40
	Cohesion	Undrained behaviour		
Resistances (γ_R)	Passive pressure mobilized	Permanent stage	1.00	1.00
		Transitory stage	1.00	1.00
	Support strength	Elastic limit	1.10	-
	Anchor block (Kranz)	Disruptive strain	1.00	-

Table C5: Partial coefficients applied with approach 1.2

C.4.2. Soil levels

AMRetain offers the possibility to "weight" the soil levels considered in the calculations (SSIM and LEM methods). This "weighting " is controlled by an 'over-excavation' parameter Δa which is user-defined for each side and each stage.

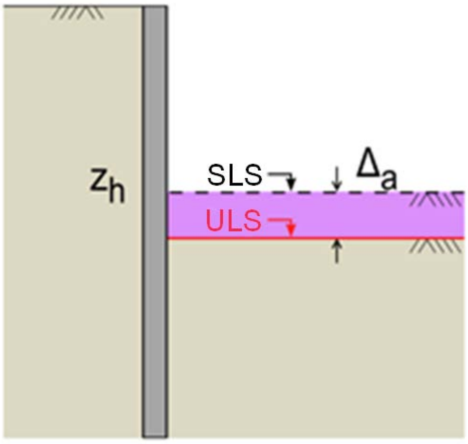


Figure C35: Soil Levels - notion of over-excavation

In the absence of control on the bottom of the excavation, standard NF P 94-282 recommends the following value:

$$\Delta a = \min(50\text{ cm}, 10\%H)$$

In which H designates the height of the effective support defined as shown in the figure below.

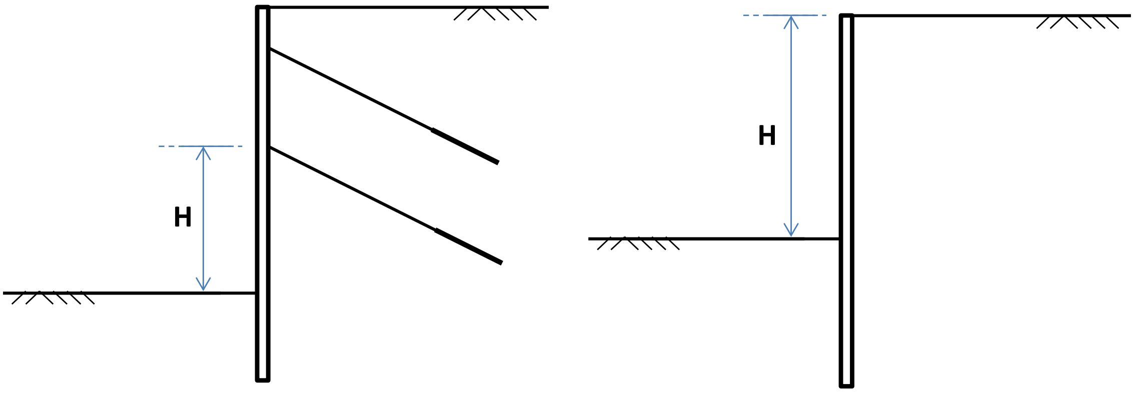


Figure C36: Notion of effective retaining height

C.4.3. Passive pressure failure check

The passive pressure failure check verifies if the embedment length available allows a high enough level of security between the mobilisable passive pressure and the level required for the wall equilibrium (ULS).

C.4.3.1. General case

For the general case of the stages where the wall has one or more anchor levels, this check is carried out on the basis of the SSIM method results, according to the following equation:

$$B_{t,d} \leq B_{m,d}$$

Where:

- $B_{t,d}$: calculation value of the result of mobilisable passive pressure (from the SSIM method);
- $B_{m,d}$: calculation value of the result of the available passive pressure (or utlimate).

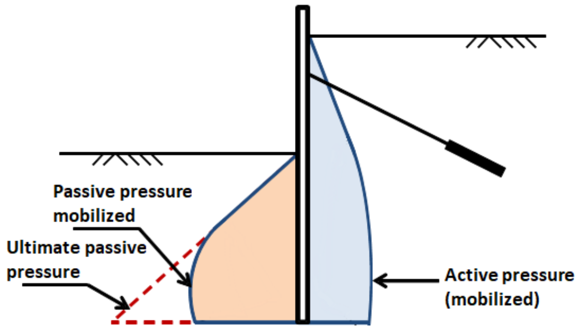


Figure C37: Mobilized and ultimate passive earth pressure for an anchored wall equilibrium

Calculation values of the mobilized and mobilisable passive pressures are defined on the basis of the following relations:

$$B_{t,d} = \gamma_E . B_{t,k} \qquad\qquad B_{m,d} = \frac{B_{m,k}}{\gamma_R}$$

The values of γ_E and γ_R are specified (for each calculation approach) in the chapter §.C.4.1. In particular, in the approach 2/2 * (NF P 94 282), the considered values by default in AMRetain (SSIM method) are the following:

Stage	γ_E	γ_R
Transitory	1,35	1,10
Permanent	1,35	1,40

*Table C6: Example of weighting applied in the approach 2/2**

C.4.3.2. Special case: stages where the wall is cantilever

C.4.3.2.1. Principle

The NF P 94-282 standard imposes the use of the limit equilibrium model (LEM) for ULS calculation when the retaining wall is cantilever.

As suggested by its name, this model consists in studying the retaining wall's equilibrium, (the wall being assumed perfectly rigid - the calculation does not consider the wall flexibility) by considering that the soil on both sides of the wall reaches the limiting earth pressure, down to a certain point called « transition point ». Beyond this point, the soil is assumed to reach the limiting counter active pressure on the downhill side of the wall, whereas on the uphill side, we check that the counter passive pressure necessary for horizontal equilibrium of the retaining wall is lower, with sufficient safety, than the limiting counter passive pressure available below the transition point (see Figure C38:).

The « transition point » is defined in paragraphs §C.4.3.2.3 and §C.4.3.2.4.

With the notations inFigure C38:, the equilibrium of the retaining wall involves the following force system:

- F_a: horizontal resultant of the active earth pressures diagram $p_{a,d}$
- F_b: horizontal resultant of the passive earth pressures diagram $p_{b,d}$
- Fc_a: horizontal resultant of the counter active earth pressures diagram $pc_{a,d}$
- Fc_b: horizontal resultant of the diagram of available counter passive earth pressures $pc_{b,d}$
- ΔU: horizontal resultant of the differential water pressures diagram $u_a – u_b$

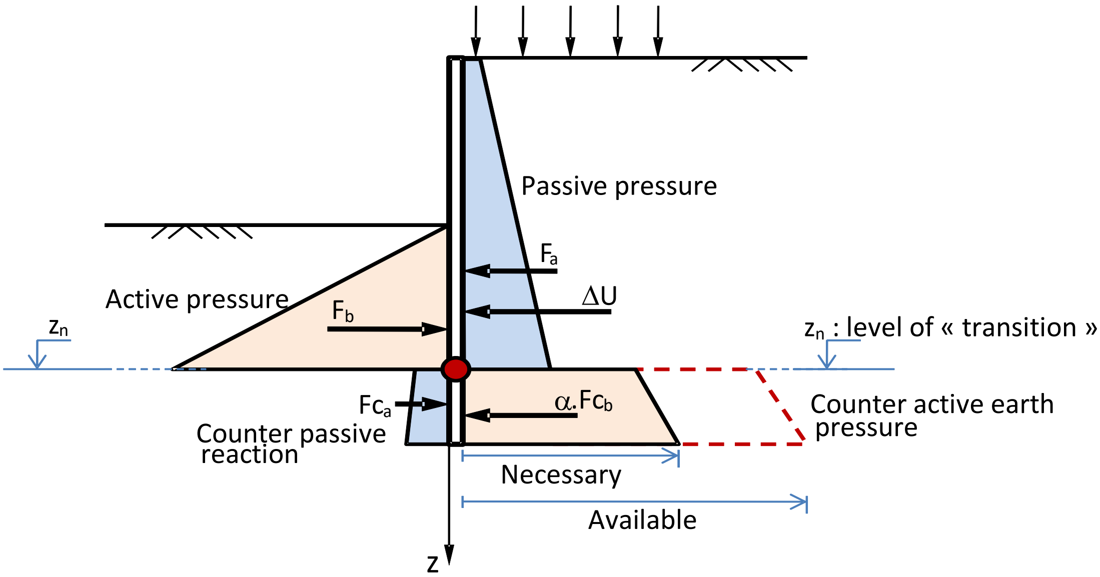


Figure C38: Conventional principles of the limit equilibrium method (LEM)

The « α » factor is called « mobilisation » factor of the counter earth resistance (passive pressures), defined as being the ratio between the counter earth resistance necessary for the horizontal equilibrium of the retaining wall and that available (or limiting). Pressure diagrams displayed above are expressed in "design values" according to the weighting system detailed in § C.4.1. The wall limit equilibrium also considers the surcharges applied directly to the retaining wall (linear force, couple, trapezoidal surcharge) also expressed in design values.

Based on this model, and according to the provisions of the NF P 94-282 standard, stability is checked with respect to passive side failure by performing the following tests:

- Check of the embedment, which consists in ensuring that the available embedment exceeds, with sufficient safety, the minimum embedment necessary for moment equilibrium.
- Check of the counter-earth resistance, which consists in verifying that the counter-earth resistance available under the transition point is sufficient to equilibrate horizontal forces. The application of this check requires determining the position of the transition point. For this, two models of calculation are available in AMRetain: approach D (applied by default) and approach F.

C.4.3.2.2. <u>Embedment check</u>

The check of the retaining wall embedment is based on the following condition (Figure C39:) :

$$f_b \geq 1{,}20\ f_0$$

Where:

- f_b: embedment « available » below the zero differential pressure point O;
- f_0: minimum embedment, below the zero differential pressure point O, required to achieve moments equilibrium (above point C);

According to the notations of the Figure C39:, we have:

$$f_b = (z_P - z_O) \text{ et } f_0 = (z_C - z_O).$$

The differential pressure mentioned, noted pd, designates the resultant diagram obtained by superposing the design values of the active earth pressures, passive earth pressures, and water pressures diagrams. So, we have, by definition (for the cases where the excavation is located on the left):

$$p_d = p_{a,right} - p_{b,left} + u_{right} - u_{left}$$

Searching point C consists in writing the general equation translating the momentum equilibrium with respect to this same point:

$$M(p_d)|_C + M(S_d)|_C = 0$$

Where:

- $M(p_d)|_C$: moment relative to point C, resultant of the differential diagram pressures p_d (between the top of the wall and point C);
- $M(S_d)|_C$: moment relative to point C, resultant of the overloads applied directly on the wall between the top and the point C.

This equation is resolved by a dichotomous search process with a relative stop criterion set to 10^{-4}.

On Figure C39:, the force R_C refers to the resultant (design value) of the horizontal forces applied over the height between the top of retaining wall and point C:

$$R_C = -R(p_d)|_C - R(S_d)|_C$$

Where:

- $R(p_d)|_C$: resultant of the differential pressures diagram p_d over the height between the top of the retaining wall and point C;
- $R(S_d)|_C$: resultant of surcharges (in design values) applied directly on the wall between its top and point C.

Checking the counter earth resistance aims at ensuring that the counter earth resistance available is sufficient to take-up the R_C load.

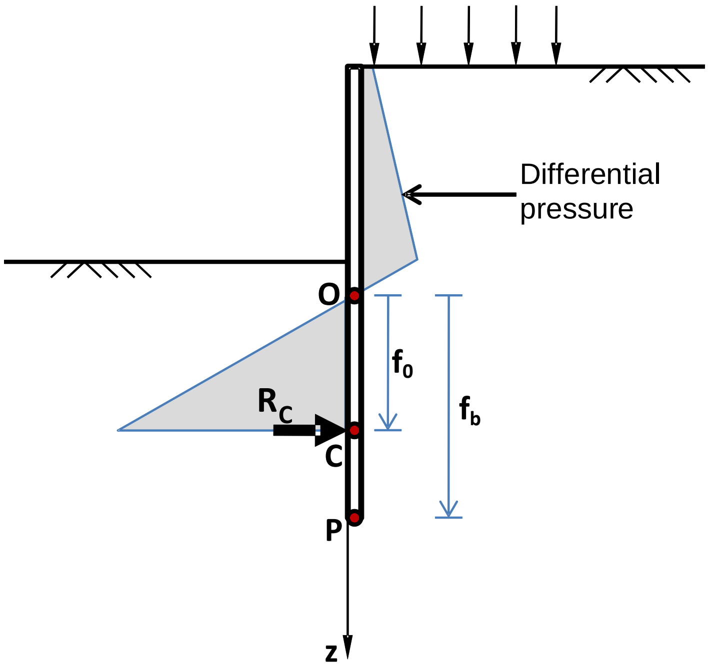


Figure C39: Notions of minimum embedment f0 and available embedment fb according to the LEM method

C.4.3.2.3. Checking failure on the passive side with approach D

This approach, applied by default in AMRetain, rigorously searches the transition point $\mathbf{z_n}$ to ensure the overall equilibrium for both forces and moments on the height of the screen (figure below).

In this method, the embedment (conventional, counted from point O) of the wall used in the calculation can be "set" according to three options (figure below):

- Option 1: embedment calculation = real embedment calculation (default option);
- Option 2: embedment calculation = 1,2 x f_0 (recommended for long embedment);
- Option 3: embedment calculation = value imposed by the user.

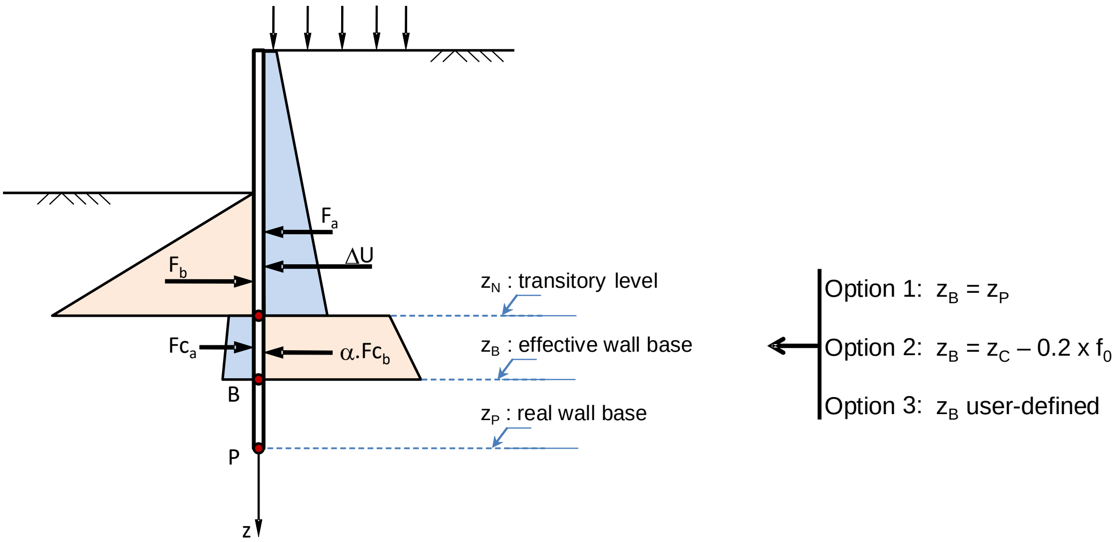


Figure C40: Counter-passive earth pressure check according to approach D

According to the notations of the previous figure, the overall equilibrium of the wall can be expressed with a system of two equations with two unknown values (**α, z_n**) :

- Forces equilibrium : $F_a - F_b + \alpha.Fc_b - Fc_a + \Delta U + R(S_d) = 0$
- Moments equilibrium : $M(F_a) - M(F_b) + \alpha.M(Fc_b) - M(Fc_a) + M(\Delta U) + M(S_d) = 0$

Where:

- F_a, F_b, Fc_a, Fc_b are respectively the resultants of the diagrams of active pressure, passive pressure, counter-active pressure and counter-passive pressure. Their values are functions of the position of the transition point $\mathbf{z_n}$;
- $M(F_a)$, $M(F_b)$, $M(Fc_a)$, $M(Fc_b)$ are respectively the forces moments F_a, F_b, CF_a, CF_b in relation to the point P (bottom of the wall). Their values are also functions of the position z_n;
- ΔU and M(ΔU) are respectively the resultant of the diagram of differential water pressures and the moment that corresponds to the point P. Their values are independent of z_n;
- $R(S_d)$ and $M(S_d)$ are respectively the resultant and the moment in relation to P of potential overloads (design values) applied directly on the wall.

Solving this equation system is carried out through a process of dichotomous research with a relative stopping criterion set by default at 10^{-4}. Using this approach allows to obtain simultaneously the transition level $\mathbf{z_n}$ and **α** factor allowing to check the counter earth resistance through the condition: $\alpha \leq 1$.

C.4.3.2.4. Checking failure on the passive side using approach F

The approach F is a simplified method that consists in assimilating the mobilized counter-passive earth resistance to a uniform pressure applied to a length equal to 0,2 f_0 on one side and from point C on the other, as shown in the figure below.

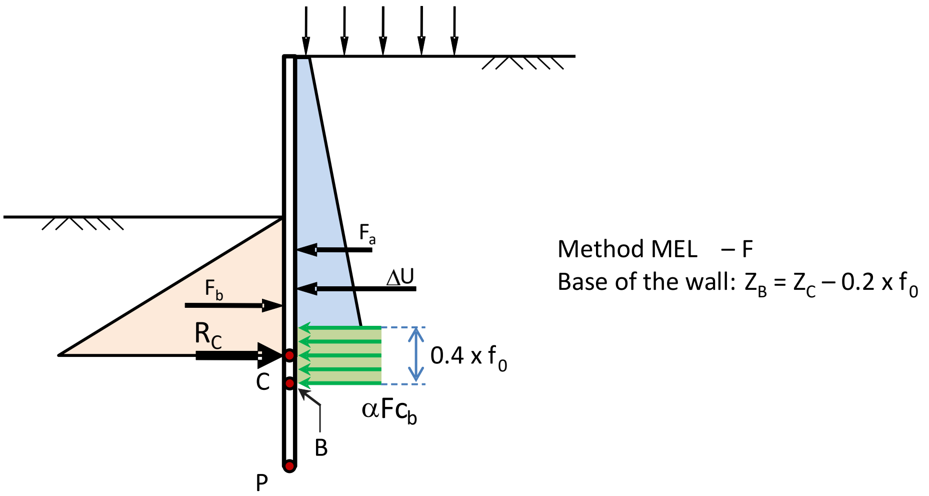


Figure C41: Counter-passive earth resistance check according to approach F

Hence, according to the notations in the figure above, the equilibrium of horizontal forces results in the equality:

$$R_C = \alpha.Fc_b - Fc_a + \Delta U_{inf} + R(S_d)\Big|_P^C$$

Where:

- $R(S_d)|_P^C$: is the resultant of surcharges (if any), applied directly on the retaining wall below point C;
- ΔU_{inf} : is the resultant of differential water pressures applied to the retaining wall below point C.

The mobilization factor « α » is thus obtained through the relation:

$$\alpha = \frac{R_C + Fc_a - \Delta U_{inf} - R(S_d)|_P^C}{Fc_b}$$

C.4.4. Calculation of ULS loads

The calculation of ULS loads is conducted according to the same method used for the passive pressure failure: SSIM for the stages when the screen is anchored, LEM for the stages when the wall is considered cantaliver. The design value of the loads on the wall and the anchors is obtained according to the following equation:

$$E_d = \gamma_E . E_k$$

As a reminder, in the case of the approach 2/2 * (NF P 94 282), the value of γ_E is equal to:

- o γ_E =1,35 for the SSIM method established by default without weighting on permanent actions and strengths;
- o γ_E =1,00 for the LEM method established by default with weighting at the source of permanent actions by 1,35 and strengths by 1/1,10 or 1/1,40.

It should be noted that in the case where the approach 3 is used, we have γ_E =1,00 for SSIM and LEM methods. These are established with weighting at the source of shear parameters by 1.25.

C.4.5. Verification of vertical equilibrium

C.4.5.1. General case

Checking vertical balance consists in estimating the vertical resultant of the forces applied to the retaining wall, and checking whether this resultant is oriented upwards (negative value), or downwards (positive value). The vertical resultant of the forces, if oriented downwards, should then be used as an input parameter to check the bearing capacity of the retaining wall (using specific calculation methods not integrated into AMRetain).

This check notably allows to consider the relevance of the values considered for the obliquities of active, passive and counter passive earth pressures.

The design value of the vertical resultant Rv_d of the forces applied to the retaining wall is given by the following general expression:

$$Rv_d = P_d + Pv_d + Fv_d + Tv_d$$

Where:

- P_d : total weight of the wall;
- Pv_d : design value of the vertical resultant of the earth pressures on the height of the wall;
- Fv_d : design value of the vertical resultant of the inclined linear forces applied to the retaining wall;
- Tv_d : design value of the vertical resultant of forces due to inclined anchors connected to the wall .

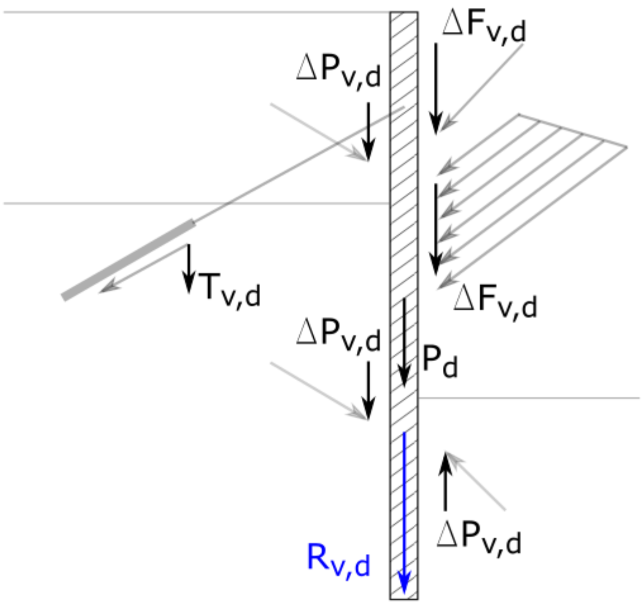


Figure C42: Vertical forces along the wall

It should be recalled that AMRetain calculates, at ULS and SLS, the axial force (vertical) at each point of the wall. The vertical resultant of the forces is none other than the value of the axial force at the base of the wall:

$$Rv_d = N^{zz}_{ULS}\left(z = z_{base}\right)$$

C.4.5.2. Case of a wall cantaliver

In the case of a wall cantaliver, the ULS equilibrium of the wall treated with a limit equilibrium mehod, the vertical component of earth pressure is directly obtained through a projection according to the "limit" inclinations (and not intermediate) of active/passive pressures defined by the user.

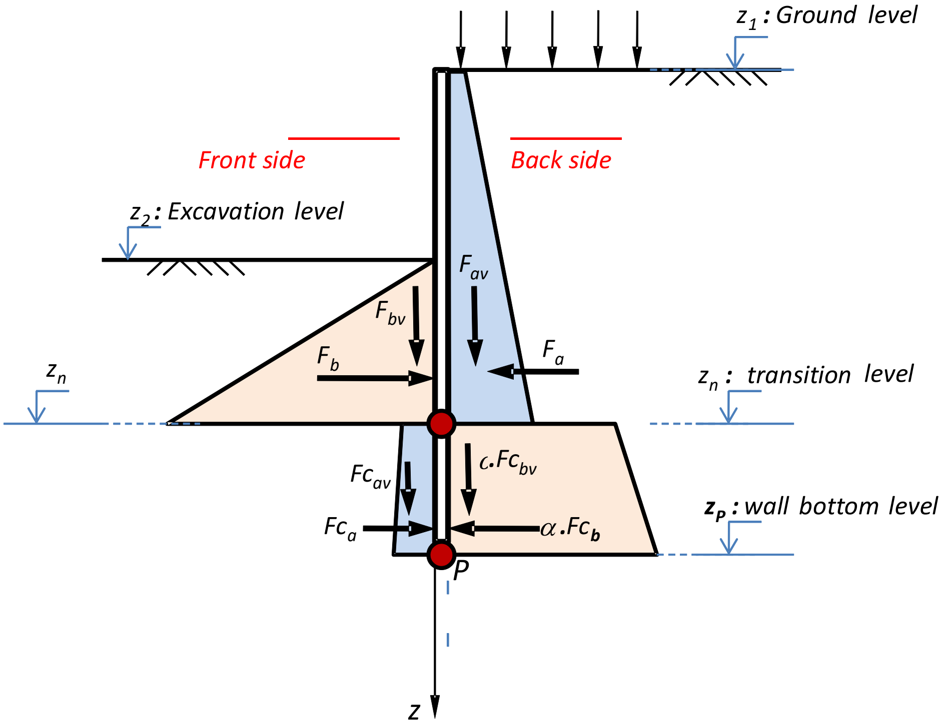


Figure C43: Assessment of the vertical forces for the limit equilibrium method (LEM)

In the case where the obtained vertical resultant is directed upwards, AMRetain offers the possibility to change, manually or automatically, the counter-passive pressures inclination in order to obtain a "relevant" vertical equilibrium (i.e. with resultant downwards). In the "automatic" mode, this adjustment is controlled by a 'Xcb' factor defined as follows:

$$(\delta/\varphi)_{\text{counter-passive earth pressure}} = Xcb \times (\delta/\varphi)_{\text{passive earth pressure}}$$

The Xcb factor has an initial value of 1.00 and then is reduced automatically (if necessary) until you obtain a downwards vertical resultant. The process stops in any case when Xcb reaches the value of -1,00.

Note that changing the inclination of the counter-passive pressure implies a recalculation of counter-passive reaction coefficients $k_{p,\,cb}$ and $k_{pc,\,cb}$, which are involved in the calculation of the counter-passive reaction available under the transition point z_n. These coefficients are re-automatically calculated by the program according to the "reference" method designated by the user ('Kerisel and Absi' by default).

C.4.6. Check of the stability of the anchoring block

C.4.6.1. General principle

The general principle of the check is to ensure that the anchor forces (for active anchors only) can be safely transferred to the ground, by checking the stability of the failure surface at the bottom of the soil block, and thus to prove that each anchor's length is sufficient.

This check is led according to the simplified « Kranz » approach mentioned in appendix G of the NF P 94 -282 standard. The method is said to be simplified as it uses a plane failure surface (CD), as shown in Figure C44:**Erreur ! Source du renvoi introuvable.**.

As specified in the notations of Figure C44:**Erreur ! Source du renvoi introuvable.**, this check consists in justifying the stability of the ABCDA block by ensuring that the anchor force remains inferior to a limit value corresponding to the ultimate equilibirum of the block, called « destabilising force ». The « Kranz » method defines an approach allowing to determine this destabilising force.

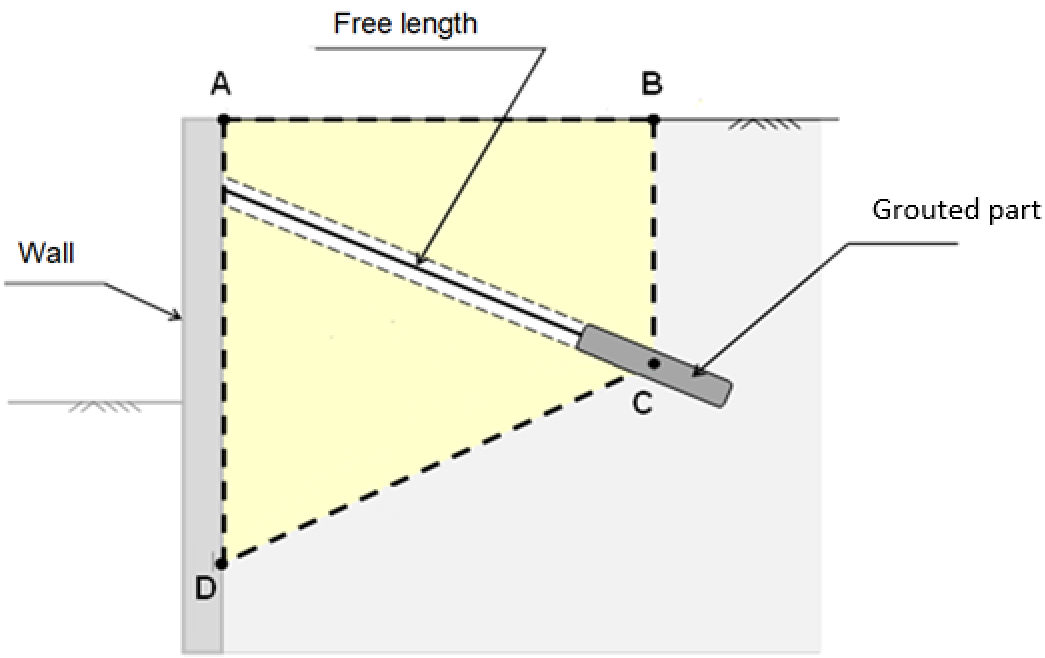


Figure C44: Simplified Kranz method - diagram

C.4.6.2. Case of a single anchor

C.4.6.2.1. Définition of the anchoring block

The anchoring block ABCDA subject of the check is bounded by the following points:

- **A**: top of the wall or intersection of the wall with the top of the first layer;
- **D**: zero shear level (taken under the bottom of the excavation);
- **C**: effective anchoring point corresponding to the effective length of the anchor $\mathbf{L_u}$;
- **B**: vertical projection of point C on the axis (AX)**;**

C.4.6.2.2. External forces

The Figure C45: summarizes the assesment of the forces applied on the block ABCDA:

- T_u: force in the anchor;
- P_1: reaction of the retaining wall, taken equal to the resultant of earth pressures on [AD];
- P_2: resultant of active pressures applied uphill the block on [BC];
- W: weight of the block (wet above the watertable, and submerged below). Groundwater level is assumed horizontal;
- F_e: resultant of external surcharges applied to or in the block;
- R_c: limit resistance due to cohesion mobilisable along [CD];
- R_f: limit resistance due to friction mobilisable along [CD].

The limit equilibrium of the block is hence converted into the vectorial equation:

$$\vec{R}_c + \vec{R}_f + \vec{W} + \vec{F}_e + \vec{P}_1 + \vec{P}_2 + \vec{T} = \vec{0}$$

The previous figures call for several comments:

- The force Fe only includes the resultant of "permanent" loads. Variable loads applied between A and B are not included because they are favourable to the stability of the block
- The friction force R_f is tilted at an angle equal to φ with respect to the normal to (CD). In the case of a homogeneous soil block, this inclination is merely equal to the soil friction angle;
- The horizontal component of P_1, noted P_{1H}, is calculated directly by integration of mobilised horizontal pressures, resulting from the horizontal equilibrium calculation of the retaining wall (SSIM method with weighting of the surcharges by 1.11). Its vertical component, noted P_{1V} is calculated with the same process as the one considered when checking vertical equilibrium of the retaining wall (see §C.4.5);
- The uphill resultant of active pressures P_2 is assumed to be horizontal ($P_{2V} = 0$). Its horizontal component P_{2H} is calculated directly from the properties of the layers encountered between B and C, and considering the surcharges applied uphill the anchoring block;
- The force R_c is calculated by simple integration of soil cohesion along the [CD] segment (taking into account the potential variation with depth).

In the next sections, T_{dsb} designates the value of T allowing to reach equilibrium of the block (destabilising anchor force).

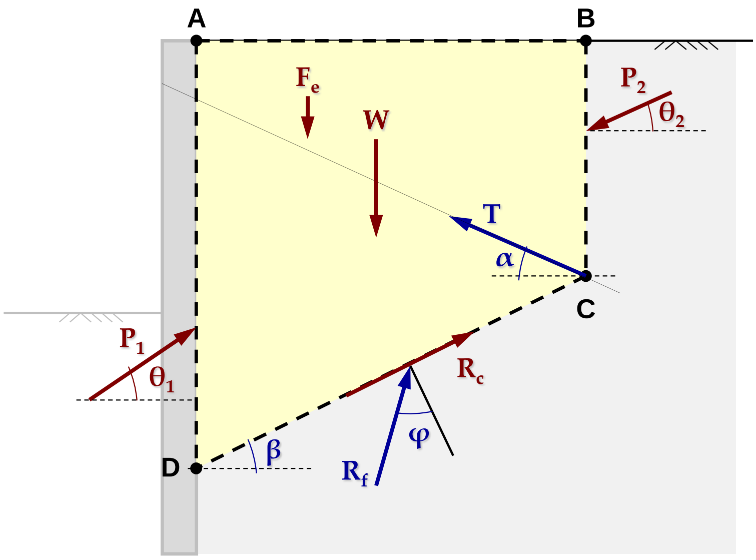


Figure C45: Schematic review of the forces exerted on the anchor

C.4.6.2.3. Discretization of the anchoring block

We consider the general case in which the assumed failure surface [CD] intersects several soil layers. In this case, the resolution of the limit equilibrium of the block requires discretising the block (ABCDA) into as many blocks as there are layers crossed, so as to ensure that the « base » of a given block is « homogeneous ». The point of this discretisation is to set the inclination of the mobilisable friction force at the base of each block (see figure below).

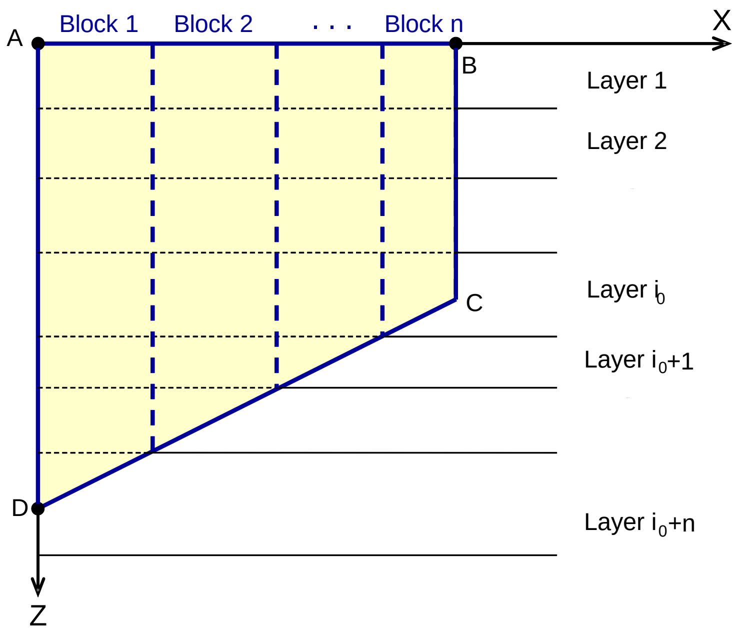


Figure C46: Discretization of the anchor in several blocks

The local equilibrium of block 'k' is governed by the system of forces that follows (figure below):

- $H_1^{(k)}$ and $V_1^{(k)}$ external reactions mobilized on the vertical left border;
- $H_2^{(k)}$ and $V_2^{(k)}$ external reactions mobilized on the vertical right border;
- $W^{(k)}$ submerged soil weight;
- $F_e^{(k)}$ resultant of the applied external overloads in block k;
- $R_c^{(k)}$ resistance due to mobilizable cohesion along segment $D^{(k)}C^{(k)}$;
- $R_f^{(k)}$ resistance due to the available friction along segment $D^{(k)}C^{(k)}$.

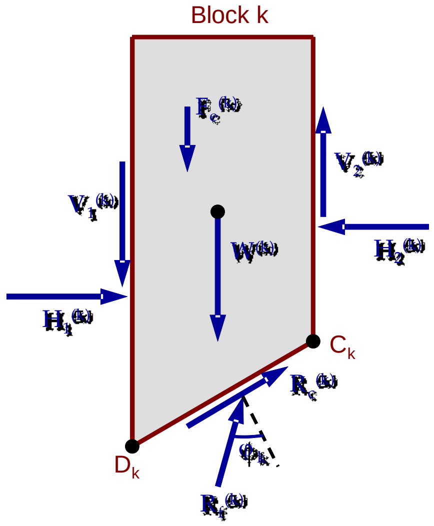


Figure C47: Local equilibrium of a block – forces assessment

In the figure above, φ_k designates the friction angle of the soil layer at the base of block « k ». For simplicity, we adopt the so-called Bishop hypothesis that consists in assuming that the reactions "interblocks" are horizontal, which means that, according to the notations of the Figure C47:

$$V_1^{(k)} = 0 \text{ and } V_2^{(k)} = 0$$

This condition is valid only along the « interblock » borders, an exception must hence be considered for the first (k = 1) and last blocks (k = n). Therefore, we end up with the general diagram of the figure below:

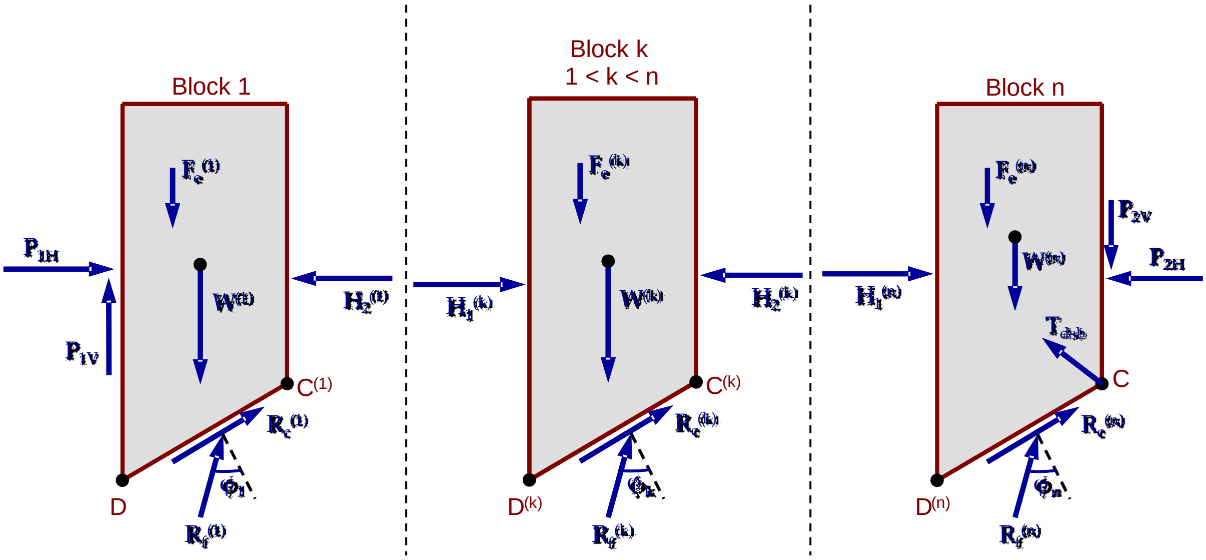


Figure C48: Local equilibrium of the blocks, taking into account the simplifying Bishop assumption

Please, note that because of successive slices, the anchor load T_{dsb} is considered only in the equilibrium of the last block (n). Actually, as the action line is unique, assigning this force to one block or the other has no impact.

C.4.6.2.4. Resolution of overall equilibrium

For a discretisation into « n » blocks, the local equilibriums lead to a system with 3n – 1 equations and 3n – 1 unknowns. More precisely, the equation system is obtained by projecting the local equilibrium of each block along Ox and Oz (i.e. 2 equations per block) and writing the action/reaction principle between two jointive blocks, translated by: $H_1^{(k)} = H_2^{(k-1)}$.

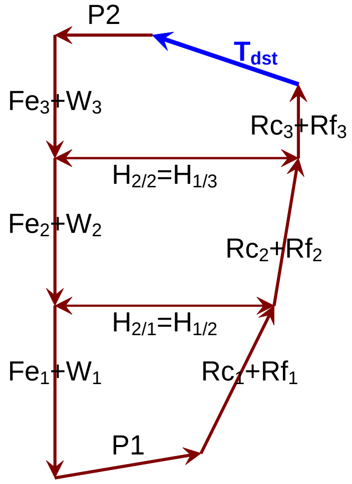


Figure C49: Example of forces for the case of 3 blocks

The resolution of this system allows to obtain the values of $H_1^{(k)}$, $H_2^{(k)}$, $R_f^{(k)}$ and $\mathbf{T_{dsb}}$.

C.4.6.2.5. Check

Obtaining the characteristic value of the destabilizing force T_{dsb} allows for checking the stability of a anchoring block at ULS:

$$T_{réf,d} = \gamma_E . T_{réf} \leq T_{dsb,d} = \frac{T_{dsb}}{\gamma_R}$$

In the case of the approach 2/2* according to the standard NF P 94 282 : γ_R = 1,10 and γ_E = 1,35.

C.4.6.3. Case of several anchors

C.4.6.3.1. General principle

We consider the case of a retaining wall anchored with several levels of anchors, as shown in the figure below. The stability of the anchoring block is checked by studying successively the stability of blocks « associated » with each anchor (the way that was defined in the previous section for the case of a single anchor). Hence, for each anchor « j », we study the stability of the AB_jC_jDA block taking into account the anchor forces of all anchors located inside block « j ».

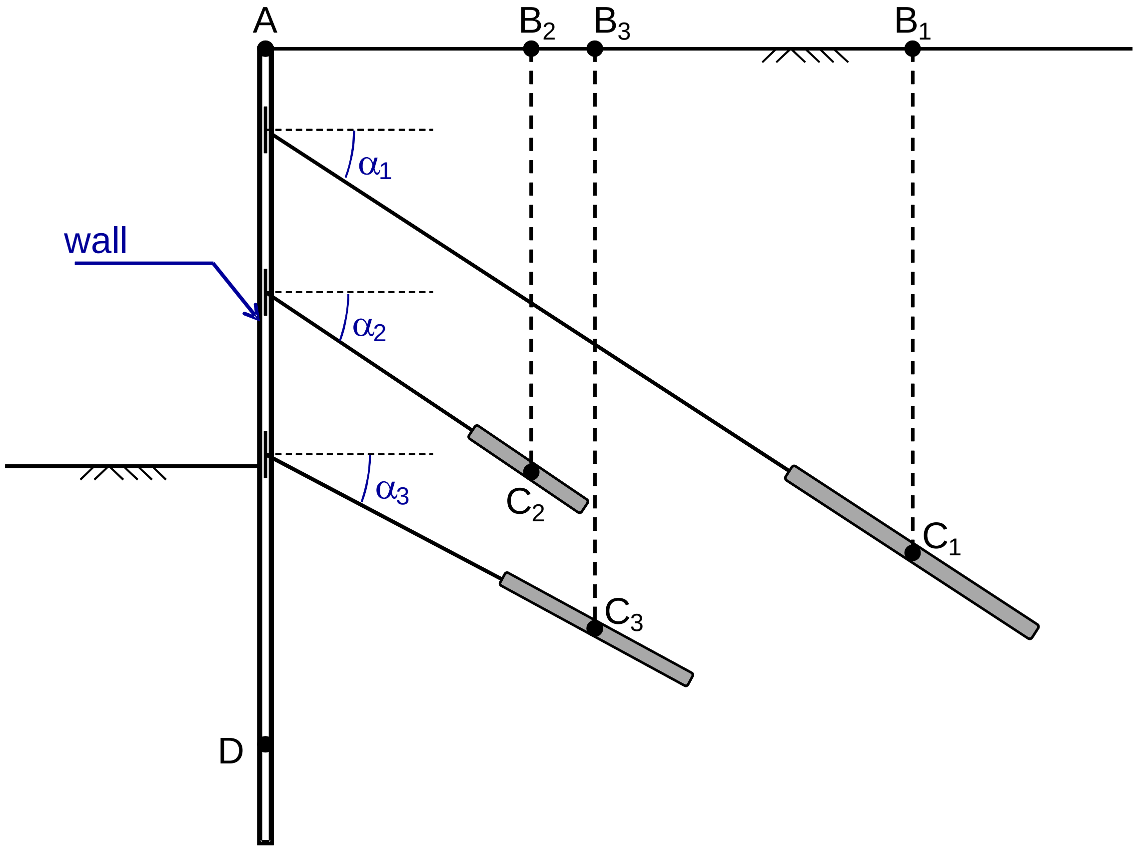


Figure C50: Generalization to the case of several layers of anchors

For example, for the case shown in the figure above, checking the stability of the anchoring block consists in examining three situations:

- Situation 1: we isolate anchoring block AB_1C_1DA associated with anchor « 1 ». The anchoring points C_2 and C_3 are located inside the block, therefore the three anchors are taken into account;

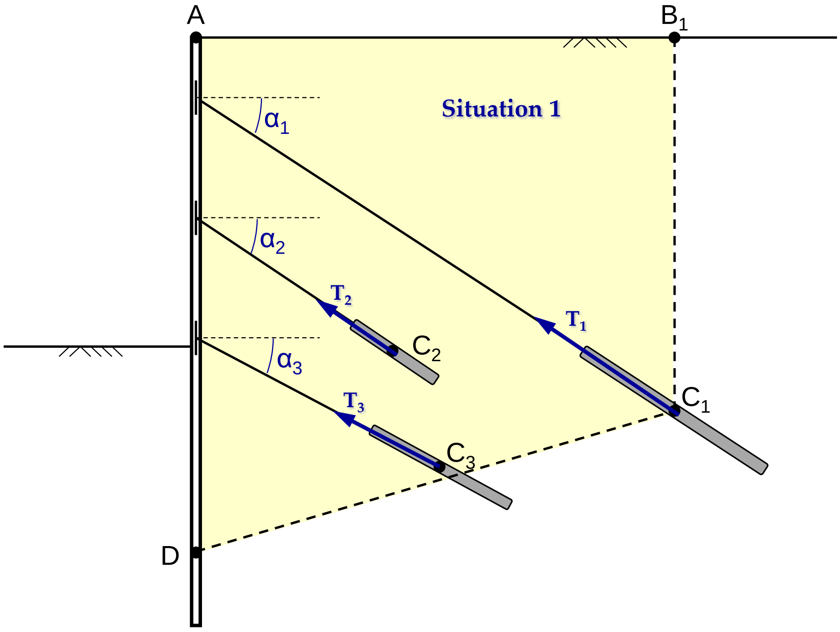


Figure C51: Sample application - Situation 01

- Situation 2: we isolate anchoring block AB_2C_2DA associated with anchor « 2 ». The anchoring points C_1 and C_3 are located outside the block, therefore only anchor « 2 » is taken into account;

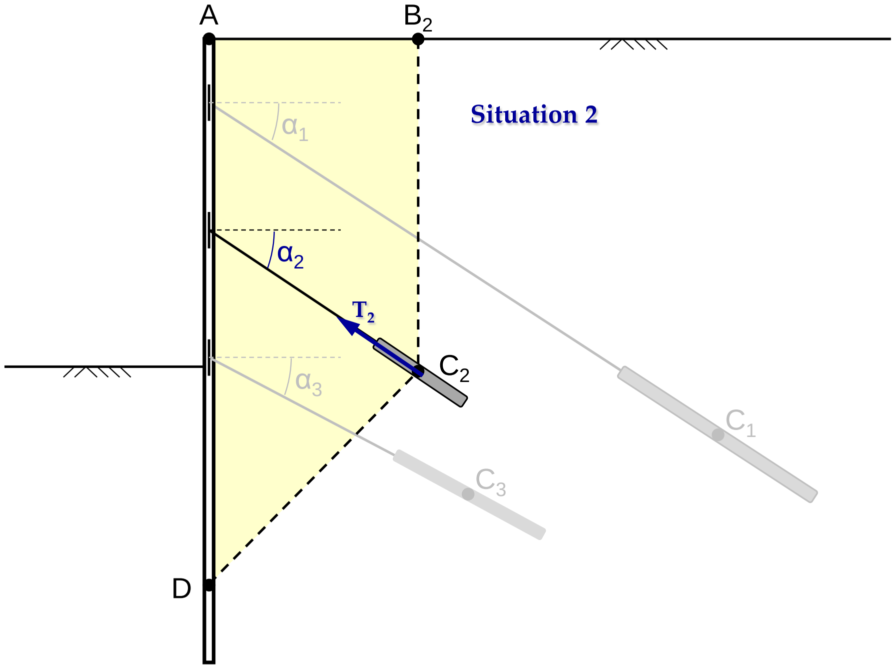


Figure C52: Application example - Situation 02

- Situation 3: we isolate anchoring block AB_3C_3DA associated with anchor « 3 ». The anchoring point C_2 is located inside the block, whereas C_3 is located outside. Anchors 2 and 3 are hence taken into account.

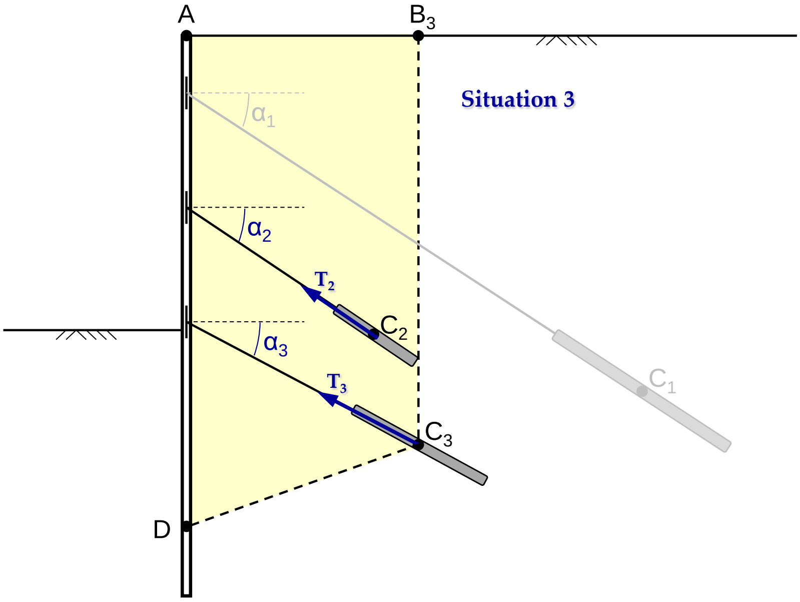


Figure C53: Application example - Situation 03

For a given situation, taking into account an anchor or not is decided depending on the relative position of its anchoring point with respect to the corresponding block boundaries. Attention is drawn to the case in which this anchoring point, although located geometrically outside the block, is close to the borders BC or CD, and in which case its influence cannot be neglected. Adapting the useful length of the anchors is necessary to allow them to be taken into account (refer to paragraph §C.4.6.3.4).

C.4.6.3.2. Efforts overview

For a given situation, we calculate the equivalent resultant T_{eq} of the forces T_i taken up by all anchors taken into account in this situation. We designate by α_{eq} the inclination of this resulting force with respect to horizontal. To study the stability of the anchoring block associated with the situation considered, we thus use an equilibrium system similar to that considered for a single anchor (figure below), with a « dummy » anchor inclined with α_{eq} with respect to horizontal and taking up a force equal to T_{eq}.

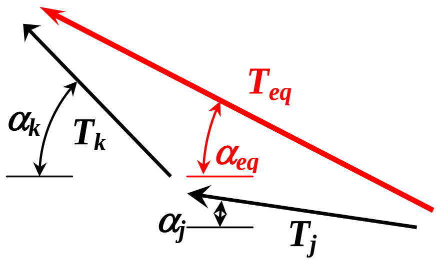


Figure C54: Result of a fictional anchor

C.4.6.3.3. Resolution

For each situation, the formulation is based on an approach similar to that followed for the case of a single draft. For a given situation, the resolution of the balance system provides the characteristic value of the destabilizing effort $T_{dsb,\,k}$ of the associated anchor. Its calculation value $T_{dsb,\,d.}$ taken equal to T_{dsb} / g_R is then compared to the design value of the anchoring effort of equivalent reference $T_{réf,d} = \gamma_E \times T_{eq}$.

The stability of the anchor is justified if for all situations, we have: $T_{réf,d} \leq T_{dsb,d}$.

C.4.6.3.4. Taking into account the bounding length

For a given anchor 'i', three configurations are distinguished (Figure C55):

- Configuration 1: anchoring point C_i (= center of grouted part) is located inside the block, in this case the anchoring effort 'i' is fully taken into account;
- Configuration 2: head of the grouted part S_i is located outside of the block, in this case the anchor 'i' is not taken into account;
- Configuration 3: intermediate case, S_i inside, C_i outside of the massif. The anchoring effort 'i' is partially taken into account in proportion to the report S_iR_i/S_iC_i, where R_i means the point of intersection of the grouted part with the external border of the massif.

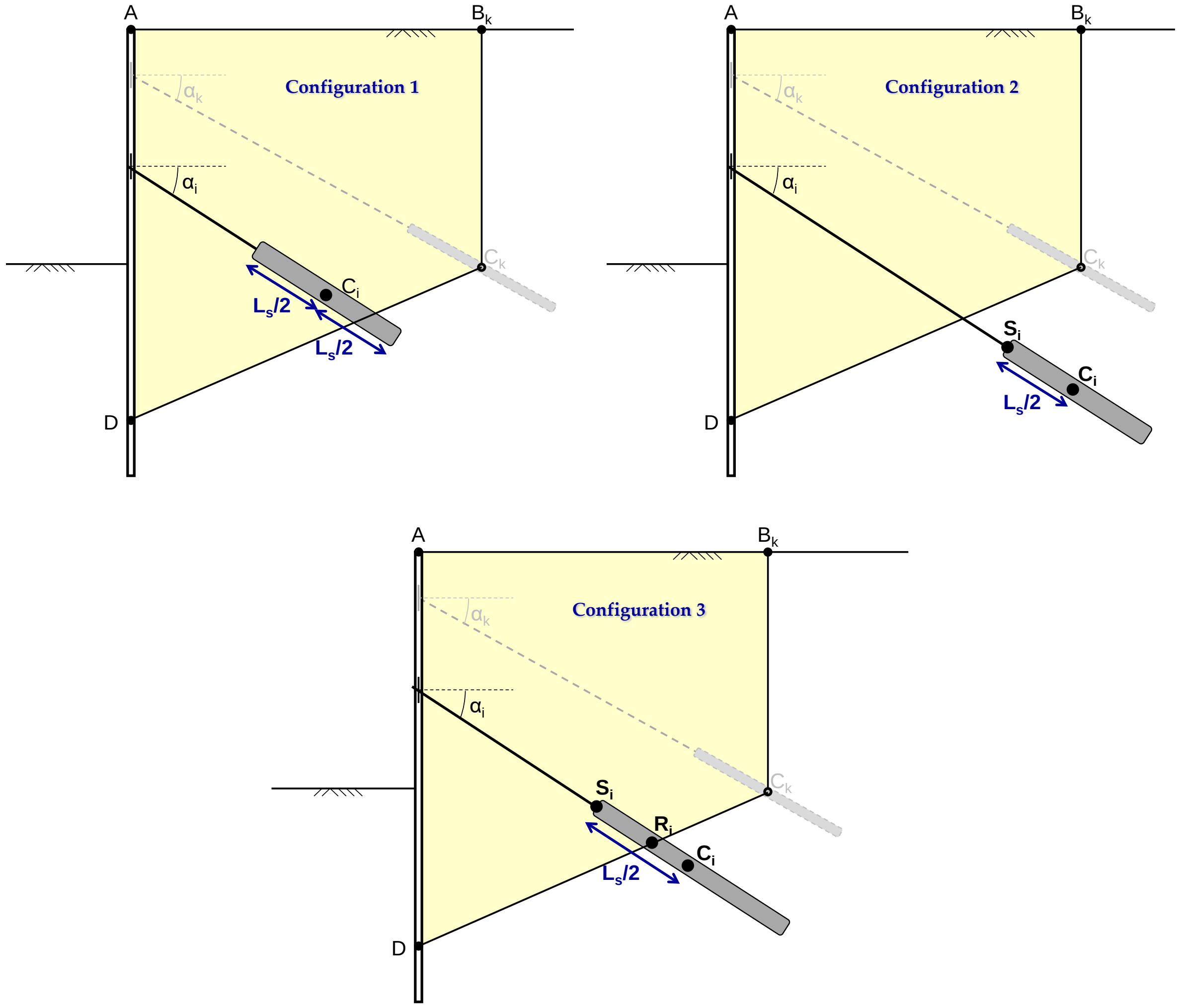


Figure C55: The 3 possible relative positions of the anchor and examinated soil blocks

With the notations above, the reference anchoring effort considered in a given situation is calculated according to the following formula:

$$\vec{T}_{réf} = \sum_i \min\left(\frac{S_iR_i}{S_iC_i};1\right).\vec{T}_i = \sum_i \frac{\min\left(2S_iR_i;L_s^i\right)}{L_s^i}.\vec{T}_i$$

C.4.6.4. Accounting for seismic conditions

The model described above can be easily adapted by introducing the inertia forces resulting from seismic action affecting the soil block.

