Foxta v3

Part J: FONDSUP Module

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J.1. Introduction

The Fondsup module is intended for the geotechnical design of a single footing according to the French application standard of Eurocode 7 for shallow foundations (NF P 94 261). It can also be used with application of the previous standard of "Fascicule 62 – Title V" (only retained for information).

The design is based on an estimation of the limit load Q_l, and the maximum authorised loads under ULS and SLS loading of a single shallow foundation, using pressuremeter test results. It is adapted to the concepts and formulations recommended by the limit state regulations in force in France (currently standard NF P 94 261).

J.2. Theoretical aspects

J.2.1. Limit states of a shallow foundation

The justification of a shallow foundation requires to verify the following limit states:

- Ultimate Limit States:
  - Punching stability (bearing capacity);
  - Tilting stability (limitation of eccentricity);
  - Sliding stability.
- Service Limit States:
  - Punching stability (limitation of soil load bearing);
  - Tilting stability (limitation of eccentricity);
  - Settlements.

The Fondsup module examines the following limit states:

- ULS: bearing and tilting;
- SLS: bearing, tilting and settlement.

In its current version, the programme does not check the sliding stability.

The calculation model used is a semi-empirical model based on the results of the pressuremeter tests.

J.2.2. Notations and conventions

"D" is the embedment depth of the foundation in relation to the groundlevel (after works). A is the supporting surface of the foundation. We take:

- A = B x 1 for a continuous foundation of width B;
- A = B² for a square foundation of width B;
- A = B x L for a rectangular foundation of width B and length L (L > B);
- A = π x B²/4 for a circular foundation of diameter B.

The foundation is assumed to be subjected to global forces and moments ($Q_{v,d}$, $Q_{h,d}$, $M_{B,d}$, $M_{L,d}$) expressed at the centre of the foundation base in accordance with the conventions in the following figure (all given in design values):

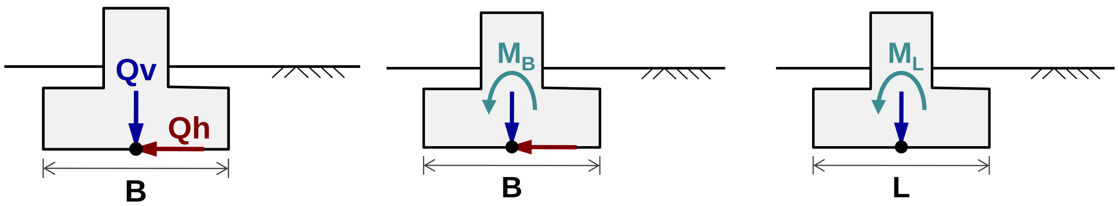


Figure J.1 : Loading of the footing - notations and conventions

J.2.3. Bearing capacity of a shallow foundation

J.2.3.1. Verification principle

According to standard NF P 94 261, the bearing capacity of a single footing is verified by means of the following equation:

$$Q_{v,d} \; - \; R_0 \; \leq \; R_{v,d}$$

Where:

- $Q_{v,d}$: design value of the vertical force to be taken up by the foundation;
- R_0: initial weight of soil at foundation base (after works);
- $R_{v,d}$: design value of net soil resistance.

The values of R_0 and $R_{v,d}$ are obtained as follows:

$$R_0 = A.q_0 \qquad\qquad R_{v,d} = A_{eff} \,.\, q_u \,/\, F_{global}$$

Where:

- A supporting surface of the foundation;
- A_{eff} effective supporting surface of the foundation (see chapter J.2.3.2);
- q_0 initial weight of soil (stress) at foundation base (after works);
- q_u soil ultimate bearing capacity (see chapter J.2.3.3);
- F_{global} "combined" global safety factor.

F_{global} is expressed as the combination of a partial resistance factor $\gamma_{R,v}$ and a coefficient of model $\gamma_{R,d}$:

$$F_{global} = \gamma_{R,d} \times \gamma_{R,v}$$

For a design based on the