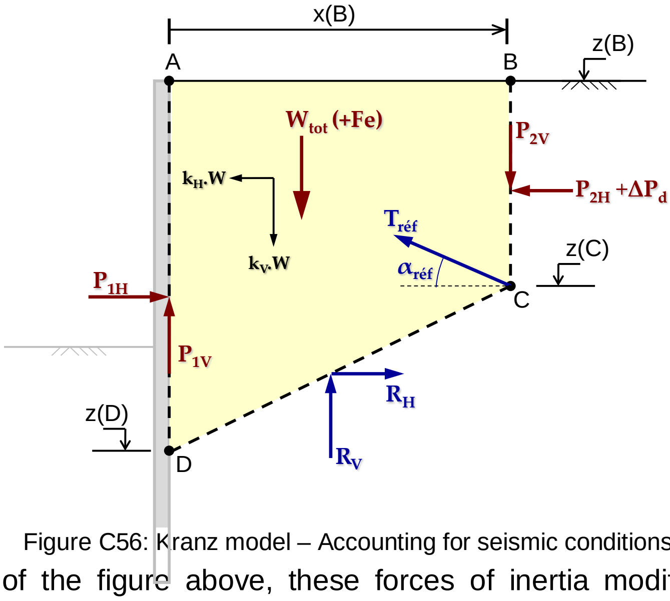


Figure C56: Kranz model – Accounting for seismic conditions

With the notations of the figure above, these forces of inertia modify the equilibrium as follows:

- A dynamic increment in the assessment of the forces of thrust upstream (P_{2H} and P_{2V}), which changes the balance of the last block;
- Introduction of the vertical and horizontal forces of inertia (proportional to the weight) in the equilibrium of each block.

Solving limit equilibrium highlights an exclusively unfavourable effect of the earthquake with a systematic reduction of the safety between the destabilizing anchoring force and that required for the balance of the wall.

C.4.6.5. Case of a double wall project

C.4.6.5.1. System of type « wall anchored on rear-wall »

Kranz model, such as detailed above for the case of a wall anchored by one or more anchors, can be adapted to the case of a system of a main wall anchored on a secondary wall as shown on the figure below.

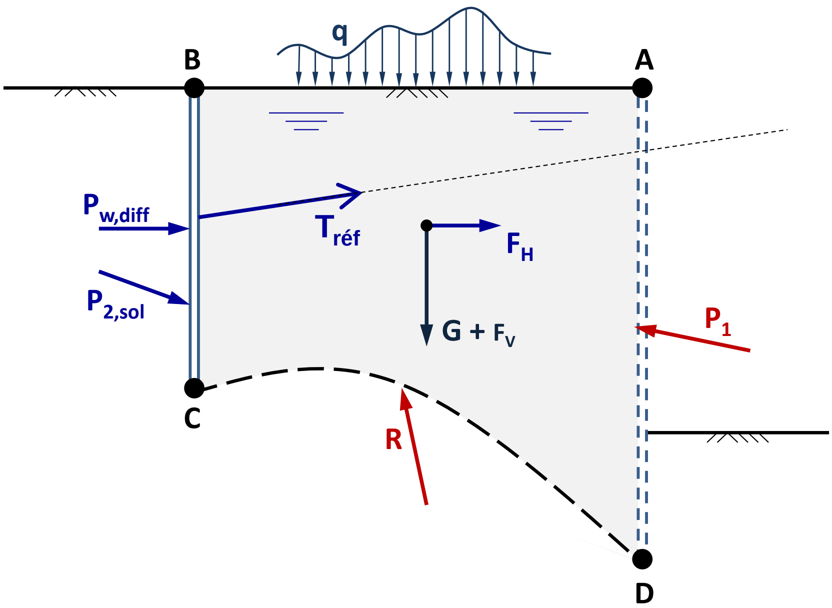


Figure C57: Limit equilibrium of the anchoring block for a double wall project

The case of a double wall requires the following adjustments:

- Geometry of the block: the upper border of the massif is in the back face of the rear-wall. Point C is confused with the foot of the rear-wall if it is short and more generally with the zero-shearing point of the rear-wall;
- The reference anchoring force (T_{ref}) corresponds to the vector sum of all the anchoring efforts mobilized in the node-to-node anchor (single or links) and those whose grout is located (at least partly) inside of the anchor ABCD ;
- The upstream active pressure effort (P2) represents the result of external forces applied to the rear-wall block. This includes on the one hand the pressure from the ground to the back of the soil bloack and the differential pressure of water between the two sides of the screen.

$$\vec{P}_2 = \vec{P}_{2,soil} + \vec{P}_{w,diff}$$

These adjustments are applied automatically by the calculations of AMRetain’s engine.

C.4.6.5.2. Case of a double anchor

AMRetain also allows to process double-walls with "dual anchors" as presented in the figure below: a (1) main wall anchored on a secondary wall (2), anchored himself by bonded anchoring ties. Points "C" and "D" are points of zero shearing force, respectively for walls 1 and 2.

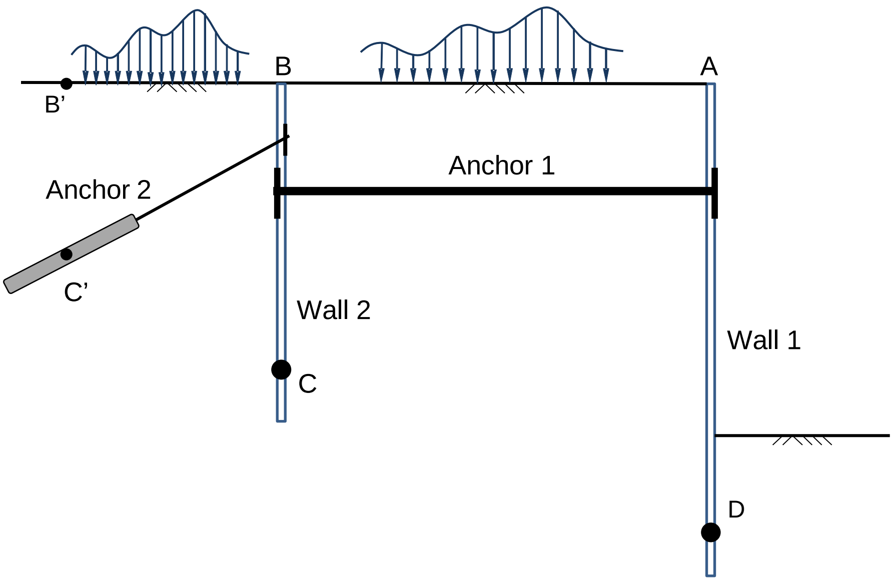


Figure C58: Limit balance of the anchor for a double screen with double anchoring

In this case, AMRetain examines (at least) two configurations that correspond to each anchoring block:

- Anchoring block ABCD associated with the main screen, whose destabilizing force is compared (weighted) to the force taken up by the linking anchor (anchor 1). For this configuration, the effort mobilized by anchor '2' is deducted from the upstream active pressure force (P2) applied to the back of the soil block;

$$\vec{P}_2 = \vec{P}_{2,soil} - \vec{T}_2$$

- Anchoring block BCC'B' associated with the secondary wall, whose destabilizing force is compared (weighted) to the effort taken up by the active anchor (2).

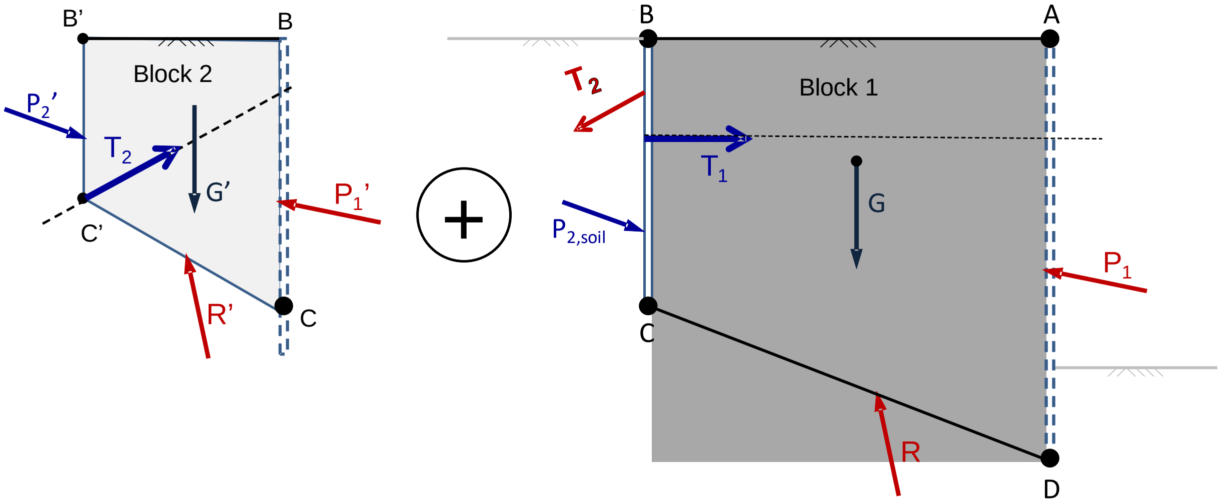


Figure C59: Soil block anchor considered in the case of a double-screen with dual anchor system

C.4.6.5.3. Case of a logarithmic spiral arc surface (Jelinek)

AMRetain allows the analysis of the stability of the anchoring block by considering a logarithmic spiral type base fracture surface (Jelinek method).

The actions acting on the block are the same as described above for the case of a plane surface (Kranz). The analysis is based on the equilibrium of moments with respect to the pole of the logarithmic spiral arc surface.

The formalism consists in evaluating the destabilizing moment of the soil block associated to the situation of limit equilibrium and comparing it to the moment generated by the effort mobilized in the tie rod.

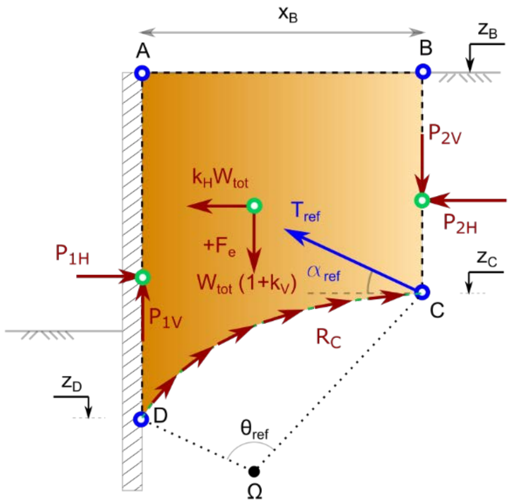
$$M_W + M_{Séisme} + M_{P1} + M_{P2} + M_{Rc} + M_{Surcharges} + M_{Tirant} = 0$$

Le programme cherche à minimiser le rapport de moments (β), mathématiquement exprimé comme suit :

$$\beta = \frac{M_W + M_{Séisme} + M_{P1} + M_{P2} + M_{Rc} + M_{Tirant}}{M_{Tref}}$$

L'effort déstabilisant est retrouvé à partir de l'effort Tref :

$$T_{dsb} = \beta_{\min} T_{ref}$$



Anchoring block balance

C.5. Theoretical bases used for data input wizards

This section describes the theoretical bases used for the different wizards proposed to the user. Handling of these wizards is described in part B of the manual (user manual).

BEWARE: WIZARDS ARE ONLY A HELP FOR THE USER, THEY ARE NOT A COMPULSORY STEP IN A PROJECT. THE USER IS RESPONSIBLE FOR THEIR USE.

C.5.1. Wizards related to soil characteristics

C.5.1.1. Coefficient k_0

The **k0 Jaky** wizard calculates the value of k_0 using the following formula:

$$k_0 = (1+\sin\beta)(1-\sin\varphi)\sqrt{OCR}$$

In which:

- β : slope inclination [°] ;
- φ : friction angle [°] ;
- OCR : overconsolidation ratio.

C.5.1.2. Coefficients k_d and k_r

The unloading and reloading ratios enable to account for the variations of horizontal stresses applied by the soil on the wall due to the loading and unloading of this soil, by modifying the zero displacement initial pressure and the values of plasticity thresholds.

- In the general case, for a normally consolidated soil, drained behaviour, we can take $k_d = k_r \approx k_0$.
- In the case of an overconsolidated soil, whose behaviour can be compared to that of an elastic material, can be $k_d = k_r = \frac{\nu_{ur}}{1-\nu_{ur}} \prec k_0$
- In the case of a normally consolidated soil with undrained behaviour, then $k_d = k_r \approx 1 \geq k_0$ (ν_{ur} ~ 0,5).

The article referenced in [6] offers a formula for the coefficient k_d value of the OCR.

Attention is drawn to the important influence of the values assigned to these parameters on the design (including in the case of very hyperstatic structures).

C.5.1.3. Coefficients $k_{a\gamma}$ and $k_{p\gamma}$

3 wizards are available in AMRetain for the determination of the coefficients $k_{a\gamma}$ and $k_{p\gamma}$.

C.5.1.3.1. *Wizards « Tables of active and passive earth pressures of Kerisel and Absi »*

This wizard is the accurate reproduction of the tables defined by Kerisel and Absi, published by Presses de l'Ecole Nationale des Ponts et Chaussées, under the title "Tables de poussée et butée des terres de Kerisel et Absi" [1].

C.5.1.3.2. *Wizard « Active and passive earth pressures according to the Coulomb formula »*

This wizard displays the result of the calculation of Coulomb formulas (from Techniques de l'ingénieur; Construction; C242; "Ouvrages de soutènement, poussée et butée" written by F. Schlosser [2]):

$$k_{a\gamma,\delta} = \frac{\cos^2(\lambda - \phi)}{\cos(\lambda + \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta).\sin(\phi - \beta)}{\cos(\lambda + \delta).\cos(\lambda - \beta)}}\right]^2}$$

$$k_{p\gamma,\delta} = \frac{\cos^2(\lambda + \phi)}{\cos(\lambda + \delta)\left[1 - \sqrt{\frac{\sin(\phi - \delta).\sin(\phi + \beta)}{\cos(\lambda + \delta).\cos(\lambda - \beta)}}\right]^2}$$

In which:

- o φ friction angle [°];
- o β angle between the soil surface and the horizontal axis (°);
- o λ angle between the wall and the vertical axis (default value is 0) (°);
- o δ/φ report of the obliquity of the constraints on the angle of friction.

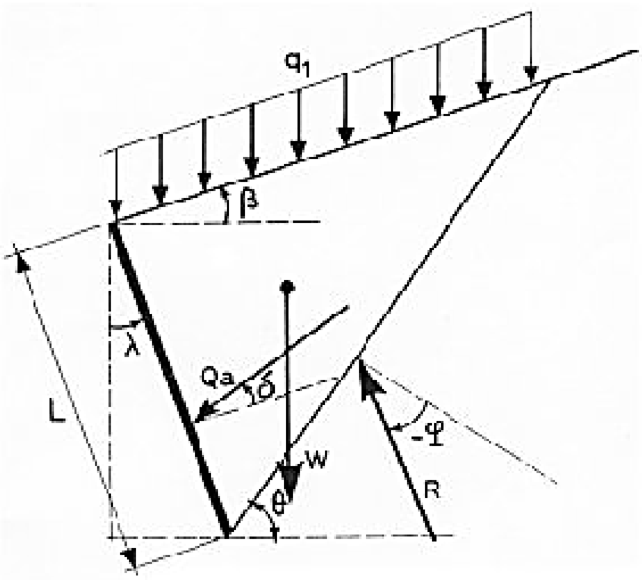


Figure C60: Data for the Coulomb formula

Coefficients $k_{a\gamma,\delta}$ and $k_{p\gamma,\delta}$ correspond to the values tilted by δ_a and δ_p. The wizard then provides the $k_{a\gamma,\delta}$ and k_p values of the horizontal active and passive ratios.

C.5.1.3.3. Wizard « Passive and active earth pressures according to the Rankine formula »

This wizard is available under 2 different forms:

- The simplified Rankine wizard corresponding to the "Rankine" button in the main soil properties dialogue box: this wizard calculates the values of $k_{a\gamma}$ and $k_{p\gamma}$ by Rankine's formula with a free horizontal surface and transfers automatically the values to the corresponding box, such as:

$$k_{a\gamma} = \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) \text{ and } k_{p\gamma} = \tan^2\left(\frac{\pi}{4} + \frac{\varphi}{2}\right).$$

  Where φ is the friction angle (°).

- The Rankine wizard allows to consider the slope inclination. It may be reached by the "kaγ/kpγ" button in the soil properties dialogue, then the « Rankine » choice: this wizard displays the result of Rankine's formulas for a retaining wall with a inclined embankment extracted from Techniques de l'ingénieur; Construction; C242; "Ouvrages de soutènement, poussée et butée" written by F. Schlosser [2] and reminded below:

$$k_{a\gamma} = \left[\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\varphi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\varphi}}\right]\cos\beta$$

$$k_{p\gamma} = \left[\frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\varphi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\varphi}}\right]\cos\beta$$

  In which:
  - φ : friction angle [°];
  - β : inclination of the free surface to the horizontal [°].

C.5.1.4. Coefficients k_{ac} and k_{pc}

Following formulas provide active/passive earth pressures coefficients due to the cohesion:

- Active pressure $$k_{ac} = \frac{1}{\tan\varphi}\left[\frac{\cos\delta_a - \sin\varphi\cos\alpha}{1+\sin\varphi}e^{-(\alpha-\delta_a)\tan\varphi}\cos\delta_a - 1\right]$$
- Passive pressure $$k_{pc} = \frac{1}{\tan\varphi}\left[\frac{\cos\delta_p + \sin\varphi\cos\alpha}{1-\sin\varphi}e^{(\alpha+\delta_p)\tan\varphi}\cos\delta_p - 1\right]$$

Where $\sin\alpha = \dfrac{\sin\delta}{\sin\varphi}$.

C.5.1.5. Coefficient k_h

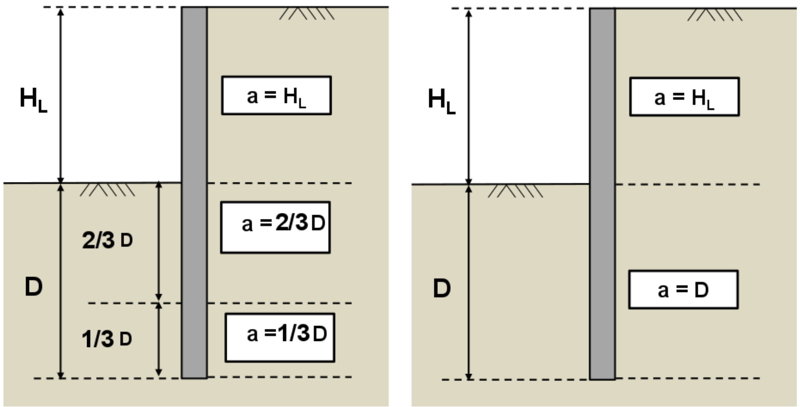
C.5.1.5.1. Balay Formula

Balay formula [4] is based on the following formula:

$$k_h = \frac{E_m}{\left(\frac{\alpha.a}{2}\right) + 0{,}133.(9.a)^{\alpha}}$$

In which:

- E_m: pressuremeter modulus (kN/m²);
- α: rheological parameter;
- a: dimensional parameter (m).



Cases where $D < H_L$ Case where $D \geq H_L$

Figure C61: Parameter is the formula of Balay

C.5.1.5.2. Schmitt formula

Schmitt's calculation method [5] relies on the following formula:

$$k_h = \frac{2{,}0.\left(\frac{E_m}{\alpha}\right)^{\frac{4}{3}}}{(EI)^{\frac{1}{3}}}$$

In which:

- E_m : pressuremeter modulus (kN/m^2);
- α : rheological parameter.

C.5.1.5.3. Chadeisson abacus

Chadeisson abacus [6] provides the value of k_h according to the soil friction angle and cohesion.

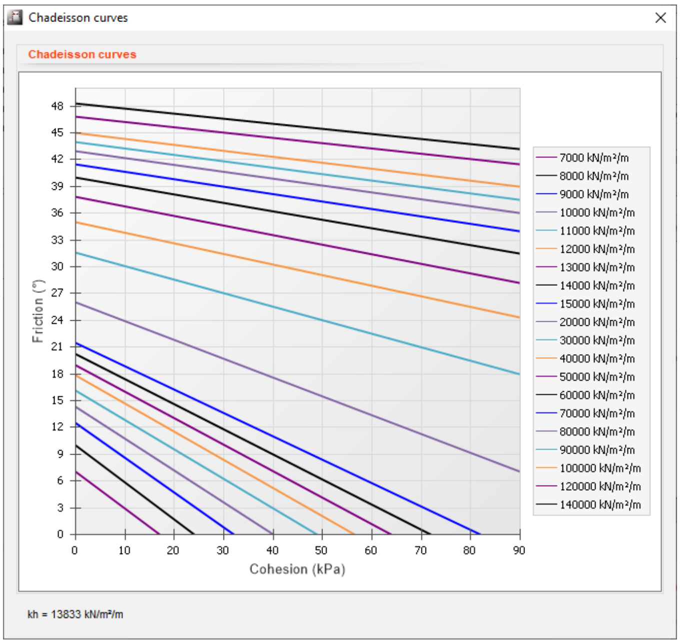


Figure C62: Chadeisson abacus

C.5.2. Anchor characteristics wizards

C.5.2.1. Anchor wizard

Use this wizard to define the stiffness and the preload per unit length of a bed of bonded anchors.

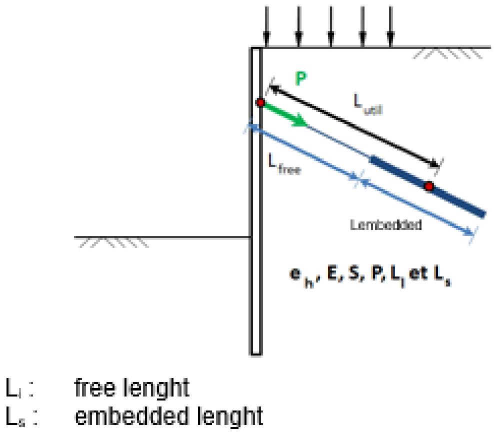


Figure C63: Diagram of sealed anchor beds

An anchor Layer is assimilated to an equivalent spring with:

- An axial stiffness per unit length:

$$K_{axial} = \frac{ES}{L_u e_h}$$

- A pre-load (axial) per unit length:

$$P_{axial} = \frac{P_t}{e_h}$$

In which:

- e_h : space between horizontal anchors (m);
- E : Young modulus of anchor (kN/m²);
- S : anchor section (m²);
- P_t : preloading applied on an anchor (kN);
- L_u : usable length of anchor (m).

Conventionally the effective length of a bed bonded anchors is defined as follows:

$$L_u = L_{free} + \frac{L_{embedded}}{2}$$

Note for a shooting angle of α with regards to the horizontal, the projection of the axial stiffness leads to horizontal stiffness equivalent equal to:

$$K_{horiz} = (\cos\alpha)^2 . K_{axial}$$

This is the considered stifness in the (horizontal) equilibrium of the screen.

C.5.2.2. Strut wizard

Use this wizard to calculate the stiffness and the preloading per unit length of a strut level.

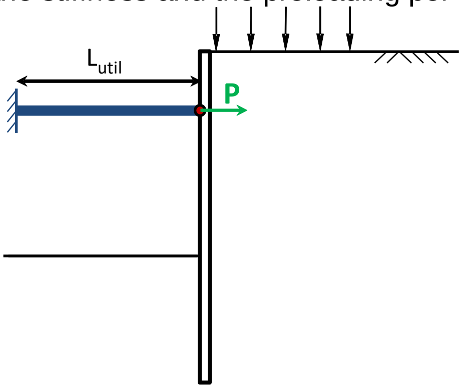


Figure C64: Diagram of level of struts

A level of struts is considered to be an equivalent spring characterized by:

- Stiffness (axial) per unit length:

$$K_b = \frac{ES}{L_u e_h}$$

- A pre-load (axial) per unit length:

$$P = \frac{P_b}{e_h}$$

In which:

- E : Young modulus of strut [kN/m²];
- S : strut section [m²];
- e_h : horizontal spacing between struts [m];
- P_b : pre stress applied on a strut [kN];
- L_u : usefull length [m].

AMRetain

D. TUTORIAL MANUAL

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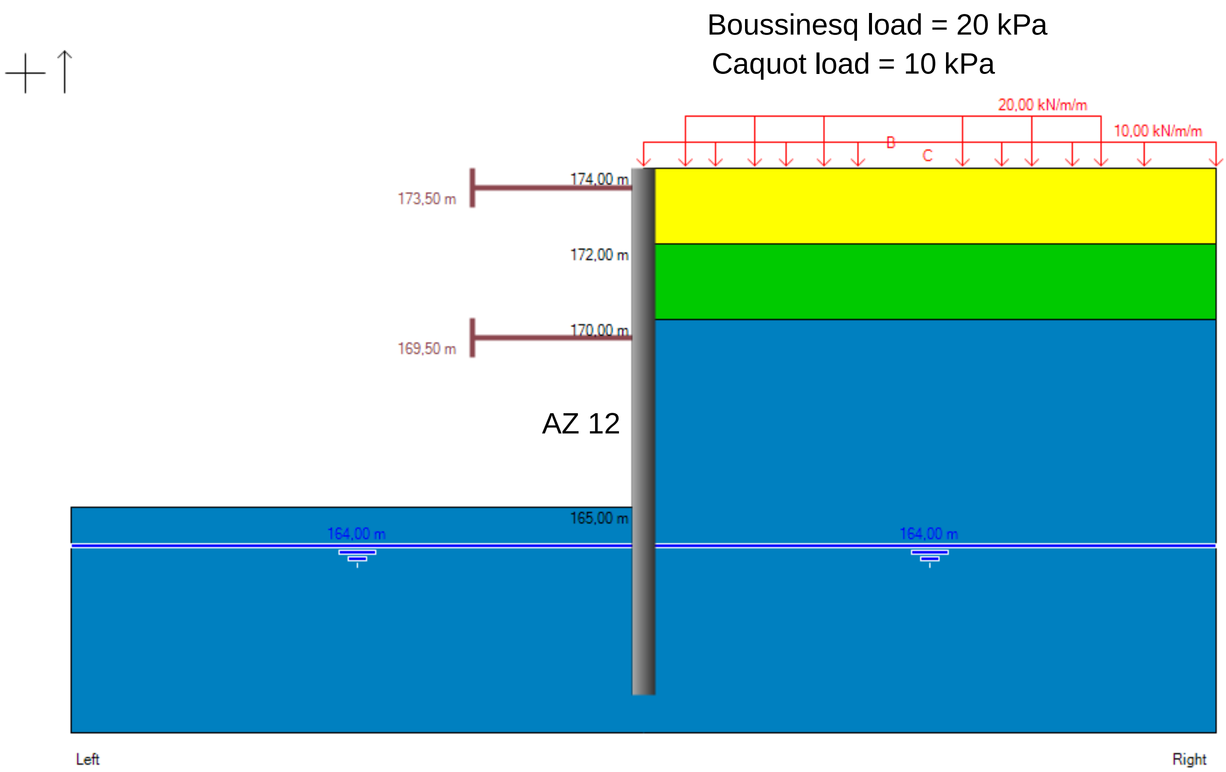
D.1. TUTORIAL 1: SINGLE SHEETPILE WALL WITH 2 STRUTS LEVELS

This example deals with the design of a single sheet pile wall with two levels of permanent struts (floors). It will be checked here with respect to SSIM calculation only. Please refer to tutorials 2 and 3 for details about ULS checks.

The wall is made of ArcelorMittal sheet piles of type AZ 12, 14 m long.

The figure below illustrates this project.

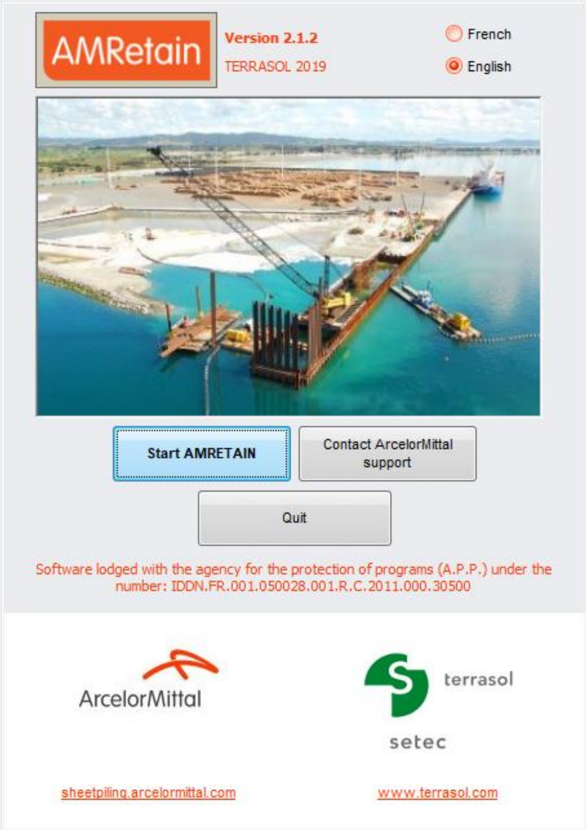


This is a first introductory example intended to illustrate the user interface and the main features of AMRetain.

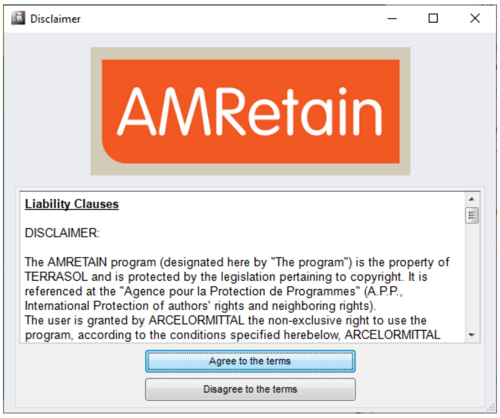
D.1.1. STEP 1: DATA INPUT

D.1.1.1. TITLE AND OPTIONS

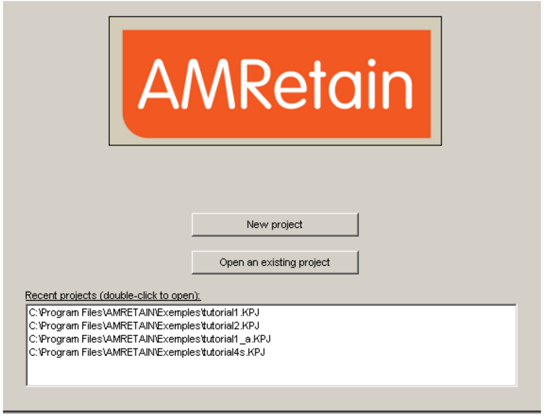
- Click on **Start, Programs, AMRetain**.



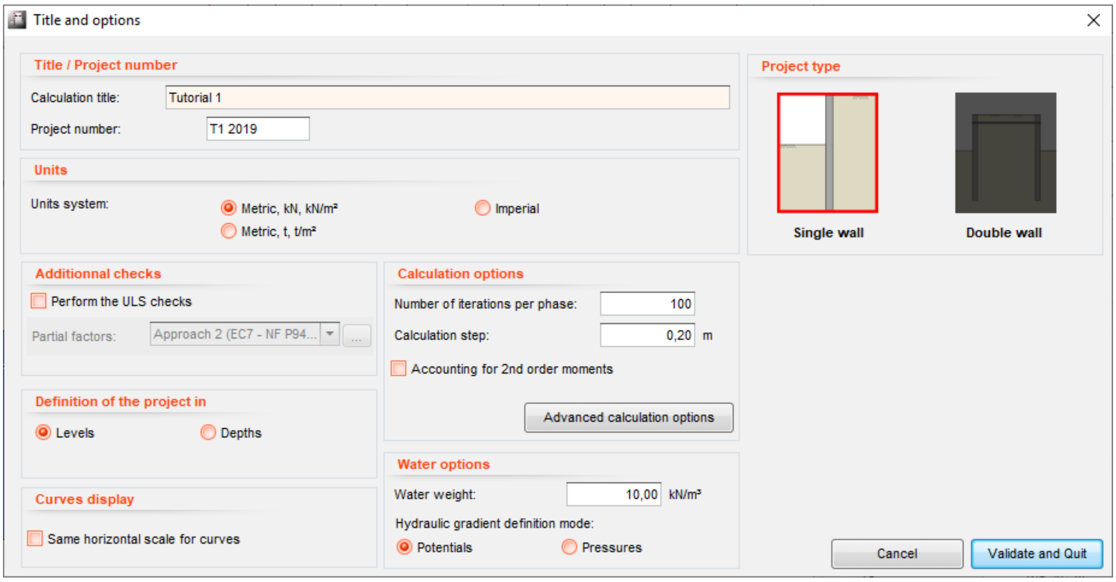
- Select **English** language, and click on **Start AMRetain**
- Check **I accept liability clauses**.



- Select **New project**.



- The dialogue box **Title and Options** is then displayed (and should be filled in with the data mentioned on the screenshot).

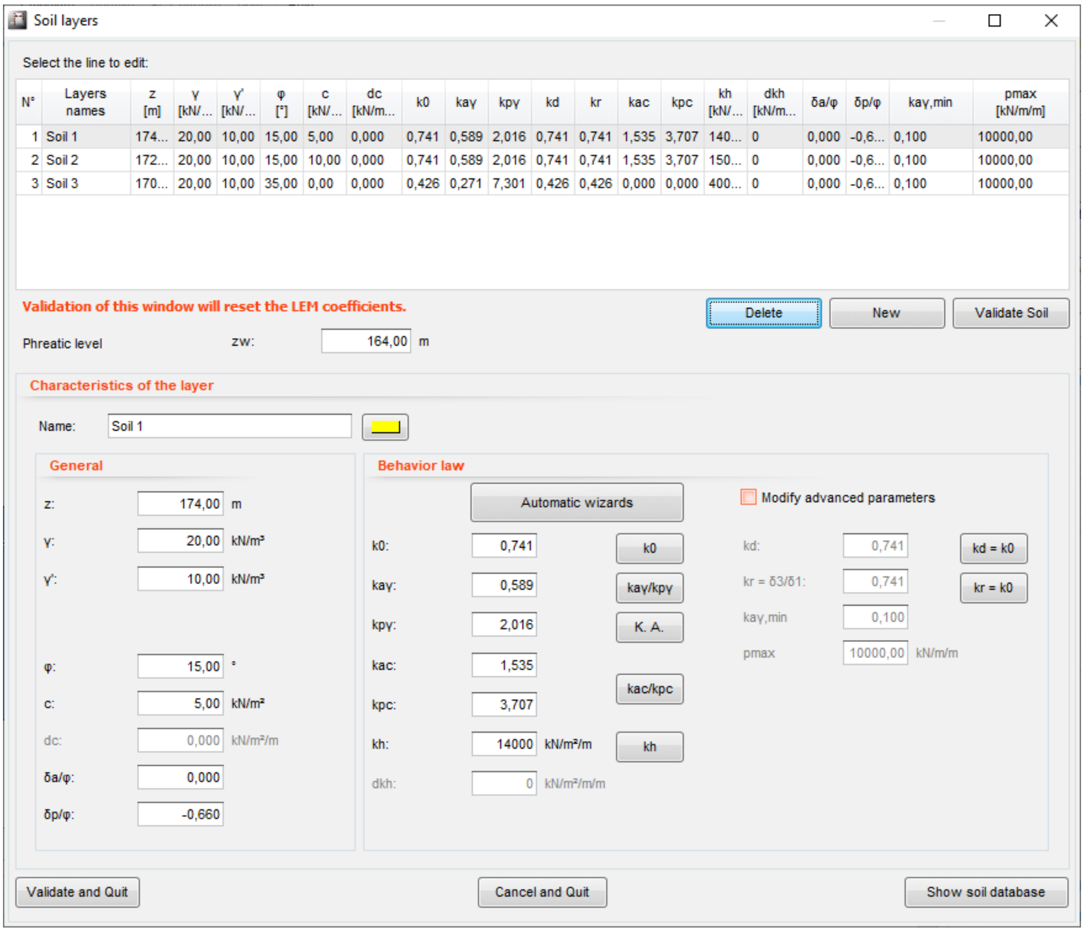


- Select **Single wall**.
- In the zone **Title / Project Number**, click on the Title blank line and define a title for the project.
- In the same, define a project number or reference.
- We will use **metric units.**
- The water weight default value is 10 kN/m^3. Let's keep this value.
- Select **Definition of the project in Levels**, which will direct the vertical axis upwards.
- In the zone **Calculation Options**, keep the default settings, i.e., **100 iterations** per calculation phase and a calculation step of **0,20 m** along the wall. We will not take into account buckling here (2^{nd} order moments).
- Leave the box **Perform the ULS checks** unchecked for this example.

D.1.1.2. DEFINITION OF SOIL PROPERTIES

- The dialogue box **Characteristics of soil layers** is then displayed and should be filled in to achieve the following screenshot.

  We should input all soil properties for the 3 soil layers.

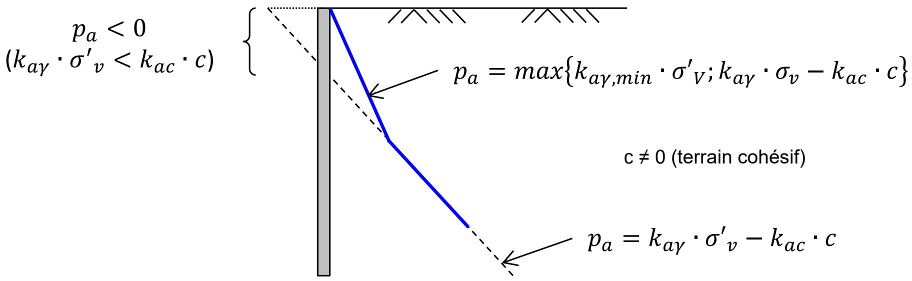


The bottom part of the dialogue box is intended for data input. Please fill in the properties of the first soil layer (LAYER1).

- To complete the coefficients k_0, $k_{a\gamma}$, $k_{p\gamma}$, k_{ac}, k_{pc}, k_d, k_r,, please, use the Automatic wizards and leave the "Modify advanced parameters" box unchecked.

These fields are filled in respect of the following principles:

  - **k_0** is calculated by Jacky's formula, with Roc = 1, β = 0 and taking into account the characteristics already entered.
  - **$k_{a\gamma}$** is calculated via the "Kerisel and Absi table" wizard - "Passive earth pressure – Weighted cohesionless soil, no overload, with λ = 0 and β/φ = 0 (horizontal ground) and taking into account the characteristics already entered.
  - **$k_{p\gamma}$** is calculated via the "Kerisel and Absi table" wizard – Active earth pressure – Weighted cohesionless soil, no overload with λ = 0 and β/φ = 0 (horizontal ground) and taking into account the characteristics already entered.
  - **k_d = k_r = k_0.**
  - **k_{ac}** and **k_{pc}** (coefficients applied on the cohesion value) are obtained via the corresponding assistant.
  - **$k_{a\gamma,min}$** is the minimum passive earth pressure coefficient required by the standard NF P 94-282. The default value is 0.1 to take into account the minimal horizontal stress corresponding to 10% of the vertical effective stress. This assumption allows to avoid negative active earth pressures in case of cohesive soils.



  - **p_{max}** represents the maximum admissible value of the soil pressure. Its value will limit the allowable limit pressure of the soil according to the standard NF P 94-282 Annex B.3.6. It corresponds to the creep pressure (p_f) or the limit pressure (p_l) according to the type of calculation (SLS or ULS respectively).
  - In this example, keep **dc** = 0.

- We just have to define the value **K_h** and his increment. For this example we consider that the value of k_h is known. We don't use any wizard to define his value. **K_h** = 14 000 kN/m²/m.
- Click on Validate Soil and then on New to fill in the characteristics of the second soil.
- Repeat the operation for the third soil.
- Click on Validate and Quit

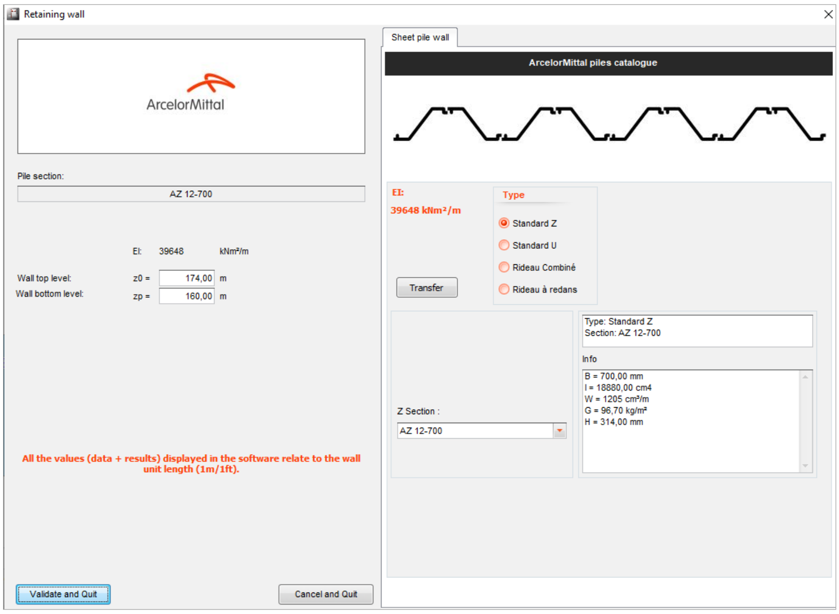
The characteristics of the layers are summarized in the following table:

	z (m)	zw (m)	γ (kN/m³)	γ_d (kN/m³)	φ (°)	c (kN/m²)	δa/φ	δp/φ
Soil 1	174	164	20	10	15	5	0	-0.66
Soil 2	172	164	20	10	15	10	0	-0.66
Soil 3	170	164	20	10	35	0	0	-0.66

	k0	ka γ	kp γ	kac	kpc	kh (kN/m²/m)
Soil 1	0.741	0.589	2.019	1.53	3.71	14000
Soil 2	0.741	0.589	2.019	1.53	3.71	15000
Soil 3	0.426	0.271	7.359	0	0	40000

D.1.1.3. DEFINITION OF WALL PROPERTIES

- The dialogue box **Retaining wall** is then displayed and should be filled in to achieve the screen shot below.



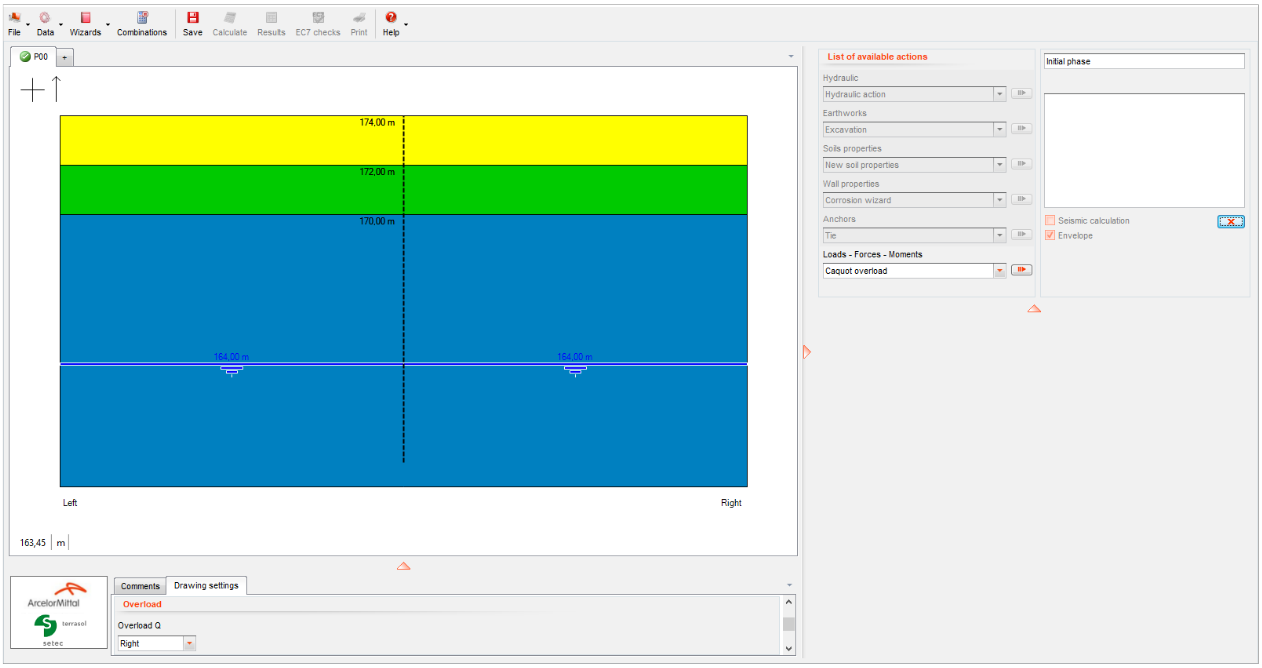
- In the zone **ArcelorMittal catalogue of steel sheet piles**, check type **Standard Z** (default selection). In the list **Z Section**, select **AZ 12-700**. Click on the button **Transfer** to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z0 and the wall bottom level Zp, with the values provided in the next table.

	Type	EI (kN/m²)	Z0 (m)	Zp (m)
Wall	AZ 12-700	39648	174	160

- Click on Validate and Quit.

D.1.2. <u>STEP 2: DEFINITION OF PHASES AND ACTIONS</u>

When data input has been completed, the main screen should be like on the screenshot below.



The AMRetain main window displays the initial phase of the project with the drawing of the wall and soil layers.

We should first define the actions for the initial phase (P00). In our case, we have to define a Caquot uniform overload of 10 kN/m/m.

Then we will define 3 construction phases.

The complete phasing for this example is illustrated in the following tables.

Phase	Actions	Properties
Initial phase Caquot overload	1. Caquot overload 2. Caquot overload	1. Load on left side, q = 10 kN/m/m 2. Load on left side, q = 10 kN/m/m
Phase 1 Excavation on the left side	1. Excavation	1. Left side, zh = 172.5 m
Phase 2 Installation of the first struts level Excavation on the left side	1. Strut 2. Excavation	1. Strut : za = 173.5 m, K = 400000 kN/m/m 2. Left side : zh = 168.5 m
Phase 3 Installation of the second struts level Excavation on the left side Boussinesq load on ground level	1. Strut 2. Excavation 3. Boussinesq overload	1. Strut : za = 169.5 m, K = 400000 kN/m 2. Left side, zh = 165.0 m 3. Boussinesq overload : z = 174 m, x = 1 m, L = 10 m, q = 20 kN/m², αe = 1,5

D.1.2.1. <u>DEFINITION OF INITIAL PHASE (“PHASE 0”)</u>

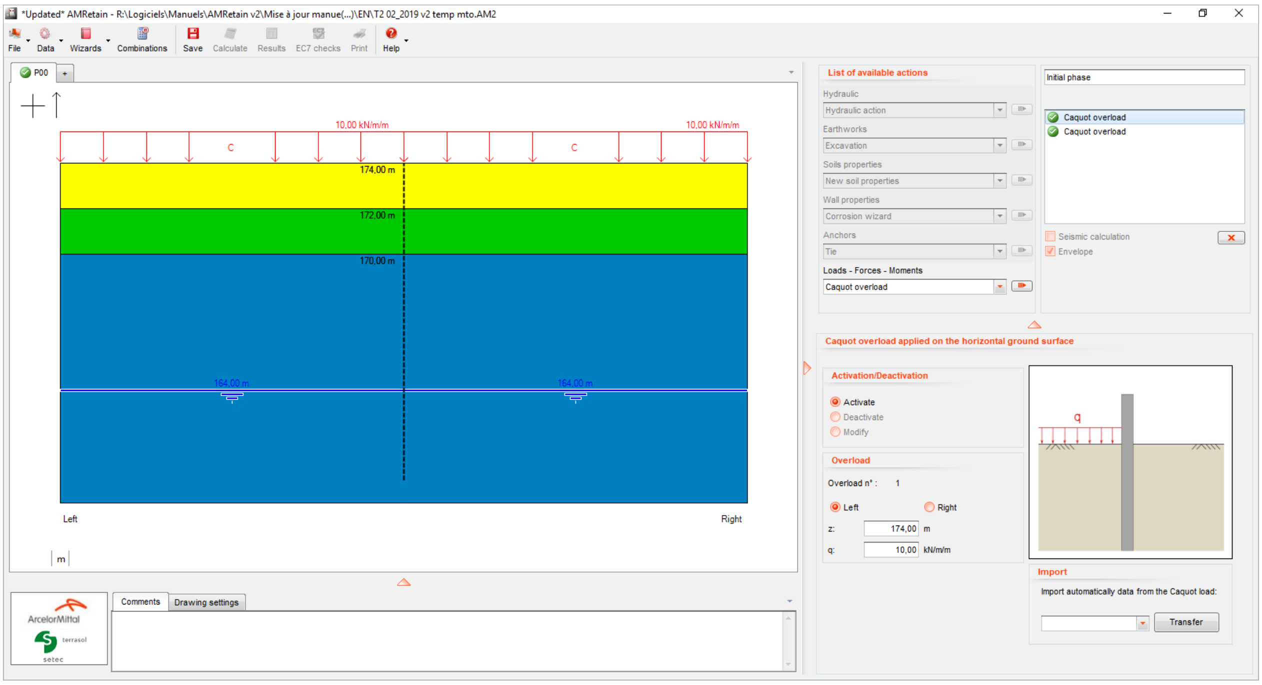
Define the Caquot load to be added by selecting again **Caquot overload** in the **Initial phase** list and click on the transfer button .

- Input the requested property in the bottom part of the screen:

Overload q = 10 kN/m/m with z=174 m

This action must be defined once to the right of the wall and once to the left of the wall (to guarantee the continuity of the vertical stresses). It is therefore advisable to repeat the operation and indicate the correct side of the wall.

When the definition of the initial phase is completed, the main screen should look like this:



D.1.2.2. <u>DEFINITION OF PHASE 1</u>

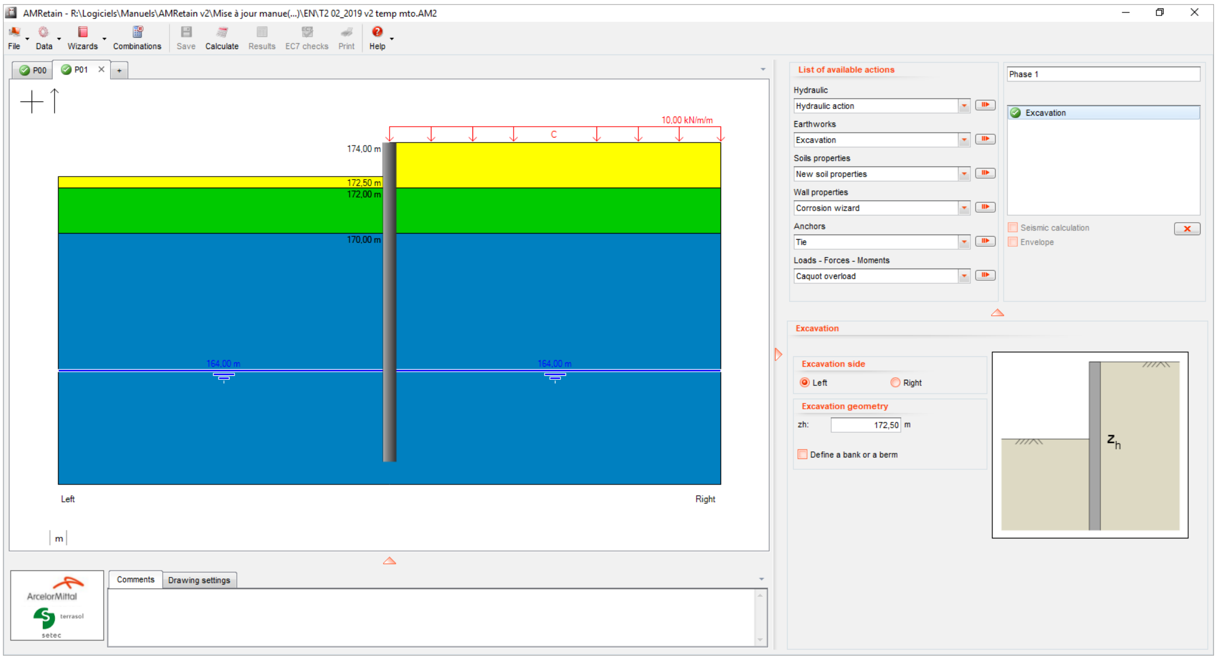
First of all, we should create a new phase.

- Click on tab [+] on the upper side of the window, next the initial phase.
- A new tab is created for phase 1 (with the same settings as the initial stage at the moment).
- Now we have to define the first excavation action to be executed in phase 1: select **Excavation** in the **Earthworks** list and click on the transfer button.
- Input the requested properties in the right bottom part of the wall:

Left side Excavation level zh = 172.5 m

The graphic is updated, taking into account the the excavation.

When the definition of this phase is completed, the main screen should look like this:



Note: the **Excavation** action on the left side automatically removes the Caquot load that had been previously defined on this side.
If we need to apply an overload on the level excavated, it is necessary to define a new action "Caquot Overload".

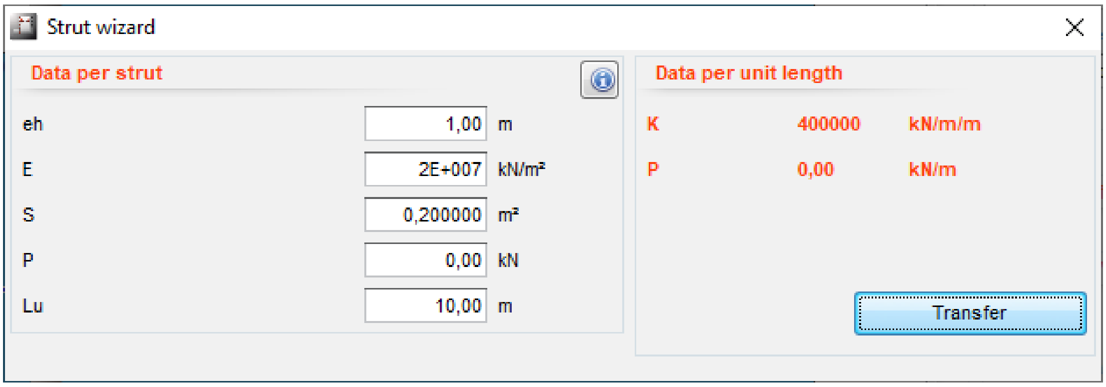
D.1.2.3. DEFINITION OF PHASE 2

The aim of the second phase is to install the first level of struts and to proceed with the next excavation.

- Click on tab + next the first phase.
- Now we have to define the first level of struts: select **Strut** in the **Anchors** list.
- Click on the transfer button.
- Input the requested properties in the right bottom part of the screen:

Activate Left side Head level za = 173.5 m Stiffness K = 400000 kN/m/m Operate under compression

The struts wizard may be used in order to define the strut stiffness K: click on the **Wizard** button, and input the following properties, corresponding to a concrete continuous floor: E = 20e^6 kPa, S = 2e^5 mm^2 (S = 20 cm thickness x 1 m unit length), Lu = 10 m, eh = 1 m (unit length). Then click on the Transfer button.



- In addition to the Struts action, define an **Excavation** with the following properties:

Left side Excavation level zh = 168.5 m

D.1.2.4. DEFINITION OF PHASE 3

The aim of the third phase is to install the second level of struts, to proceed with the next excavation, and finally to add a Boussinesq load on ground level.

- Click on tab + on the upper side of the window.
- Now we have to define the second level of struts, with the following properties:

Activate a new anchor Left side Head level za = 169.5 m Stiffness K = 400000 kN/m Operate under compression

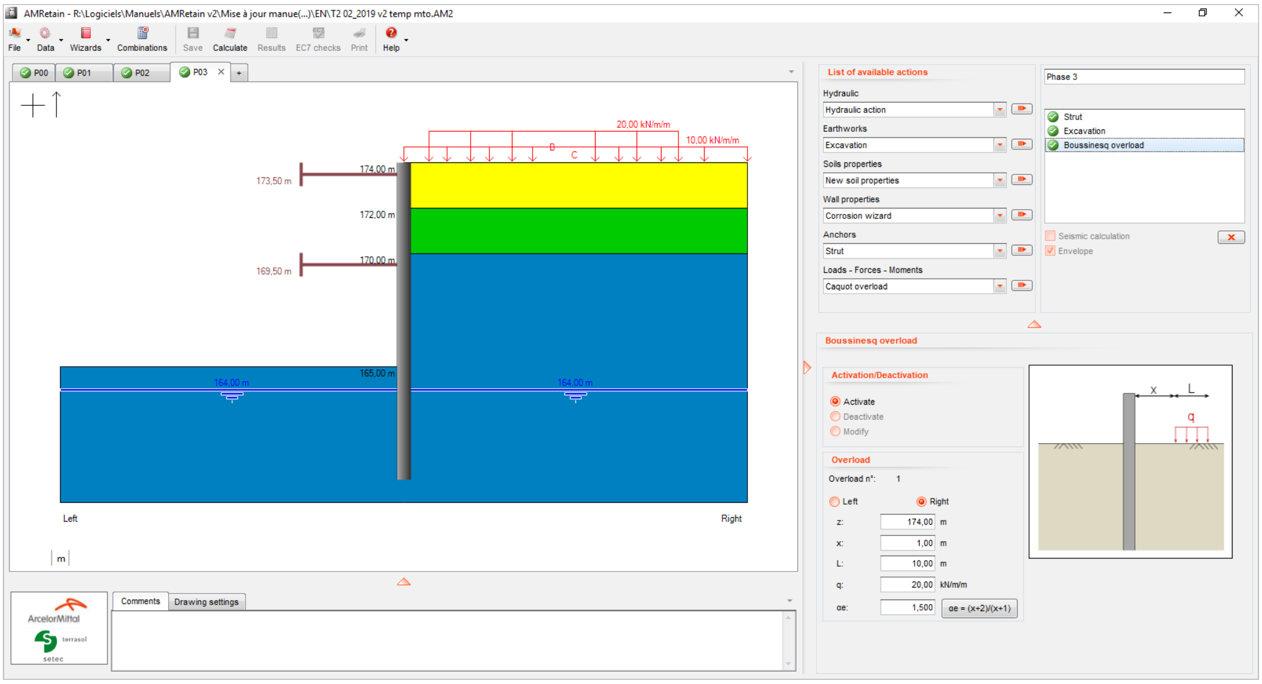
- In addition to the Struts action, define an **Excavation** with the following properties:

Left side Excavation level zh = 165.0 m

- Finally, define a **Boussinesq overload** (**Loads – Forces – Moments** list) with the following properties:

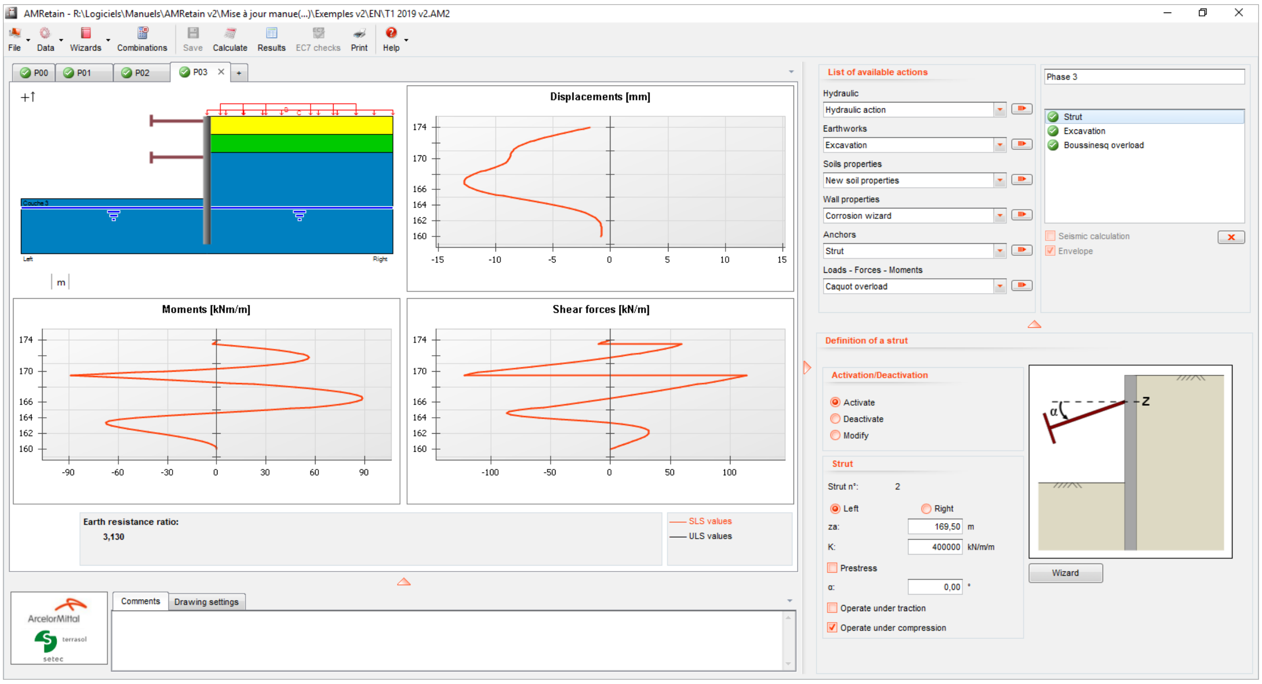
Right side Application level z = 174.0 m x = 1 m L = 10 m q = 20 kN/m^2 αe = 1,5

The main screen should now look like this:



D.1.3. STEP 3: CALCULATION AND OUTPUT

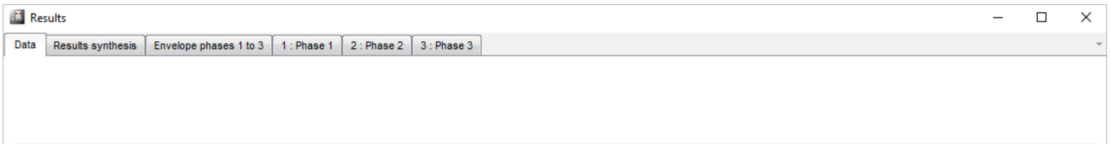
To perform the calculation of the 3 phases, please click on the Calculate button.
The following screenshots illustrate the results obtained after calculation for the **last calculation phase.**



To view the details of results (curves and tables), click on the button Results.

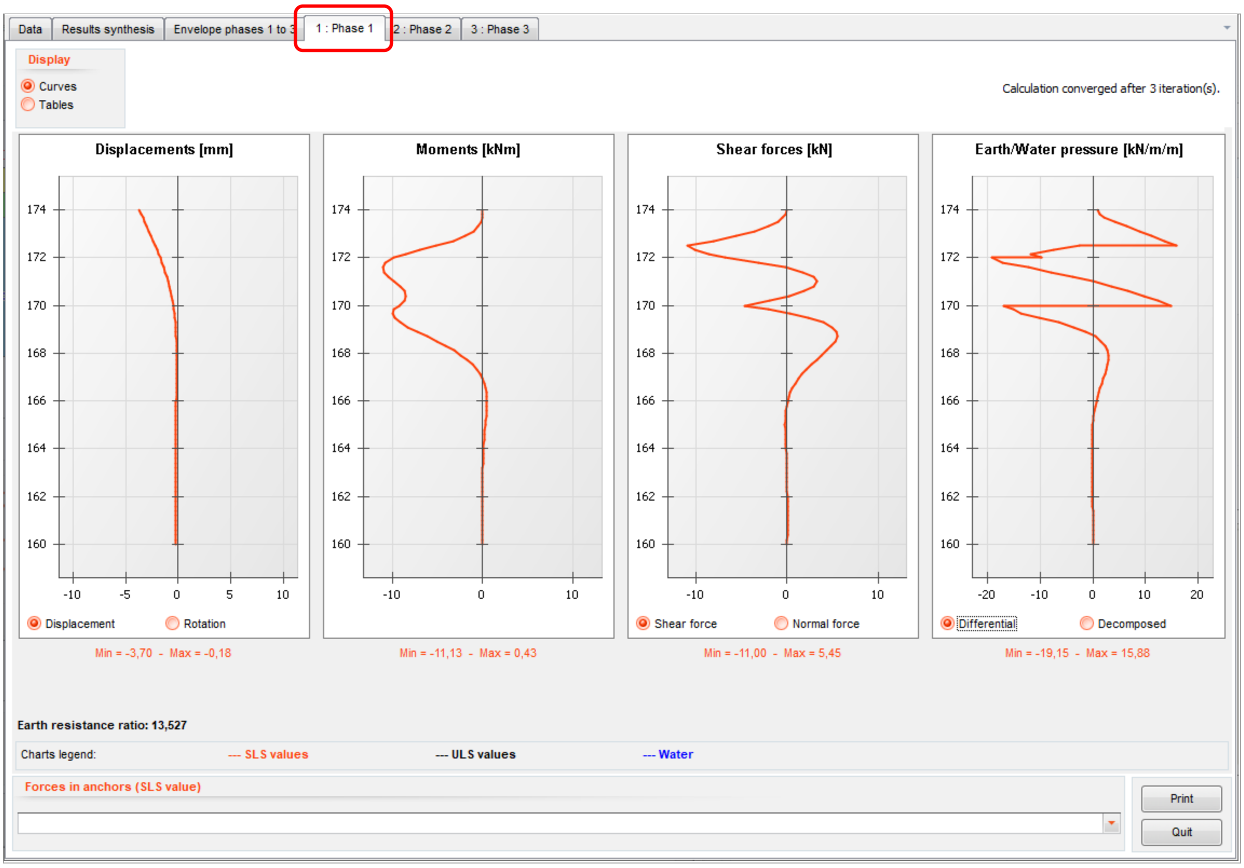
The following screenshots illustrate the various results available in AMRetain for a calculation without ULS checks.

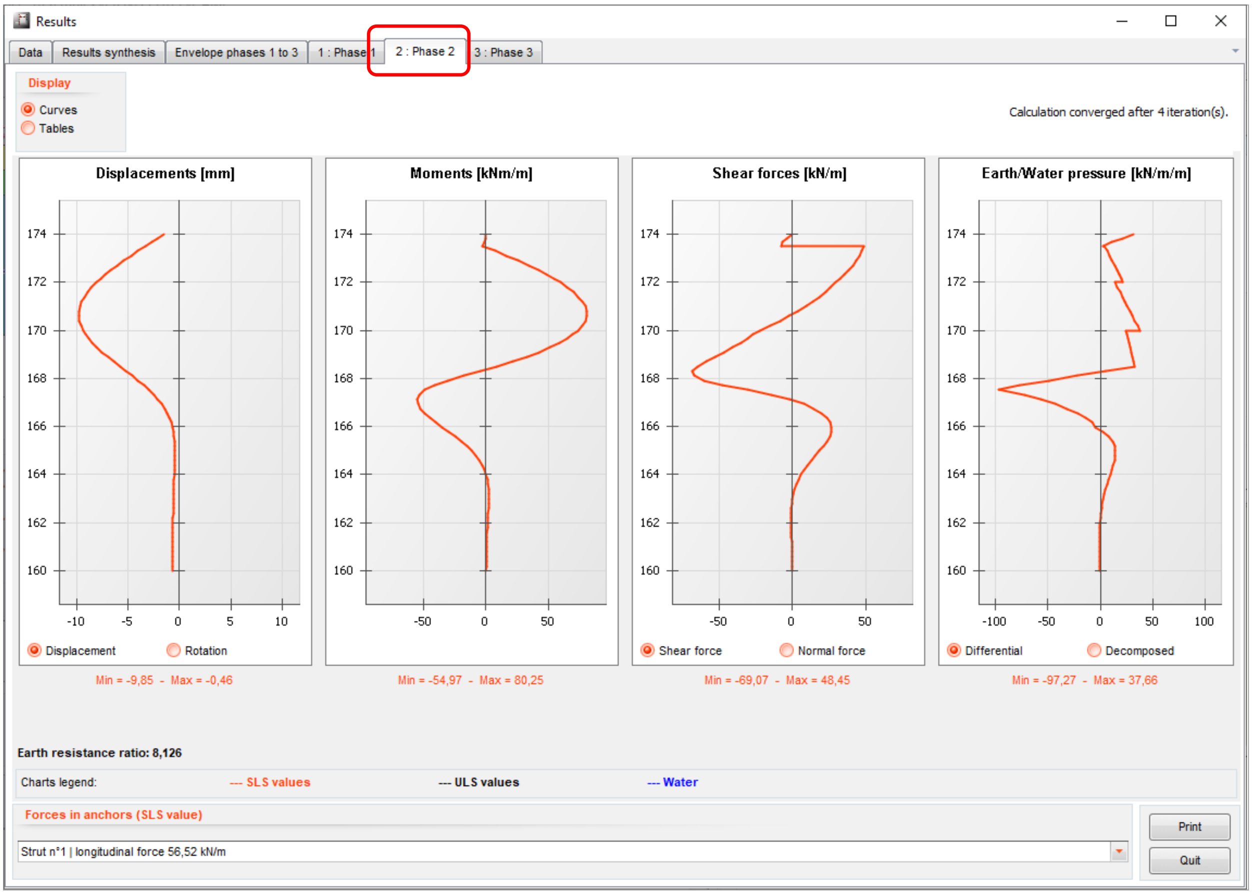
The first tab that is displayed by default is a summary of the project data: soil and wall properties, initial phase actions, etc.

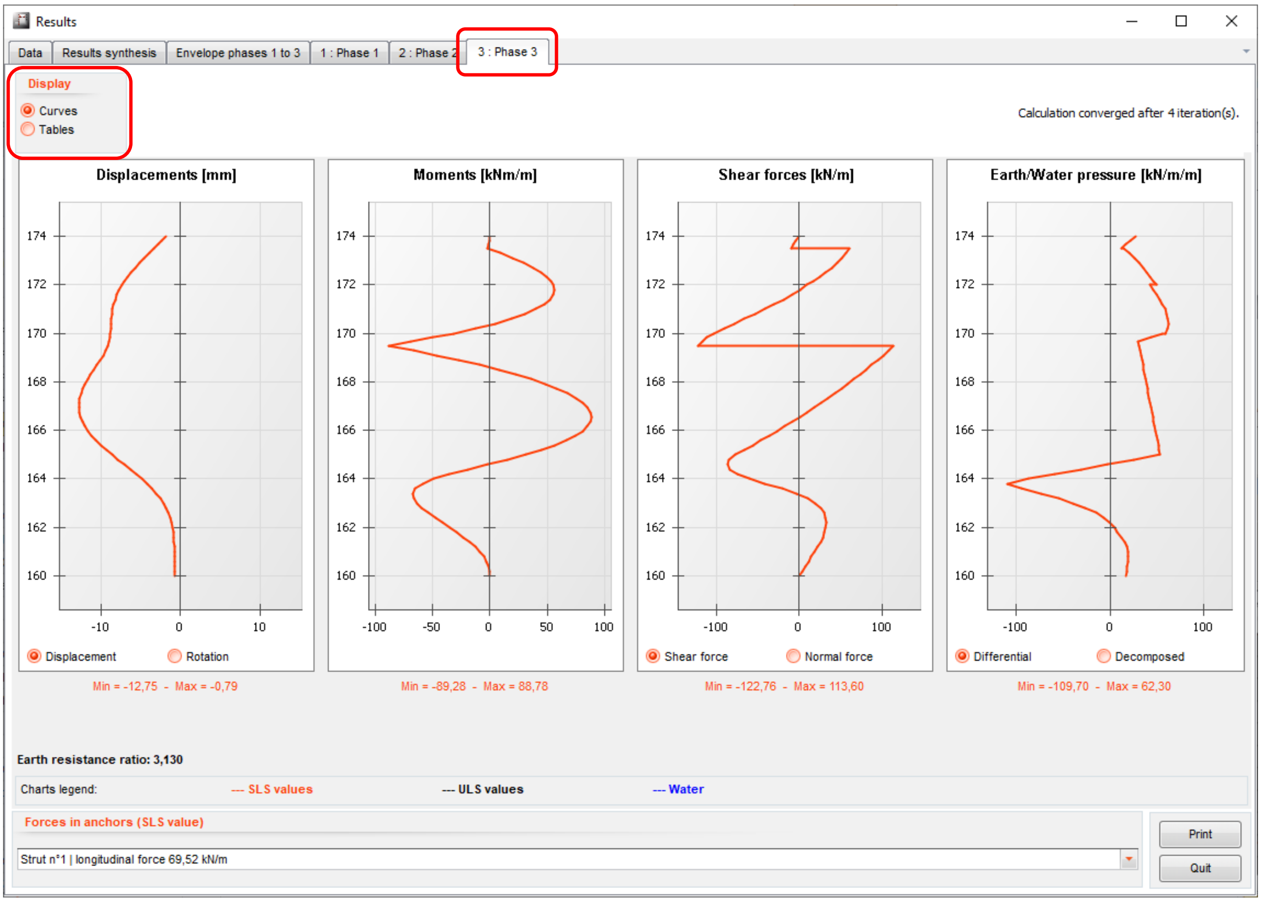


GENERAL SETTINGS																		
Units system:	Metric, kN, kN...																	
Weight density of water:	10,00 kN/m³																	
Number of iterations:	100																	
Calculation step:	0,20 m																	
Taking account of anchors buc...	No																	
Project definition:	Levels																	
SOIL PARAMETERS (character...																		
Layer	z	zw	γ	γ'	φ	c	dc	k0	kaγ	kpγ	kd	kr	kac	kpc	kh	dkh	δa/φ	δp/φ
	m	m	kN/m³	kN/m³	°	kN/m²	kN/m²/m								kN/m²/m	kN/m²/...		
Couche 1	174,00	164,00	20,00	10,00	15,00	5,00	0,000	0,741	0,589	2,016	0,741	0,741	1,535	3,707	14000	0	0,000	-0,660
Couche 2	172,00	164,00	20,00	10,00	15,00	10,00	0,000	0,741	0,589	2,016	0,741	0,741	1,535	3,707	15000	0	0,000	-0,660
Couche 3	170,00	164,00	20,00	10,00	35,00	0,00	0,000	0,426	0,271	7,301	0,426	0,426	0,000	0,000	40000	0	0,000	-0,660
WALL PROPERTIES																		
z0	174,00 m																	
Section	z,base	EI	Rc	W														
	m	kNm²/m	kN/m³	kN/m/m														
1	160,00	39648	0	0,97														

The next tabs enable to access the detailed results for each phase, as described in part B of the manual.

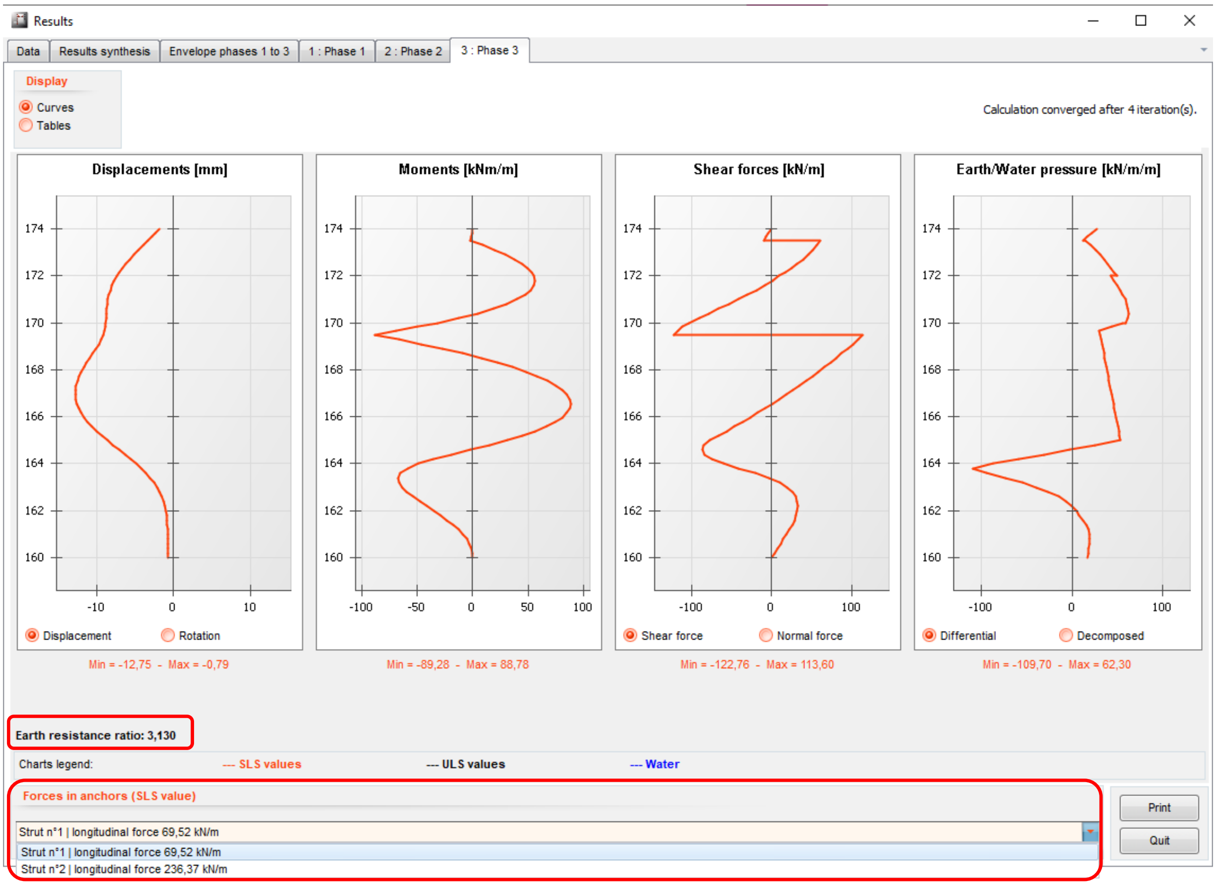




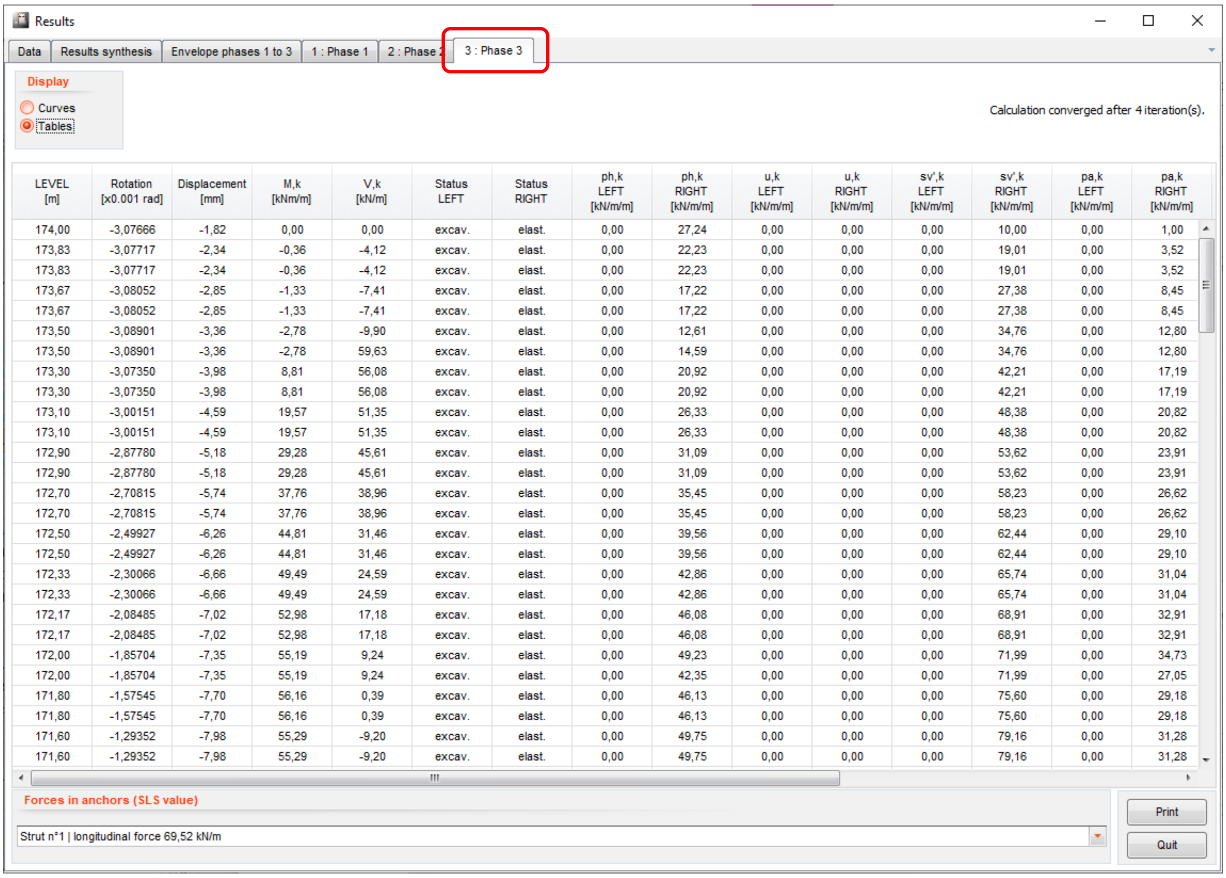


By default, the results are displayed as curves: displacements, moments, shear forces, and earth/water pressures (differential pressure is proposed by default, but it’s possible to switch to a display of decomposed pressures). The maximum values are provided for each curve.

When anchors (active anchors or struts) are active in a given phase, the axial forces in these anchors are also available for each phase at the bottom of the screen.
Finally, the earth resistance ratio (available/mobilised passive earth pressures) is displayed as well.

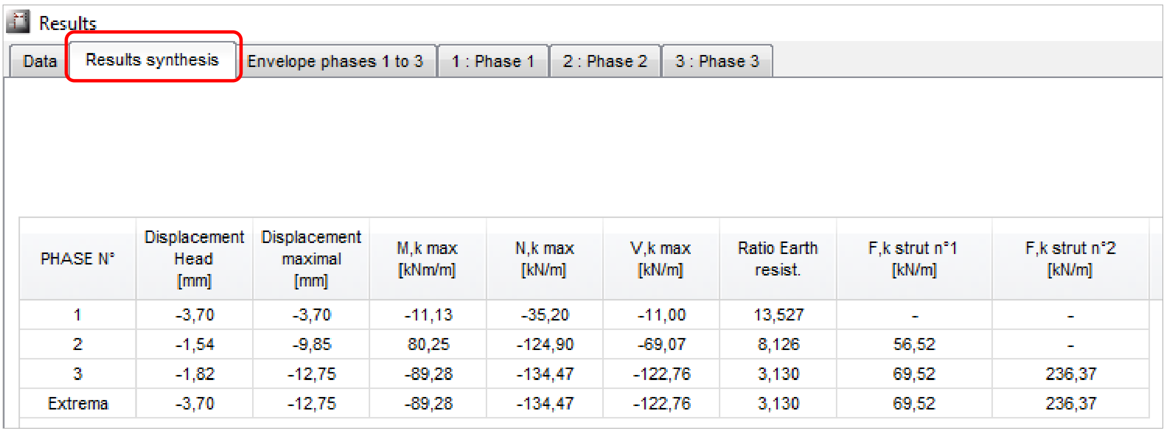


For each phase, it is also possible to display more detailed results in tables (the content of each column is detailed in part B of the manual):

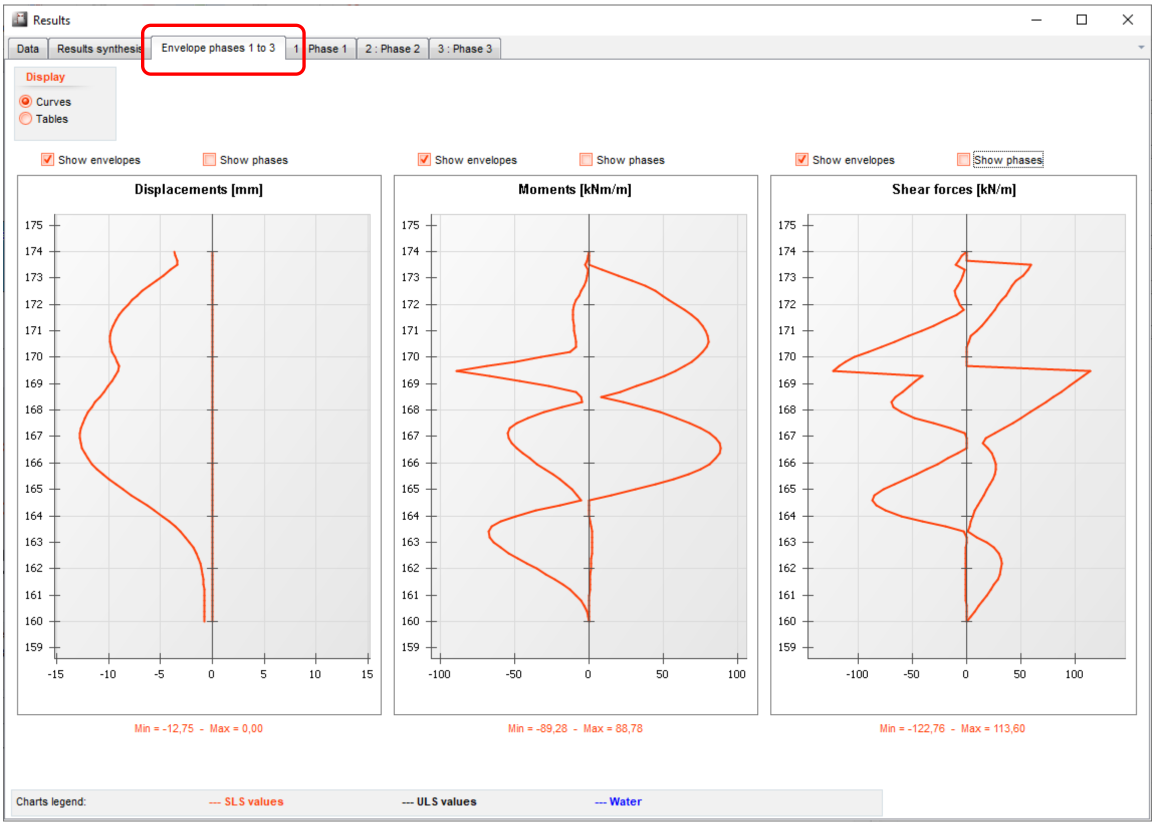


LEVEL [m]	Rotation [x0.001 rad]	Displacement [mm]	M,k [kNm/m]	V,k [kN/m]	Status LEFT	Status RIGHT	ph,k LEFT [kN/m/m]	ph,k RIGHT [kN/m/m]	u,k LEFT [kN/m/m]	u,k RIGHT [kN/m/m]	sv',k LEFT [kN/m/m]	sv',k RIGHT [kN/m/m]	pa,k LEFT [kN/m/m]	pa,k RIGHT [kN/m/m]
174,00	-3,07666	-1,82	0,00	0,00	excav.	elast.	0,00	27,24	0,00	0,00	0,00	10,00	0,00	1,00
173,83	-3,07717	-2,34	-0,36	-4,12	excav.	elast.	0,00	22,23	0,00	0,00	0,00	19,01	0,00	3,52
173,83	-3,07717	-2,34	-0,36	-4,12	excav.	elast.	0,00	22,23	0,00	0,00	0,00	19,01	0,00	3,52
173,67	-3,08052	-2,85	-1,33	-7,41	excav.	elast.	0,00	17,22	0,00	0,00	0,00	27,38	0,00	8,45
173,67	-3,08052	-2,85	-1,33	-7,41	excav.	elast.	0,00	17,22	0,00	0,00	0,00	27,38	0,00	8,45
173,50	-3,08901	-3,36	-2,78	-9,90	excav.	elast.	0,00	12,61	0,00	0,00	0,00	34,76	0,00	12,80
173,50	-3,08901	-3,36	-2,78	59,63	excav.	elast.	0,00	14,59	0,00	0,00	0,00	34,76	0,00	12,80
173,30	-3,07350	-3,98	8,81	56,08	excav.	elast.	0,00	20,92	0,00	0,00	0,00	42,21	0,00	17,19
173,30	-3,07350	-3,98	8,81	56,08	excav.	elast.	0,00	20,92	0,00	0,00	0,00	42,21	0,00	17,19
173,10	-3,00151	-4,59	19,57	51,35	excav.	elast.	0,00	26,33	0,00	0,00	0,00	48,38	0,00	20,82
173,10	-3,00151	-4,59	19,57	51,35	excav.	elast.	0,00	26,33	0,00	0,00	0,00	48,38	0,00	20,82
172,90	-2,87780	-5,18	29,28	45,61	excav.	elast.	0,00	31,09	0,00	0,00	0,00	53,62	0,00	23,91
172,90	-2,87780	-5,18	29,28	45,61	excav.	elast.	0,00	31,09	0,00	0,00	0,00	53,62	0,00	23,91
172,70	-2,70815	-5,74	37,76	38,96	excav.	elast.	0,00	35,45	0,00	0,00	0,00	58,23	0,00	26,62
172,70	-2,70815	-5,74	37,76	38,96	excav.	elast.	0,00	35,45	0,00	0,00	0,00	58,23	0,00	26,62
172,50	-2,49927	-6,26	44,81	31,46	excav.	elast.	0,00	39,56	0,00	0,00	0,00	62,44	0,00	29,10
172,50	-2,49927	-6,26	44,81	31,46	excav.	elast.	0,00	39,56	0,00	0,00	0,00	62,44	0,00	29,10
172,33	-2,30066	-6,66	49,49	24,59	excav.	elast.	0,00	42,86	0,00	0,00	0,00	65,74	0,00	31,04
172,33	-2,30066	-6,66	49,49	24,59	excav.	elast.	0,00	42,86	0,00	0,00	0,00	65,74	0,00	31,04
172,17	-2,08485	-7,02	52,98	17,18	excav.	elast.	0,00	46,08	0,00	0,00	0,00	68,91	0,00	32,91
172,17	-2,08485	-7,02	52,98	17,18	excav.	elast.	0,00	46,08	0,00	0,00	0,00	68,91	0,00	32,91
172,00	-1,85704	-7,35	55,19	9,24	excav.	elast.	0,00	49,23	0,00	0,00	0,00	71,99	0,00	34,73
172,00	-1,85704	-7,35	55,19	9,24	excav.	elast.	0,00	42,35	0,00	0,00	0,00	71,99	0,00	27,05
171,80	-1,57545	-7,70	56,16	0,39	excav.	elast.	0,00	46,13	0,00	0,00	0,00	75,60	0,00	29,18
171,80	-1,57545	-7,70	56,16	0,39	excav.	elast.	0,00	46,13	0,00	0,00	0,00	75,60	0,00	29,18
171,60	-1,29352	-7,98	55,29	-9,20	excav.	elast.	0,00	49,75	0,00	0,00	0,00	79,16	0,00	31,28
171,60	-1,29352	-7,98	55,29	-9,20	excav.	elast.	0,00	49,75	0,00	0,00	0,00	79,16	0,00	31,28

In addition to these results by phase, 2 additional tabs are available: **Results synthesis** and **Envelope phases 1 to 3**.



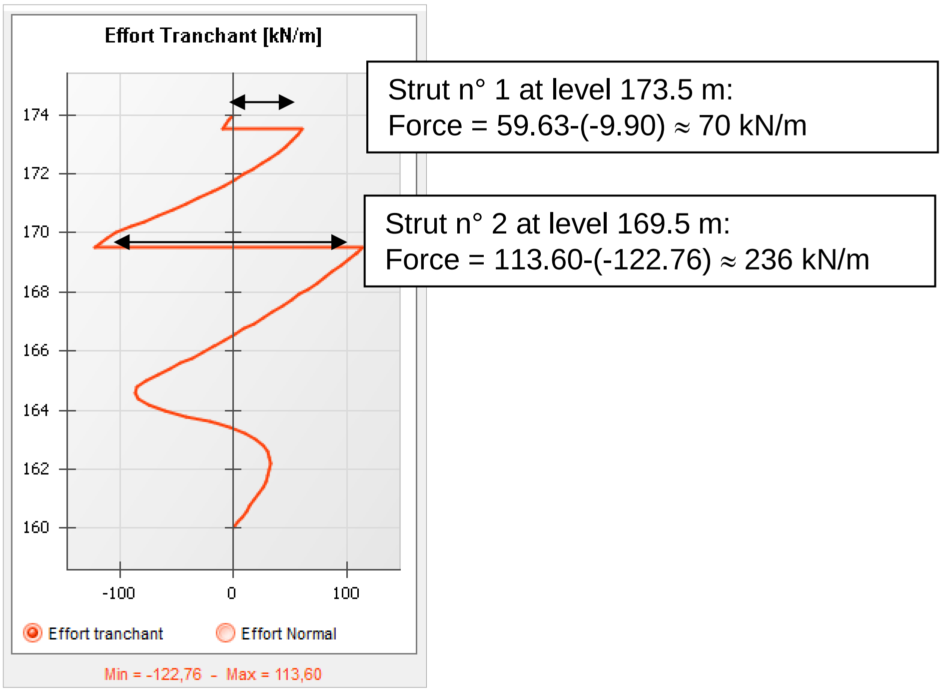
PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k strut n°1 [kN/m]	F,k strut n°2 [kN/m]
1	-3,70	-3,70	-11,13	-35,20	-11,00	13,527	-	-
2	-1,54	-9,85	80,25	-124,90	-69,07	8,126	56,52	-
3	-1,82	-12,75	-89,28	-134,47	-122,76	3,130	69,52	236,37
Extrema	-3,70	-12,75	-89,28	-134,47	-122,76	3,130	69,52	236,37



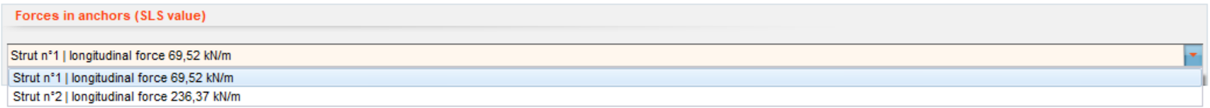
Comments on the results of the calculation

- The maximum displacement is 13 mm. It is reached in the last phase, at level 167.0 m. The shape of the displacement curves changes depending on the number of supports (struts) along the wall. For instance, in the first phase (no strut), the maximum displacement is reached at the top of the wall (4 mm).
- The maximum moment is 89 kNm/m. It is reached in the last phase, at level 166.5 m.
- The maximum shear force is 123 kN/m. It is reached in the last phase, at the same level as the second struts levels (169.5 m). The struts forces can be “read” directly on the shear force curve:

Phase 3



As mentioned before, they are also provided at the bottom of the screen (here for phase 3):



Finally, they are also included in the results synthesis.

- The force in strut n° 1 is maximum in the last phase, with 57 kN/m.
- The force in strut n° 2 is about 236 kN/m.

The second strut level takes a much higher force than the first level.

The earth resistance ratio decreases with each phase, from 13.5 in the first phase, to 3.1 in the last phase: it decreases because the embedment of the wall is each time smaller, due to the excavation on the left side. But the final value of 3.1 is largely acceptable.

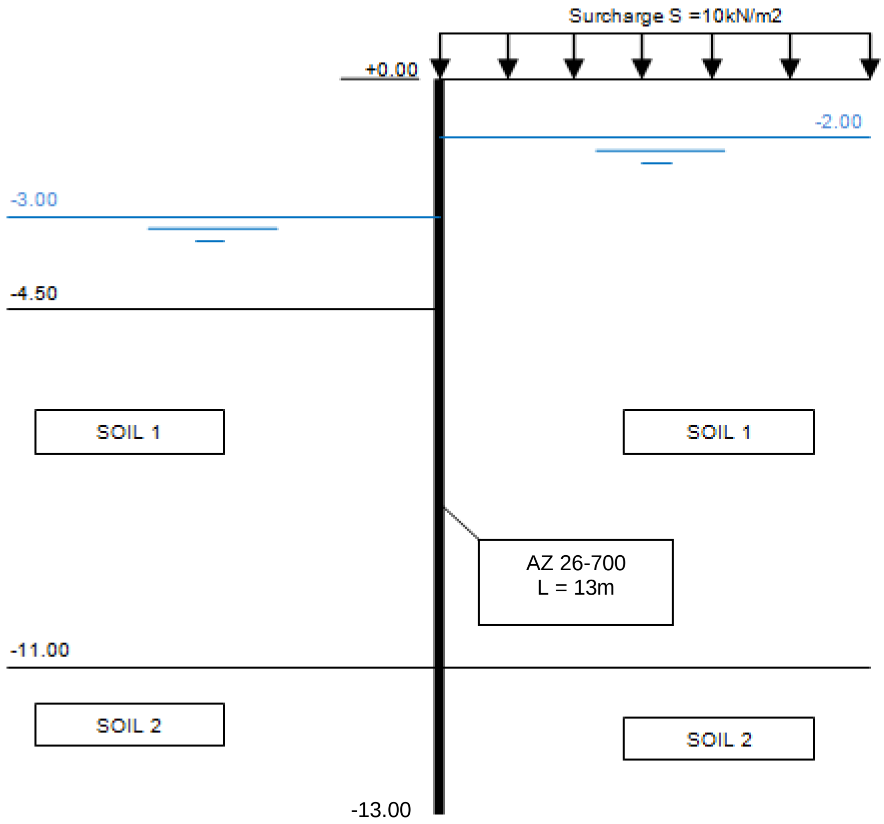
D.2. TUTORIAL 2: CANTILEVER WALL WITH ULS CHECKS

This example deals with the design of a permanent sheet pile cantilever (embedded) wall.

The wall is made of ArcelorMittal sheet piles of type AZ 26-700, 13 m long.

No anchor is installed, and the wall is thus cantilever (embedded).

The figure below illustrates this project.



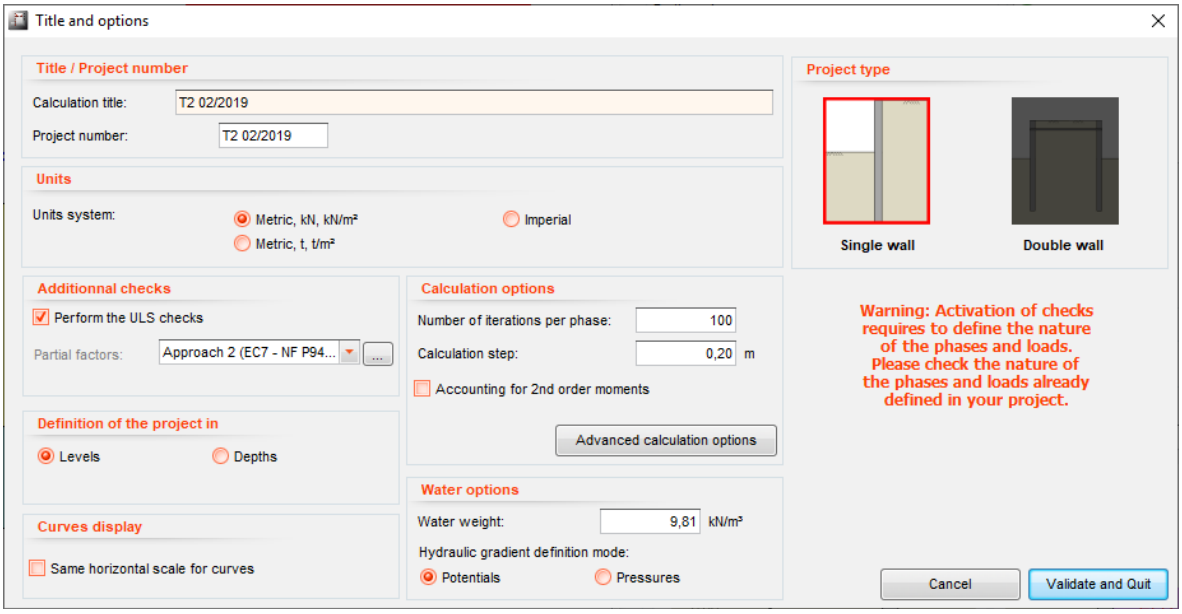
In this example, we will detail the ULS checks. The embedment of the wall is not long enough with respect to these checks and thus we will have to make some changes to the project: this procedure is detailed here.

At the end of this example, we will also compare the use of methods D and F for LEM calculations.

D.2.1. <u>STEP 1: DATA INPUT</u>

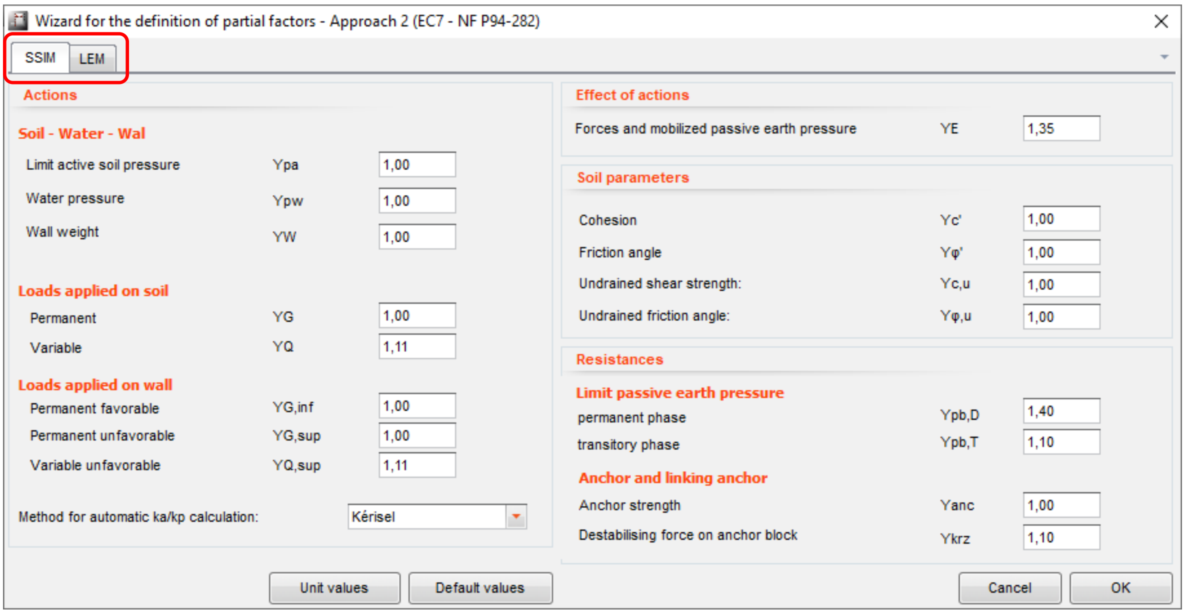
D.2.1.1. <u>TITLE AND OPTIONS</u>

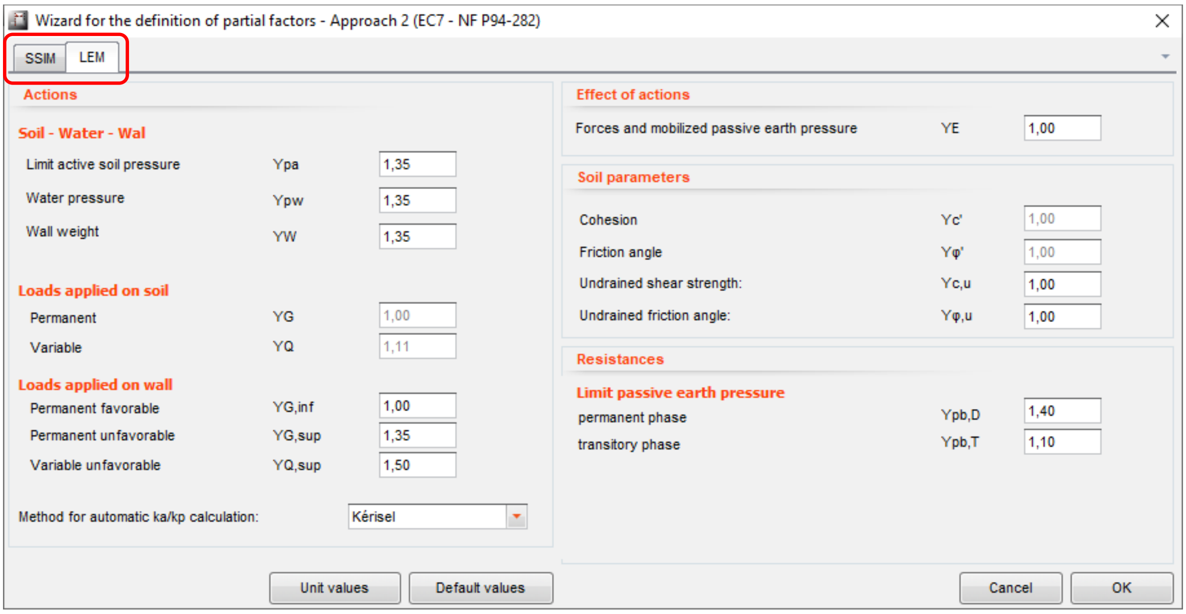
- Click on **Start, Programs, AMRetain**.
- Select **English** language, and click on **Start AMRetain**
- Check **I accept liability clauses**.
- Select **New project**.
- The dialogue box **Title and Options** is then displayed (and should be filled in with the data mentioned on the screenshot).



- Select **Single wall**.
- In the zone **Title / Project Number**, click on the Title blank line and define a title for the project.
- In the same, define a project number or reference.
- We will use **metric units kN, kN/m².**
- The water soil weight may be changed it will here be replaced with **9.81** kN/m^3.
- Select **Definition of the project in Levels**, which will direct the vertical axis upwards.
- In the zone **Calculation Options**, keep the default settings, i.e., 100 iterations per calculation phase and a calculation step of 0,20 m along the wall. We will not take into account buckling here (2nd order moments).
- Check the box **Perform the ULS checks**, and keep the default safety factors **NF 94-282 (Eurocode 7)**.

  You may display the set of partial factors by clicking the [...] button.





- Click on [OK] when you are finished with this screen.
- Click on [Validate and Quit].
- Save the project with the name and in the directory you wish to use.

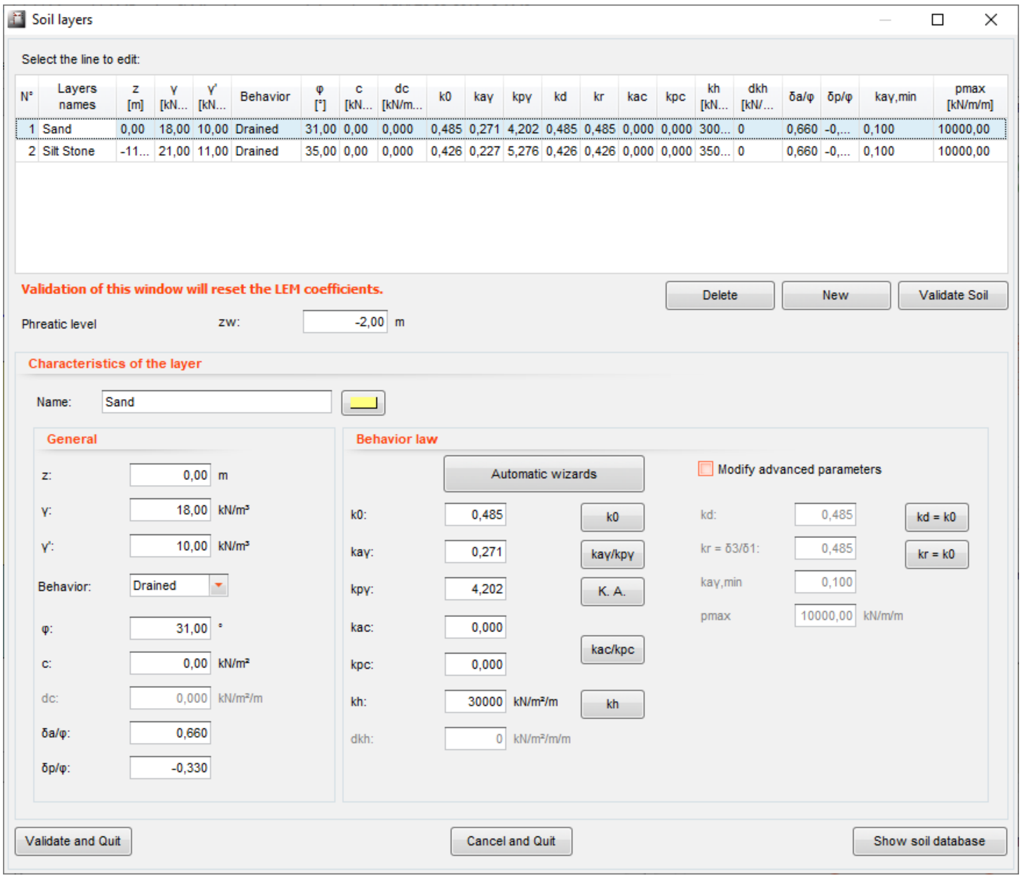
D.2.1.2. DEFINITION OF SOIL PROPERTIES

The soil properties summarised in the table below:

	z (m)	zw (m)	γ (kN/m³)	γd (kN/m³)	φ (°)	c (kN/m²)	δa/φ	δp/φ
Sand	0	-2	18	10	31	0	0.66	-0.33
Silt stone	-11	-2	21	11	35	0	0.66	-0.33

	k0	ka γ	kp γ	kac	kpc	kh (kN/m³)
Sand	0.485	0.271	4.202	0	0	30000
Silt stone	0.426	0.227	5.276	0	0	35000

The dialogue box **Characteristics of soil layers** is then displayed and should be filled in to achieve the following screenshot. The bottom part of the dialogue box is intended for data input. Please fill in the properties of the first soil layer (SOIL1 SAND). Then click on **New** to fill the characteristics of the soil layer Silt Stone.

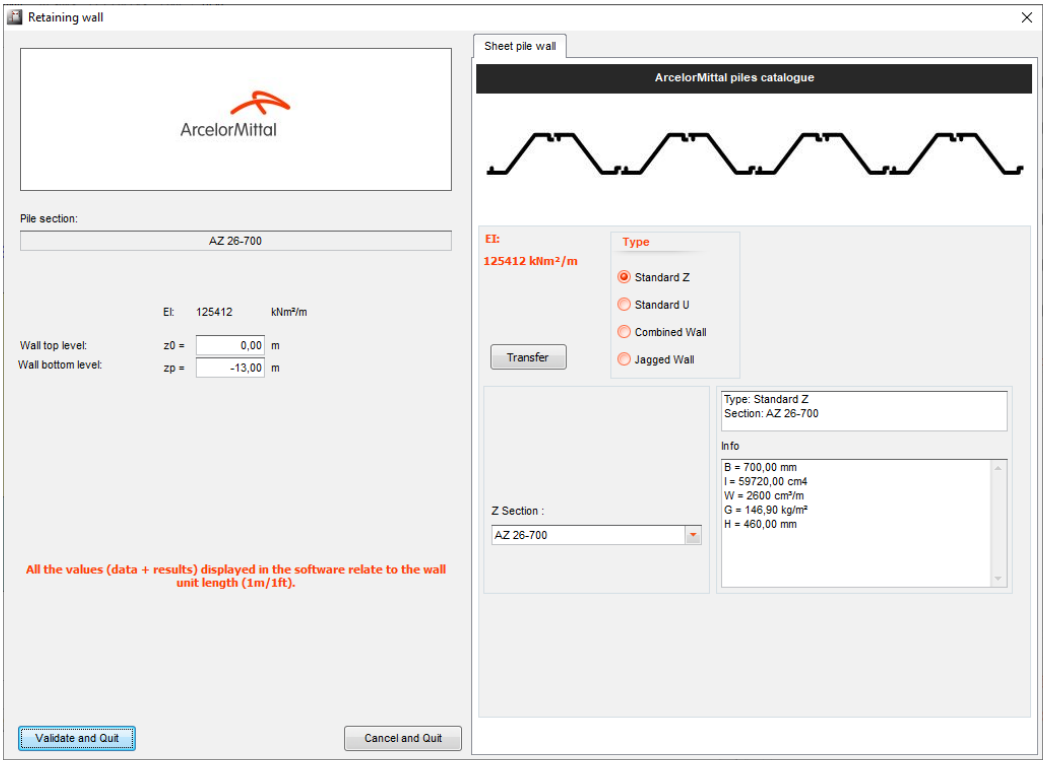


To complete the coefficients k_0, $k_{a\gamma}$, $k_{p\gamma}$, k_{ac}, k_{pc}, k_d, k_r, we will use here the automatics wizards. See tutorial 1 for more details about automatic wizards.

Click on Validate Soil button and then on Validate and Quit.

D.2.1.3. DEFINITION OF WALL PROPERTIES

- The dialogue box **Retaining wall** is then displayed and should be filled in to achieve the screen shot below.



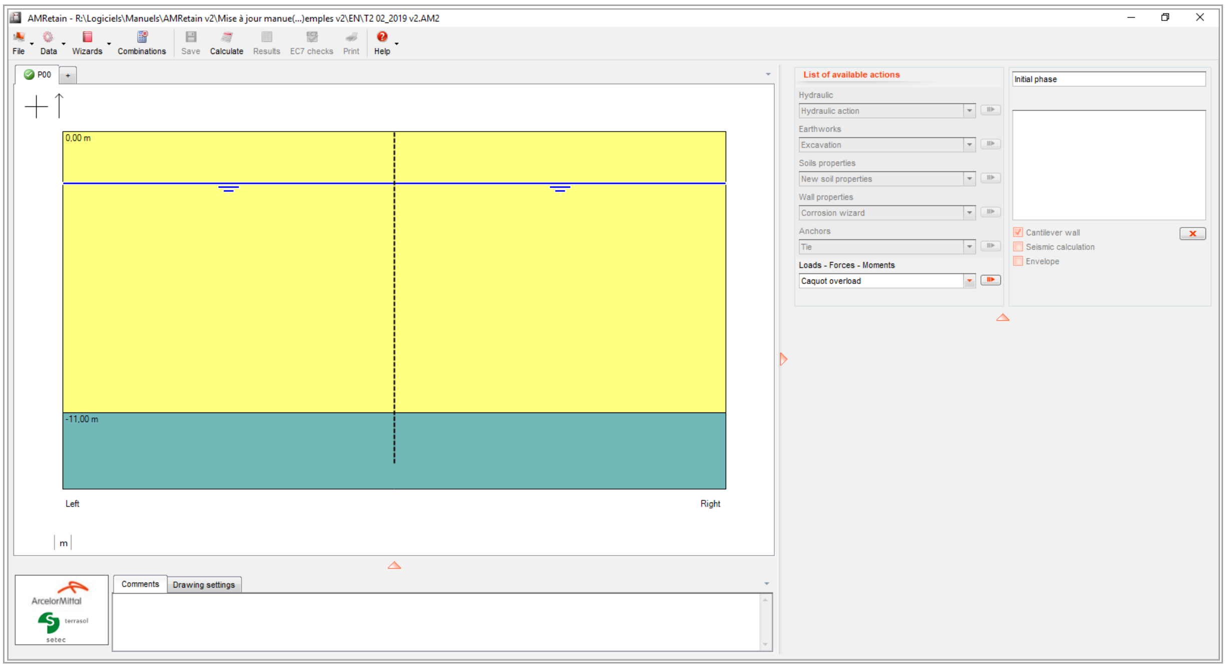
- In the zone **ArcelorMittal catalogue of steel sheet piles**, check type **Standard Z** (default selection). In the list **Z Section**, select **AZ 26-700**. Click on the button [Transfer] to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z0 and the wall bottom level Zp, with the values provided in the next table.

	Type	EI (kNm^2/m)	Z0 (m)	Zp (m)
Wall	AZ 26-700	125412	0	-13

- Click on [Validate and Quit].

D.2.2. <u>STEP 2: DEFINITION OF PHASES AND ACTIONS</u>

When data input has been completed, the main screen should be like on the screenshot below.



The AMRetain main window displays the initial phase of the project with the drawing of the wall and soil layers.

We should first define the actions for the initial phase (phase 0). But in our case, there's no action to be defined for the initial stage.

We will thus start with the creation of phase 1, as indicated below.

The complete phasing for this example is illustrated in the following tables.

Phase	**Actions**	**Properties**
Initial phase	-	-
Phase 1 (temporary) Excavation on the left side and overload on the ground level on the right side	1. Excavation 2. Loads	1. Left side, zh = -4.5 m, 2. Caquot overload, right side, zh = 0 m, q = 10 kN/m/m (**variable**)
Phase 2 (permanent) Change of the water level on the left side	1. Hydraulic action	1. Left side, zw = -3 m

D.2.2.1. <u>DEFINITION OF PHASE 1</u>

First of all, we should create a new phase.

- Click on  on the upper side of the window, near the Phase 0 tab .
- A new tab is created for phase 1 (with the same settings as the initial stage at the moment).

- This project (and thus this phase) includes no anchor, and the wall is cantilever. Furthermore, we have activated the ULS checks earlier in the data input. So:
  - The checkbox **Cantilever wall (LEM calculation)** has been automatically checked.
  - The action **LEM coefficients (Limit Equilibrium Method)** has been automatically added: it's intended to control the properties of counter-earth resistance. By default, these parameters (counter-passive earth pressures) are the same as those for passive earth pressures (values for δp/φ , $k_{p\gamma}$ and k_{pc} identical to those defined initially for each soil layer). In this example, we will keep these values (see screenshot on next page). The "cb" notation in this screen refers to counter-earth resistance.

    Please note that the inclination of counter earth resistance should be checked and adjusted if necessary in order to ensure the consistency of the vertical forces check.

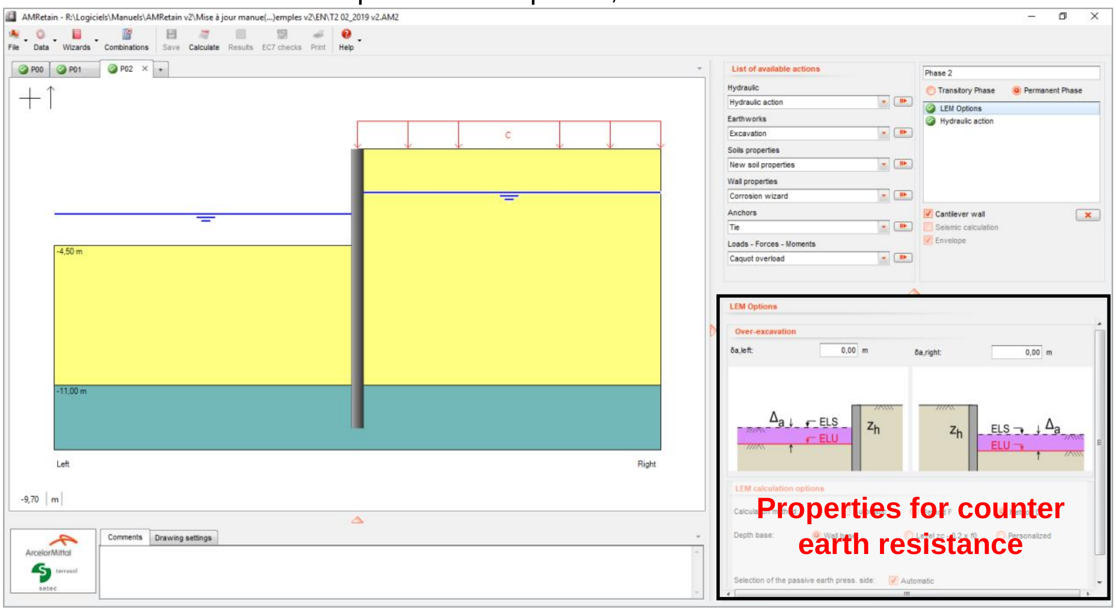
    The calculation method here is **method D**: please uncheck the case "Automatic" and check the radio-button "Method D".
  - Phase 1 should be marked as "**temporary**" (just above the actions list)
- Now we have to add the first « physical » action to be executed in phase 1: select **Excavation** in the **Earthworks** list.
- Click on the transfer button next to it.
- Input the requested properties in the right bottom part of the screen:

Left side
Excavation level zh = -4.5 m

- The graphic is updated, taking into account the the excavation.
- Define the extra action to be added in phase 1 by selecting again **Caquot overload** in the **loads** list.
- Click on the transfer button
- Input the requested properties:

Right side
Excavation level zh = 0 m
Overload q = 10 kN/m/m (**to be defined as variable)**

When the definition of this phase is completed, the main screen should look like this:



D.2.2.2. DEFINITION OF PHASE 2

The aim of the second phase is to change the water level on the left side of the wall.

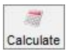
- Click on [+] in the bottom part of the main window.
- The wall is still cantilever, and the LEM calculation is thus automatically activated again, with the creation of an action **LEM coefficients**. The properties relating to counter-earth resistance for each layer are by default the same as for phase 1. We can keep them unchanged.

  Also here, unchecked the “Automatic” case and check the radio-button “**Method D**”

  Phase 2 should be marked as “**permanent**” (just above the actions list).
- Define an **hydraulic action** with the following properties:

Left side Water level z_w = -3 m

D.2.3. STEP 3: CALCULATION AND OUTPUT

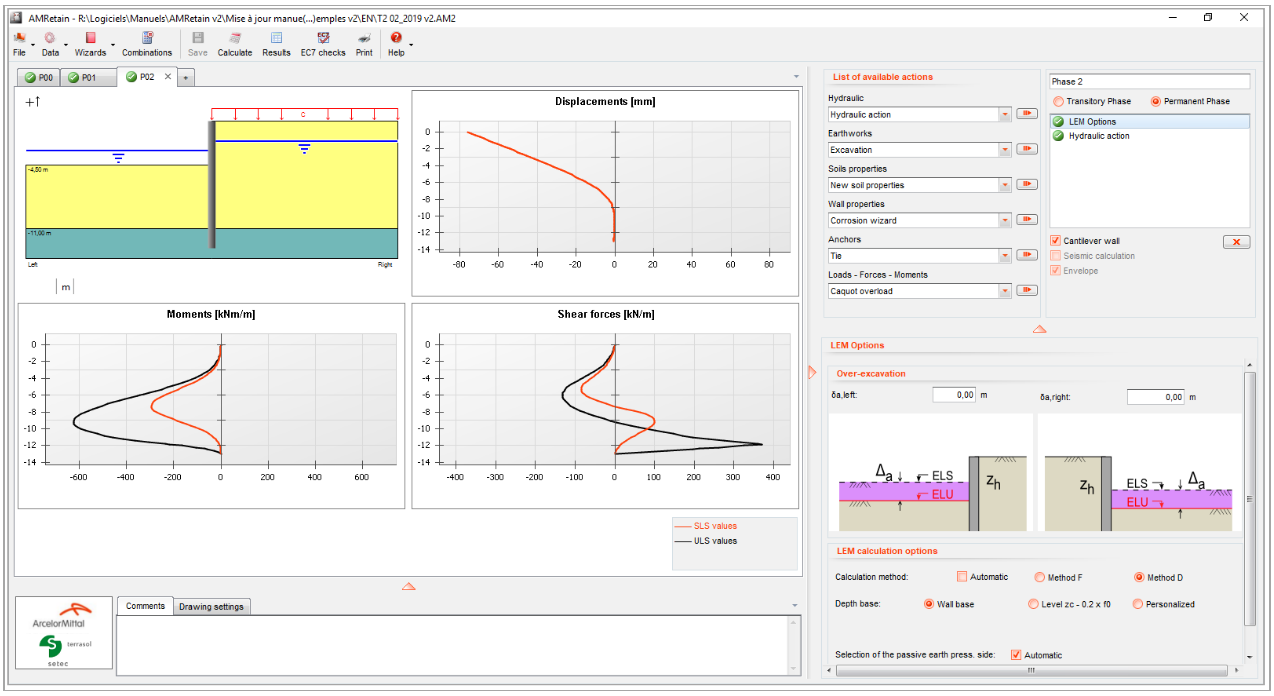
To perform the calculation of both phases, please click on the 

button.

Note: calculations may be run at any moment as soon as all input data have been filled in.

The curves for shear forces and bending moments are displayed on each phase tab (phase 2 for instance on the screenshot below). In this case, these curves display the ULS design values of the moments and shear forces in the wall. They should be used as input data for the check of the internal resistance of the wall (the values of shear forces and moments will be detailed later on, when checking detailed results).

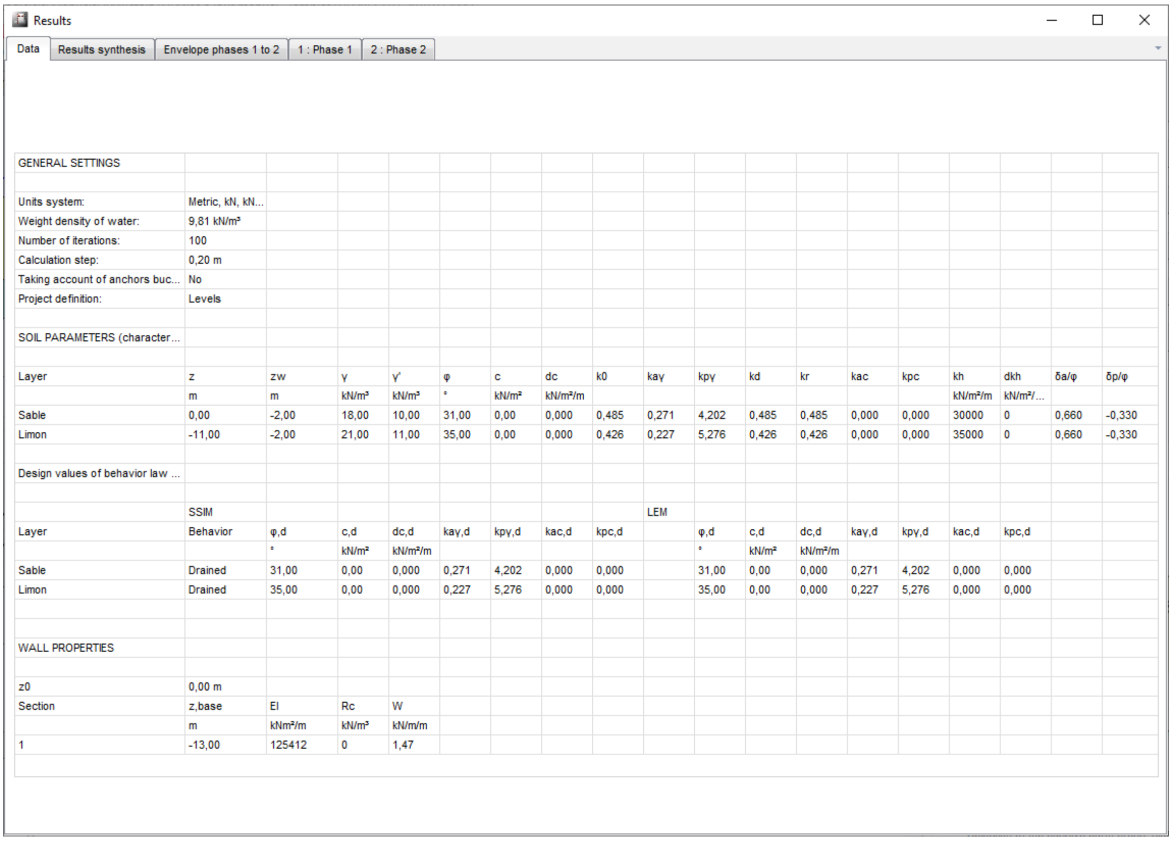
The displacements are not displayed in this case (blank zone) because it's a LEM calculation.



To view the details of results (curves and tables), click on the 

button.

The following screen is displayed:

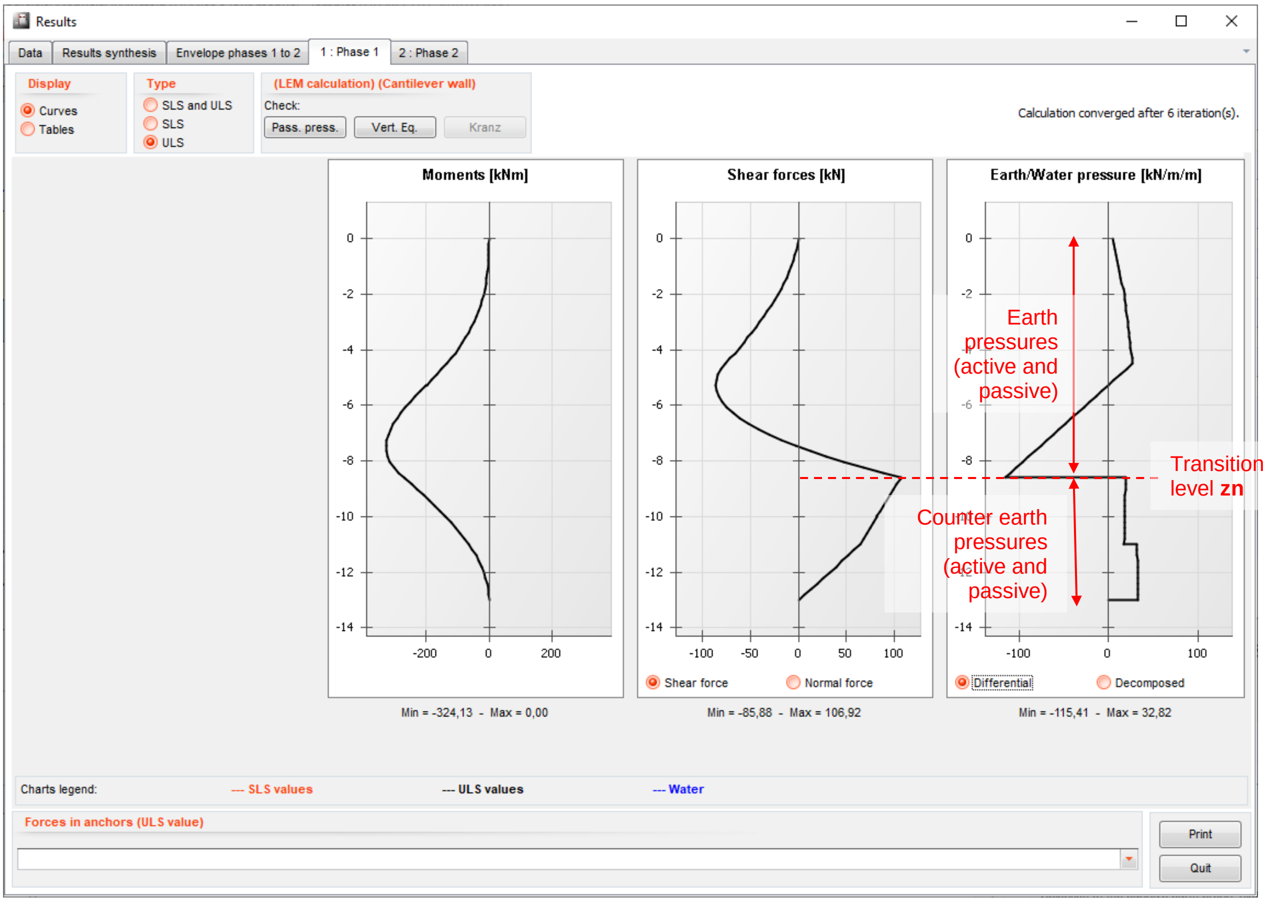


GENERAL SETTINGS																		
Units system:	Metric, kN, kN...																	
Weight density of water:	9,81 kN/m³																	
Number of iterations:	100																	
Calculation step:	0,20 m																	
Taking account of anchors buc...	No																	
Project definition:	Levels																	
SOIL PARAMETERS (character...																		
Layer	z	zw	γ	γ'	φ	c	dc	k0	kay	kpy	kd	kr	kac	kpc	kh	dkh	δa/φ	δp/φ
	m	m	kN/m³	kN/m³	°	kN/m²	kN/m²/m								kN/m²/m	kN/m²/...		
Sable	0,00	-2,00	18,00	10,00	31,00	0,00	0,000	0,485	0,271	4,202	0,485	0,485	0,000	0,000	30000	0	0,660	-0,330
Limon	-11,00	-2,00	21,00	11,00	35,00	0,00	0,000	0,426	0,227	5,276	0,426	0,426	0,000	0,000	35000	0	0,660	-0,330
Design values of behavior law ...																		
	SSIM								LEM									
Layer	Behavior	φ,d	c,d	dc,d	kay,d	kpy,d	kac,d	kpc,d		φ,d	c,d	dc,d	kay,d	kpy,d	kac,d	kpc,d		
		°	kN/m²	kN/m²/m						°	kN/m²	kN/m²/m						
Sable	Drained	31,00	0,00	0,000	0,271	4,202	0,000	0,000		31,00	0,00	0,000	0,271	4,202	0,000	0,000		
Limon	Drained	35,00	0,00	0,000	0,227	5,276	0,000	0,000		35,00	0,00	0,000	0,227	5,276	0,000	0,000		
WALL PROPERTIES																		
z0	0,00 m																	
Section	z,base	EI	Rc	W														
	m	kNm²/m	kN/m³	kN/m/m														
1	-13,00	125412	0	1,47														

It includes all data and results in various tabs:

- The **Data** tab displays all the project data: units system, water weight, soil properties, wall properties, initial phase options, etc...
- The tab **Results synthesis** displays a summary of main SLS and ULS results.
- The tab **Envelope** displays the envelope curves and tables for the project results over all phases.
- The tabs for **Calculation phases** include the detailed results. On each tab, it is possible to switch from mode **Curves** mode to **Tables** mode (and back) depending on what you wish to view, and to display the results of the ULS checks.

The following screenshot illustrates the **ULS curves** for **phase 1** of this example:

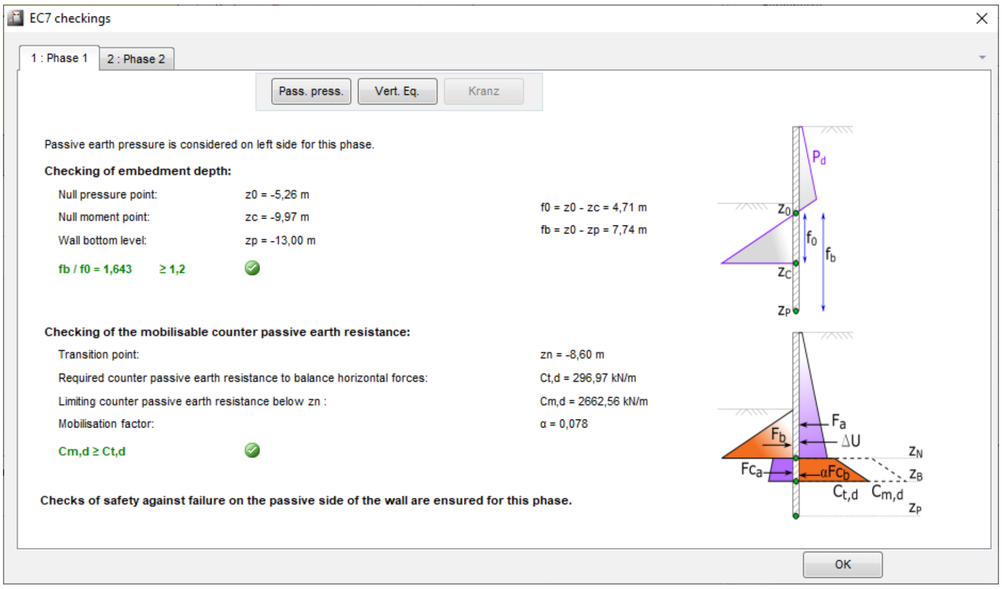


As explained in part C of the manual (and illustrated on the screenshot above):

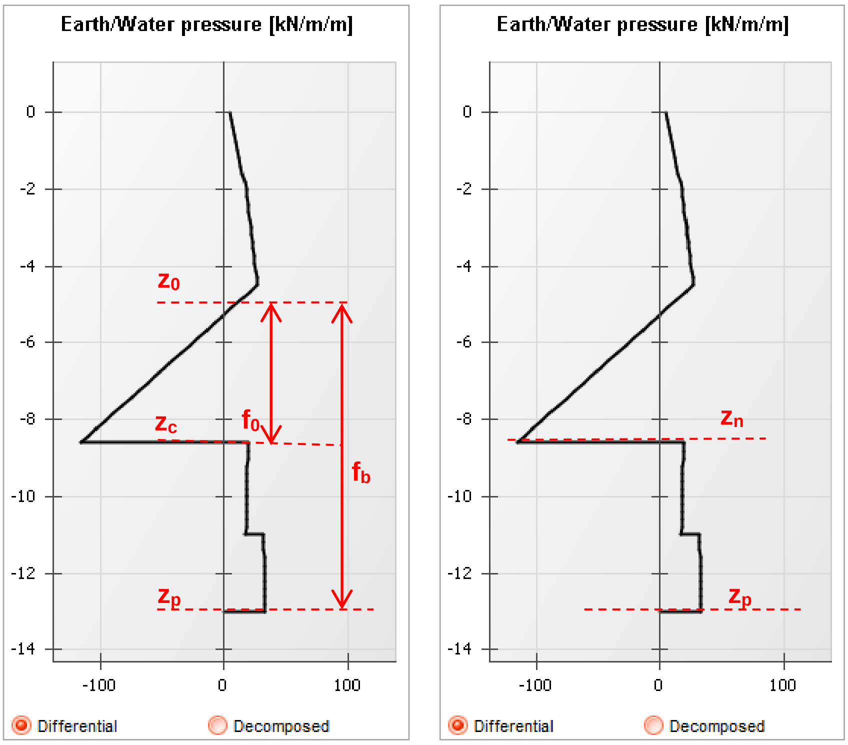
- Earth pressures are considered down to transition level zn; below this level, counter earth pressures are considered.
- This maximum shear force is reached at the transition level zn.

In this window, please click on buttons **Pass. Press**. and **Vert. Eq.** to get to the ULS checks results.

Check of the failure on the passive side



The figure below illustrates the various levels calculated and displayed in the screenshot, as well as f0 (minimum requested embedment) and fb (available embedment). Please also refer to part C of the manual to check the details about the calculation method, and the meaning of these levels.

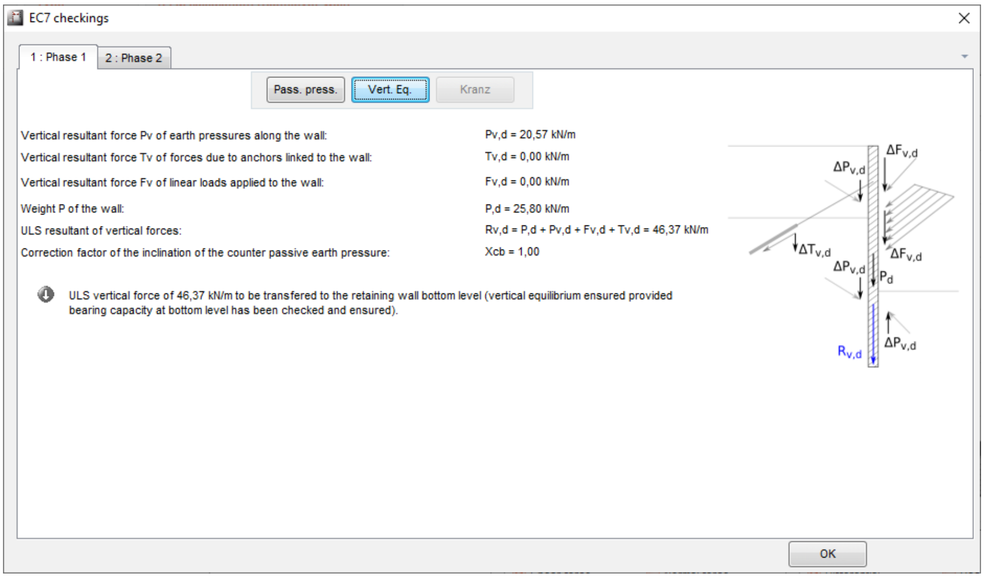


The screenshot here above illustrates that the check is composed of 2 parts (for a LEM calculation):

- Check of the embedment: AMRetain calculates the “critical” point C corresponding to the minimum embedment ensuring moments equilibrium. It then checks that the available embedment is superior to this minimum embedment with a sufficient safety (1.20 according to the French Standard NF P 94-282). The safety obtained here is 1.64 > 1.20. The embedment check is thus satisfactory.

- Check of the failure on the passive side: we chose method D, so AMRetain calculates the level of “transition” point z_n. This transition point corresponds to the switch level between the active/passive pressures zone to the counter-active/counter-passive pressures zone, so that equilibrium of moments and horizontal forces is ensured. This calculation enables to evaluate the mobilization factor α equal to the ratio of counter passive earth pressure requested to ensure forces equilibrium to counter passive earth pressure available below point z_n. Here, we have $\alpha = 0.078 < 1.00$. The check of the failure on the passive side is thus satisfactory.

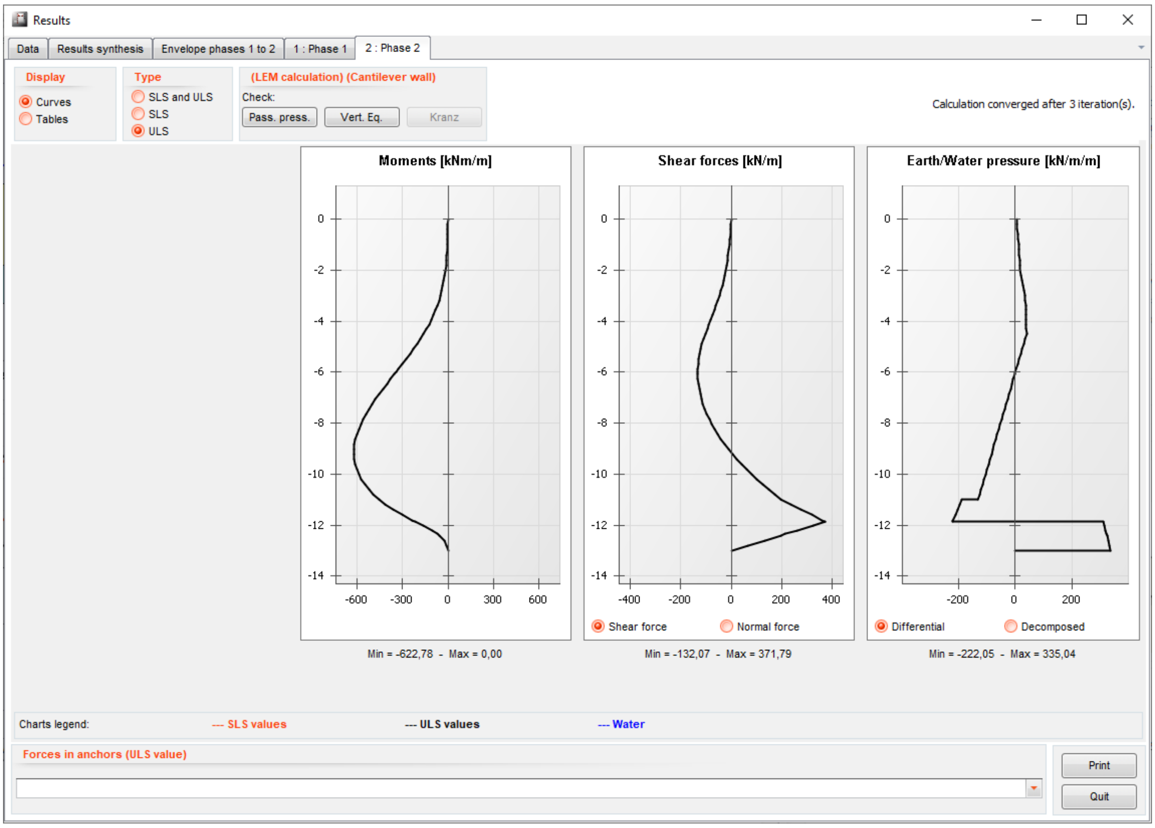
Check of the vertical equilibrium (vertical forces applied to the wall)



During this check, AMRetain calculates the balance of the vertical forces mobilised along the wall height, including the weight of the wall itself. The vertical resultant of forces is directed downwards and its value is 46.37 kN/m. This force should be checked by the user with respect to bearing capacity (separately from AMRetain).

This check is also “satisfactory”: the resultant of vertical forces is positive (i.e. directed downwards).

The following screenshot illustrates the **ULS curves** for **phase 2** of this example:

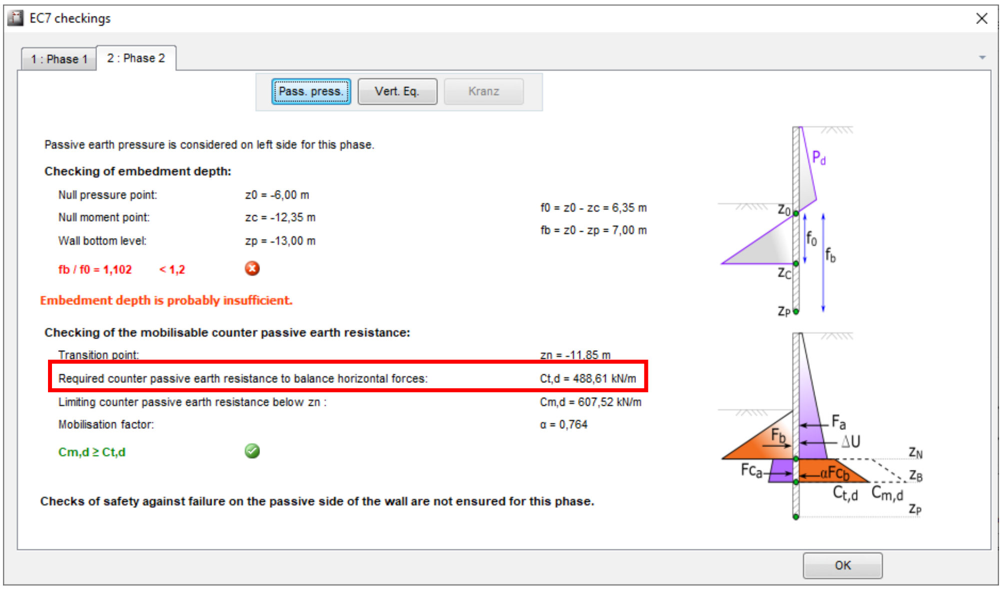


The maximum moment is 623 kNm/m.

The maximum shear force is 372 kN/m, and it is reached at the transition level.

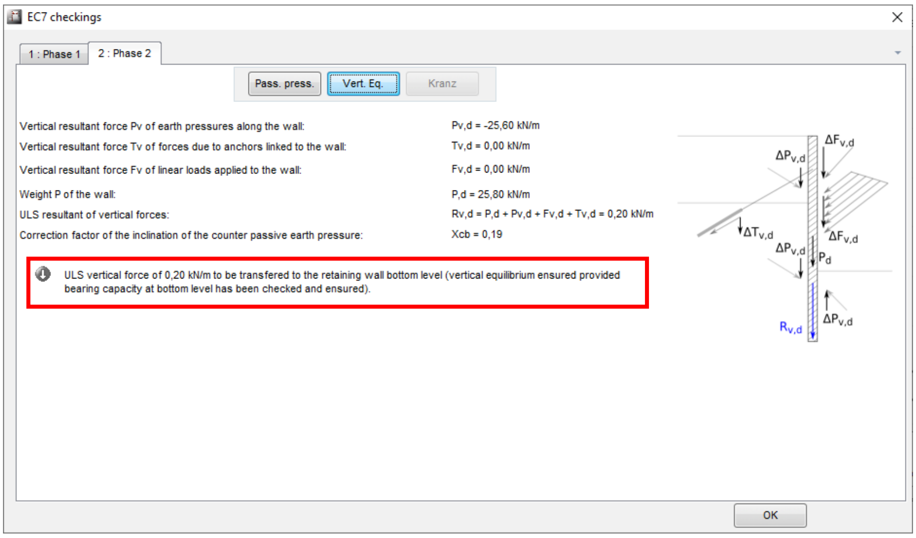
In this window, please click on buttons **Pass. Press**. and **Vert. Eq.** to get to the ULS checks results.

<u>Check of the failure on the passive side</u>



But the embedment ratio f_b/f_0 is equal to 1.10, and thus inferior to 1.20, which is the minimum required value according to the French Standard NF P 94-282): so the embedment is not satisfactory. This check is not satisfactory anymore. The mobilization factor "α" is higher than in phase 1 (0.77) but is still far inferior to 1.0.

Check of the vertical equilibrium (vertical forces applied to the wall)



This check is also satisfactory: the resultant of vertical forces is positive (i.e. directed downwards). It should be noted that the inclination of the counter passive earth resistance was sought by AMRetain to ensure the vertical balance.

D.2.4. STEP 4: ADJUSTMENT OF THE PROJECT DATA IN ORDER TO SATISFY THE ULS CHECKS CONDITIONS

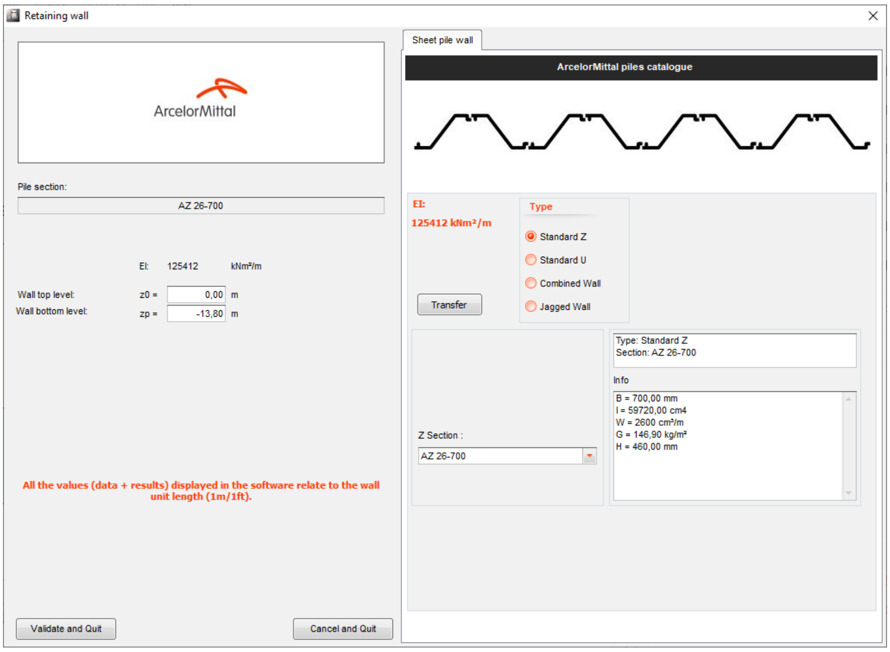
Close the ULS checks and then **Save as** your file with a new file name.

D.2.4.1. FAILURE ON THE PASSIVE SIDE

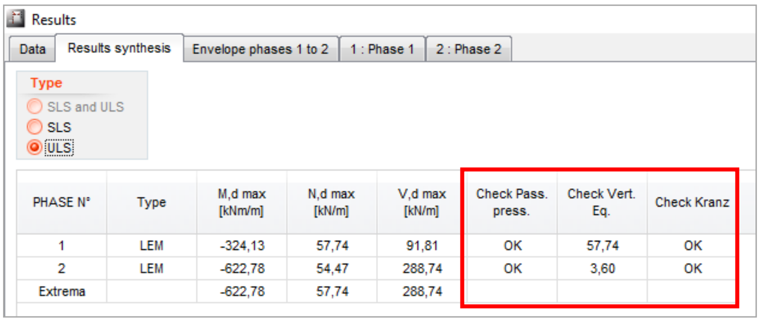
As indicated in the analysis of the output, we need to increase the wall embedment and run the calculation again.

We will thus change the level of the bottom of the wall from -13,0 to -13,8 m (i.e. increase of 80 cm of the available embedment).

- In the main window, select menu **Data / Retaining wall** to display the dialogue box for the wall definition.
- Change level zp to -13,80 m (Figure below), and click on [Validate and Quit].



- Run the calculations again (using the [Calculate] button on the main window for instance).
- Click on the [Results] button, and on the tab **Results synthesis.** Select **ULS** results**.**

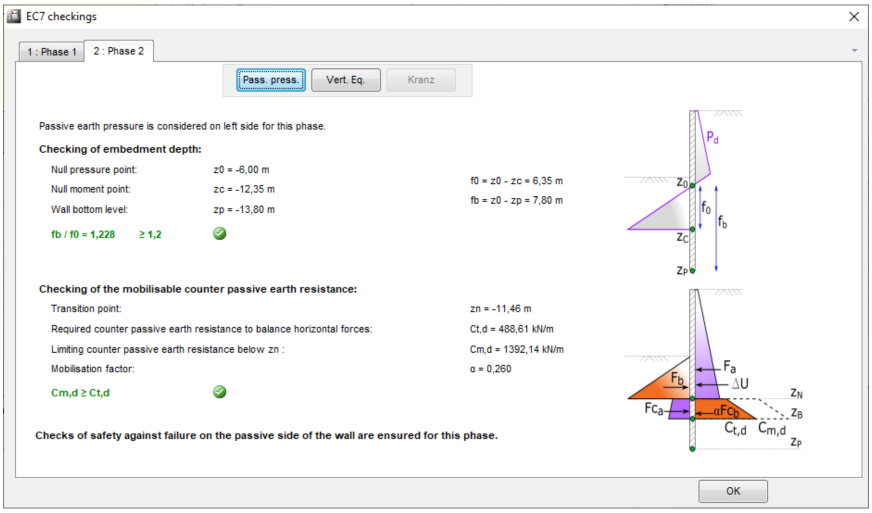


PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-324,13	57,74	91,81	OK	57,74	OK
2	LEM	-622,78	54,47	288,74	OK	3,60	OK
Extrema		-622,78	57,74	288,74			

This is another way to check very quickly whether all checks are now satisfactory or not.

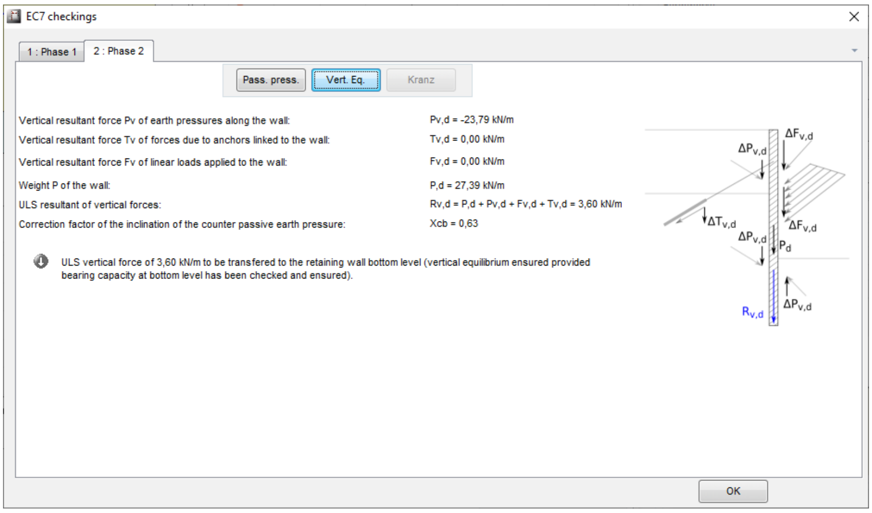
In this case, the check of failure on the passive side is now satisfactory for both phases, meaning the embedment is now correct.

Let's click on the tab **Phase 2**, and on the button **Pass. Pressure** to check that in more detail.



This verification is indeed satisfactory: the ratio of the sheet heights fb / f0 is 1.23 (≥ 1.20), and the mobilization factor "α" is 0.260 (≤ 1.0).

D.2.4.2. BALANCE OF VERTICAL FORCES



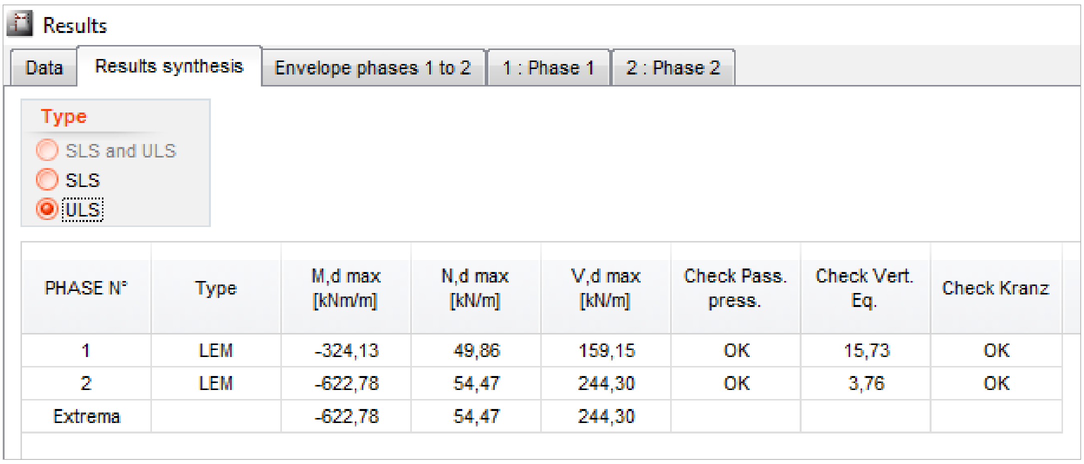
This check is satisfactory: the resultant of vertical forces is positive (i.e. directed downwards).

D.2.5. STEP 5: COMPARISON OF METHODS D AND F FOR LEM CALCULATIONS

We will here compare 2 calculations with the same parameters except for the LEM calculation method which will be switched from method D to method F. Please check part C of this manual for additional information about these calculation methods.

- Close the ULS checks (OK button) window and then results window (Quit button).
- Then **Save** your file and open the file for tutorial 2 corresponding to the first solution considered in chapter **Erreur ! Source du renvoi introuvable.** (with zp = -13,80 m, and modified counter-passive earth pressures properties).
- **Save as** your file with another new name, and let's change the calculation method for LEM calculations from method D (default method) to method F ("French" method):
- In each of the both phase, select "MEL option" and check the "method D" radio-button.

- Leave all the other project settings unchanged. Click on Calculate and open the results window. Here's the **Results synthesis** tab:



PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-324,13	49,86	159,15	OK	15,73	OK
2	LEM	-622,78	54,47	244,30	OK	3,76	OK
Extrema		-622,78	54,47	244,30			

The table below summarises the main relevant values in order to compare both calculations with methods D and F:

		Méthode D	Méthode F
Phase 1	Moments	-324 / 0 kNm/m	-324 / 0 kNm/m
	Shear forces	-86 / 92 kN/m	-86 / 159 kN/m
	Transition level zn	zn = -8.47 m	zc = -9.97 m
	Check of failure on the passive side	OK fb/f0 = 1,81 α = 0,064	OK fb/f0 = 1,82 α = 0,151
	Vertical resultant	OK (58 kN)	OK (16 kN)
Phase 2	Moments	- 623 / 0 kNm/m	-623 / 0 kNm/m
	Shear forces	-132 / 289 kN/m	-132 / 244 kN/m
	Transition level zn	zn = -11.46 m	zc = -12.35 m
	Check of failure on the passive side	OK fb/f0 = 1,22 α = 0,260	OK fb/f0 = 1,22 α = 0,850
	Vertical resultant	OK (3,60 kN/m)	OK (3,76 kN/m)

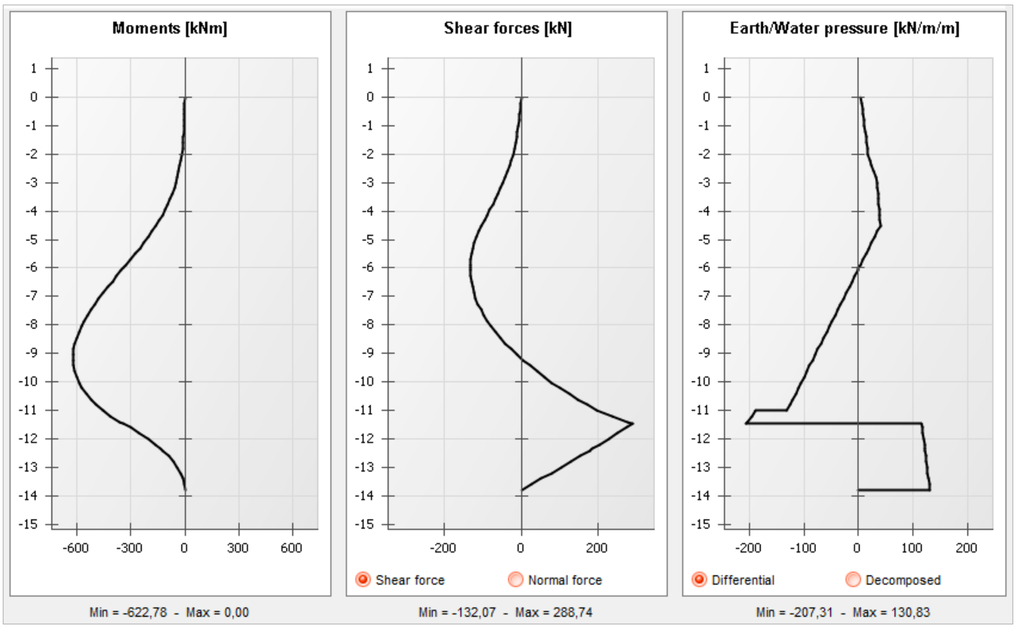
We can check in the table that the difference between the levels of the transition points calculated by both methods are 1.50 m in phase 1, and 0.89 m in phase 2.

The following figures illustrate the superposition of differential pressures, moments and shear forces for calculations with methods D and F for phase 2.

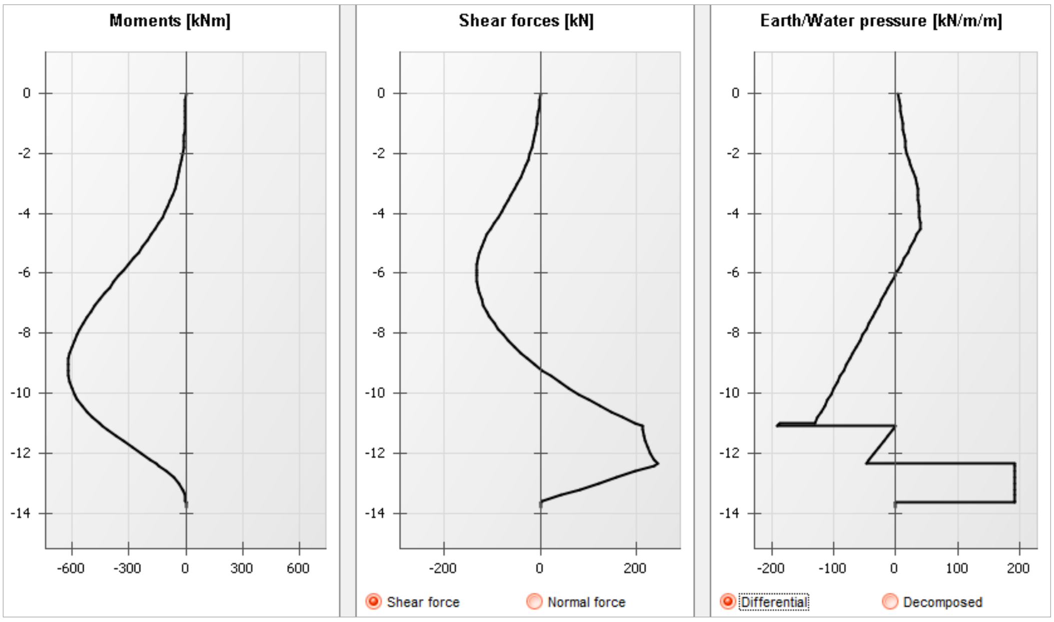
- Differential pressures: it's visible that counter passive earth pressure is assumed to be mobilised below z_n for method D, and below z_c for method F (z_c being deeper than z_n). Thus the shape of differential pressures is the same for both methods down to z_n, and is different below z_n.
- Moments: the maximum moment has the same value for both calculations.
- Shear forces: the shear forces are identical down to z_n, but they are different below z_n. Another important difference to point out is that the maximum values for shear forces are this time different for both methods. But it is usually of little influence on the wall design, mainly controlled by moments.

Please refer to part C of the manual for more details.

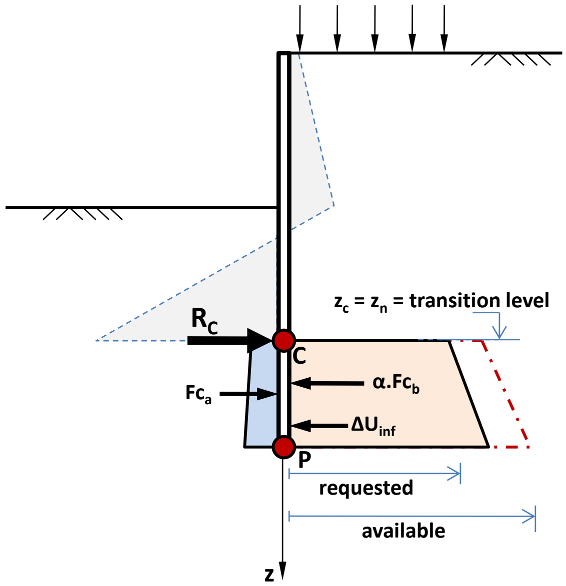
Curves of results Method D:



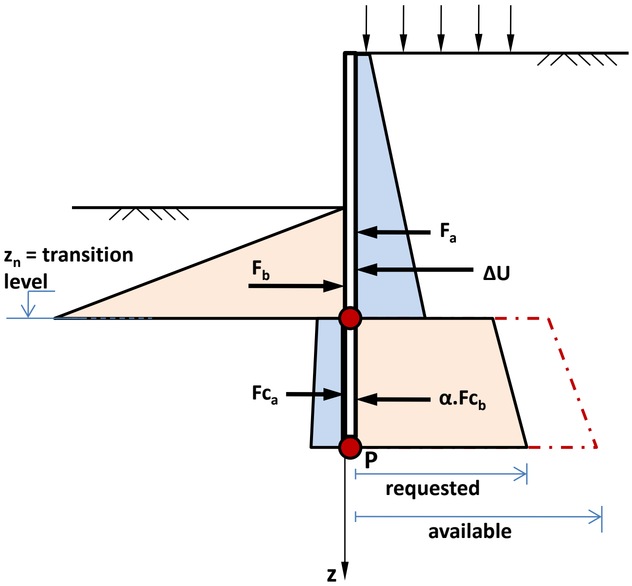
Curves of results Method F:



- Check of the failure on the passive side: methods D and F correspond to different approaches of the transition point z_n.
  - ✓ Method F is a simplified method assuming that the transition point z_n is the same as the critical point z_c and thus considering the counter passive earth pressures available below z_c. But strictly speaking, the counter passive earth pressures should extend on both sides of z_c, in order to ensure both the equilibrium of moments and the equilibrium of horizontal forces.
  - ✓ Method D is a more "rigorous" approach determining the position of the transition point which ensures both the equilibrium of moments and the equilibrium of horizontal forces along the wall, as shown on the next figure.



Approach F



Approach D

- As mentioned before, the difference between the levels of the transition points calculated by both methods are 1.50 m in phase 1, and 0.89 m in phase 2.
  - ✓ The transition point is not taken into account when checking the embedment depth. Thus fb/f0 ratios are identical for both calculations (for each phase).
  - ✓ But the transition point is taken into account in the calculation of $C_{m,d}$, which is the mobilisable counter earth resistance under the transition point, and thus of the mobilisation ratio α. In this example, the conclusion for each phase whether this check is satisfactory or not is the same for both methods, but the differences in α value are significant.
- Check of the vertical resultant: the vertical resultant of earth pressures $P_{v,d}$ also depends on the position of the transition point and values of the vertical resultant force on the wall calculated by both methods are very different from each other. Let's consider for instance phase 1: method D concludes that the resultant is directed downwards and method F concludes that the resultant is directed upwards.

  So the choice between method D and method F may lead to quite different results and conclusions.

  - Method F is a "French" method which is known to overestimate the value of α and which does not allow to estimate the moment under point C.
  - On the contrary, method D is a more rigorous approach which allows for the determination of the position of the transition point zn.

It is thus advised to use method D, but the use of method F may be necessary in cases where the wall embedment is very long (temporary excavation phases for instance): in these cases, method D leads to "unrealistic" moments in the wall. Please also refer to part C, and to the last section of part B of the manual.

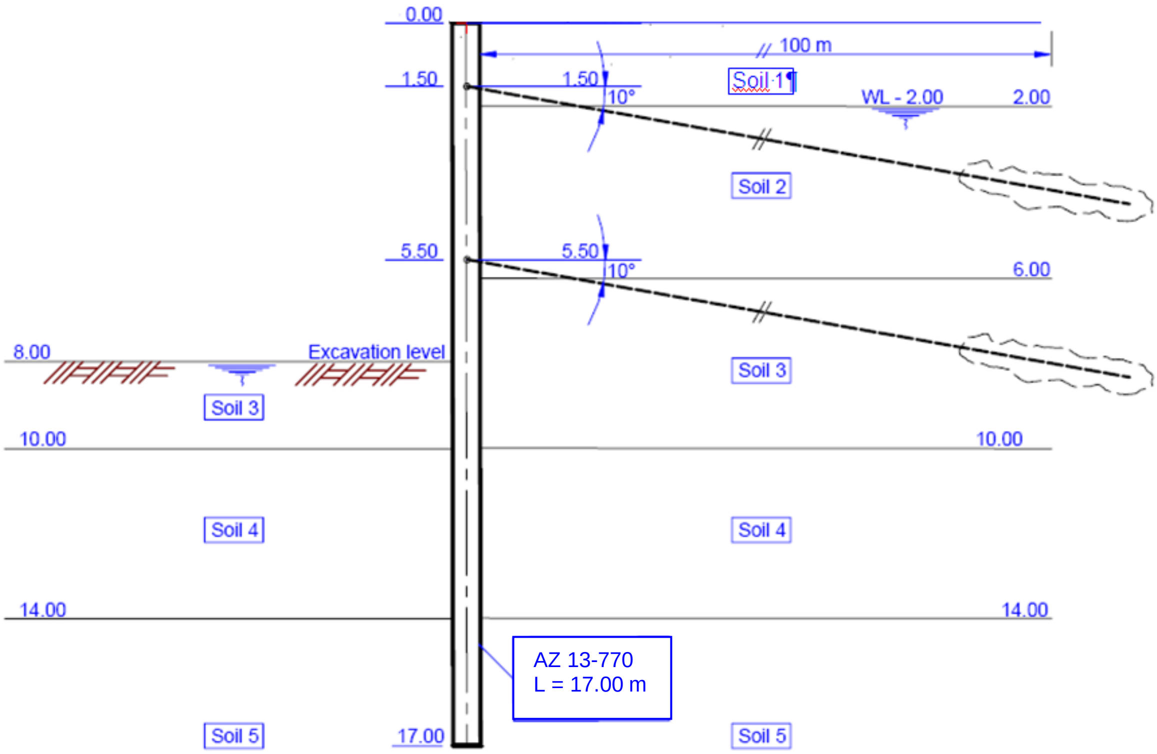
D.3. TUTORIAL 3: MULTI-ANCHORED SHEETPILE WALL WITH ULS CHECKS

This project relates to the design of a retaining wall enabling the construction of a multiple floor building.

The wall is made of ArcelorMittal sheet piles of type AZ 13-770, 17 m long; it is supported by 2 levels of anchors, inclined by 10°. The anchors were optimized with respect to the equilibrium of the anchoring block according to the simplified Kranz approach available in AMRetain.

We will perform ULS checks on this project (with the Kranz checks of the anchoring block for instance).

The project is illustrated on the figure below:



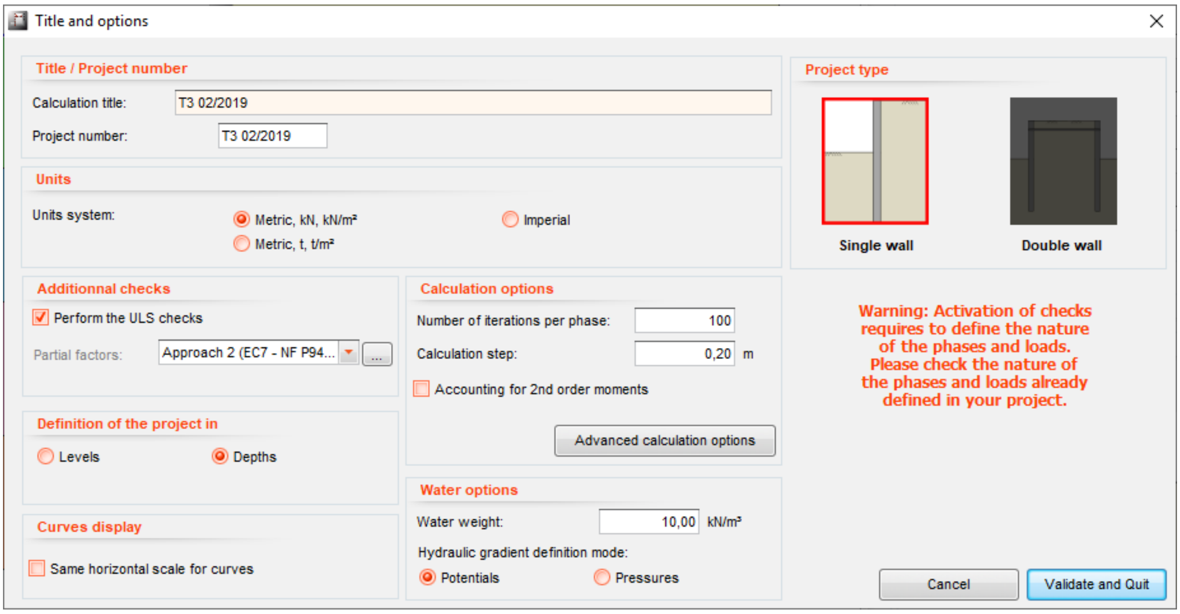
At the end of this example, we will consider an alternative solution using a Standard U sheet pile (AU 14), and illustrate the use of the beta.D coefficient.

D.3.1. STEP 1: DATA INPUT

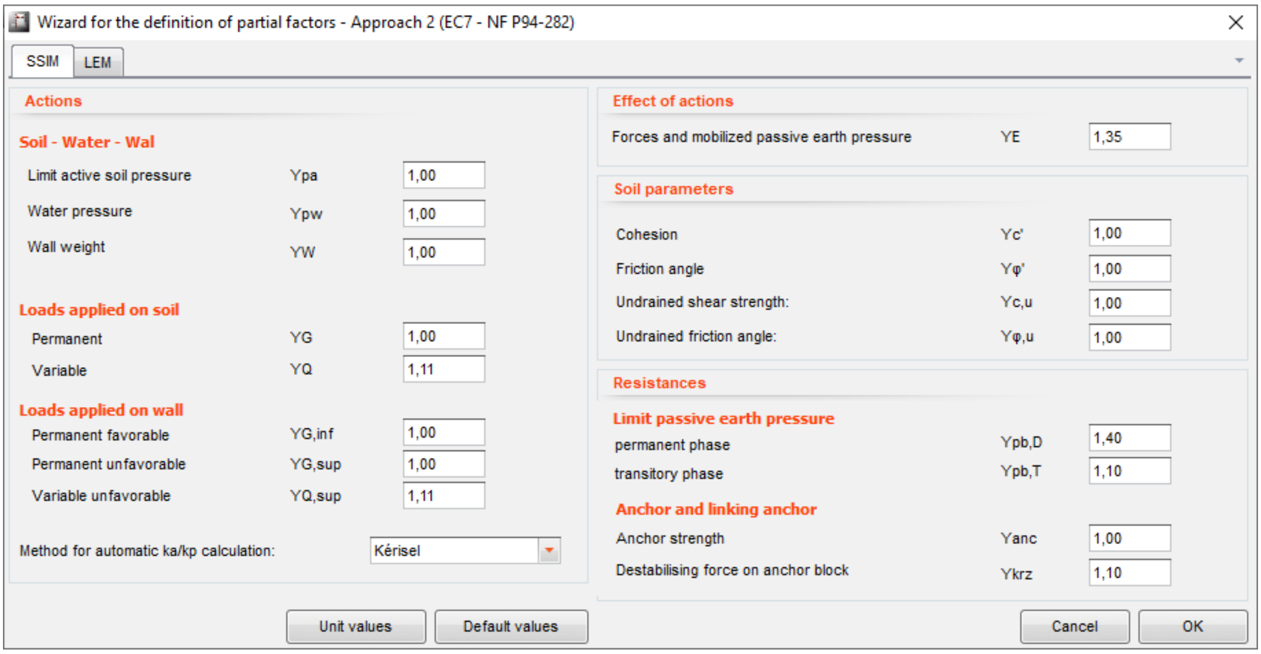
D.3.1.1. TITLE AND OPTIONS

In this example, we will work in **depths** (vertical axis directed downwards), and all other default settings in the dialogue box **Title and options** are kept unchanged.

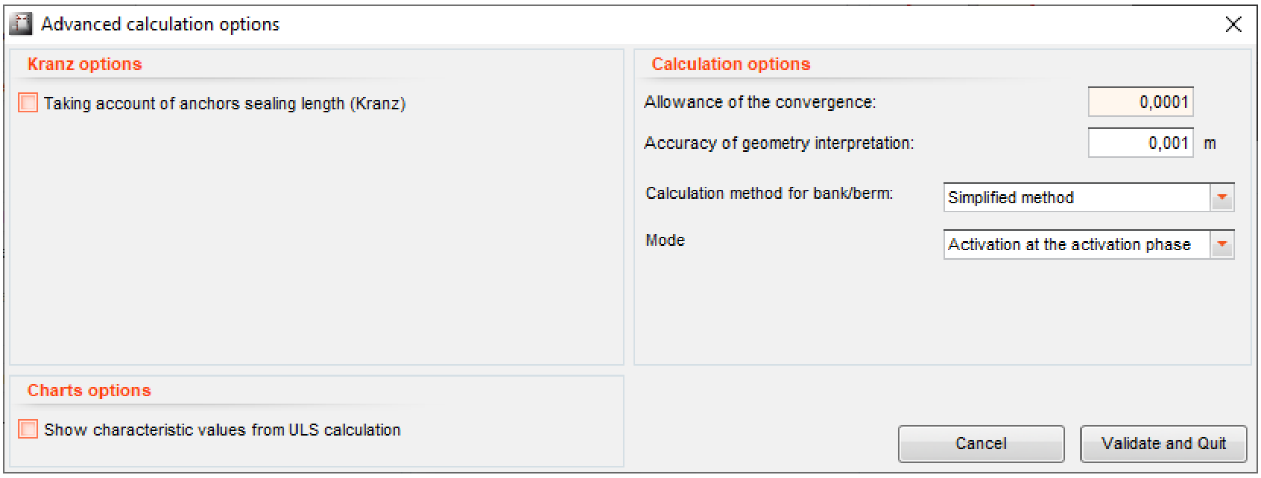
The following screenshot displays the relevant data:



The detailed NF P 94-282 partial safety factors may be viewed by clicking on the [...].



In this example, the anchors sealing length is not taking account.
Open the [Advanced calculation options] and uncheck the box "Taking account of anchors sealing length (Kranz)".



D.3.1.2. DEFINITION OF SOIL PROPERTIES

In the dialogue box **Characteristics of soil layers**, 5 soil layers have to be defined for this example.

All the properties for the 5 layers are summarised in the table below:

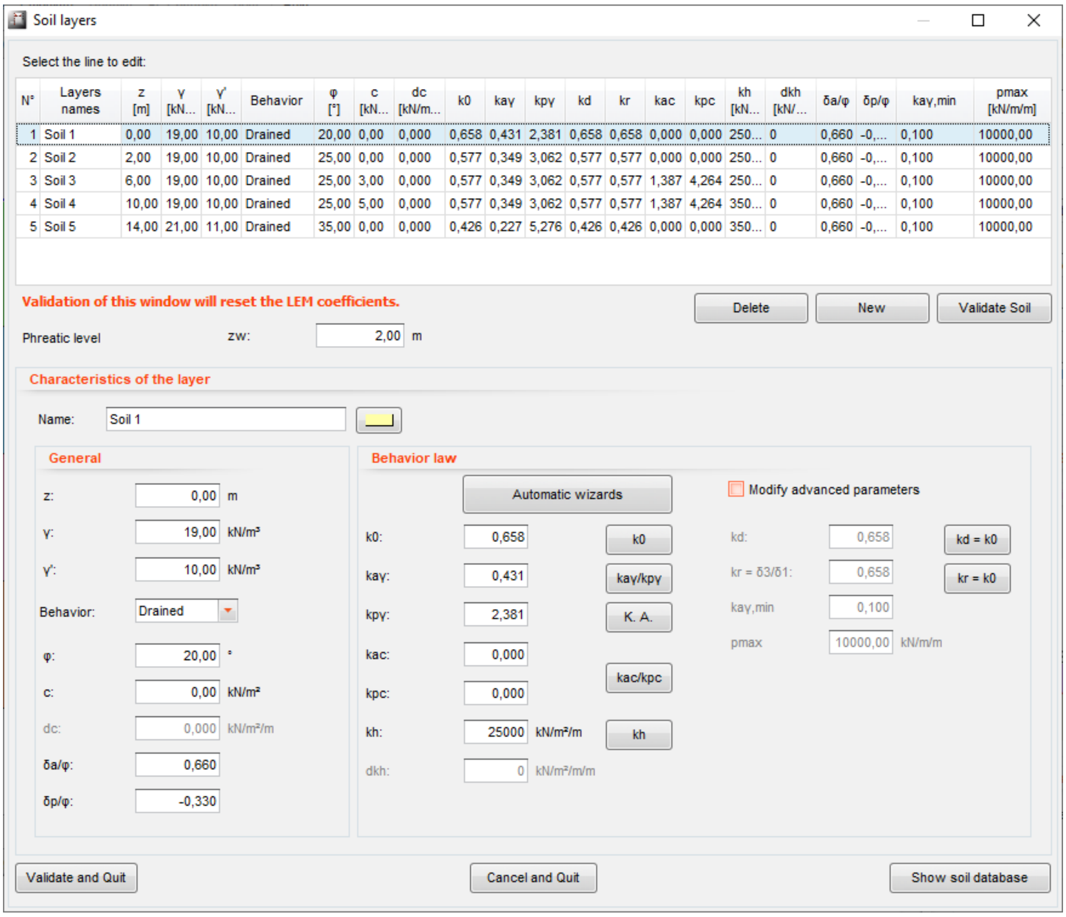
	z (m)	z_w (m)	γ (kN/m^3)	γ_d (kN/m^3)	φ (°)	c (kN/m^2)	δ_a/φ	δ_p/φ
Soil 1	0	2	19	10	20	0	0.66	-0.33
Soil 2	2	2	19	10	25	0	0.66	-0.33
Soil 3	6	2	19	10	25	5	0.66	-0.33
Soil 4	10	2	19	10	25	10	0.66	-0.33
Soil 5	14	2	21	11	35	0	0.66	-0.33

	k_0	$k_{a\gamma}$	$k_{p\gamma}$	k_{ac}	k_{pc}	k_h (kN/m²/m)
Soil 1	0.658	0.431	2.381	0	0	25000
Soil 2	0.577	0.349	3.062	0	0	25000
Soil 3	0.577	0.349	3.062	1.387	4.264	25000
Soil 4	0.577	0.349	3.062	1.387	4.264	35000
Soil 5	0.426	0.227	5.276	0	0	35000

To complete the coefficients k_0, $k_{a\gamma}$, $k_{p\gamma}$, k_{ac}, k_{pc}, k_d, k_r, we will use here the automatics wizards.

Click on [Automatic wizards] and leave the box "Modify advanced parameters" un checked.

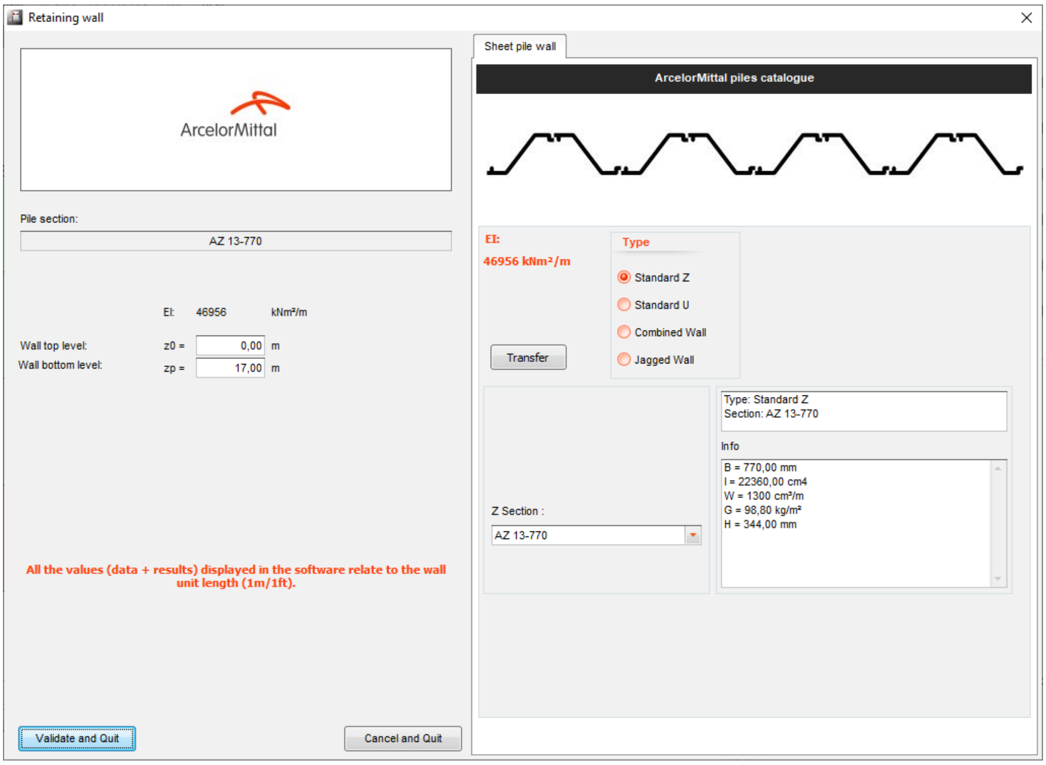
Only $\mathbf{k_h}$ needs to be completed manually.



Note: it is possible to use the Soil database to export/import soil layers when they have similar properties, rather than defining each soil layer from scratch.

D.3.1.3. DEFINITION OF WALL PROPERTIES

The wall is made of sheet piles of type AZ 13-770, 17 m long.



D.3.2. STEP 2: DEFINITION OF PHASES AND ACTIONS

The complete phasing for this example is illustrated in the following tables.

Phase	Actions	Properties
Initial phase	-	-
Phase 1 (temporary) Excavation on left side	Excavation	Excav. left side, z_h = 2 m
Phase 2 (temporary) Installation of the first anchor level	Anchors	Tie, right side, z_a = 1.5 m, K = 5000 kN/m/m, P = 200kN/m, α = 10°, Lu = 2 0m.
Phase 3 (temporary) Excavation with change of the water level on the left side	Excavation Hydraulic action	Excav. left side, z_h = 6 m Hydraul. left side, z_w = 6 m
Phase 4 (temporary) Installation of the second anchor level	Anchors	Tie, right side, z_a = 5.5 m, K = 5000 kN/m/m, P = 400kN/m, α = 10°, Lu = 20m.
Phase 5 (permanent) Excavation with change of the water level on the left side	Excavation Hydraulic action	Excav. left side, z_h = 8 m Hydraul. Côté gauche z_w = 8 m

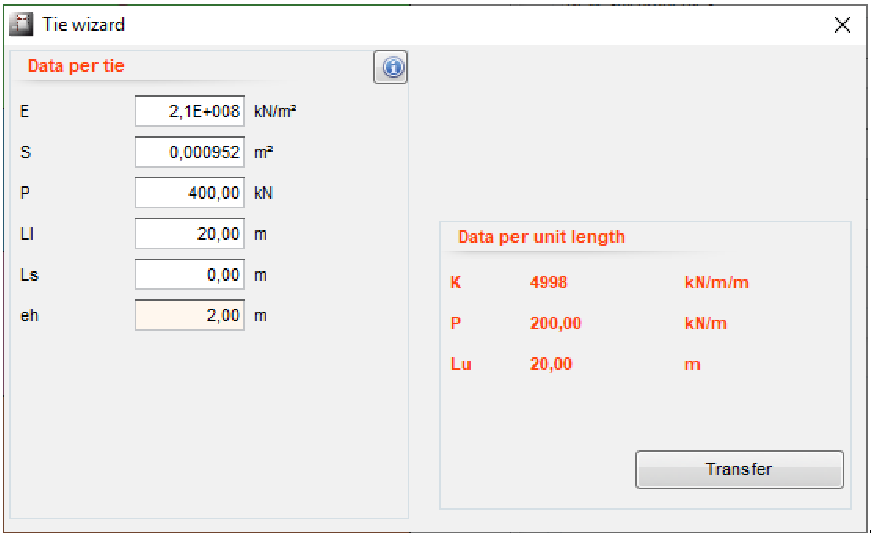
The illustrated summary of the stages is also provided in the next pages.

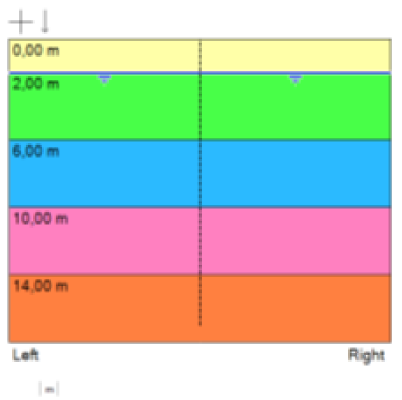
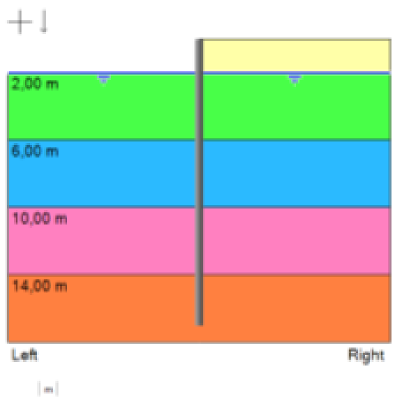
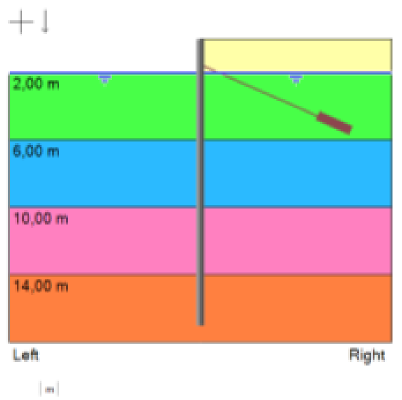
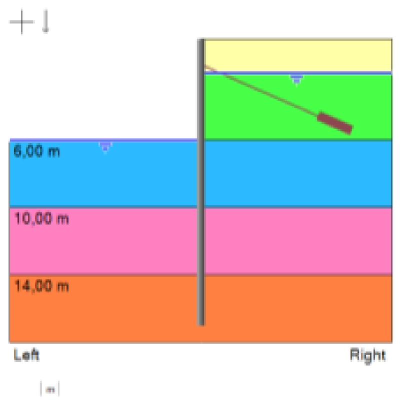
Comments about phases 1 and 2:

- When defining phase 1, the wall is cantilever (no anchor installed yet), and the ULS checks being activated for the project, AMRetain automatically activates the LEM calculation, and the action **LEM coefficients** to define the properties for the counter-earth resistance (refer to tutorial 2).
- When creating phase 2, AMRetain behaves the same until the definition and validation of the active anchor (in case of a passive anchor, the phase would still be cantilever anyway). Indeed, until then, AMRetain doesn't "know" that the wall is not cantilever anymore. But after the anchor validation, the LEM calculation is automatically deactivated, and associated **LEM coefficients** action is automatically removed.

Comments about phases 2 and 4:

- The useful length of anchors (Lu) is used for the check of the anchoring block stability. In the case of grouted anchors, the useful length Lu is usually defined as the free length plus half the grouted part length.
  - The stiffness K of the anchors can be calculated using the anchor wizard, depending on the Young modulus E, section S, useful length Lu and horizontal spacing eh of the anchors (next screenshot). Click on the Transfer button to transfer the K value to the anchors parameters. The wizard may also be used to calculate the prestress force for the anchors. Please refer to part C of the manual for more information about the calculations performed by this wizard.

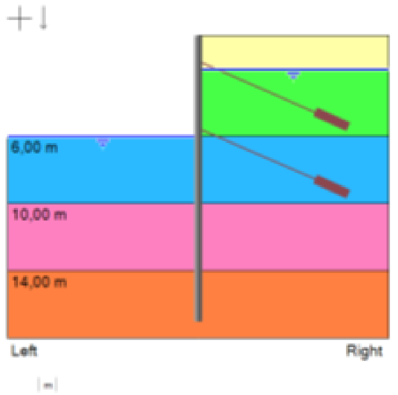


AMRetain v.2.1.2	PROJECT T3 02/2019 T3 02/2019		
STAGE CONSTRUCTION SYNTHESIS			
Initial phase 	Phase 1 : Transitory Phase 	Phase 2 : Transitory Phase 	Phase 3 : Transitory Phase 
	- Excavation (left side): zh [m] = 2,00	- Installation of tie (right side): n°1 za [m] = 1,50 K [kN/m/m] = 5000 P [kN/m] = 200,00 α [°] = 10,00	- Excavation (left side): zh [m] = 6,00 - Hydraulic action: (left): zw [m] = 6,00
ArcelorMittal	Calculated by: Terrasol		terrasol setec

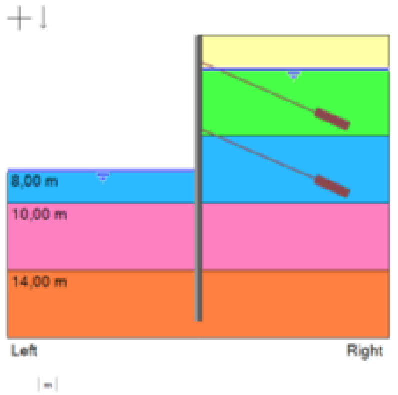
AMRetain v.2.1.2	PROJECT T3 02/2019
	T3 02/2019

STAGE CONSTRUCTION SYNTHESIS

Phase 4 : Transitory Phase



Phase 5 : Permanent Phase



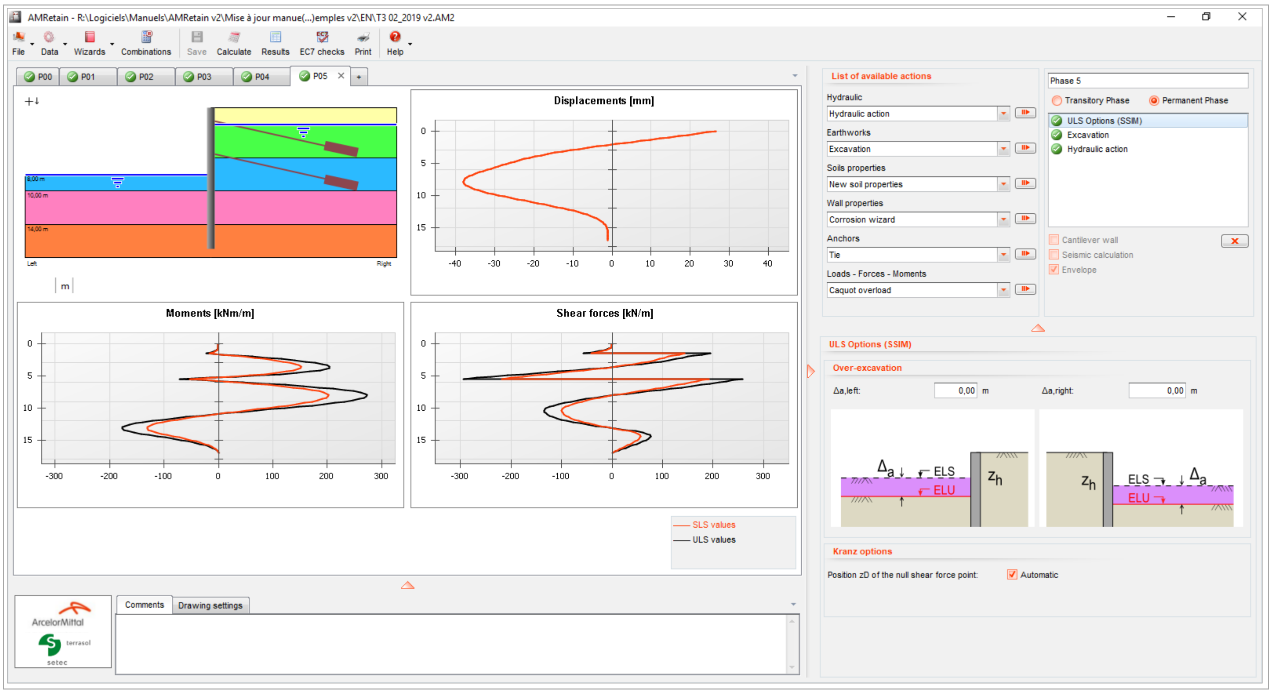
- Installation of tie (right side): n°2
  za [m] = 5,50
  K [kN/m/m] = 5000
  P [kN/m] = 400,00
  α [°] = 10,00

- Excavation (left side):
  zh [m] = 8,00
- Hydraulic action: (left):
  zw [m] = 8,00

Calculated by: Terrasol

D.3.3. STEP 3: CALCULATION AND OUTPUT

Please click on the Calculate button. The following screenshots illustrate the results obtained after calculation for the **last calculation phase.**



Click on Results to get to the results details.

Let's start with the results synthesis tab, in order to quickly check that all ULS checks are satisfied.

Results

Data | Results synthesis | Envelope phases 1 to 5 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5

Type
- SLS and ULS
- SLS
- ULS

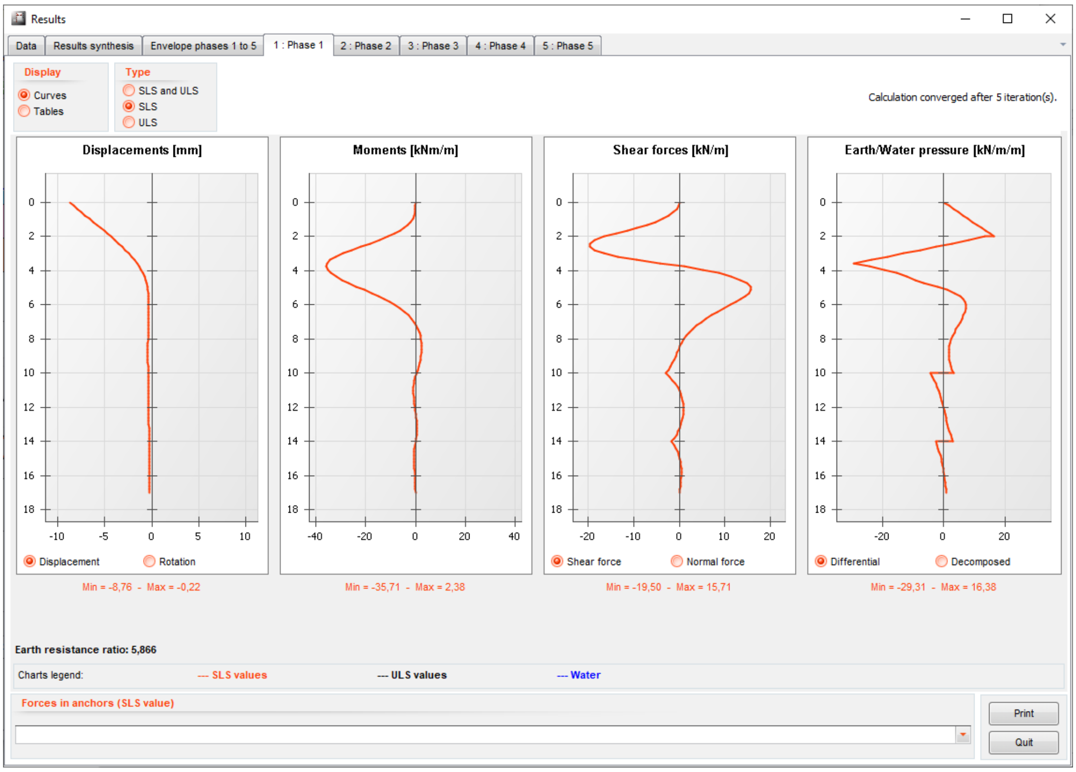
PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	F,d tie n°1 [kN/m]	F,d tie n°2 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-77,53	93,22	-29,04	-	-	OK	93,22	OK
2	SSIM	113,97	53,66	197,19	270,00	-	OK	53,66	OK
3	SSIM	279,55	96,91	184,77	257,38	-	OK	96,91	OK
4	SSIM	256,85	97,12	-295,00	258,19	540,00	OK	95,26	OK
5	SSIM	208,01	125,66	-303,90	256,37	553,23	OK	114,18	OK
Extrema		279,55	125,66	-303,90	270,00	553,23			

We can see that:

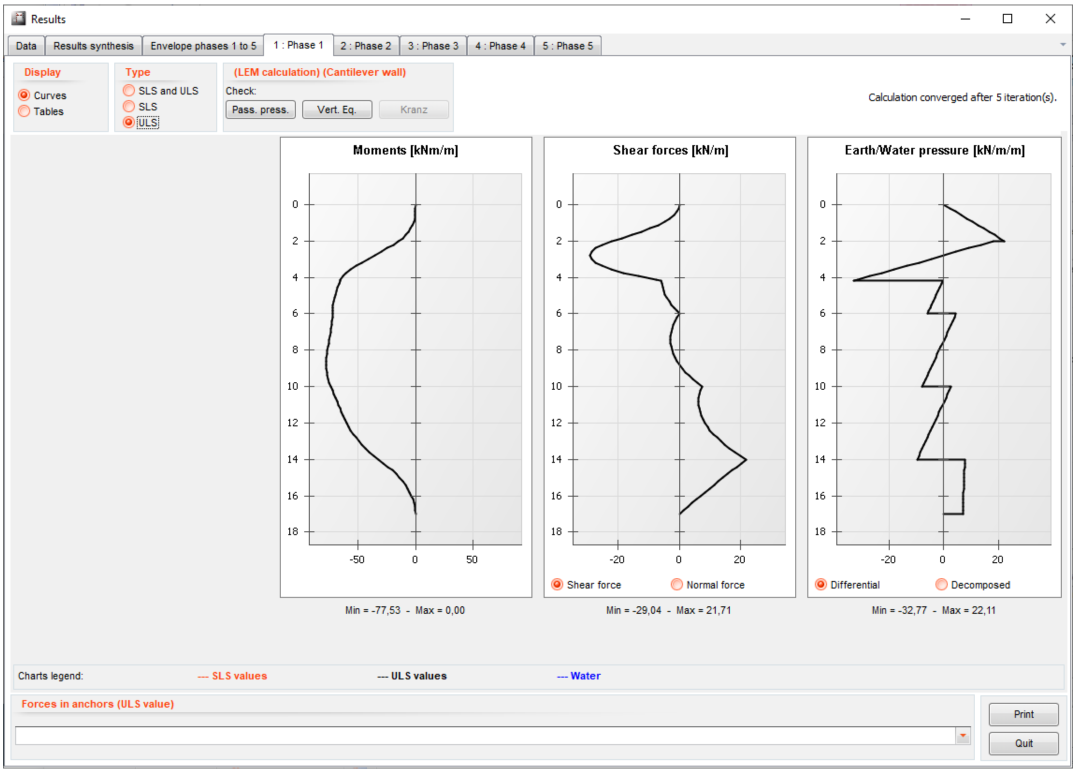
- The check of the failure on the passive side is satisfactory for all phases (LEM and SSIM): the wall embedment is ok.
- The vertical forces resultant is positive for all phases, which is also satisfactory.
- The check of the anchoring block stability (Kranz) is ok for phases 2 to 5 (all phases with at least one anchor).

Let's have a look at the more detailed results, for phase 1, and then for phase 5 (final stage).

<u>SLS curves (phase 1)</u>



<u>ULS curves (phase 1)</u>



<u>SLS results for phase 1:</u>

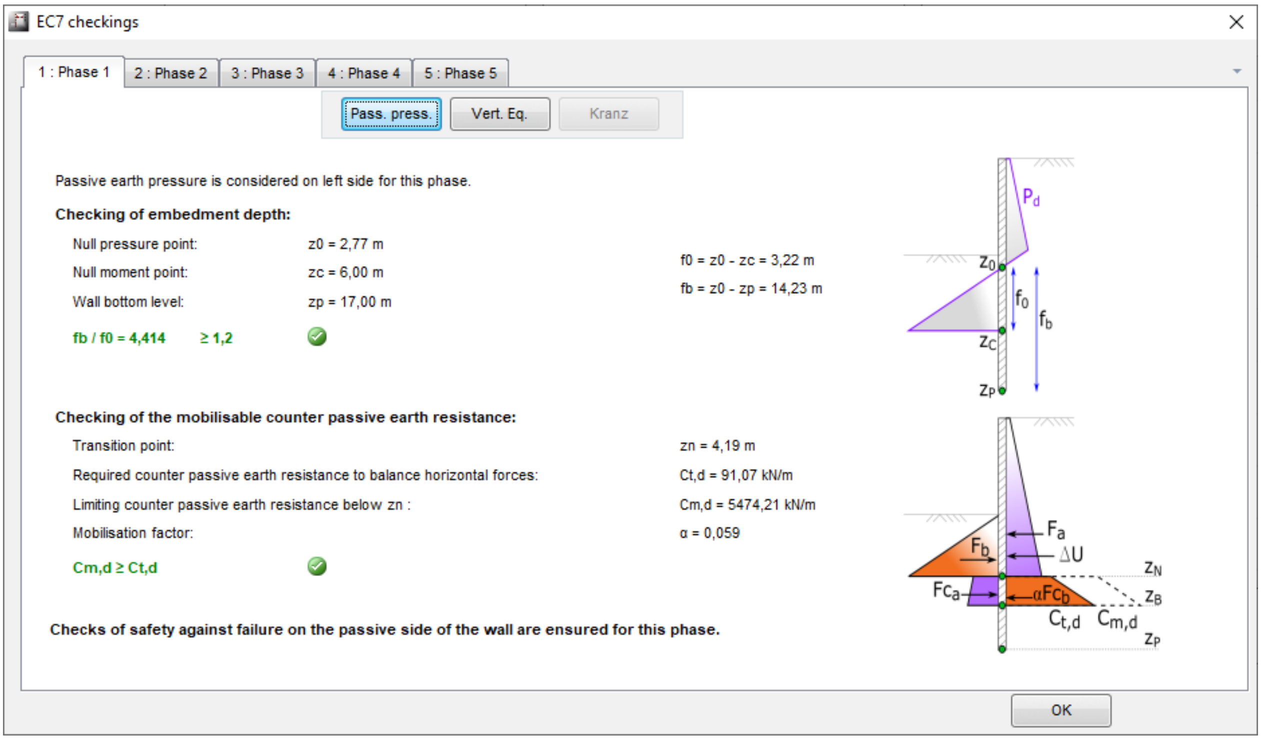
- The maximum displacement is 9 mm.
- The maximum moment is 36 kNm/m.
- The maximum shear force is 19.50 kN/m.

ULS results for phase 1 (LEM calculation):

- This phase has been defined as a cantilever phase with a LEM calculation. Thus the ULS calculation provides neither displacements nor characteristics values for moments and shear forces. It provides design values for moments and shear forces (please refer to Tutorial 2 and parts B and C of the manual).
- The maximum moment (design value) is 78 kNm/m.
- The maximum shear force (design value) is 29 kN/m.

From the ULS results screen, 3 buttons enable to access the detailed results of the 3 ULS check types.

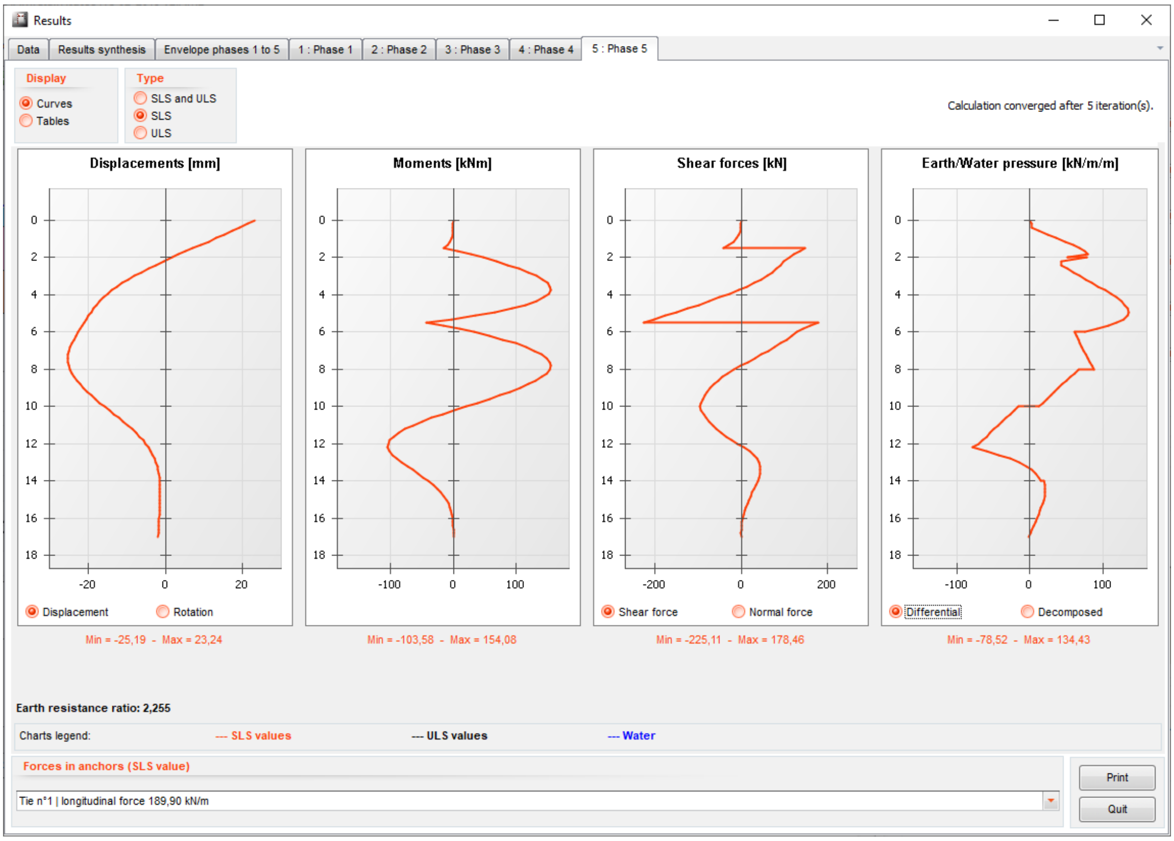
Let's consider for example the check against failure on the passive side for phase 1.



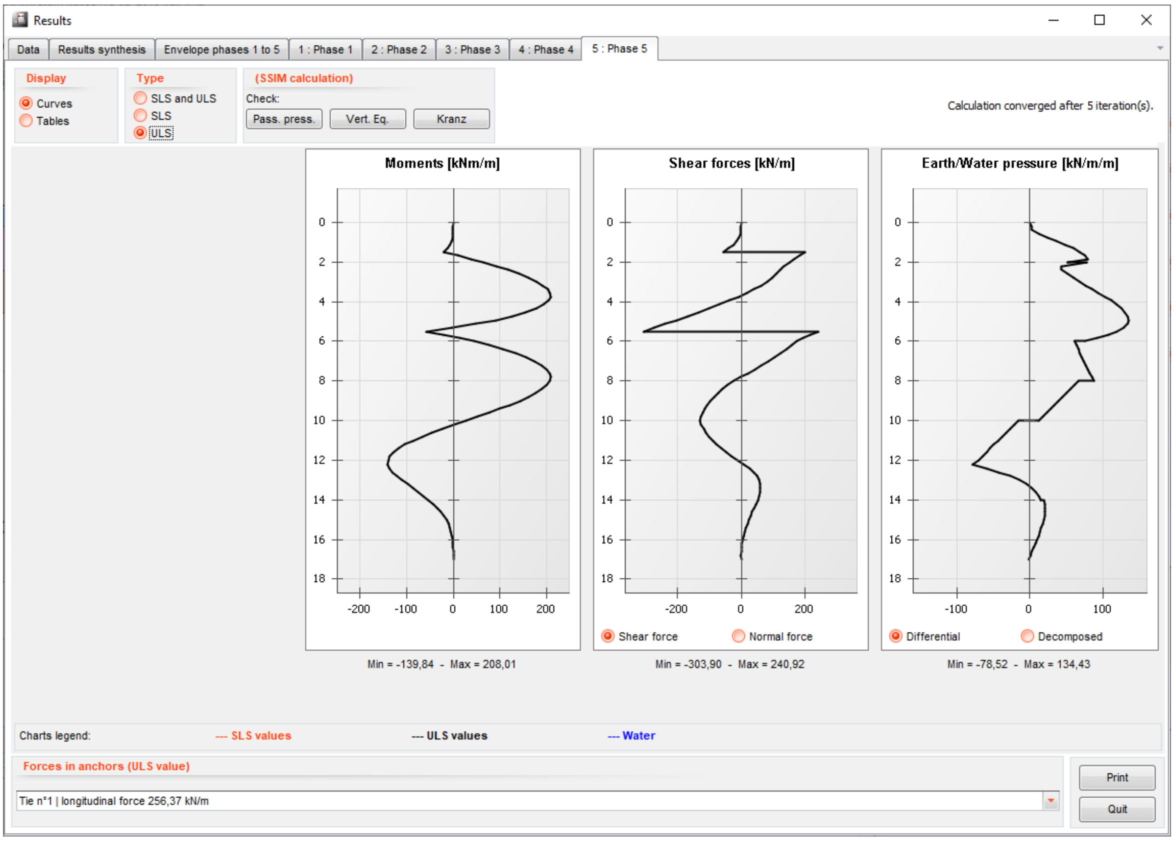
This check is satisfactory with respect to the embedment ratio as well as to the mobilisation factor (please also refer to Tutorial 2 for more details).

Again, in the case of this first phase, the calculations for this check are based on the LEM calculation. It will not be the case of phases 2 to 5, which are anchored and thus the ULS calculations and checks will be based on a SSIM calculation.

SLS curves (phase 5)



ULS curves (phase 5)



Global results of the calculation

SLS results:

- The maximum displacement is 25 mm. It is reached in the last phase, and in the middle part of the wall.
- The maximum moment is 207 kNm/m. It is reached in phase 3.
- The maximum shear force is 225 kN/m. It is reached in the last phase.

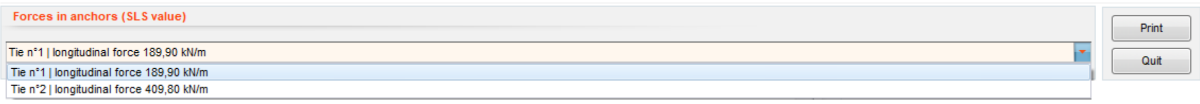
ULS results (LEM calculation for phase 1, SSIM calculations for phases 2 to 5):

- The maximum moment is 280 kNm/m. It is reached in phase 3.
- The maximum shear force is 304 kN/m. It is reached in the last phase.

Note: in the case of phases with anchors with a ULS SSIM calculation, design values of moments or shear forces are equal to characteristic values multiplied by γ_{mt} (and with the French Standard NF P 94-282 we are using here, γ_{mt} = 1.35).

We can check that in our example, ULS characteristic results (k) are identical (for all phases) to SLS results, because the project includes no (variable) overload (only overloads are weighted for the SSIM calculation of characteristic values and can lead to different results).

Forces in anchors can also be checked from the detailed results window for each phase:

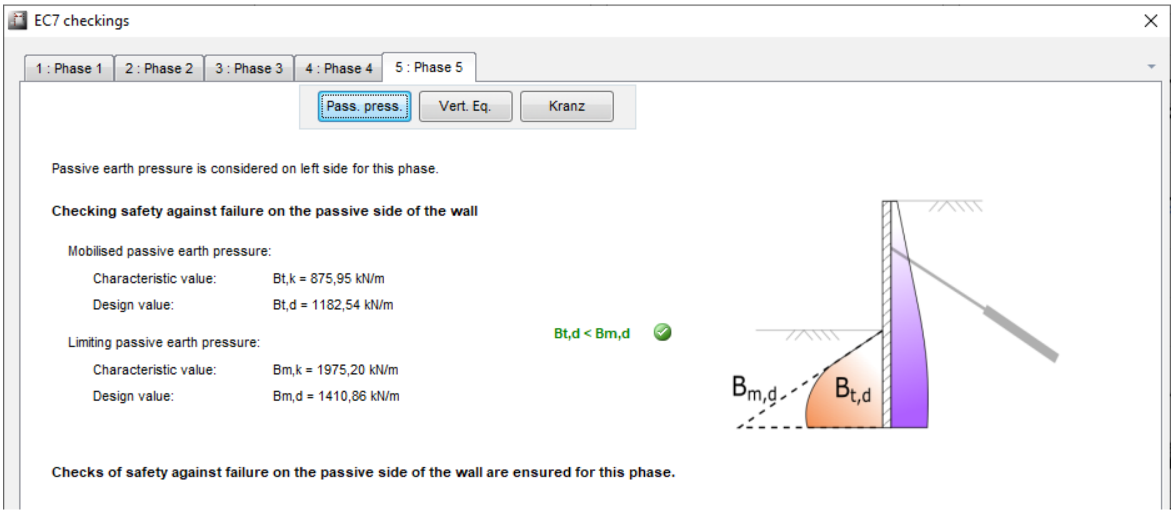


The screenshot here above shows the forces in anchors for phase 5.

- The force in anchor n° 1 is maximum at its installation phase (prestress value, 200 kN/m). Then it decreases a little and its final value is 190 kN/m (characteristic value).
- The force in anchor n° 2 is maximum in the last stage (increase from the prestress value, 400 kN/m to 410 kN/m in the last stage, in characteristic values).

From the ULS results screen, 3 buttons enable to access the detailed results of the 3 ULS check types.

Check of safety against failure on the passive side of the wall (phase 5)



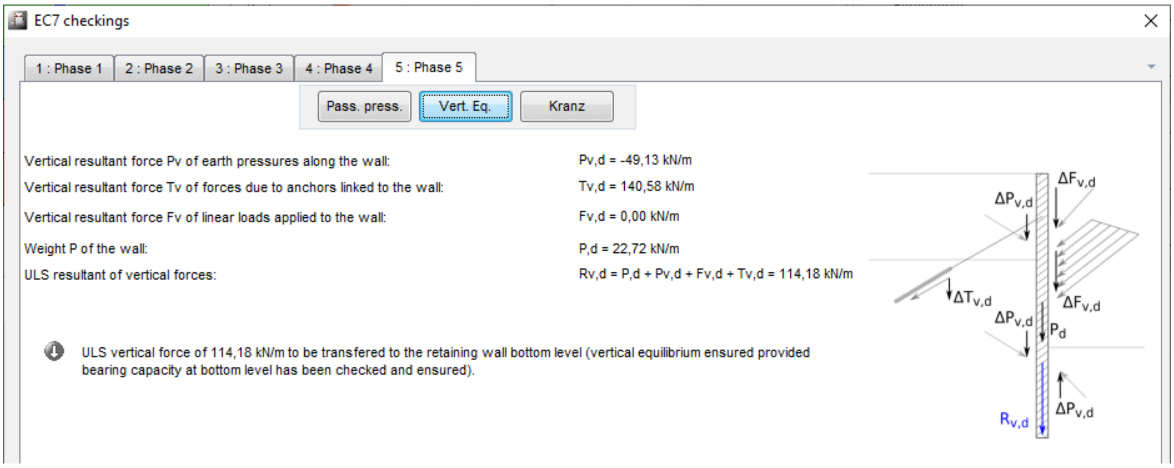
In phase 5, the wall is supported by 2 levels of anchors, and thus the verification of failure on the passive side is based directly on the SSIM model results. It consists in checking that the available (limiting) passive pressure is larger with sufficient safety to the passive pressure requested (mobilised) to ensure the horizontal equilibrium of the wall.

Here, the design value of the available passive pressure is Bm,d = 1975 / 1.40 = 1411 kN/m

The design value of the limiting passive pressure is Bt,d = 876 x 1.35 = 1183 kN/m < Bm,d

The application of the « 1.40 » factor on the available passive pressure is explained by the fact that phase 5 is considered as « permanent ».

Vertical balance check (phase 5)



The summary of vertical forces takes into account:

- The vertical component of earth pressures mobilised along the wall. It is calculated from the horizontal equilibrium of the wall (SSIM);
- The vertical component of the anchor forces;
- The weight of the wall itself.

The evaluation of the vertical component of earth pressures along the wall is based on a « prorata » approach: for a horizontal component of earth pressure which is « intermediate » (neither a limiting active pressure value nor a limiting passive pressure value), the corresponding vertical component is calculated as a prorata of the horizontal mobilisation, considering that the vertical component is zero for zero displacement (reference point). This is detailed and illustrated in part C of the manual (chapter C.3.3.2.1).

It should be mentioned that this evaluation is valid only in the case of layers that are horizontal.

Kranz (phases 2 to 5)

For phases 2 to 5, the presence of anchors implies to perform an additional check, which is the check of the anchoring block stability.

This check is carried out with the « Kranz » model: for each phase, several situations are considered (corresponding to each anchoring block associated with each active anchor in a given phase).

For each situation, one or several anchors are taken into account depending whether their effective anchor point (defined by « Lu ») is inside or outside the considered anchoring block.

Let's consider for instance phases 3 and 5:

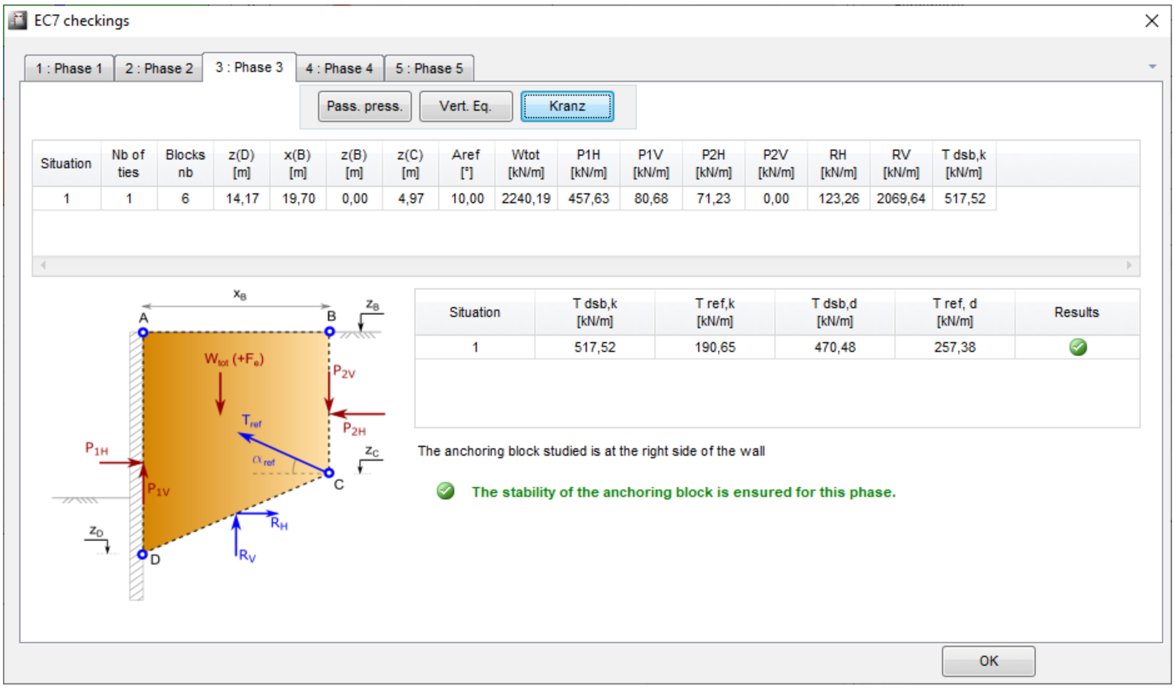
- in phase 3 , 1 single situation is considered: situation 1 with the anchor "1";
- in phase 5, 2 situations have to be considered:
  - Situation 1 with only one anchor taken into account;
  - Situation 2 with both anchors taken into account.

For a given situation, the check of the anchoring block equilibrium may require to separate this anchoring block into several elementary « blocks » along the interfaces of soil layers intersected by the assumed failure surface (CD, according to the figure in the screenshot below). In our example, for phase 5, a separation into 4 elementary blocks was considered for situation 1, into 3 blocks for situation 2.

For each situation, AMRetain displays the geometrical properties of the considered anchoring block, and the summary of forces obtained by writing the equilibrium of the block.

This Kranz verification consists in checking for each situation, and thus for the anchoring block, that the destabilizing force (corresponding to limit equilibrium) is superior, with sufficient safety, to the « resultant » force taken by the anchors taken into account for this situation.

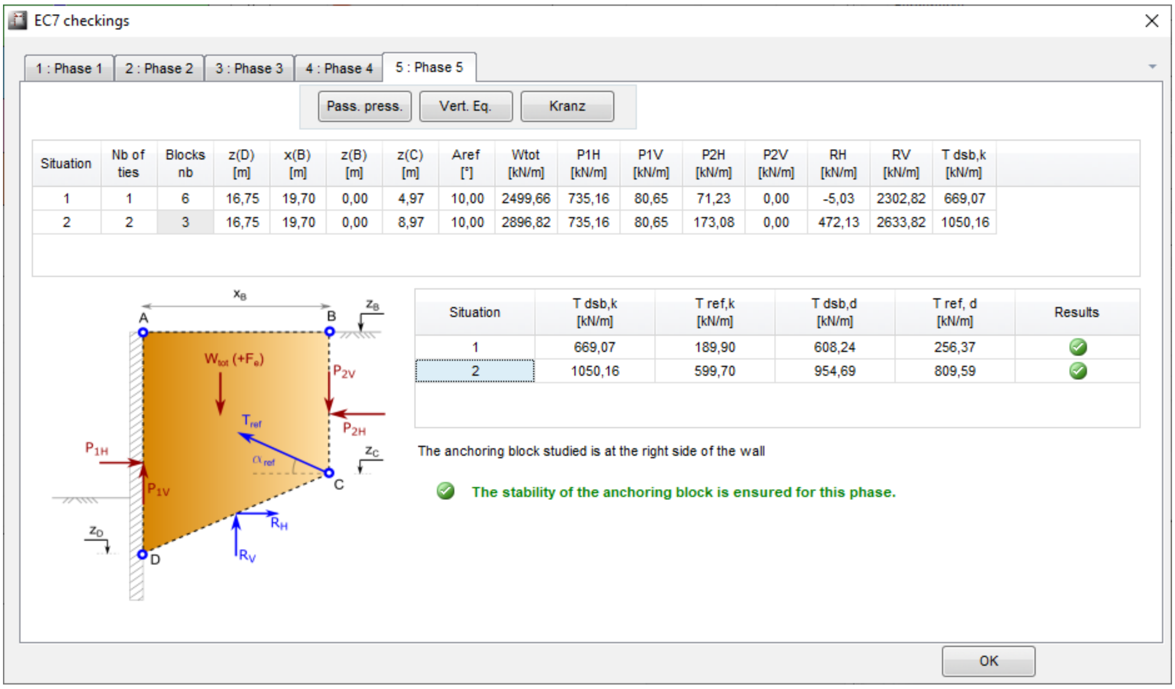
<u>Kranz results for phase 3 (one situation)</u>:



<u>Kranz results for phase 5 (2 situations)</u>:

For instance, for situation 2:

- The design value of the destabilizing force of the considered anchoring block is Tdsb,d = 1050 kN/m / 1,10 = 955 kN/m ;
- Both anchors are taken into account, they are parallel to each other, the resultant force is calculated here as Tref,k = 189 + 410 = 599 kNm/ml. The corresponding design value is thus Tref,d = 599 x 1,35 = 809 kN/m < Tdsb,d.



Important note:
For a given situation, taking into account an anchor or not is decided depending on the relative position of its anchoring point with respect to the corresponding block boundaries. Attention is drawn to the case in which this anchoring point, although located geometrically outside the block, is close to the borders BC or CD, and in which case its influence cannot be neglected. Adapting the useful length of the anchors is necessary to allow them to be taken into account.

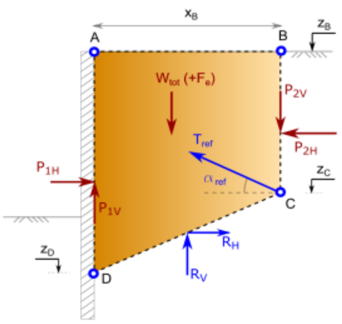
To illustrate this comment, let's compare the Kranz calculation above for phase 5 with a new calculation where Lu_1 for the first anchor is set to 20.5 m (instead of 20 m), which means that for situation 2, the effective anchor point of the first anchor will be outside the anchoring block, and thus anchor 1 will not be taken into account for situation 2.

EC7 checkings

1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5

Pass. press. | Vert. Eq. | Kranz

Situation	Nb of ties	Blocks nb	z(D) [m]	x(B) [m]	z(B) [m]	z(C) [m]	Aref [°]	Wtot [kN/m]	P1H [kN/m]	P1V [kN/m]	P2H [kN/m]	P2V [kN/m]	RH [kN/m]	RV [kN/m]	T dsb,k [kN/m]
1	1	6	16,75	20,19	0,00	5,06	10,00	2570,96	735,16	80,65	73,29	0,00	28,68	2368,55	701,19
2	1	3	16,75	19,70	0,00	8,97	10,00	2896,82	735,16	80,65	173,08	0,00	472,13	2633,82	1050,16



Situation	T dsb,k [kN/m]	T ref,k [kN/m]	T dsb,d [kN/m]	T ref, d [kN/m]	Results
1	701,19	189,90	637,45	256,37	✓
2	1050,16	409,80	954,69	553,23	✓

The anchoring block studied is at the right side of the wall

The stability of the anchoring block is ensured for this phase.

OK

Indeed, in the screenshot above, we can check that:

- Only one anchor (anchor 2) is considered when checking situation 2 (instead of both anchors considered for the same situation in the initial calculation with Lu_1 = 20 m).
- The values for T_{dsb} didn't change with respect to the initial calculation with Lu = 20 m for anchor 1, which was expected as Lu_1 has no influence on the calculation of T_{dsb} (the geometry of the anchoring block n°2 has not been changed, it depends on Lu_2).
- The values of T_{ref} did change. $T_{ref,k}$ (respectively $T_{ref,d}$) was equal to 600kN (resp. 809 kN) for Lu_1 = 20 m and is equal to 410 kN (resp. 553 kN) for Lu_1 = 20,5 m. In this case, the check with respect to $T_{dsb,d}$ is satisfactory in both cases, but the difference between both values is important (for only 0,5 m change in the Lu length of one anchor !) and in some cases, it could make the Kranz check conclusion change from "unsatisfactory" to "satisfactory".
- So again, when the anchoring point of an anchor is located geometrically outside the block but close to the borders BC or CD, its influence cannot be neglected. Adapting the useful length of the anchors is necessary to allow them to be taken into account.

Note: the values for T_{dsb} in situation 1 changed a little, because the position of point C for the anchoring block changed when Lu_1 changed.

D.3.4. STEP 4: ALTERNATIVE PROJECT WITH STANDARD U SHEETPILES

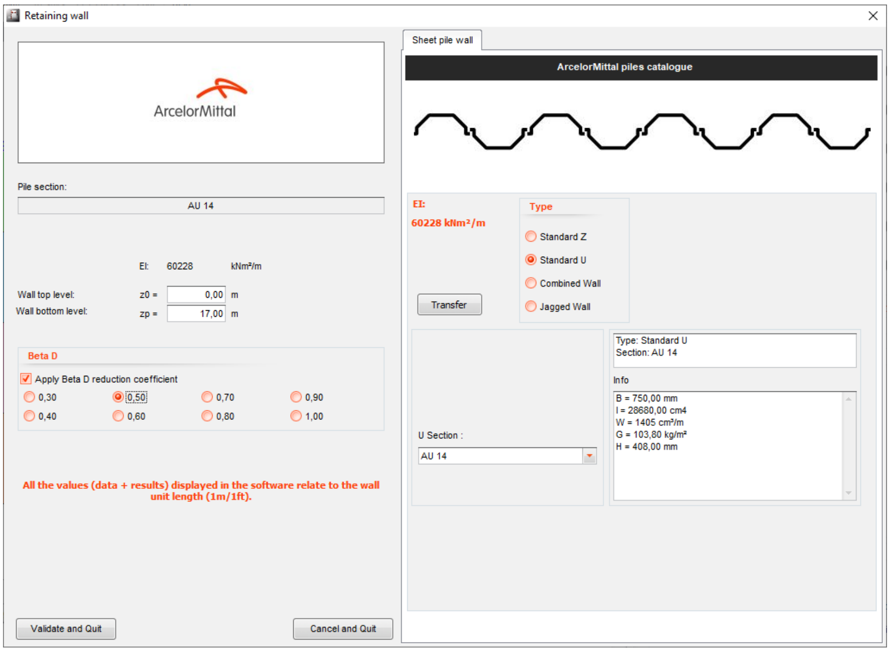
Please quit the results window, and "save as" your project under a new name.

The wall is now assumed to be made of U-shaped sheet piles. As these are installed by doubles, the effective bending stiffness may be considered via the beta.D coefficient as referenced by the standards. As this coefficient is generally a function of the soil conditions and the number of active anchors or struts, it can be changed during the different construction stages.

This chapter details this alternative project: data input and new results.

D.3.4.1. MODIFICATION OF WALL PROPERTIES

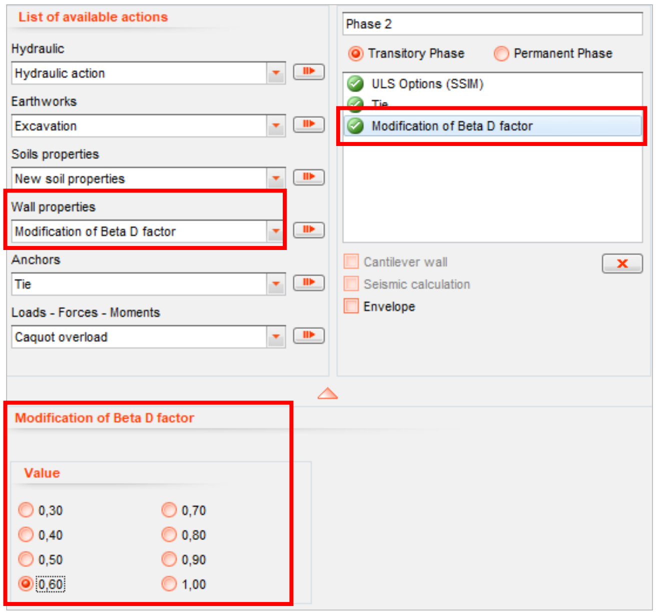
The wall is now assumed to be made of sheet piles of type AU 14, 17 m long, with the definition of a beta.D coefficient equal to 0.5.



D.3.4.2. MODIFICATION OF PHASES 2 AND 4

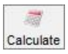
We will change the beta.D coefficient each time a new anchor level is installed, i.e. in phases 2 and 4:

- Select phase 2, and then add an action **Modification of factor beta.D** (from the category Anchors-Wall) to the phase actions. Then change the beta.D value to 0,6 (meaning the EI used for the wall in the calculations will be increased from 50 % to 60 % of the catalogue value).



- Select phase 4, and then add an action **Modification of factor beta.D**. Then change the beta.D value to 0,8 (meaning the EI used for the wall in the calculations will be increased from 60 % to 80 % of the catalogue value).

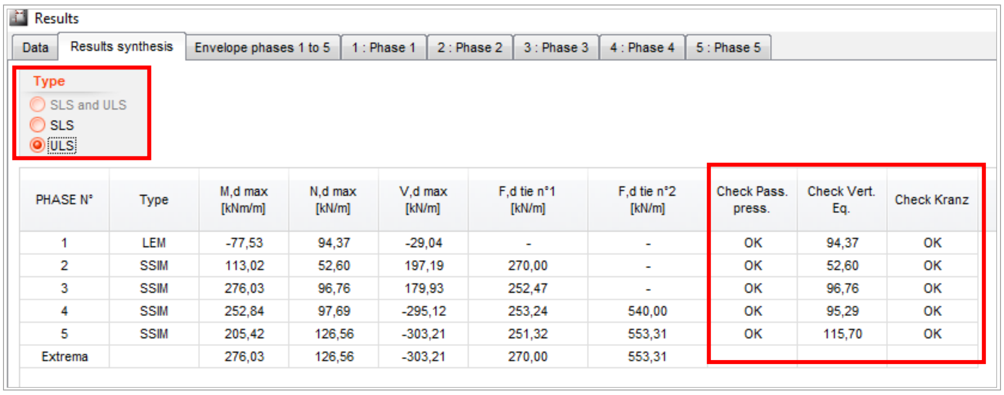
D.3.4.3. RESULTS

Click on 

and then on 

to get to the detailed results.

Let's start with the results synthesis tab, in order to quickly check that all ULS checks are satisfied.



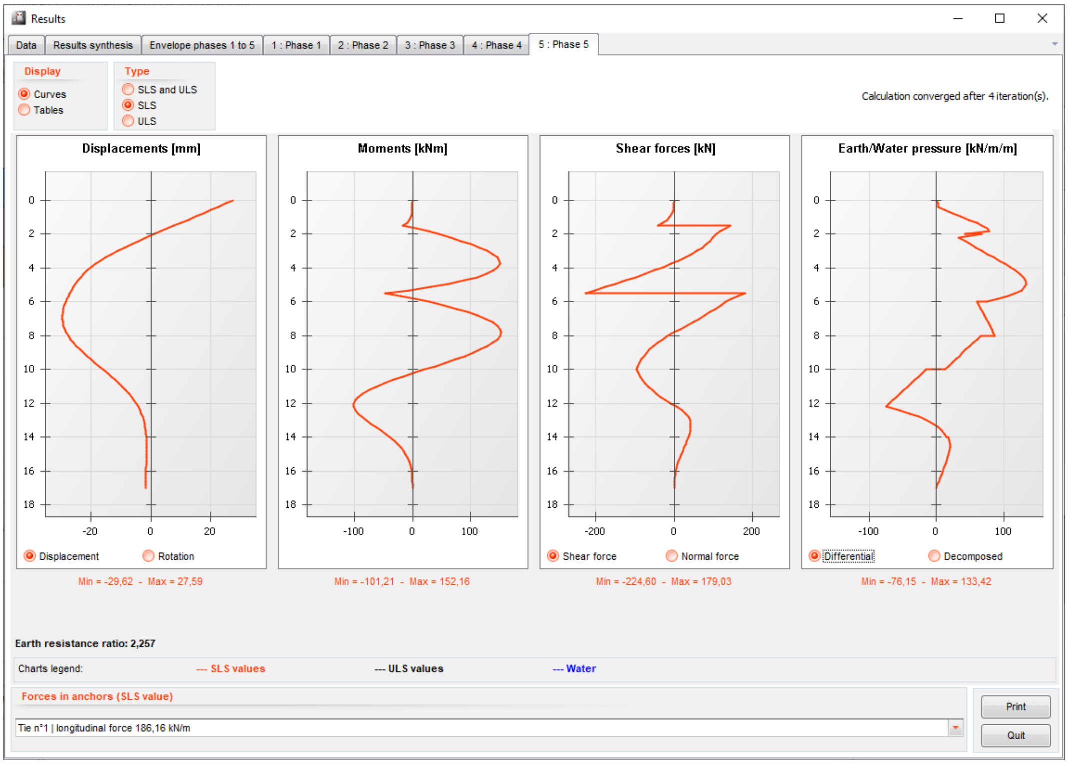
PHASE N°	Type	M,d max [kN/m/m]	N,d max [kN/m]	V,d max [kN/m]	F,d tie n°1 [kN/m]	F,d tie n°2 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-77,53	94,37	-29,04	-	-	OK	94,37	OK
2	SSIM	113,02	52,60	197,19	270,00	-	OK	52,60	OK
3	SSIM	276,03	96,76	179,93	252,47	-	OK	96,76	OK
4	SSIM	252,84	97,69	-295,12	253,24	540,00	OK	95,29	OK
5	SSIM	205,42	126,56	-303,21	251,32	553,31	OK	115,70	OK
Extrema		276,03	126,56	-303,21	270,00	553,31			

We can see that:

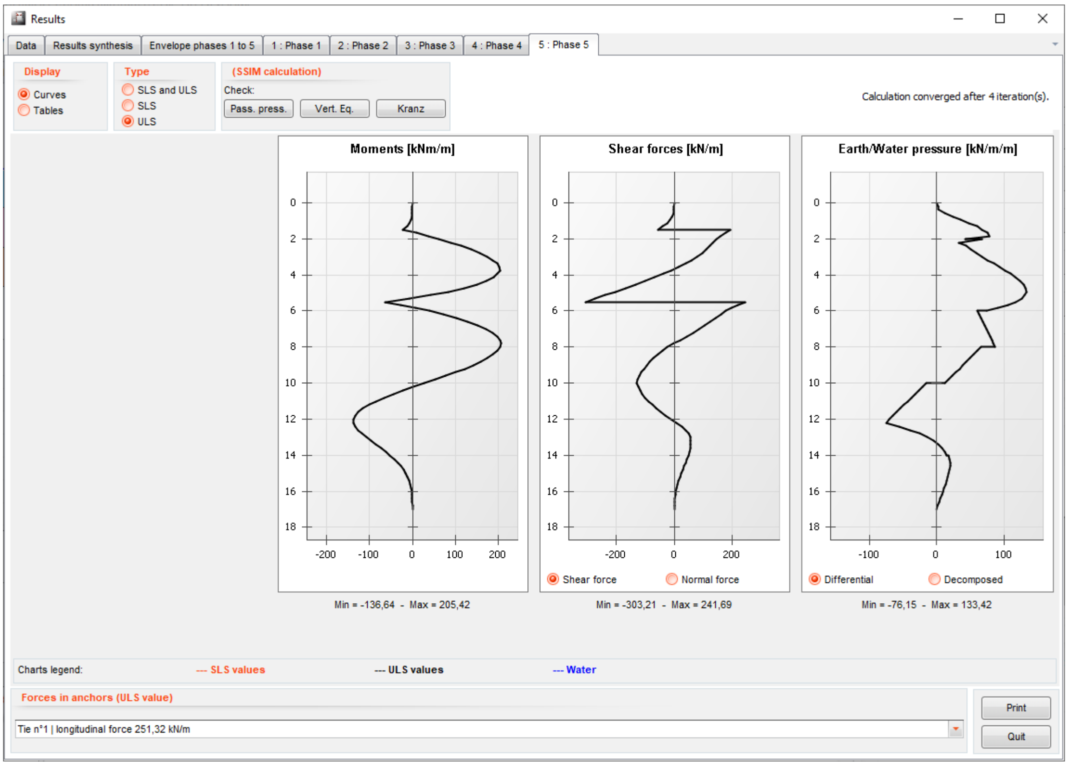
- The check of the failure on the passive side is satisfactory for all phases (LEM and SSIM): the wall embedment is ok.
- The vertical forces resultant is positive for all phases, which is also satisfactory.
- The check of the anchoring block stability (Kranz) is ok for phases 2 to 5 (all phases with at least one anchor).

Let's now have a look at the more detailed results.

SLS Curves (phase 5)



ULS Curves (phase 5)



SLS results:

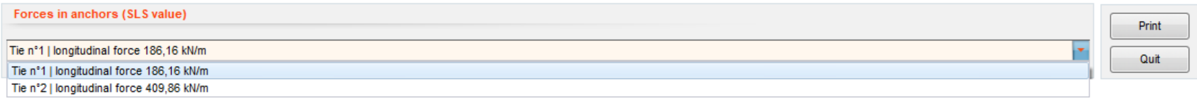
- The maximum displacement is 30 mm. It is reached in the last phase, and in the middle part of the wall.
- The maximum moment is 204 kNm/m. It is reached in phase 3.
- The maximum shear force is 225 kN/m. It is reached in the last phase.

<u>ULS results</u>:

- The maximum moment is 276 kNm/m. It is reached in phase 3.
- The maximum shear force is 303 kN/m. It is reached in the last phase.

We can check that in our example, ULS characteristic results (k) are identical (for all phases) to SLS results, because the project includes no (variable) overload (only variable overloads are weighted for the SSIM calculation of characteristic values and can lead to different results).

Forces in anchors can also be checked from the detailed results window for each phase:



The screenshot here above shows the forces in anchors for phase 5.

- The force in anchor n° 1 is maximum at its installation phase (prestress value, 200 kN/m). Then it decreases a little and its final value is 185 kN/m.
- The force in anchor n° 2 is maximum in the last stage (increase from the prestress value, 400 kN/m to 410 kN/m in the last stage).

The results are quite close to those of the calculation using the Standard Z sheet pile. The differences (for instance the maximum displacement is 25 mm with the standard Z sheet pile and it is 30 mm with the Standard U sheet pile) are due only to the difference in the EI value of the wall between both calculations:

- Standard Z sheet pile (AZ 13-770): the EI value is 46956 kN.m^2 for the whole project.
- Standard U sheet pile (AU 14): the EI value is 30114 kN.m^2 for phase 1 (beta.D = 0,5), it is 36137 kN.m^2 for phases 2 and 3 (beta.D = 0.6), and it is 48182 kN.m^2 for phases 4 and 5 (beta.D = 0.8).

The EI values for the AU 14 sheet pile are smaller than those of the AZ 13-770 sheet pile for phases 1 to 3, and are almost the same for phases 4 and 5, which leads to higher displacements for the solution with AU 14 sheet piles.

You may also check the details of the new ULS checks results as shown in the previous section. Details are not presented here.

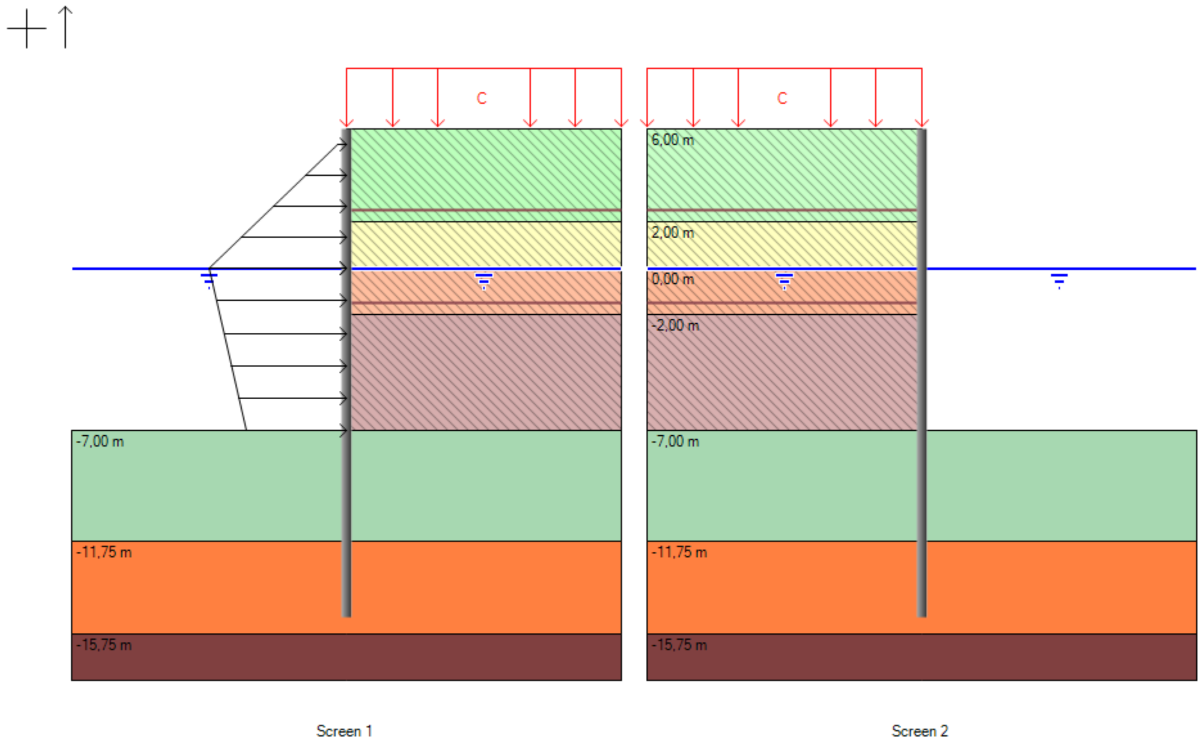
D.4. TUTORIAL 4: TYPICAL CASE OF A DOUBLE SHEETPILE WALL (COFFERDAM)

This case is an example of a double sheet pile wall (cofferdam) connected by 2 levels of horizontal linking anchors.

These anchors are assumed to work in unilateral mode (traction only).

The left wall is made of sheet piles of type AZ 26, 21 m long.

The right wall is made of sheet piles of type AZ 24-700, 21 m long too.



The construction stages are mainly symmetrical: most actions are performed simultaneously on the right side of the left wall (wall 1) and on the left side of the right wall (wall 2) (change of water levels, installation of linking anchors, fill levels, etc).

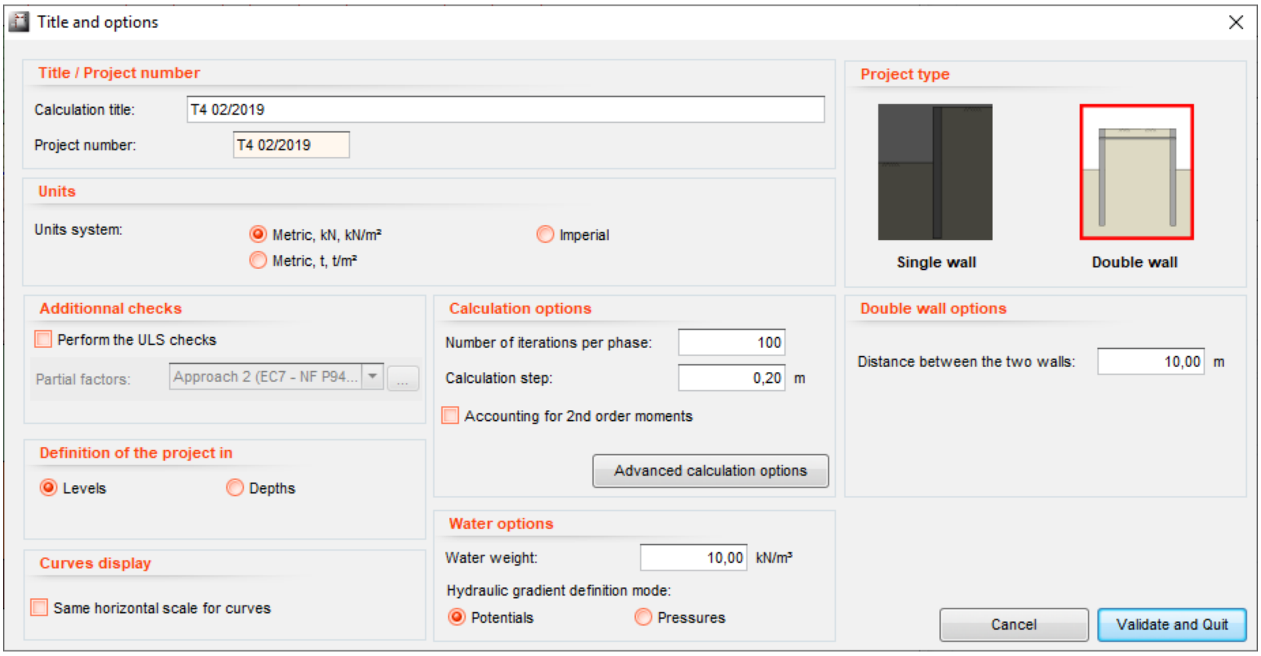
Only in the last 2 stages, some actions are applied only on the left side of the left wall (water level changes, and simulation of wave effect).

Note: this project doesn't include any ULS checks.

D.4.1. STEP 1: DATA INPUT

D.4.1.1. TITLE AND OPTIONS

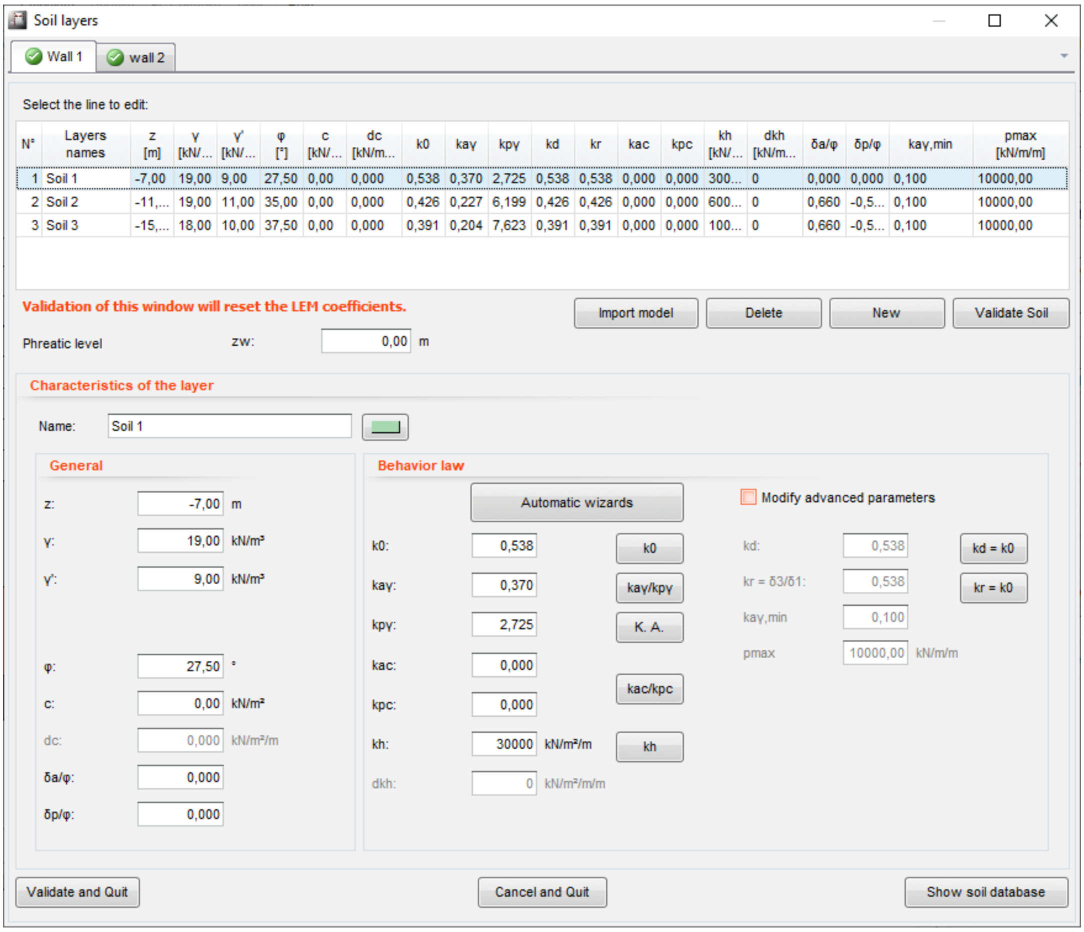
The following screenshot displays the relevant data.



- In the zone **Project type**, select **Double Wall**.
- In the zone **Double wall options**, Distance between the two walls is **10,00** m
- In the zone **Title / Project number**, input the relevant information.
- We will use **metric units.**
- We will use **levels** for this example.
- In the zone **Calculation options**, keep the default settings again, which are **100** for the maximum number of iterations per calculation step and **0.20** m for the calculation step.
- Keep the default value in **water options**, water weight equal to 10 kN/m^3 and “Potentials” checked for hydraulic gradient definition mode.
- Click on Validate and Quit.
- Save the project with the name and in the directory you wish to use.
- The dialogue box Characteristics of **Soil layers** is then displayed, one tab for each wall.

D.4.1.2. DEFINITION OF SOIL PROPERTIES

The dialogue box Characteristics of **Soil layers – Wall 1** should be filled in to achieve the following screenshot:



This dialogue box enables to fill in the soil properties relating to **wall 1**.

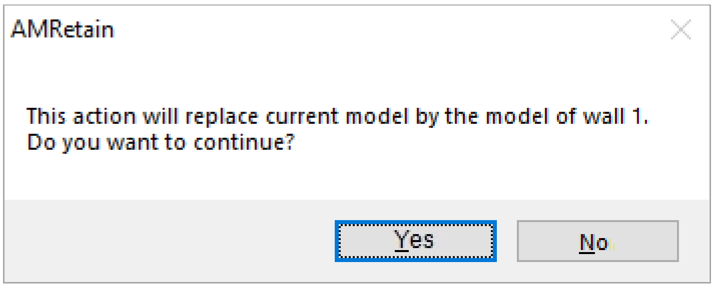
- In the bottom zone, fill in the properties for soil layer 1. Soil properties are provided in the tables here below (the same wizards as for previous examples may be used):

	z (m)	z_w (m)	γ (kN/m³)	γ_d (kN/m³)	φ (°)	c (kN/m²)	δ_a/φ	δ_p/φ
Layer 1	-7	0	19	9	27.5	0	0	0
Layer 2	-11.75	0	19	11	35	0	0.66	-0.5
Layer 3	-15.75	0	18	10	37.5	0	0.66	-0.5

	k_0	$k_{a\gamma}$	$k_{p\gamma}$	k_{ac}	k_{pc}	k_h (kN/m²/m)
Layer 1	0.538	0.370	2.725	0	0	30000
Layer 2	0.426	0.227	6.199	0	0	60000
Layer 3	0.391	0.204	7.623	0	0	100000

- Click on [Validate Soil] and then on [New] to fill in the properties for soil layers 2 and 3.
- Click on [Validate and Quit].

- The tab “wall 2” is displayed but empty. AMRetain can import the layers of the wall 1 for the wall 2. In the case of this project, the characteristics of the layers for the 2 walls are identical.
    - In this project, we can use this option. Click on [Import model] to proceed. Clcik [Yes] button on the window bellow:

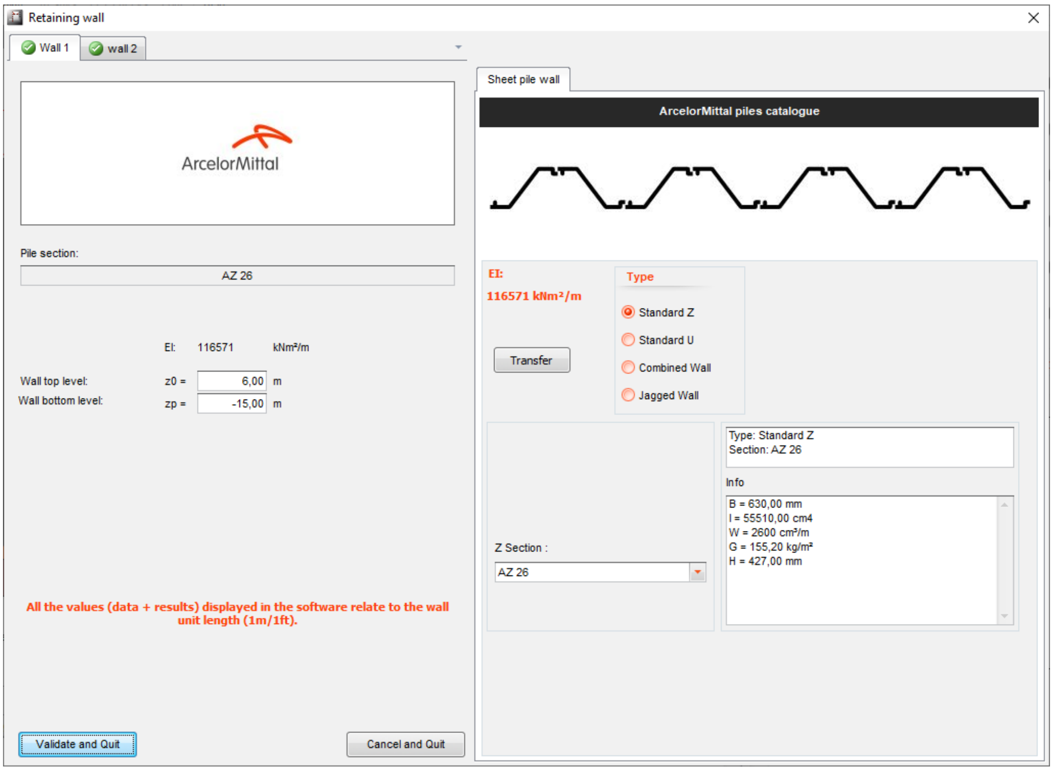


<u>Note:</u> In the case of a project with identical soil layers for both walls, AMRetain let us to import all soil data defined for wall 1 directly to wall 2

- The same soil properties are then displayed for Wall 2, in case you need to make some changes. In our case, the properties are exactly the same as for wall 1. So just click on [Validate and Quit].

D.4.1.3. <u>DEFINITION OF WALL PROPERTIES</u>

The dialogue box **Retaining wall - Wall 1** is then displayed and should be filled in to achieve the screen shot below.



This dialogue box enables to define the properties of **Wall 1**.

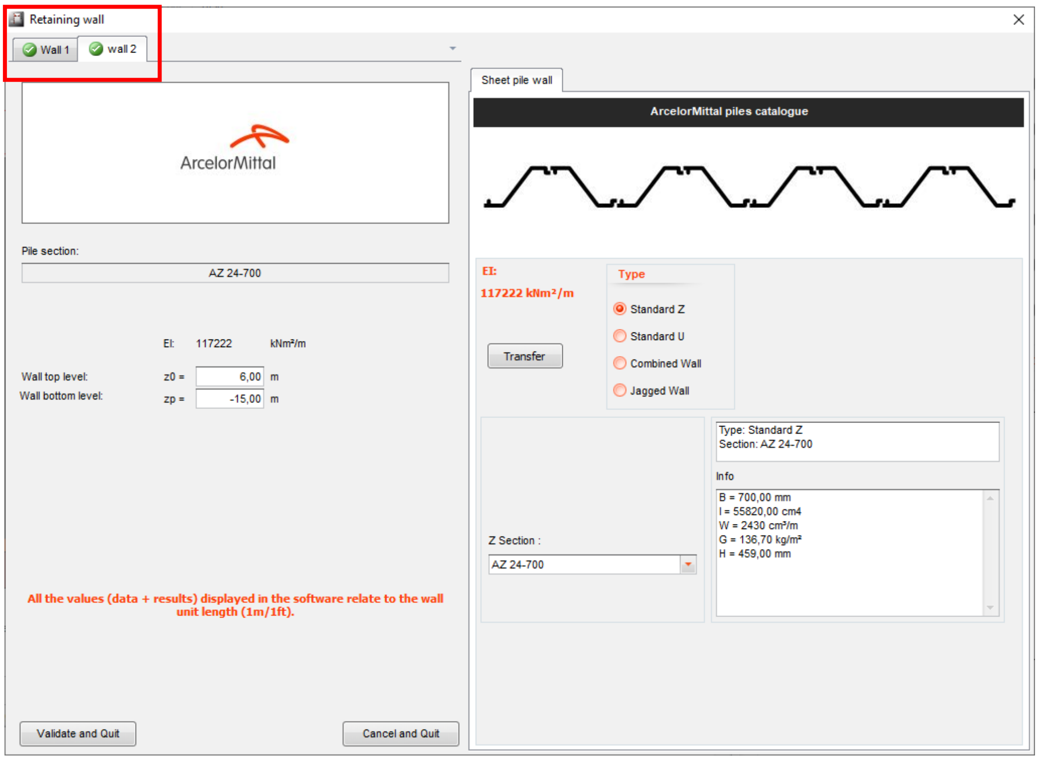
- In the zone **ArcelorMittal catalogue of steel sheet piles**, check type **Standard Z**. In the sheet piles list for **Z Section**, select **AZ 26**.

- Click on the [Transfer] button to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z0 and the wall bottom level Zp, with the values provided in the next table

	Type	EI (kN.m^2/m)	Z0 (m)	Zp (m)
Wall 1	AZ 26	116571	6	-15

- Click on [Validate and Quit].

The dialogue box **Retaining wall** is then displayed:



This dialogue box enables to define the properties of **Wall 2**.

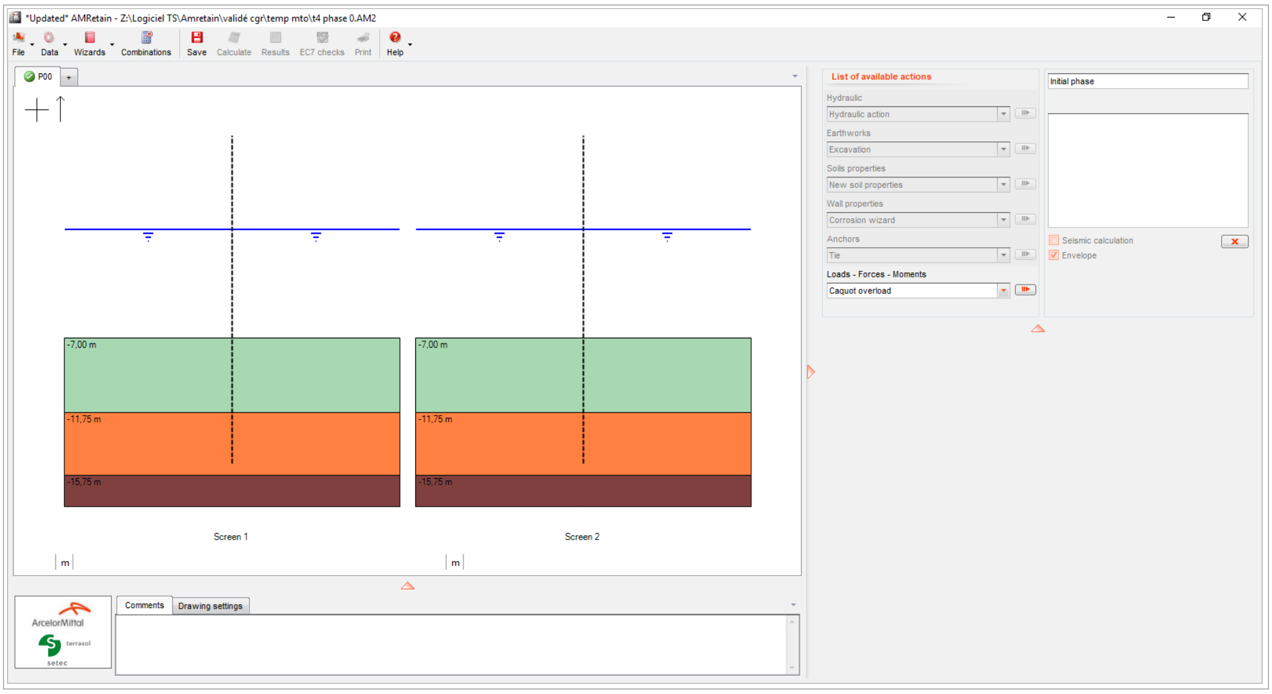
- In the zone **ArcelorMittal catalogue of steel sheet piles**, check type **Standard Z**. In the sheet piles list for **Z Section**, select **AZ 24-700**.
- Click on the [Transfer] button to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z0 and the wall bottom level Zp, with the values provided in the next table

	Type	EI (kN.m^2/m)	Z0 (m)	Zp (m)
Wall 2	AZ 24-700	117222	6	-15

- Click on [Validate and Quit].
- The drawing with soil layers and both walls is then displayed in the main screen (refer to next screenshot).

D.4.2. STEP 2: DEFINITION OF PHASES AND ACTIONS

When data input has been completed, the main screen should be like on the screenshot below.



There's no action to be defined for the initial stage.

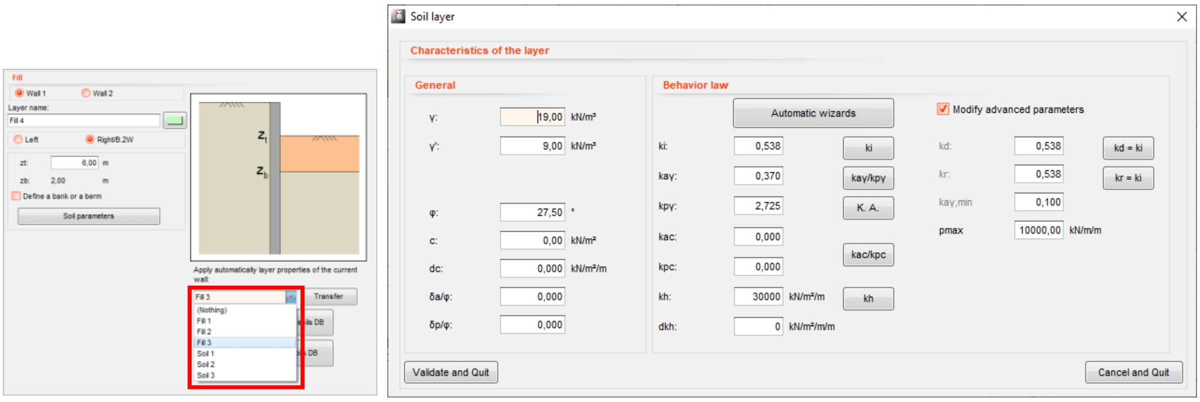
We will thus start with the creation of phase 1, as indicated below.

The complete phasing for this example is illustrated in the following tables.

The recommended procedure to define the phases and actions for both walls is the following:

- When defining successive fill actions for Wall 1: the properties of the fill have to be filled in for the first fill action for Wall 1.

  For the next fill actions (for the same wall), and provided all fill levels have the same properties (which is the case for this example), it is possible to copy the properties from the first fill level (screenshot).



Several fill actions for wall 2: properties of this fill can be transfered from the fill of wall 1.

Phase	Actions for wall 1 (left wall)	Phase properties	Actions for wall 2 (right wall)	Phase properties
Initial phase		-		-
Phase 1	Fill 1	Fill on the right side: z_t=-2m, z_b=-7m, Fill properties: γ=19kN/m^3, γ_d=9 kN/m^3, φ=27.5°, c=0kN/m^2, k_i=0.538, $k_a\gamma$=0.37, $k_p\gamma$=2.725, k_{ac}=0, k_{pc}=0, δ_a/φ=0, δ_p/φ=0, k_h=30000 kN/m^2/m	Fill 1	Fill on the left side: z_t=-2m, z_b=-7m, Propriétés du remblai : γ=19kN/m^3, γ_d=9 kN/m^3, φ=27.5°, c=0kN/m^2, k_i=0.538, $k_a\gamma$=0.37, $k_p\gamma$=2.725, k_{ac}=0, k_{pc}=0, δ_a/φ=0, δ_p/φ=0, k_h=30000 kN/m^2/m
Phase 2	Linking anchor	Linking anchor: Tie, z_{aa}=-1.5m, z_{ab}=-1.5m, K=65000kN/m/m, α=0°	Linking anchor	Linking anchor: tie, z_{aa}=-1.5m, z_{ab}=-1.5m, K=65000kN/m, α=0°
Phase 3	Hydraulic action	Hydraulic action on the right side: z_w=-2m,	Hydraulic action	Hydraulic action on the left side: z_w=-2m
Phase 4	Fill 2 Hydraulic action	Fill on right side: same characteristics as Fill1 with z_t=0m, z_b=-2m Hydraulic action on right side : z_w=0m	Fill 2 Hydraulic action	Fill on left side: same characteristics as Fill1 with z_t=0m, z_b=-2m, q=0kN/m^2 Hydraulic action on right side : z_w=0m
Phase 5	Fill 3	Fill on the right side: Same characteristics than Fill1 with z_t=2m, z_b=0m	Fill 3	Fill on the left side: Same characteristics than Fill1 with z_t=2m, z_b=0m
Phase 6	Linking anchor	Linking anchor: tie, z_{aa}=2.5m, z_{ab}=2.5m, K=15000kN/m/m, α=0°	Linking anchor	Linking anchor: tie, z_{aa}=2.5m, z_{ab}=2.5m, K=15000kN/m, α=0°
Phase 7	Fill 4	Fill on the right side: same characteristics as Fill1 with z_t=6m, z_b=2m	Fill 4	Fill on the left side: same characteristics as Fill1 with z_t=6m, z_b=2m
Phase 8	Caquot overload Hydraulic action	Caquot overload on the right side: q=20kN/m/m Hydraulic action on the left side: z_w=-2.3m	Caquot overload	Caquot overload on the left side: q=20kN/m/m (change of the overload value)
Phase 9	Hydraulic action Trapezoidal overload Trapezoidal overload	Hydraulic action on the left side: z_w=0m Trapezoidal overload with z_t=5.32m, z_b=0m, α=0°, q_{ht}=0kN/m/m, q_{hb}=44.1kN/m/m Trapezoidal overload with z_t=0m, z_b=-7m, α=0°, q_{ht}=44.1 kN/m/m, q_{hb}=32.2 kN/m/m (these horizontal loads simulate a wave effect)		

AMRetain v.2.1.2

PROJECT T4 02/2019

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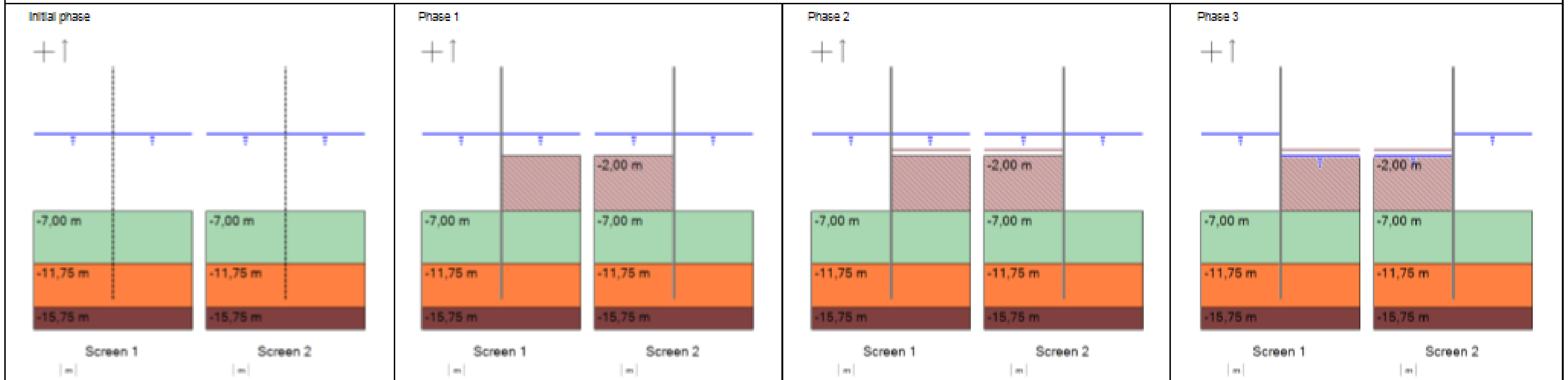
STAGE CONSTRUCTION SYNTHESIS



Phase 1

Wall 1
- Fill (right): Remblaiement 1

zt [m] = -2,00	φ [°] = 27,50
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 9,00	γ [kN/m³] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m²/m] = 30000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Wall 2
- Fill (left): Remblaiement 1

zt [m] = -2,00	φ [°] = 27,50
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 9,00	γ [kN/m³] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m²/m] = 30000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Phase 2

Wall 1
- Installation of linking anchor: n°1
  - zaa [m] = -1,50
  - zab [m] = -1,50
  - K [kN/m/m] = 65000
  - α [°] = 0,00
  - P [kN/m] = 0,00

Phase 3

Wall 1
- Hydraulic action: (right):
  - zw [m] = -2,00

Wall 2
- Hydraulic action: (left):
  - zw [m] = -2,00

ArcelorMittal

Calculated by: Terrasol

terrasol setec

Project filename: R:\Logiciels\Manuels\AMRetain v2\Mise à jour manuels 2019\Exemples v2\EN\T4 02 2019 v2.AM2 printed on 13/03/2019 12:43 calculated on 13/03/2019 at 12:25computed on 13/03/2019 12:25 Page : 1

AMRetain v.2.1.2

PROJECT T4 02/2019

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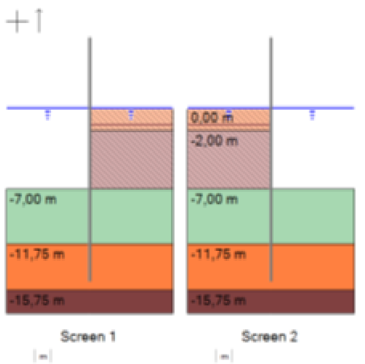
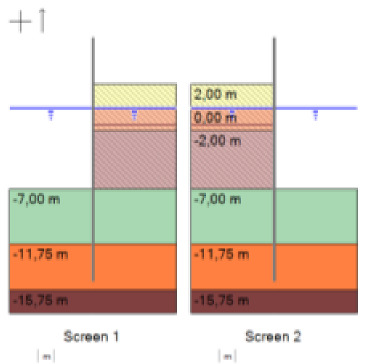
STAGE CONSTRUCTION SYNTHESIS

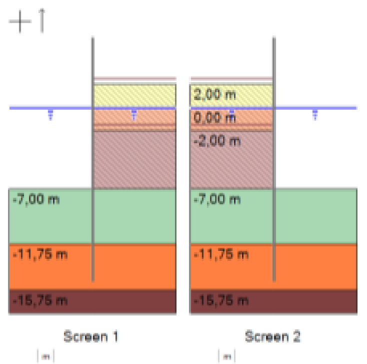
Phase 4



Phase 5



Phase 6



Phase 4

Wall 1
- Fill (right): Remblaiement 2

zt [m] = 0,00	φ [°] = 27,50
c [kN/m^2] = 0,00	dc [kN/m^2/m] = 0,000
γ' [kN/m^3] = 9,00	γ [kN/m^3] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m^2/m] = 30000
dkh [kN/m^2/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

- Hydraulic action: (right):
  zw [m] = 0,00

Wall 2
- Fill (left): Remblaiement 2

zt [m] = 0,00	φ [°] = 27,50
c [kN/m^2] = 0,00	dc [kN/m^2/m] = 0,000
γ' [kN/m^3] = 9,00	γ [kN/m^3] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m^2/m] = 30000
dkh [kN/m^2/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

- Hydraulic action: (left):
  zw [m] = 0,00

Phase 5

Wall 1
- Fill (right): Remblaiement 3

zt [m] = 2,00	φ [°] = 27,50
c [kN/m^2] = 0,00	dc [kN/m^2/m] = 0,000
γ' [kN/m^3] = 9,00	γ [kN/m^3] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m^2/m] = 30000
dkh [kN/m^2/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Wall 2
- Fill (left): Remblaiement 3

zt [m] = 2,00	φ [°] = 27,50
c [kN/m^2] = 0,00	dc [kN/m^2/m] = 0,000
γ' [kN/m^3] = 9,00	γ [kN/m^3] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m^2/m] = 30000
dkh [kN/m^2/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Phase 6

Wall 1
- Installation of linking anchor: n°2
  zaa [m] = 2,50
  zab [m] = 2,50
  K [kN/m/m] = 15000
  α [°] = 0,00
  P [kN/m] = 0,00

ArcelorMittal

Calculated by: Terrasol

terrasol setec

Project filename: R:\Logiciels\Manuels\AMRetain v2\Mise à jour manuels 2019\Exemples v2\EN\T4 02 2019 v2.AM2   printed on 13/03/2019 12:43 calculated on 13/03/2019 at 12:25computed on 13/03/2019 12:25   Page : 2

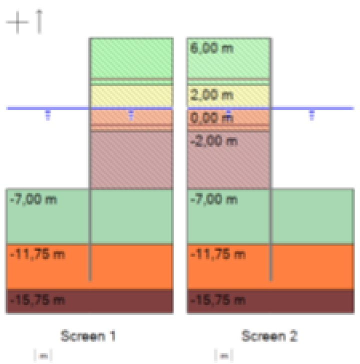
AMRetain v.2.1.2

PROJECT T4 02/2019

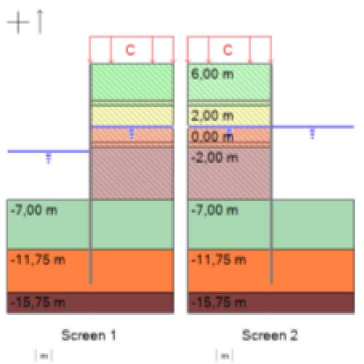
T4 02/2019

STAGE CONSTRUCTION SYNTHESIS

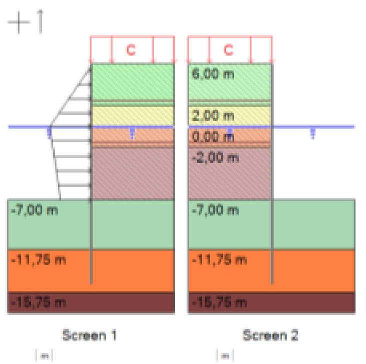
Phase 7



Phase 8



Phase 9



Phase 7

Wall 1
- Fill (right): Remblaiement 4

zt [m] = 6,00	φ [°] = 27,50
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 9,00	γ [kN/m³] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m²/m] = 30000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Wall 2
- Fill (left): Remblaiement 4

zt [m] = 6,00	φ [°] = 27,50
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 9,00	γ [kN/m³] = 19,00
kay = 0,370	kac = 0,000
kpy = 2,725	kpc = 0,000
kl = 0,538	kd = 0,538
kr = 0,538	kh [kN/m²/m] = 30000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

Phase 8

Wall 1
- Caquot surchage: (right side):
  q [kN/m/m] = 20,00
- Hydraulic action: (left):
  zw [m] = -2,30

Wall 2
- Caquot surchage: (left side):
  q [kN/m/m] = 20,00

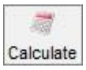
Phase 9

Wall 1
- Hydraulic action: (left):
  zw [m] = 0,00
- Horizontal load on wall: 1
  zt [m] = 5,32
  zb [m] = 0,00
  α [°] = 0,00
  qht [kN/m/m] = 0,00
  qhb [kN/m/m] = 44,10
- Horizontal load on wall: 2
  zt [m] = 0,00
  zb [m] = -7,00
  α [°] = 0,00
  qht [kN/m/m] = 44,10
  qhb [kN/m/m] = 32,20

ArcelorMittal | Calculated by: Terrasol | terrasol setec

Project filename: R:\Logiciels\Manuels\AMRetain v2\Mise à jour manuels 2019\Exemples v2\EN\T4 02 2019 v2.AM2 printed on 13/03/2019 12:43 calculated on 13/03/2019 at 12:25computed on 13/03/2019 12:25 Page : 3

D.4.3. STEP 3: CALCULATION AND OUTPUT

Please click on the  button.

In the main window, you may view the main results (displacements, moments and shear forces) for each phase and each wall (exactly as for single walls).

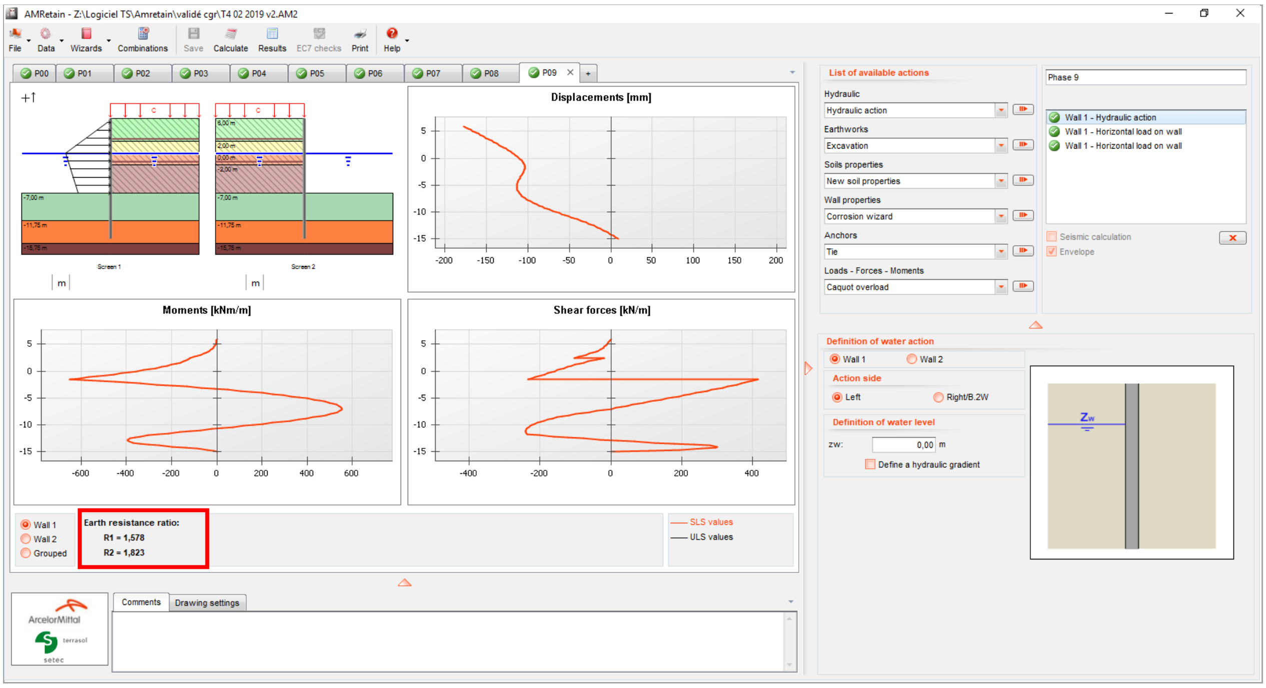
It is also possible, thanks to the display option **Grouped**, to superimpose results for both walls on the same graphs with the same scales (screenshot next page).

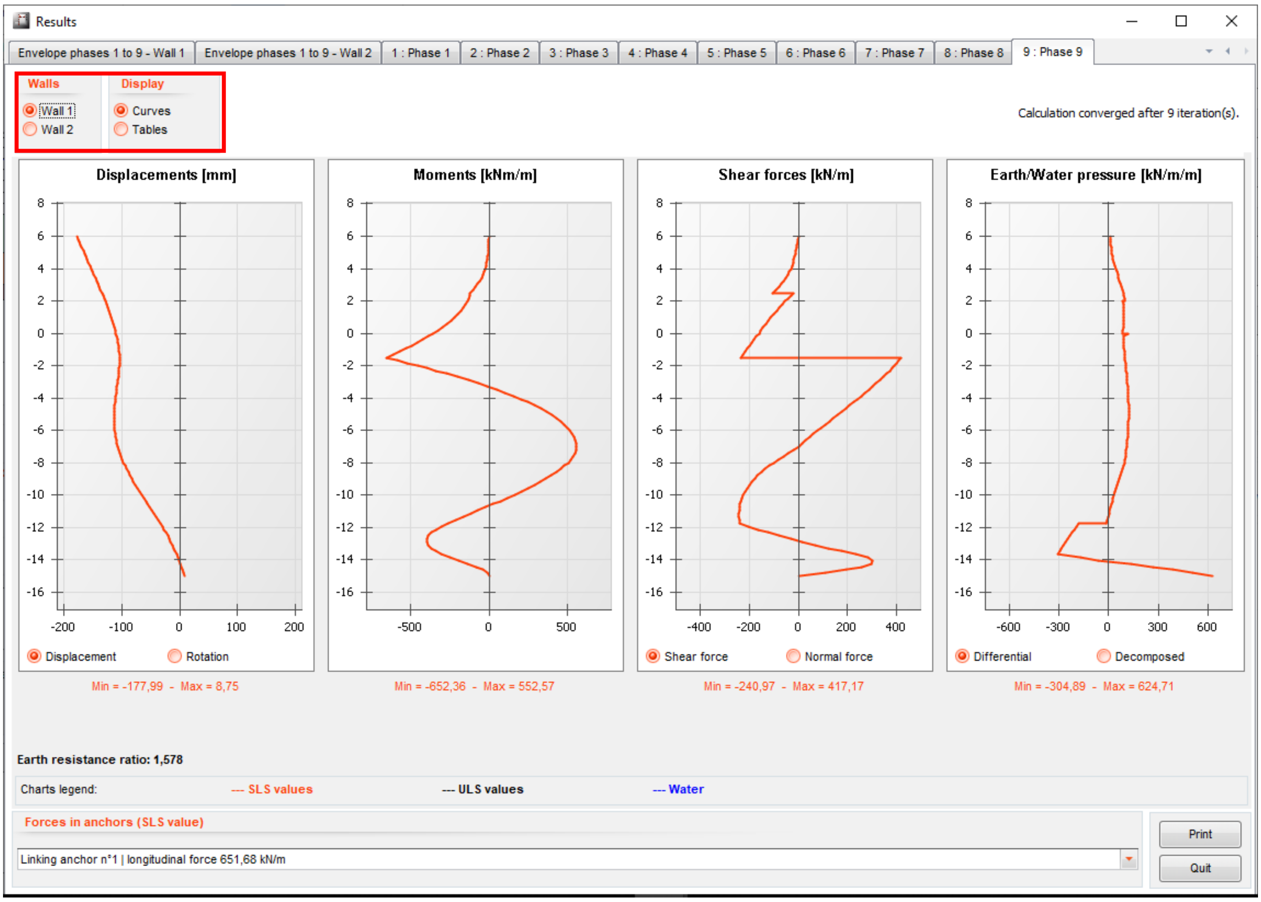
In this case, the thick curves relate to the selected wall, and the thin curves relate to the other wall.

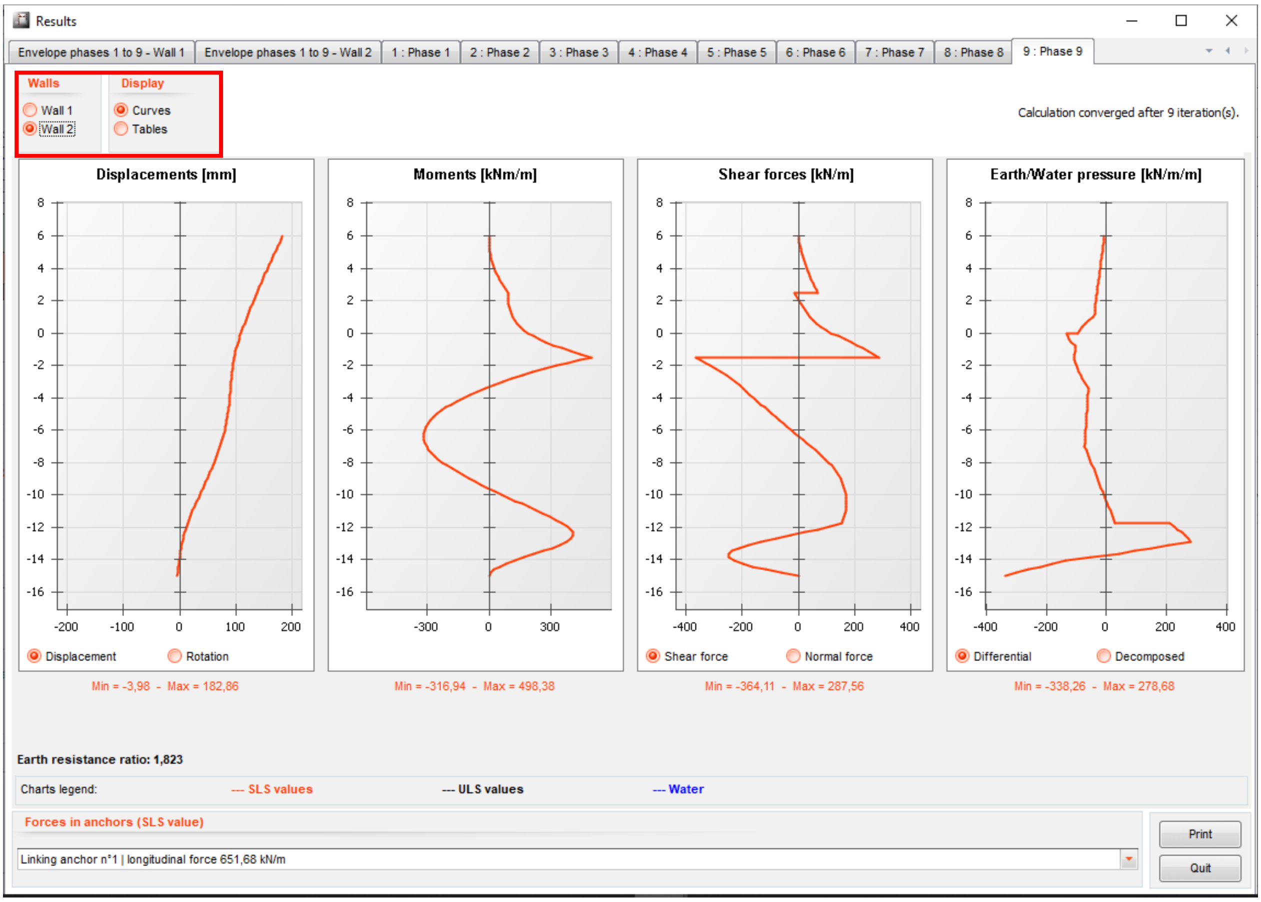
The  button enables to access to the detailed results (curves and tables).

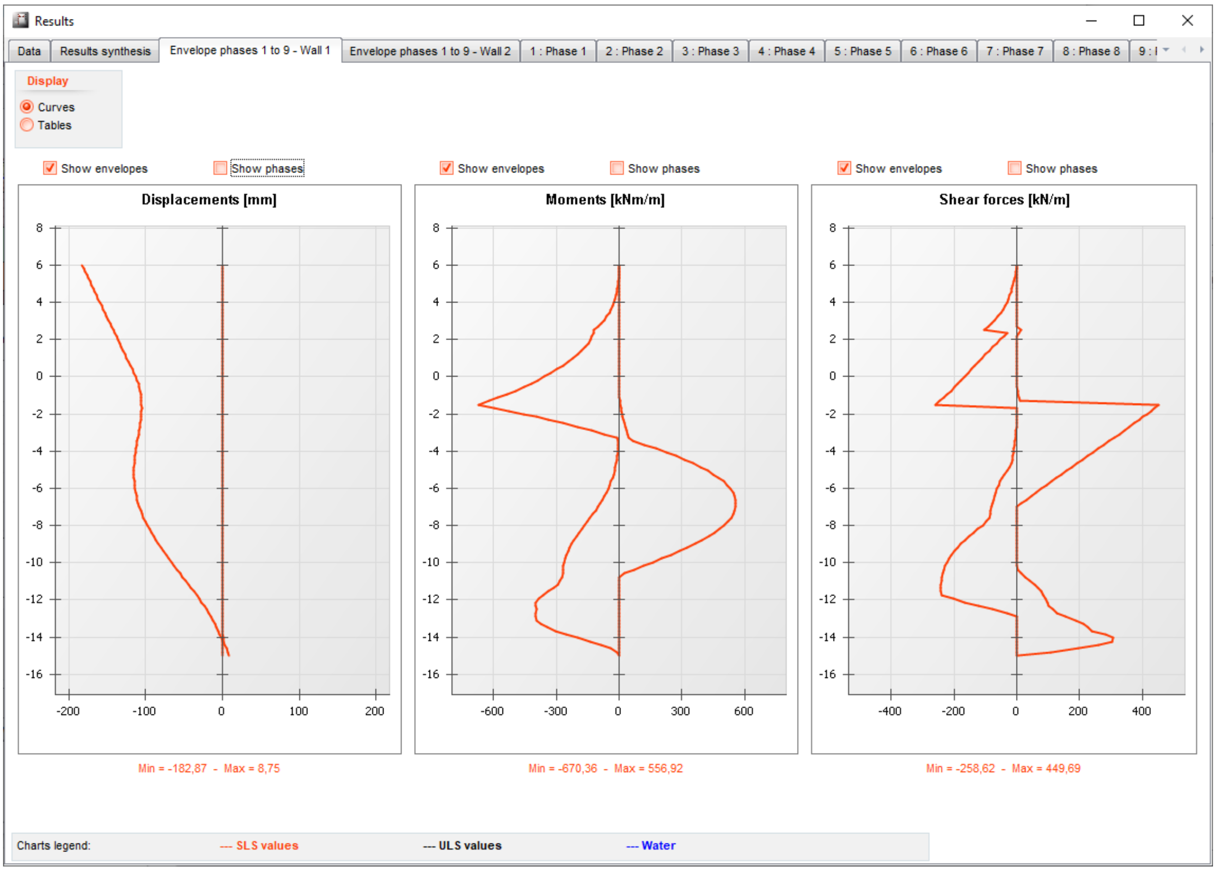
The following screenshots illustrate the output obtained for phase 9 (the last stage of this project), as well as the results synthesis and the envelopes curves for the project.

In the detailed results window, it is possible for each phase, at any moment, to switch from results of **Wall 1** (left wall) to those of **Wall 2** (right wall).




Results
Envelope phases 1 to 9 - Wall 1
Envelope phases 1 to 9 - Wall 2
1 : Phase 1
2 : Phase 2
3 : Phase 3
4 : Phase 4
5 : Phase 5
6 : Phase 6
7 : Phase 7
8 : Phase 8
9 : Phase 9
Walls
Wall 1
Wall 2
Display
Curves
Tables
Calculation converged after 9 iteration(s).
Displacements [mm]
Moments [kNm/m]
Shear forces [kN/m]
Earth/Water pressure [kN/m/m]
Displacement
Rotation
Shear force
Normal force
Differential
Decomposed
Min = -177,99 - Max = 8,75
Min = -652,36 - Max = 552,57
Min = -240,97 - Max = 417,17
Min = -304,89 - Max = 624,71
Earth resistance ratio: 1,578
Charts legend:
--- SLS values
--- ULS values
--- Water
Forces in anchors (SLS value)
Linking anchor n°1 | longitudinal force 651,68 kN/m
Print
Quit


Results
Envelope phases 1 to 9 - Wall 1
Envelope phases 1 to 9 - Wall 2
1 : Phase 1
2 : Phase 2
3 : Phase 3
4 : Phase 4
5 : Phase 5
6 : Phase 6
7 : Phase 7
8 : Phase 8
9 : Phase 9
Walls
Wall 1
Wall 2
Display
Curves
Tables
Calculation converged after 9 iteration(s).
Displacements [mm]
Moments [kNm/m]
Shear forces [kN/m]
Earth/Water pressure [kN/m/m]
Displacement
Rotation
Shear force
Normal force
Differential
Decomposed
Min = -3,98 - Max = 182,86
Min = -316,94 - Max = 498,38
Min = -364,11 - Max = 287,56
Min = -338,26 - Max = 278,68
Earth resistance ratio: 1,823
Charts legend:
--- SLS values
--- ULS values
--- Water
Forces in anchors (SLS value)
Linking anchor n°1 | longitudinal force 651,68 kN/m
Print
Quit



Results

Data | Results synthesis | Envelope phases 1 to 9 - Wall 1 | Envelope phases 1 to 9 - Wall 2 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5 | 6 : Phase 6 | 7 : Phase 7 | 8 : Phase 8

Wall 1

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]	F,k slab anchor n°2 [kN/m]
1	-182,87	-182,87	-264,21	33,64	99,94	4,429	-	-
2	-182,87	-182,87	-264,21	33,64	99,94	4,429	0,00	-
3	-154,46	-154,46	-266,88	27,51	99,44	5,229	0,00	-
4	-175,18	-175,18	-264,32	27,51	104,83	3,766	25,73	-
5	-166,17	-166,17	-301,96	27,51	143,84	2,899	162,19	-
6	-166,17	-166,17	-301,96	27,51	143,84	2,899	162,19	0,00
7	-176,53	-176,53	-399,22	-100,35	256,43	1,958	431,62	76,28
8	-177,86	-177,86	-670,36	-207,44	449,69	1,443	708,31	88,39
9	-177,99	-177,99	-652,36	-216,27	417,17	1,578	651,68	82,93
Extrema	-182,87	-182,87	-670,36	-216,27	449,69	1,443	708,31	88,39

Wall 1

Wall 2

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]	F,k slab anchor n°2 [kN/m]
1	181,92	181,92	264,21	29,89	-99,87	4,429	-	-
2	181,92	181,92	264,21	29,89	-99,87	4,429	0,00	-
3	153,65	153,65	266,87	24,32	-99,37	5,231	0,00	-
4	174,30	174,30	264,32	24,32	-104,78	3,767	25,73	-
5	165,31	165,31	301,86	24,32	-143,77	2,899	162,19	-
6	165,31	165,31	301,86	24,32	-143,77	2,899	162,19	0,00
7	175,60	175,60	398,95	-103,99	-256,45	1,958	431,62	76,28
8	182,41	182,41	521,48	-122,32	-391,04	1,823	708,31	88,39
9	182,86	182,86	498,38	-122,35	-364,11	1,823	651,68	82,93
Extrema	182,86	182,86	521,48	-122,35	-391,04	1,823	708,31	88,39

Wall 2

<u>A few comments about the results</u>:

- The global behaviour of the system is almost symmetrical. There are only minor differences because both walls don't have the same stiffness, and because the actions in the last stages are not symmetrical either.
- The forces obtained in linking anchor n° 1 for walls 1 and 2 are opposite and have the same absolute value (action/reaction), except for the small convergence allowance of 0,1 kN. It's the same for linking anchor n° 2.
- The traction forces in the linking anchors are positive for wall 1 (left wall), and negative for wall 2 (right wall).
- In phase 2, the anchor being passive, it is not taken into account (installation phase). It is taken into account from the next phase (phase 3).
- For linking anchor n° 1, the forces are zero while it is submitted to compression (phase 3): indeed, the linking anchors are defined to behave in the unilateral mode in this example, i.e. they won't take any compression forces: when submitted to compression (this is being checked separately for each anchor), their stiffness is not taken into account and "everything happens as if" the anchors were deactivated.

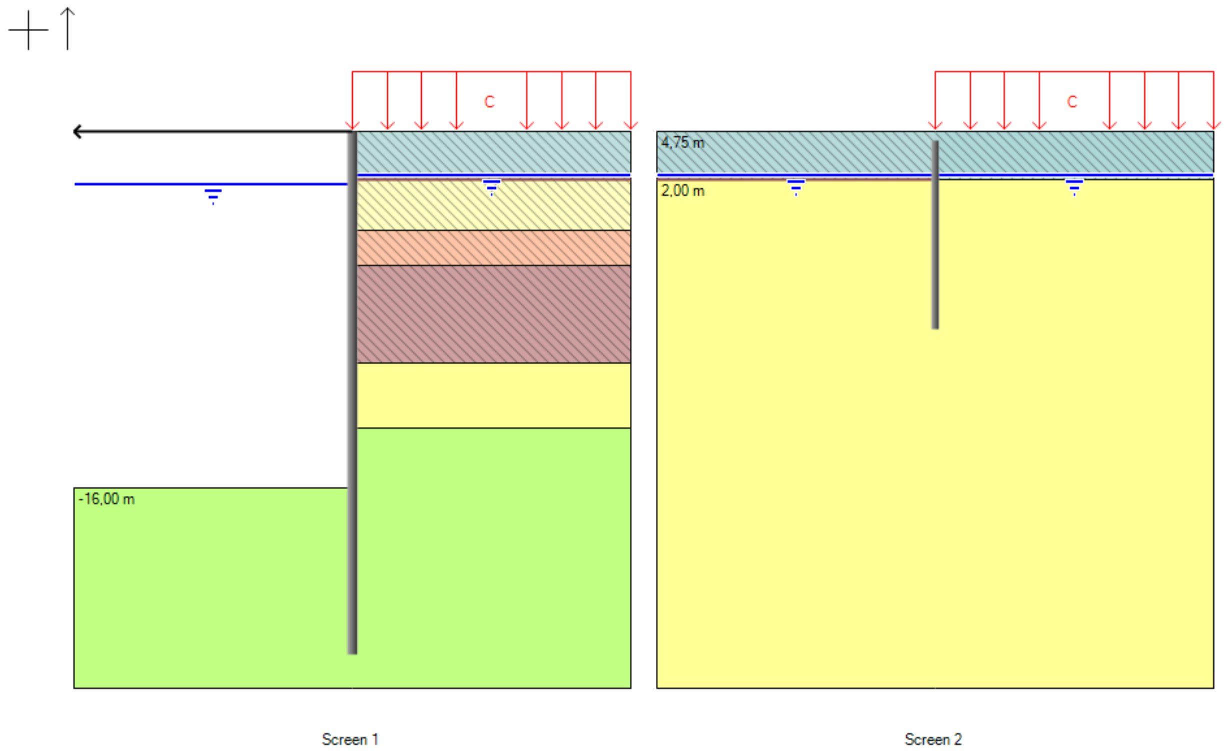
D.5. TUTORIAL 5: MAIN WALL ANCHORED WITH A SHORTER REAR WALL

This example deals with a double sheet pile wall used for the construction of a quay wall.

The main long wall (left wall) is made of sheet piles of type HZM 880 A-12 / AZ 13-770-D, 30.5 m long. It is attached to a shorter rear wall (right wall) made of sheet piles of type AZ 38-700, 11 m long, through a horizontal level of linking anchors.

The system installation includes several fill levels between both walls.

The soil is then excavated in front of the main wall (left side) and a linear force is applied to the top of the main wall (mooring force).



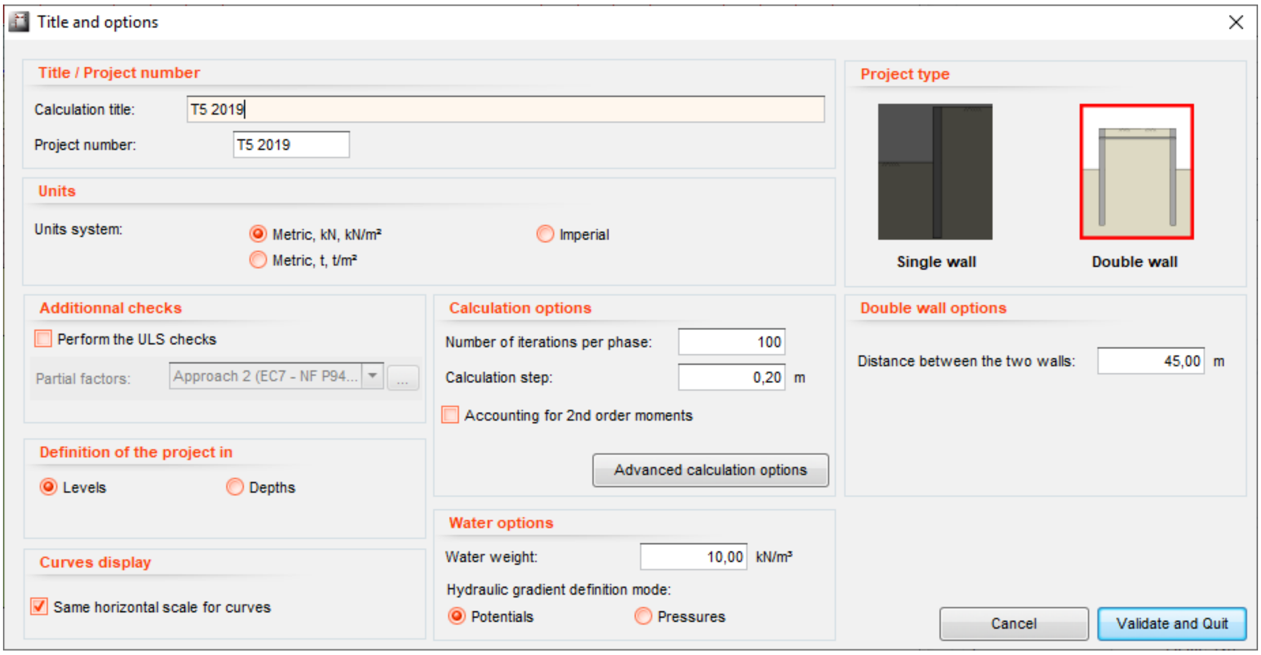
D.5.1. STEP 1: DATA INPUT

To start AMRetain:

- Click on **Start, Programs, AMRetain**.
- Select **English** language, and click on **Start AMRetain**
- Check **I accept liability clauses**.
- Select **New project**.
- The dialogue box **Title and Options** is then displayed.

D.5.1.1. TITLE AND OPTIONS

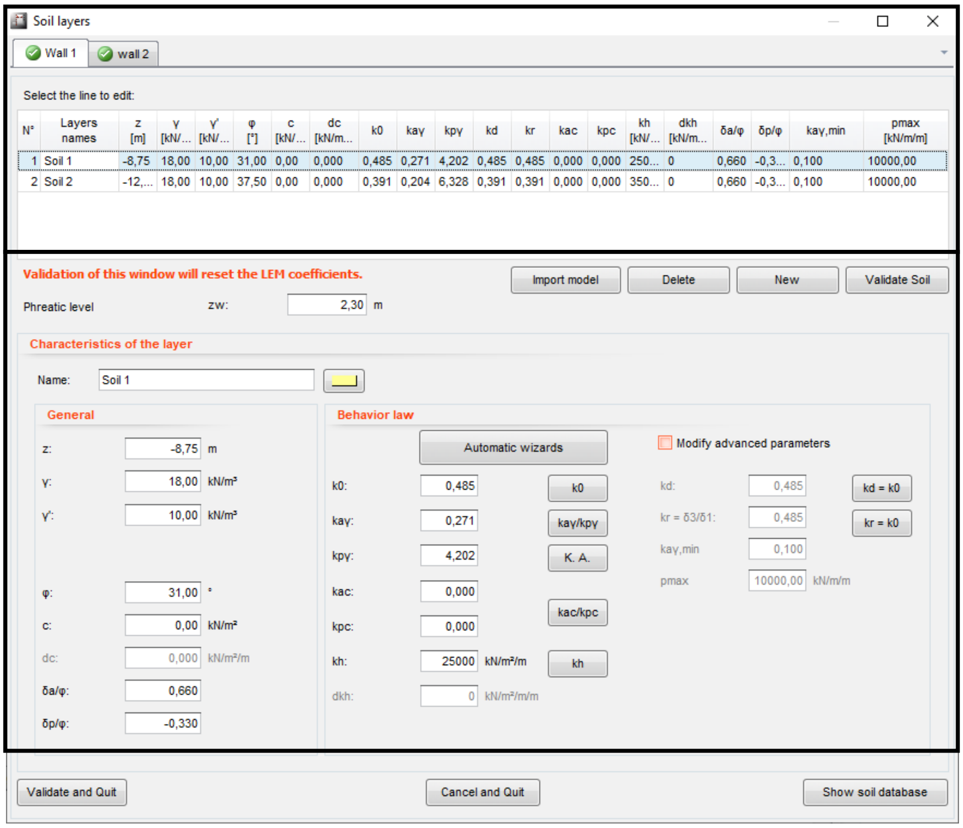
The dialogue box **Title and options** enables to define the general settings for the project. The following screenshot displays the relevant data.



- In the zone **Project type**, select **Double Wall**.
- In the zone **Double wall options**, distance between the two walls is **45,00 m**.
- In the zone **Title / Project number**, input the relevant information.
- We will use **metric units.**
- Keep the default water weight **10 kN/m³**.
- We will use **levels** for this example.
- In the zone **Calculation options**, keep the default settings again, which are **100** for the maximum number of iterations per calculation step and **0,2** m for the calculation step, and keep the **Accounting for 2nd order moments** box unchecked.
- In the zone **Curves display**, keep the **Same horizontal scale for curves** box checked**.**
- Click on [Validate and Quit].
- Save the project with the name and in the directory you wish to use.

D.5.1.2. DEFINITION OF SOIL PROPERTIES

- The dialogue box **Characteristics of soil layers** is then displayed and should be filled in to achieve the following screenshot.



Soil layers relating to Wall 1

Input zone (here with **SOIL 1** data)

This dialogue box enables to fill in the soil properties relating to **wall 1**.

In the bottom zone, fill in the properties for soil layer 1. Soil properties are provided in the tables here below:

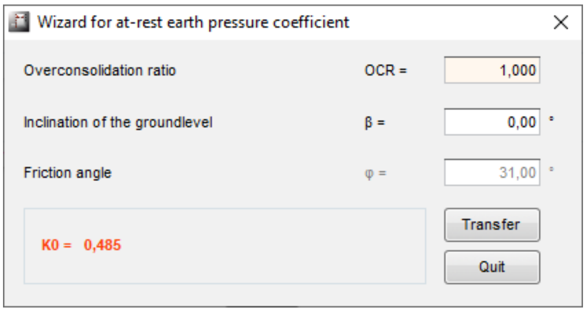
	z (m)	z_w (m)	γ (kN/m³)	γ_d (kN/m³)	φ (°)	c (kN/m²)	δ_a/φ	δ_p/φ
Soil 1	-8.75	2.3	18	10	31	0	0.66	-0.33
Soil 2	-12.5	2.3	18	10	37.5	0	0.66	-0.33

	k_0	$k_{a\gamma}$	$k_{p\gamma}$	k_{ac}	k_{pc}	k_h
Soil 1	0.485	0.271	4.202	0	0	25000
Soil 2	0.391	0.204	6.328	0	0	35000

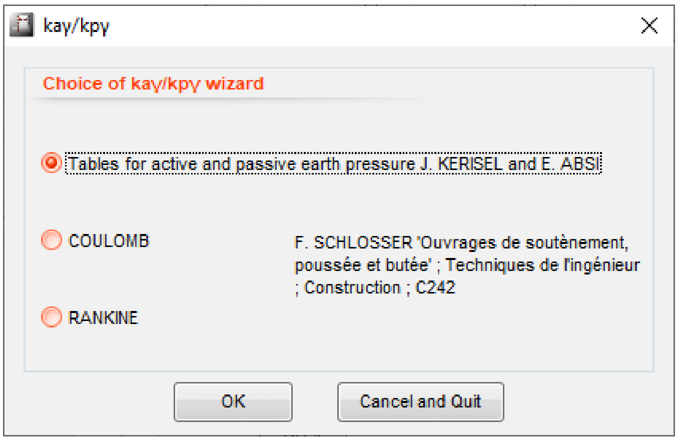
To fill the **Behavior law** you should use the Automatic wizards.

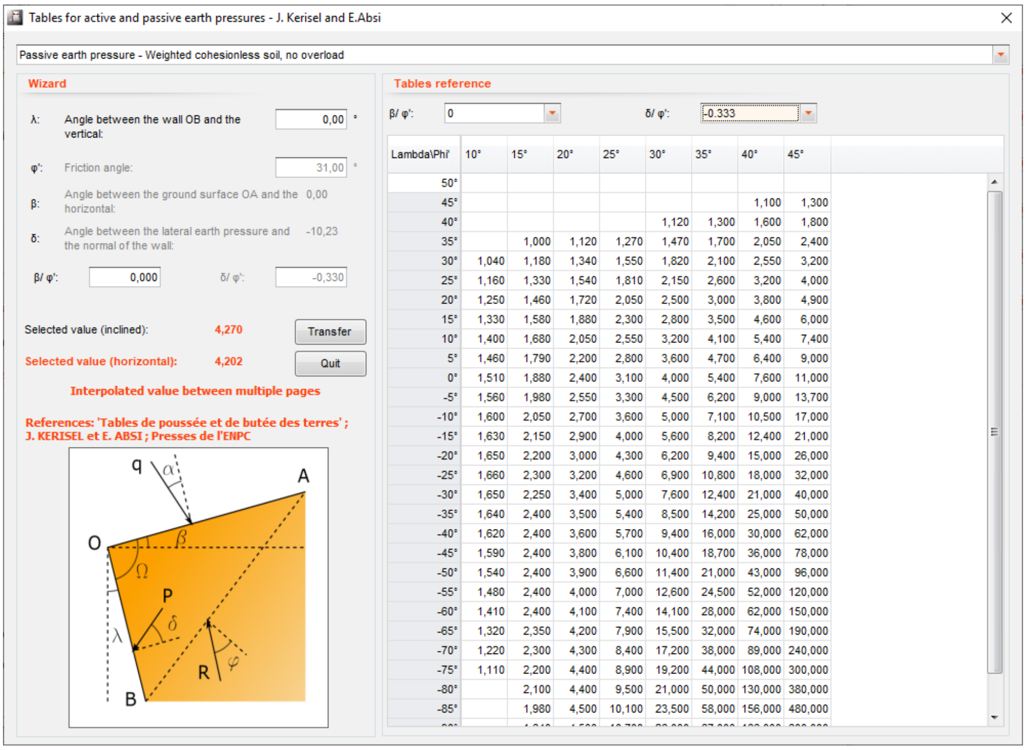
The following wizards may also be used:

- **k0**: keep the default settings (here below for the first layer):



- **kaγ / kpγ:** please use Tables **by KERISEL and ABSI**. Select « Active earth pressure » (respectively « Passive earth pressure ») and click on **Transfer** to copy each value to the main soils dialogue box.





Lambda\Phi'	10°	15°	20°	25°	30°	35°	40°	45°
50°								
45°							1,100	1,300
40°					1,120	1,300	1,600	1,800
35°		1,000	1,120	1,270	1,470	1,700	2,050	2,400
30°	1,040	1,180	1,340	1,550	1,820	2,100	2,550	3,200
25°	1,160	1,330	1,540	1,810	2,150	2,600	3,200	4,000
20°	1,250	1,460	1,720	2,050	2,500	3,000	3,800	4,900
15°	1,330	1,580	1,880	2,300	2,800	3,500	4,600	6,000
10°	1,400	1,680	2,050	2,550	3,200	4,100	5,400	7,400
5°	1,460	1,790	2,200	2,800	3,600	4,700	6,400	9,000
0°	1,510	1,880	2,400	3,100	4,000	5,400	7,600	11,000
-5°	1,560	1,980	2,550	3,300	4,500	6,200	9,000	13,700
-10°	1,600	2,050	2,700	3,600	5,000	7,100	10,500	17,000
-15°	1,630	2,150	2,900	4,000	5,600	8,200	12,400	21,000
-20°	1,650	2,200	3,000	4,300	6,200	9,400	15,000	26,000
-25°	1,660	2,300	3,200	4,600	6,900	10,800	18,000	32,000
-30°	1,650	2,250	3,400	5,000	7,600	12,400	21,000	40,000
-35°	1,640	2,400	3,500	5,400	8,500	14,200	25,000	50,000
-40°	1,620	2,400	3,600	5,700	9,400	16,000	30,000	62,000
-45°	1,590	2,400	3,800	6,100	10,400	18,700	36,000	78,000
-50°	1,540	2,400	3,900	6,600	11,400	21,000	43,000	96,000
-55°	1,480	2,400	4,000	7,000	12,600	24,500	52,000	120,000
-60°	1,410	2,400	4,100	7,400	14,100	28,000	62,000	150,000
-65°	1,320	2,350	4,200	7,900	15,500	32,000	74,000	190,000
-70°	1,220	2,300	4,300	8,400	17,200	38,000	89,000	240,000
-75°	1,110	2,200	4,400	8,900	19,200	44,000	108,000	300,000
-80°		2,100	4,400	9,500	21,000	50,000	130,000	380,000
-85°		1,980	4,500	10,100	23,500	58,000	156,000	480,000

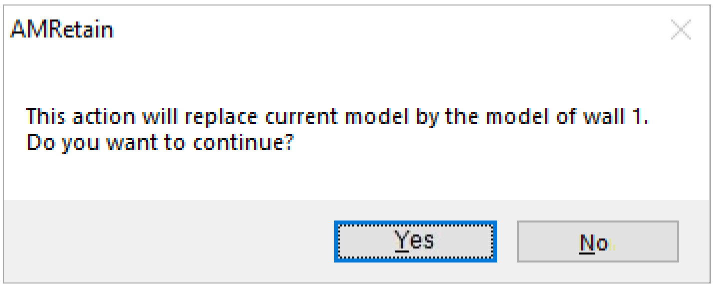
- **kd = k0** and **kr = k0**

For this example, the other soils data were provided with the project data and the use of other wizards is not requested.

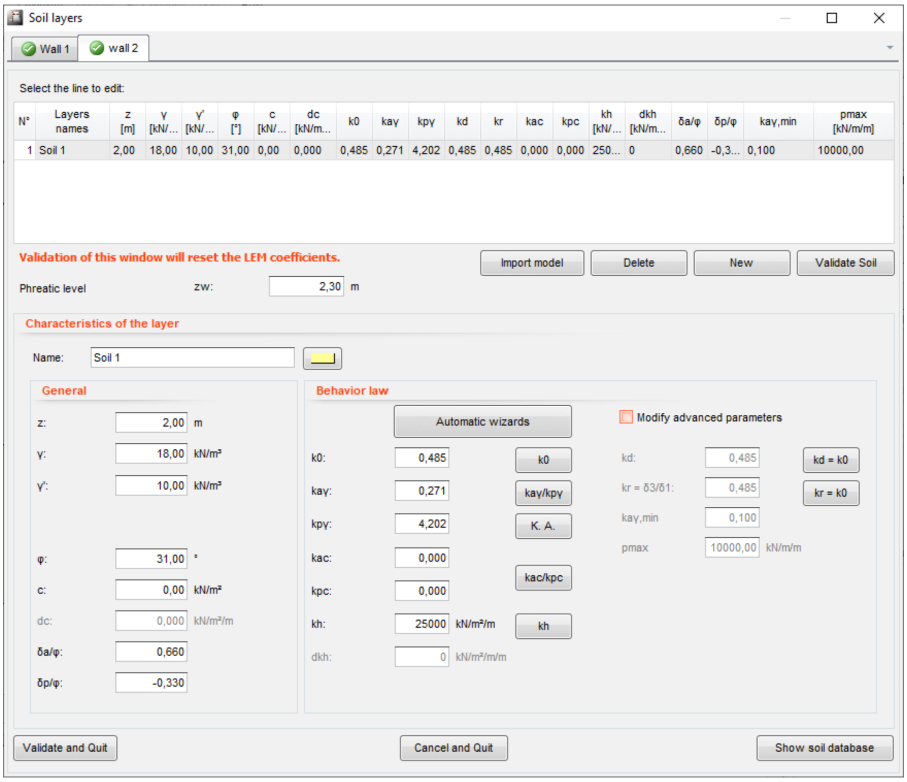
- Click on Validate Soil and then on New to fill in the properties for soil layers 2 and 3.
- Click on Validate and Quit.
- The tab "wall 2" is displayed.

Note: In the case of a project with identical soil layers for both walls, AMRetain let us to import all soil data defined for wall 1 directly to wall 2

The following message is displayed, click on Yes button.



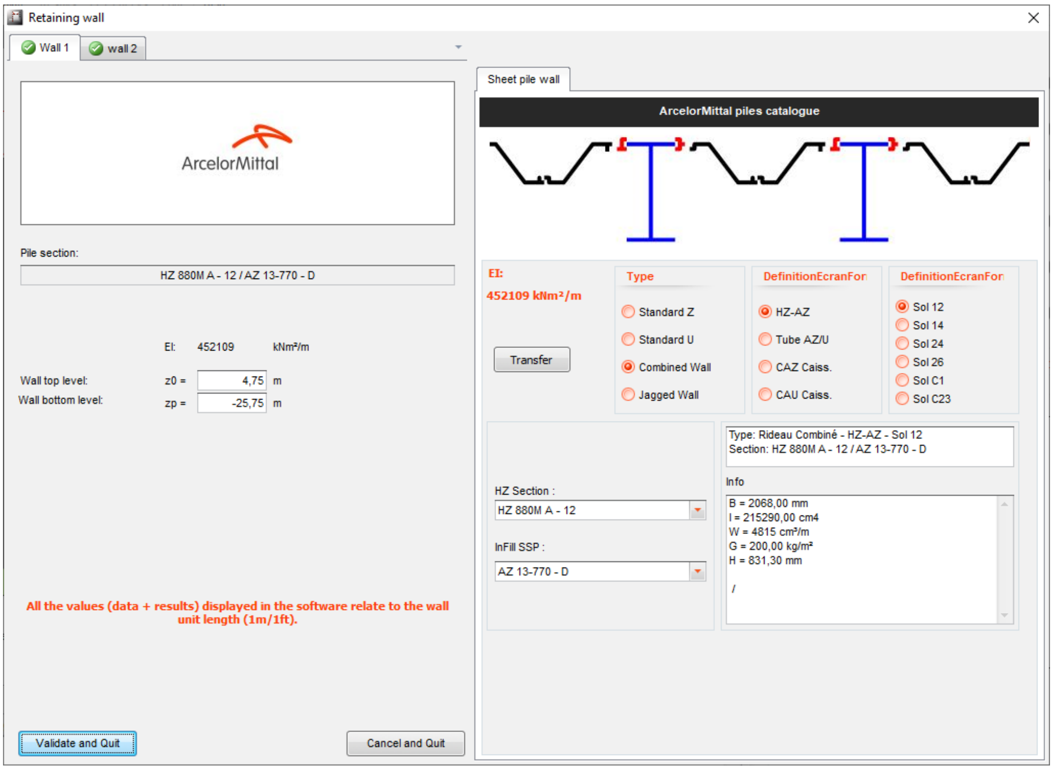
- In the case of this tutorial, the soils to define for **wall 2** are partially the same as the soils defined for **Wall 1**, so click on the Import model button. The same soil properties are then displayed for **Wall 2**.
- In our case, we need to delete Soil 2 and to change the top level of Soil 1. Click on Soil 2 and then press the Delete button, so that Soil 2 is not used for **wall 2.**
- Then change the top level z for Soil 1, so that this top level is at level 2 m for **Wall 2**. The dialogue box for **Wall 2** should then be like on the next screenshot.



- Click on Validate Soil and then Validate and Quit.

D.5.1.3. DEFINITION OF WALLS

The dialogue box **Retaining wall** is then displayed and should be filled in to achieve the screen shot below.



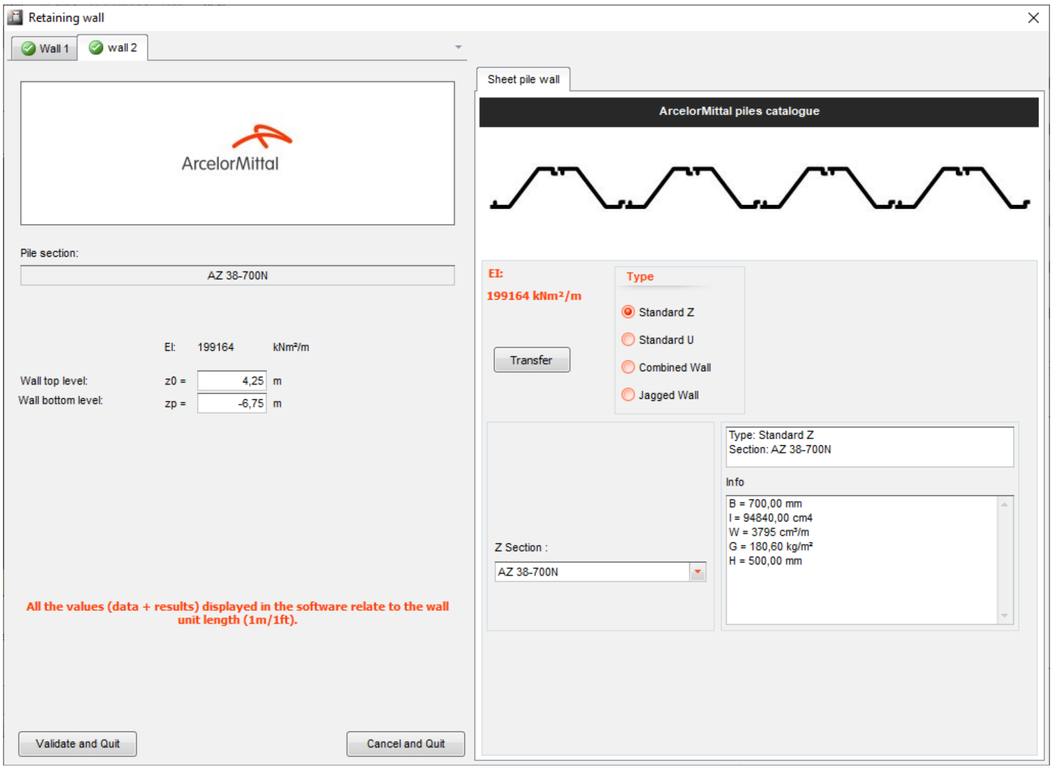
This dialogue box show the tab “Wall 1” which enables to define the properties of Wall 1.

- In the zone ArcelorMittal catalogue of steel sheet piles, check type **Combined wall, HZ-AZ, Sol 12**. In the list **HZ Section**, select **HZM 880M A - 12**, and in the list Infill SSP, select **AZ 13-770 - D**
- Click on the [Transfer] button to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z0 and the wall bottom level Zp, with the values provided in the next table.

	Type	EI (kNm²/m)	Z_0 (m)	Z_p (m)
Wall 1	HZM 880 A-12 / AZ 13-770-D	451668	4.75	-25.75

- Click on [Valider et Quitter], the tab “Wall 2” opens.

The dialogue box **Retaining wall** is then displayed and should be filled in with the following data:



- In the zone ArcelorMittal catalogue of steel sheet piles, check type Standard Z. In the sheet piles list for Z Section, select AZ 38-700N.
- Click on the Transfer button to copy the sheet pile properties (name and EI value) to the project data (left part of the window).
- In the left part of the window, fill in the sheet pile wall top level Z_0 and the wall bottom level Z_p, with the values provided in the next table

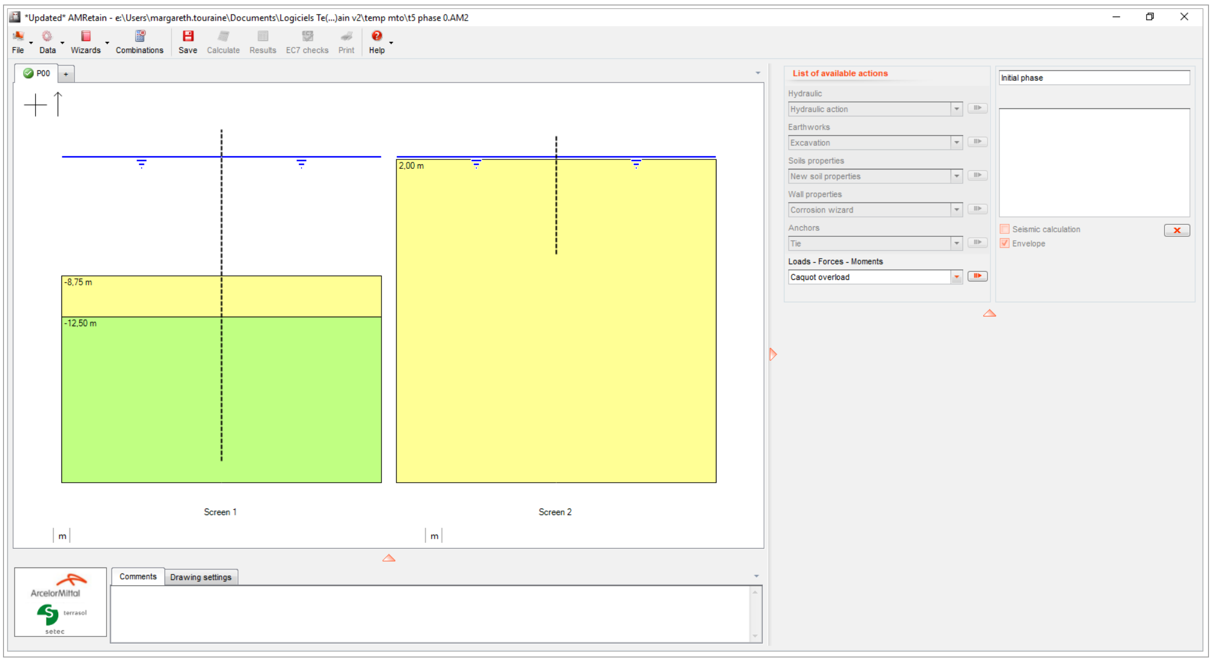
	Type	EI (kN.m^2)	Z_0 (m)	Z_p (m)
Wall 2	AZ 38 - 700	199164	4.25	-6.75

  - Click on Validate and Quit.

- The drawing with soil layers and both walls is then displayed in the main screen (refer to next screenshot).

D.5.2. STEP 2: DEFINITION OF PHASES AND ACTIONS

When data input has been completed, the main screen should be like on the screenshot below.



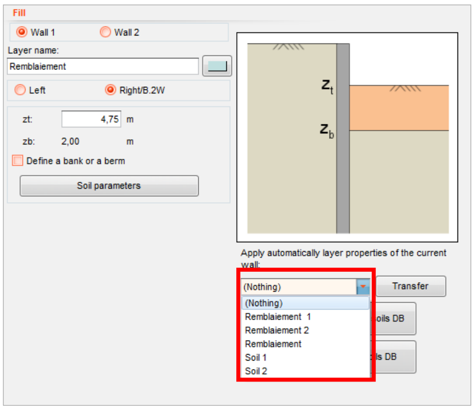
There's no action to be defined for the initial stage, so we will thus start with the creation of phase 1, as indicated below.

The complete phasing for this example is illustrated in the following tables.

The recommended procedure to define the phases and actions for both walls is the following:

When defining successive fill actions for Wall 1: the properties of the fill have to be filled in for the first fill action for Wall 1.

For the next fill actions (for the same wall), and provided all fill levels have the same properties (which is the case for this example), it is possible to copy the properties from the first fill level (screenshot).



Phase	Actions for wall 1 (left wall)	Phase properties	Actions for wall 2 (right wall)	Phase properties
Initial phase				
Phase 1 Fill on the right side of left wall and	1. Fill 1 2. Caquot overload	1. Fill on the right side: z_t =-3m, z_b =-8.75m 2. Fill properties : γ=18 kN/m^3, γ_d=10 kN/m^3, φ=30°, c=0 kN/m^2, k_i=0.500, $k_a\gamma$=0.333, $k_p\gamma$=3.000, δ_a/φ=0, k_{ac}=0, k_{pc}=0, δ_p/φ=0, k_h=20000kN/m^2/m 3. Caquot overload on the right side z=-3, q=15kN/m/m		
Phase 2 Fill for each wall + linking anchor	1. Fill 2 2. Caquot overload 3. Linking anchor	1. Fill on the right side: same characteristics as Fill1, with avec z_t=-1m, z_b=-3m, 2. Caquot overload on the right side z=-1, q=15kN/m/m 3. Tie : z_{aa}=2m, z_{ab}=2m, K=16146kN/m, α=0°	1. Fill 1 2. Linking anchor	1. Fill on the left side: z_t=4.75m, z_b=2.0m, 2. Fill properties: γ=18 kN/m^3, γ_d=10 kN/m^3, φ=30°, c=0 kN/m^2, k_i=0.500, $k_{a\gamma}$=0.333, $k_{p\gamma}$=3.000, δ_a/φ=0, k_{ac}=0, k_{pc}=0, δ_p/φ=0, k_h=20000 kN/m^3 3. Tie : z_{aa}=2m, z_{ab}=2m, K=16146 kN/m, α=0°
Phase 3 Fill for each wall	1. Fill 3 2. Caquot overload	1. Fill on the right side: same characteristics as Fill1 with z_t=2m, z_b=-1m 2. Caquot overload on the right side: z=2m, q=15kN/m/m	1. Fill 2 2. Caquot overload	1. Fill on the right side: same characteristics as Fill1 with z_t=4.75m, z_b=2m 2. Caquot overload z=4.75m, q=15kN/m/m
Phase 4 Fill and excavation-water for wall 1	1. Fill 4 2. Caquot overload 3. Excavation	1. Fill on the right side: Same characteristics as Fill1 with z_t=4.75m, z_b=2m 2. Caquot overload z=4.75m, q=15kN/m/m 3. Excavation on the left side: z_h=-16m		
Phase 5 Excavation-water for both walls	1. Caquot overload 2. Hydraulic action	1. Caquot overload on the right side: z=4.75, q=35kN/m/m (change of the overload value) 2. Hydraulic action on the left side: z_w=1.75m	1. Caquot overload	1. Caquot overload on the right side: q=35kN/m/m (change of the overload value)
Phase 6 Linear force on wall 1	1. Linear force	1. z=4.75m, F=-50kN/m, α=0°		

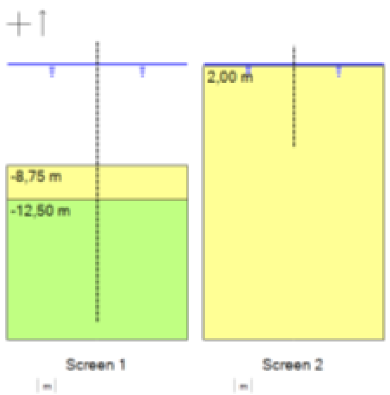
AMRetain v.2.1.2

PROJECT T5 2019

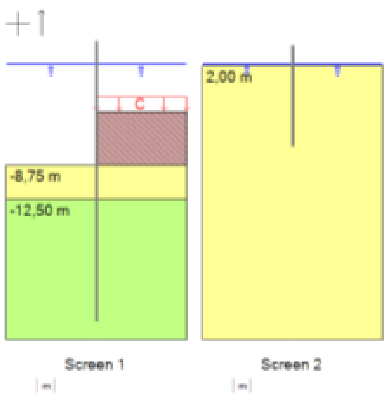
T5 2019

STAGE CONSTRUCTION SYNTHESIS

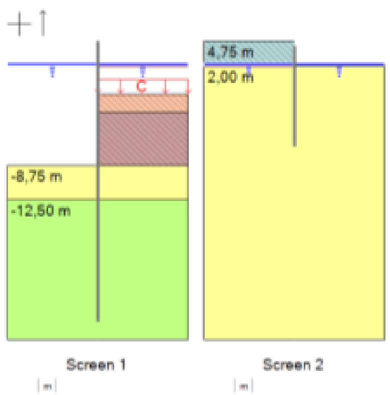
Initial phase



Phase 1



Phase 2



Wall 1
- Fill (right): Fill 1

zt [m] = -3,00
c [kN/m²] = 0,00
γ' [kN/m³] = 10,00
kay = 0,333
kpy = 3,000
kl = 0,500
kr = 0,500
dkh [kN/m²/m/m] = 0
kay,min = 0,100

φ [°] = 30,00
dc [kN/m²/m] = 0,000
γ [kN/m³] = 18,00
kac = 0,000
kpc = 0,000
kd = 0,500
kh [kN/m²/m] = 20000
pmax [kN/m/m] = 10000,00

- Caquot surchage: (right side):
  q [kN/m/m] = 15,00

Wall 1
- Caquot surchage: (right side):
  q [kN/m/m] = 15,00

- Installation of linking anchor: n°1
  zaa [m] = 2,00
  zab [m] = 2,00
  K [kN/m/m] = 16146
  α [°] = 0,00
  P [kN/m] = 0,00

- Fill (right): Fill 2

zt [m] = -1,00
c [kN/m²] = 0,00
γ' [kN/m³] = 10,00
kay = 0,333
kpy = 3,000
kl = 0,500
kr = 0,500
dkh [kN/m²/m/m] = 0
kay,min = 0,100

φ [°] = 30,00
dc [kN/m²/m] = 0,000
γ [kN/m³] = 18,00
kac = 0,000
kpc = 0,000
kd = 0,500
kh [kN/m²/m] = 20000
pmax [kN/m/m] = 10000,00

Wall 2
- Fill (left): Fill1

zt [m] = 4,75
c [kN/m²] = 0,00
γ' [kN/m³] = 10,00

φ [°] = 30,00
dc [kN/m²/m] = 0,000
γ [kN/m³] = 18,00

kpy = 3,000
kl = 0,500
kr = 0,500
dkh [kN/m²/m/m] = 0
kay,min = 0,100

kac = 0,000
kpc = 0,000
kd = 0,500
kh [kN/m²/m] = 20000
pmax [kN/m/m] = 10000,00

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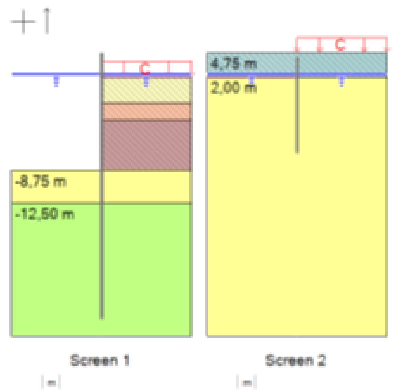
AMRetain v.2.1.2

PROJECT T5 2019

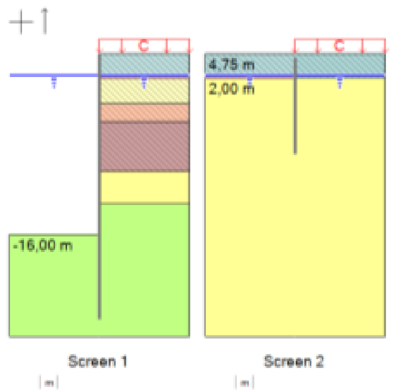
T5 2019

STAGE CONSTRUCTION SYNTHESIS

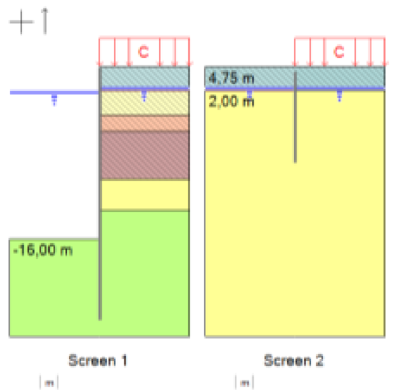
Phase 3



Phase 4



Phase 5



Phase 3

Wall 1
- Fill (right): Fill

zt [m] = 2,00	φ [°] = 30,00
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 10,00	γ [kN/m³] = 18,00
kay = 0,333	kac = 0,000
kpy = 3,000	kpc = 0,000
kl = 0,500	kd = 0,500
kr = 0,500	kh [kN/m²/m] = 20000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

- Caquot surchage: (right side):
  q [kN/m/m] = 15,00

Wall 2
- Fill (right): Fill 2

zt [m] = 4,75	φ [°] = 30,00
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 10,00	γ [kN/m³] = 18,00
kay = 0,333	kac = 0,000
kpy = 3,000	kpc = 0,000
kl = 0,500	kd = 0,500
kr = 0,500	kh [kN/m²/m] = 20000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

- Caquot surchage: (right side):
  q [kN/m/m] = 15,00

Phase 4

Wall 1
- Fill (right): Fill

zt [m] = 4,75	φ [°] = 30,00
c [kN/m²] = 0,00	dc [kN/m²/m] = 0,000
γ' [kN/m³] = 10,00	γ [kN/m³] = 18,00
kay = 0,333	kac = 0,000
kpy = 3,000	kpc = 0,000
kl = 0,500	kd = 0,500
kr = 0,500	kh [kN/m²/m] = 20000
dkh [kN/m²/m/m] = 0	pmax [kN/m/m] = 10000,00
kay,min = 0,100	

- Caquot surchage: (right side):
  q [kN/m/m] = 15,00
- Excavation (left side):
  zh [m] = -16,00

Phase 5

Wall 1
- Caquot surchage: (right side):
  q [kN/m/m] = 35,00
- Hydraulic action: (left):
  zw [m] = 1,75

Wall 2
- Caquot surchage: (right side):
  q [kN/m/m] = 35,00

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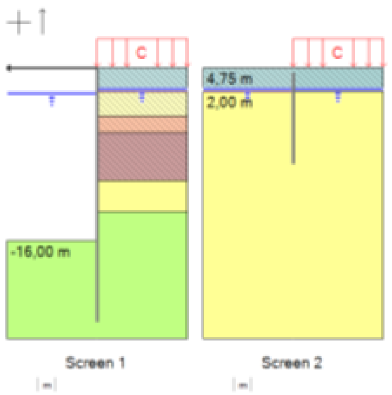
AMRetain v.2.1.2	PROJECT T5 2019
	T5 2019

STAGE CONSTRUCTION SYNTHESIS

Phase 6



Wall 1
- Installation of line force n°1
  - z [m] = 4,75
  - F [kN/m] = -50,00
  - α [°] = 0,00

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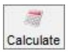
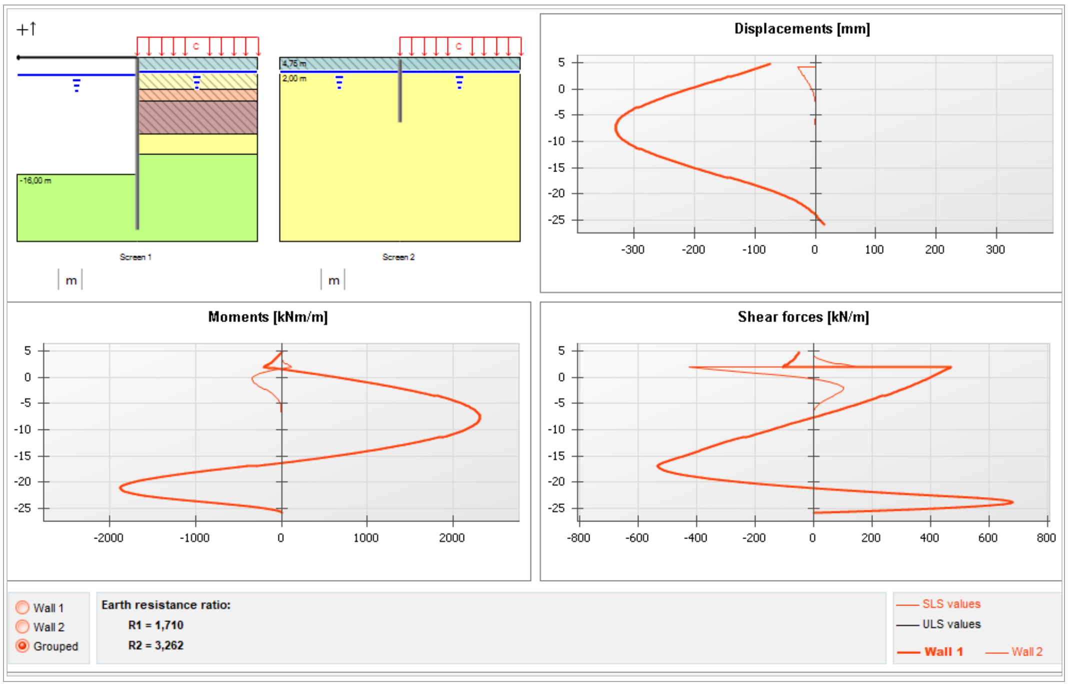
D.5.3. STEP 3: CALCULATION AND OUTPUT

Please click on the  button.

In the main window, you may view the main results (displacements, moments and shear forces) for each phase and each wall (exactly as for single walls).

It is also possible, thanks to the display option **Grouped**, to superimpose results for both walls on the same graphs with the same scales (screenshot below for phase 6).

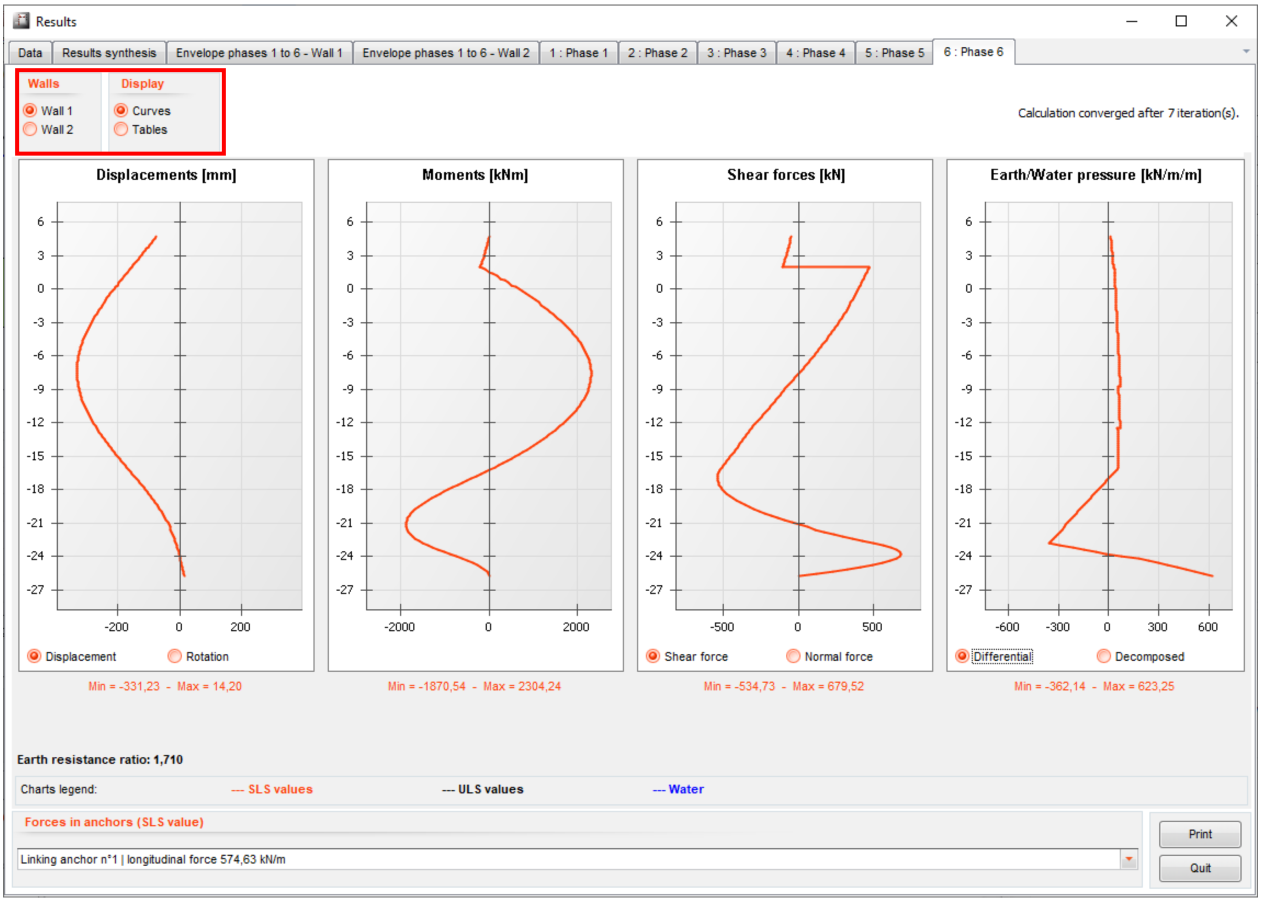
In this case, the thick curves relate to the selected wall, and the thin curves relate to the other wall.

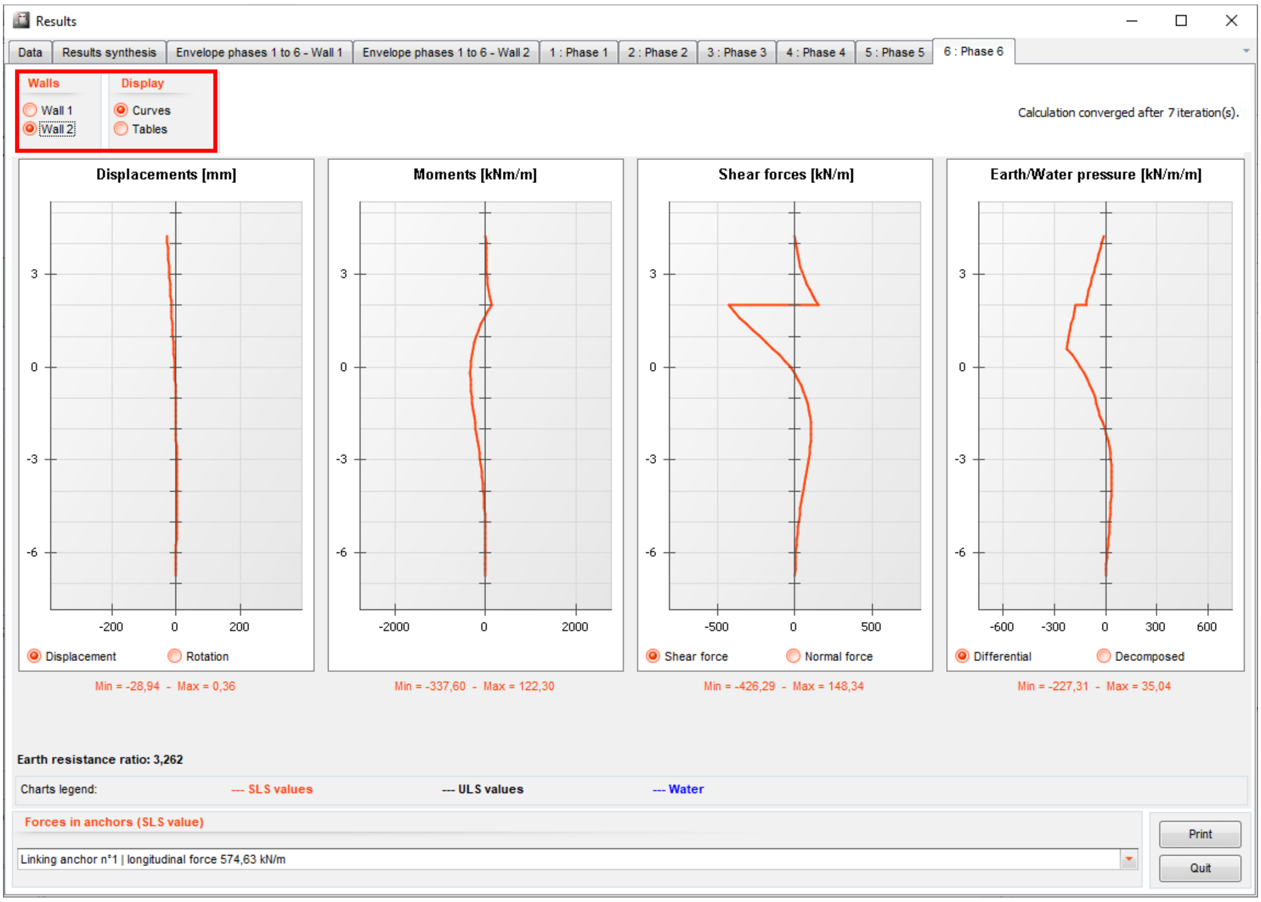


The  button enables to access to the detailed results (curves and tables).

The following screenshots illustrate the output obtained for phase 6 (the last stage of this project), as well as the results synthesis and the envelopes curves for the project.

In the detailed results window, it is possible for each phase, at any moment, to switch from results of **Wall 1** (left wall) to those of **Wall 2** (right wall).


Results
Data
Results synthesis
Envelope phases 1 to 6 - Wall 1
Envelope phases 1 to 6 - Wall 2
1 : Phase 1
2 : Phase 2
3 : Phase 3
4 : Phase 4
5 : Phase 5
6 : Phase 6
Walls
Wall 1
Wall 2
Display
Curves
Tables
Calculation converged after 7 iteration(s).
Displacements [mm]
Moments [kNm]
Shear forces [kN]
Earth/Water pressure [kN/m/m]
Displacement
Rotation
Shear force
Normal force
Differential
Decomposed
Min = -331,23 - Max = 14,20
Min = -1870,54 - Max = 2304,24
Min = -534,73 - Max = 679,52
Min = -362,14 - Max = 623,25
Earth resistance ratio: 1,710
Charts legend:
--- SLS values
--- ULS values
--- Water
Forces in anchors (SLS value)
Linking anchor n°1 | longitudinal force 574,63 kN/m
Print
Quit


Results
Data
Results synthesis
Envelope phases 1 to 6 - Wall 1
Envelope phases 1 to 6 - Wall 2
1 : Phase 1
2 : Phase 2
3 : Phase 3
4 : Phase 4
5 : Phase 5
6 : Phase 6
Walls
Wall 1
Wall 2
Display
Curves
Tables
Calculation converged after 7 iteration(s).
Displacements [mm]
Moments [kNm/m]
Shear forces [kN/m]
Earth/Water pressure [kN/m/m]
Displacement
Rotation
Shear force
Normal force
Differential
Decomposed
Min = -28,94 - Max = 0,36
Min = -337,60 - Max = 122,30
Min = -426,29 - Max = 148,34
Min = -227,31 - Max = 35,04
Earth resistance ratio: 3,262
Charts legend:
--- SLS values
--- ULS values
--- Water
Forces in anchors (SLS value)
Linking anchor n°1 | longitudinal force 574,63 kN/m
Print
Quit

Results

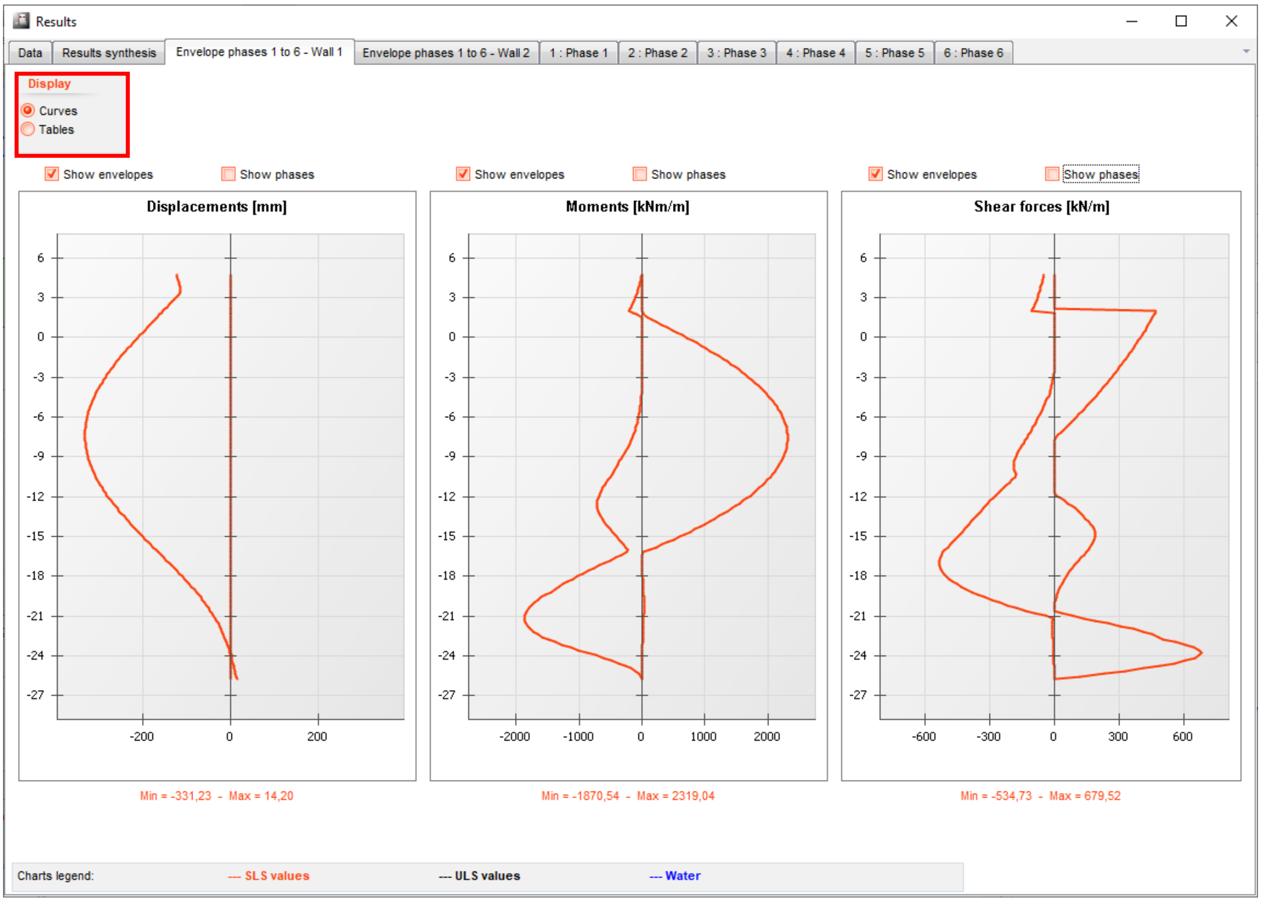
Data | Results synthesis | Envelope phases 1 to 6 - Wall 1 | Envelope phases 1 to 6 - Wall 2 | 1 : Phase 1 | 2 : Phase 2 | 3 : Phase 3 | 4 : Phase 4 | 5 : Phase 5 | 6 : Phase 6

Wall 1

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]
1	-122,66	-122,66	-571,26	71,91	149,14	8,945	-
2	-119,84	-119,84	-588,52	83,04	154,40	8,315	18,59
3	-120,43	-120,43	-720,62	86,56	189,63	7,199	86,92
4	-73,71	-247,46	1743,71	210,50	526,28	2,114	392,53
5	-68,69	-331,20	2319,04	228,41	679,51	1,710	552,24
6	-74,66	-331,23	2304,24	226,30	679,52	1,710	574,63
Extrema	-122,66	-331,23	2319,04	228,41	679,52	1,710	574,63

Wall 2

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]
1	0,00	0,00	0,00	19,91	0,00	8,664	-
2	3,75	3,75	43,97	42,22	32,73	5,324	18,59
3	2,08	2,08	59,11	25,53	51,57	6,453	86,92
4	-6,32	-6,32	139,15	-15,96	-229,21	4,356	392,53
5	-25,23	-25,23	-298,62	-54,22	-403,90	3,346	552,24
6	-28,94	-28,94	-337,60	-59,76	-426,29	3,262	574,63
Extrema	-28,94	-28,94	-337,60	-59,76	-426,29	3,262	574,63



<u>A few comments about the results</u>:

The global behaviour of the system is not symmetrical at all.

The maximum displacement of wall 1 is 331 mm (last phase), whereas the maximum displacement of wall 2 is 29 mm (last phase again).

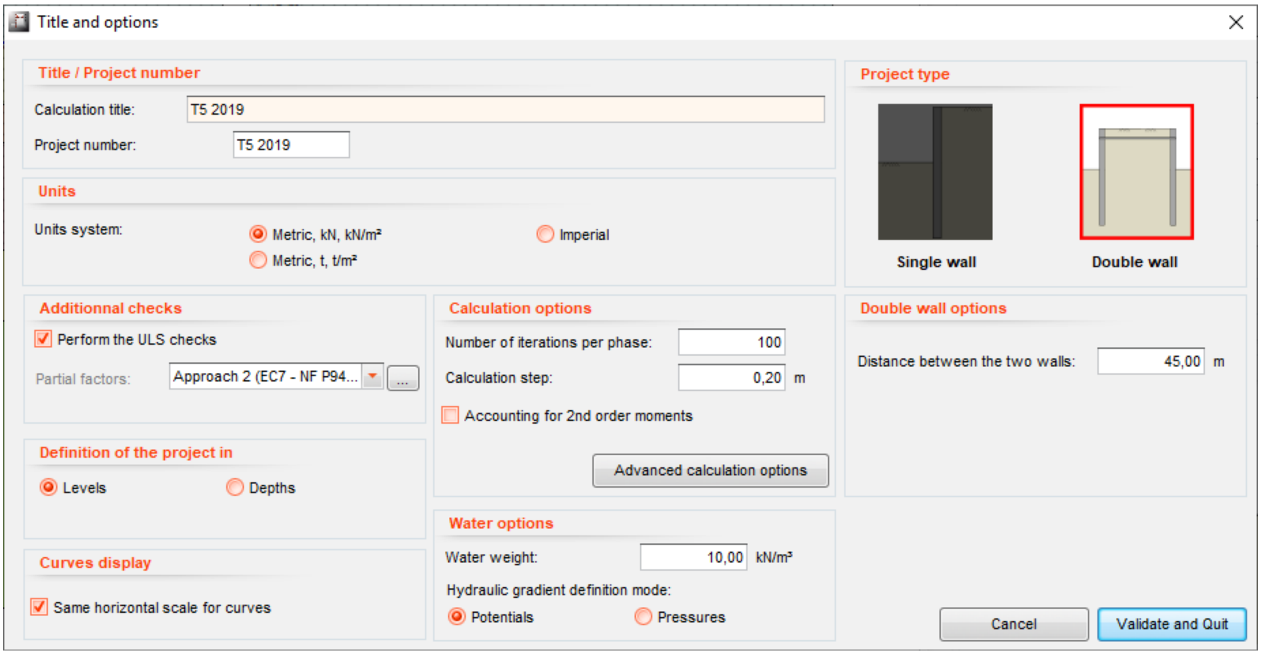
The maximum displacement of the top of wall 1 is reached in the first phase (before the anchor is activated).

D.5.4. <u>STEP 4: ULS CHECKS</u>

ULS checks are “directly” available for double sheet pile walls in AMRetain

<u>Activation of ULS checks</u>

- Next step is to activate the ULS checks: go to menu **Data**, **Title and Options**. Switch the checkbox **ULS checks** on, and then Validate and Quit.



We need check the nature of each phase:

Phase 1 (construction)	Temporary (cantilever, LEM)
Phase 2 (construction)	Temporary (anchored, SSIM)
Phase 3 (construction)	Temporary (anchored, SSIM)
Phase 4 (end of construction)	Permanent (anchored, SSIM)
Phase 5 (overload on soil + change of water level)	Temporary (anchored, SSIM)
Phase 6 (temporary mooring force)	Temporary (anchored, SSIM)

- Check for each action whether it's permanent/variable and favourable/unfavourable, according to the following data:

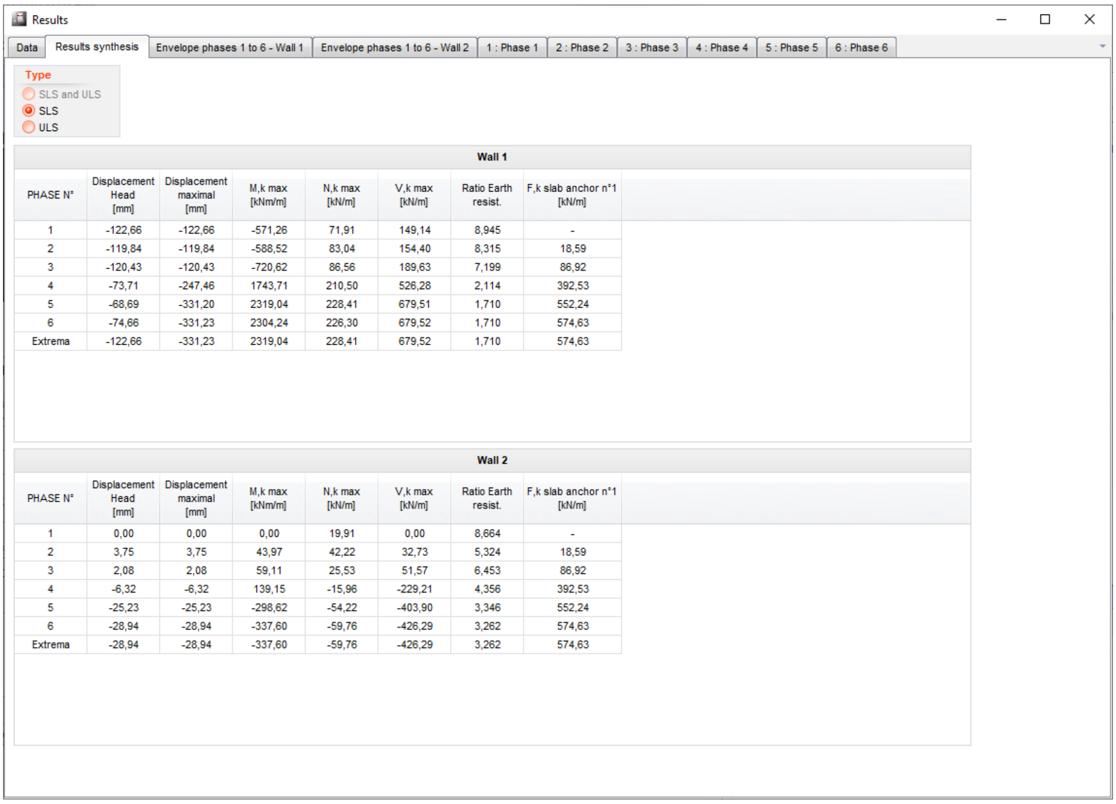
Phase 1	LEM coefficients (action automatically created when cantilever mode is selected)	Keep the default settings
Phase 2	Caquot overload	Permanent action
Phase 3	Caquot overload	Permanent action
Phase 4	Caquot overload	Permanent action
Phase 5	Caquot overload	Permanent load on right side and left side
Phase 6	Linear force (simulating the mooring force)	Permanent and **unfavourable** action

Note 1: the nature of each phase and action should be defined according to the project data.

Note 2: if you define some unfavourable actions as variable, this implies that they will be weighted by a partial factor of 1.11 in the SSIM calculation (cf parts B and C of the manual), which means that this SSIM calculation of the single wall is not completely compatible with the double wall calculation anymore. In this case, the double wall calculation could be performed with a "manual weighting" of the loads by the user (i.e. the user could multiply the variable loads by 1.11 in the double wall calculation in order to get forces in the linking anchor that are compatible with the ULS SSIM calculation performed afterwards for the left wall as a single wall).

- You can then perform the calculation again, and check the results.

Let's first check that the SLS results are the same as the results before activation of ULS checks. This is indeed the case:



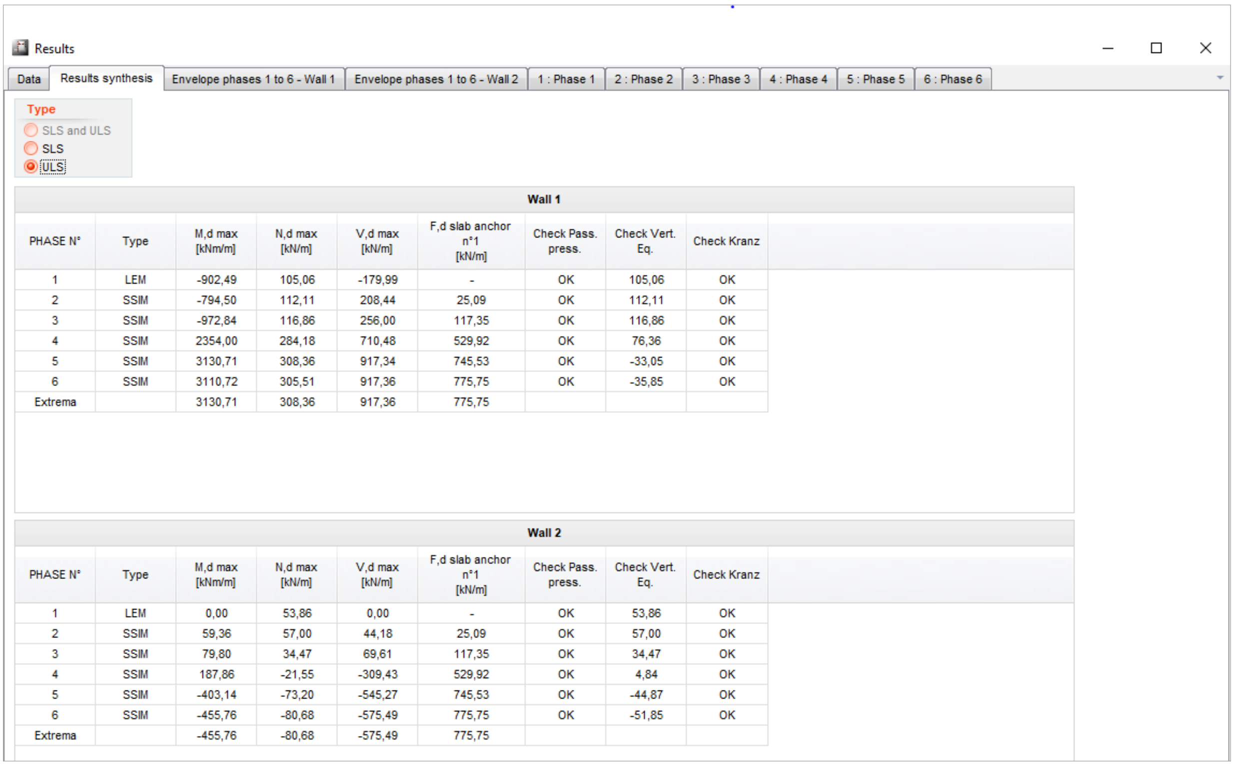
Wall 1

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]
1	-122,66	-122,66	-571,26	71,91	149,14	8,945	-
2	-119,84	-119,84	-588,52	83,04	154,40	8,315	18,59
3	-120,43	-120,43	-720,62	86,56	189,63	7,199	86,92
4	-73,71	-247,46	1743,71	210,50	526,28	2,114	392,53
5	-68,69	-331,20	2319,04	228,41	679,51	1,710	552,24
6	-74,66	-331,23	2304,24	226,30	679,52	1,710	574,63
Extrema	-122,66	-331,23	2319,04	228,41	679,52	1,710	574,63

Wall 2

PHASE N°	Displacement Head [mm]	Displacement maximal [mm]	M,k max [kNm/m]	N,k max [kN/m]	V,k max [kN/m]	Ratio Earth resist.	F,k slab anchor n°1 [kN/m]
1	0,00	0,00	0,00	19,91	0,00	8,664	-
2	3,75	3,75	43,97	42,22	32,73	5,324	18,59
3	2,08	2,08	59,11	25,53	51,57	6,453	86,92
4	-6,32	-6,32	139,15	-15,96	-229,21	4,356	392,53
5	-25,23	-25,23	-298,62	-54,22	-403,90	3,346	552,24
6	-28,94	-28,94	-337,60	-59,76	-426,29	3,262	574,63
Extrema	-28,94	-28,94	-337,60	-59,76	-426,29	3,262	574,63

Then let's switch to ULS results:



Wall 1

PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	F,d slab anchor n°1 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	-902,49	105,06	-179,99	-	OK	105,06	OK
2	SSIM	-794,50	112,11	208,44	25,09	OK	112,11	OK
3	SSIM	-972,84	116,86	256,00	117,35	OK	116,86	OK
4	SSIM	2354,00	284,18	710,48	529,92	OK	76,36	OK
5	SSIM	3130,71	308,36	917,34	745,53	OK	-33,05	OK
6	SSIM	3110,72	305,51	917,36	775,75	OK	-35,85	OK
Extrema		3130,71	308,36	917,36	775,75			

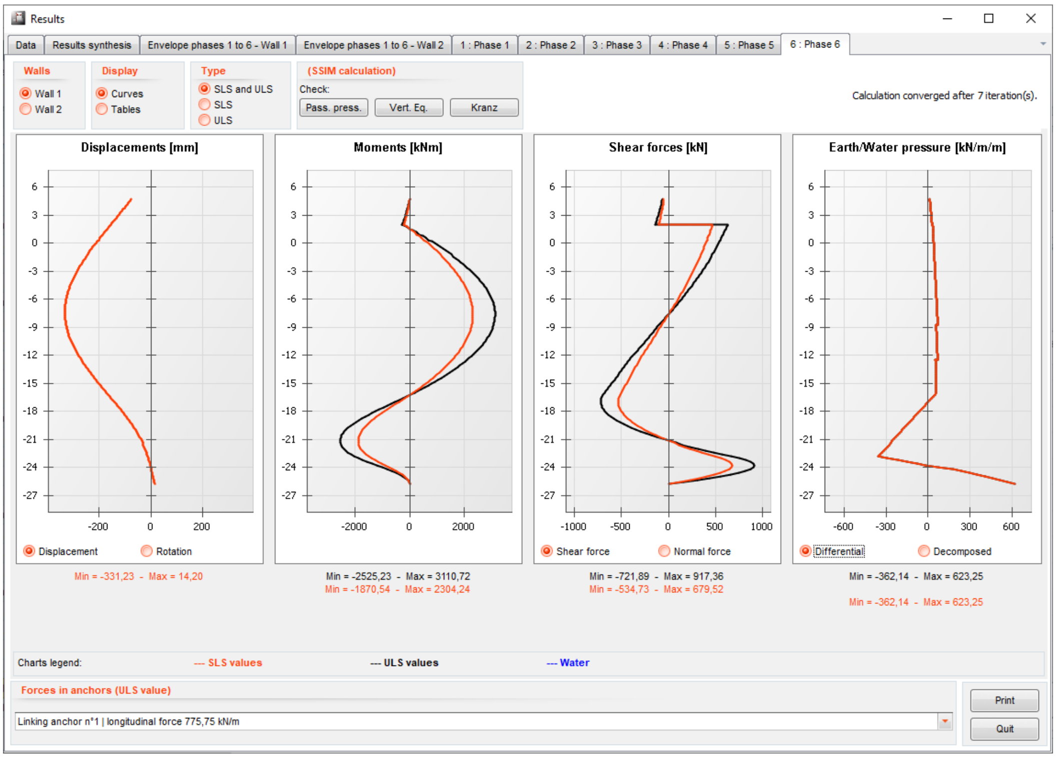
Wall 2

PHASE N°	Type	M,d max [kNm/m]	N,d max [kN/m]	V,d max [kN/m]	F,d slab anchor n°1 [kN/m]	Check Pass. press.	Check Vert. Eq.	Check Kranz
1	LEM	0,00	53,86	0,00	-	OK	53,86	OK
2	SSIM	59,36	57,00	44,18	25,09	OK	57,00	OK
3	SSIM	79,80	34,47	69,61	117,35	OK	34,47	OK
4	SSIM	187,86	-21,55	-309,43	529,92	OK	4,84	OK
5	SSIM	-403,14	-73,20	-545,27	745,53	OK	-44,87	OK
6	SSIM	-455,76	-80,68	-575,49	775,75	OK	-51,85	OK
Extrema		-455,76	-80,68	-575,49	775,75			

We can see that:

- The check of the failure on the passive side is satisfactory for all phases (LEM and SSIM): the wall embedment is ok.
- The vertical forces resultant is positive for phases 1 to 4, which is also satisfactory, but is negative for phases 5 and 6 (meaning the resultant vertical force is directed upwards for these phases).
    - It has been indicated in tutorial 2 that in the case of a vertical resultant directed upwards for a cantilever phase, the inclination of counter passive earth pressures can be changed in order to obtain a final vertical resultant directed downwards.
    - But in the case on an anchored wall, when obtaining a vertical resultant oriented upwards, it's usual to adjust (first) the inclinations of passive earth pressures (in the range [-0.66 ; 0]). If this adjustment doesn't allow to obtain a vertical resultant directed downwards, then it may also be considered adjusting the inclinations of active earth pressures (in the range [0 ; 0.66]).
- There was no Kranz check because the linking anchor is not modelled with an anchor, but with a linear load.

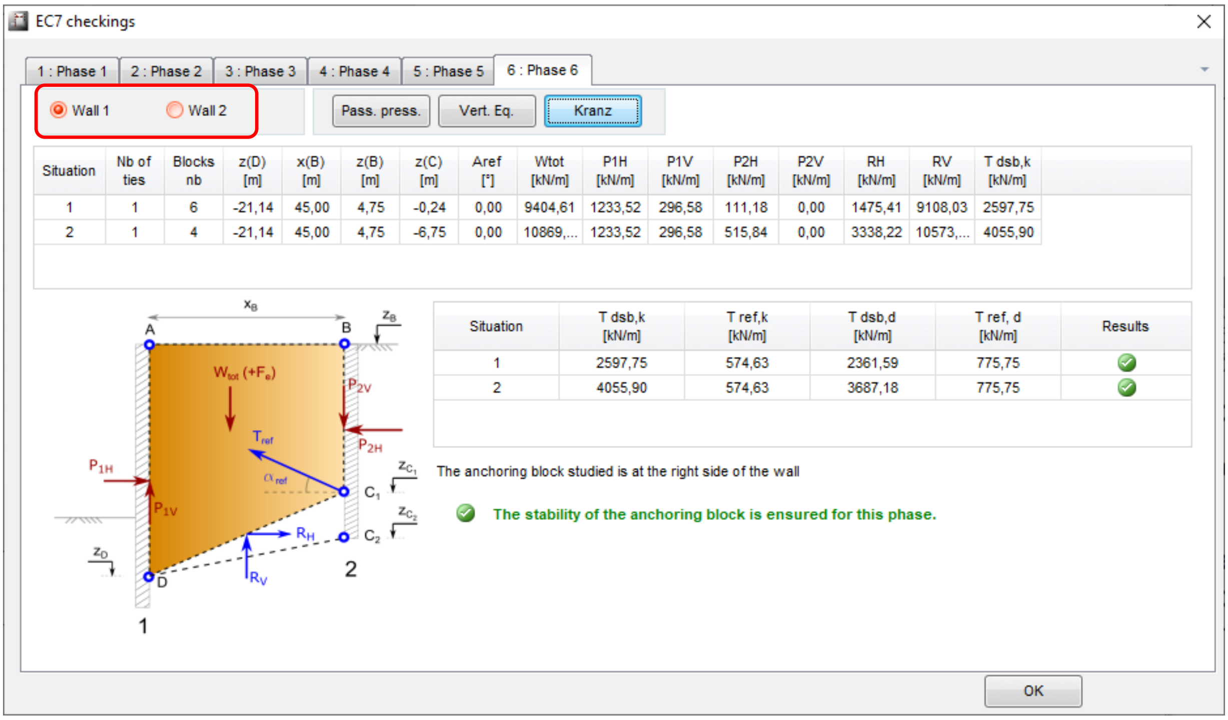
Let's now have a look at the more detailed results.



- The maximum moment ELS is 2319 kNm/m. It is reached in phase 5. The maximum moment ULS is 3131 kNm/m. It is reached in phase 5.
- The maximum shear force (characteristic value) is 680 kN/m. It is reached in the last phase (phase 6). The maximum shear force (design value) is 917 kN/m. It is reached in the last phase.

We can check that in our example, ULS characteristic results (k) are identical (for all phases) to SLS results, because the project includes no variable overload (only variable overloads are weighted for the SSIM calculation of characteristic values and can lead to different results).

Let's check the details of the Kranz check for phase 6:



Situation	Nb of ties	Blocks nb	z(D) [m]	x(B) [m]	z(B) [m]	z(C) [m]	Aref [°]	Wtot [kN/m]	P1H [kN/m]	P1V [kN/m]	P2H [kN/m]	P2V [kN/m]	RH [kN/m]	RV [kN/m]	T dsb,k [kN/m]
1	1	6	-21,14	45,00	4,75	-0,24	0,00	9404,61	1233,52	296,58	111,18	0,00	1475,41	9108,03	2597,75
2	1	4	-21,14	45,00	4,75	-6,75	0,00	10869,...	1233,52	296,58	515,84	0,00	3338,22	10573,...	4055,90

Situation	T dsb,k [kN/m]	T ref,k [kN/m]	T dsb,d [kN/m]	T ref, d [kN/m]	Results
1	2597,75	574,63	2361,59	775,75	✓
2	4055,90	574,63	3687,18	775,75	✓

As expected, one situation (i.e. one anchor) has been considered and calculated.

Situation 1: this calculation leads to a destabilising force T_{dsb} de 2598 kN in characteristic value, and 2362 kN in design value. The Tref (k and d) values are 575 kN in characteristic value, and 776 kN in design value. Then we have $T_{ref,d} \leq T_{dsb,d}$ for this situation

Situation 2: this calculation leads to a destabilising force T_{dsb} 4056 kN in characteristic value, and 3687 kN in design value. T_{ref} values are 575 kN n characteristic value, and 776 kN in design value. Then we also have $T_{ref,d} \leq T_{dsb,d}$ for this situation.

AMRetain shows that we get $T_{ref,d} \leq T_{dsb,d}$ for both situation, so we can conclude that the Kranz check of the second wall is satisfying.

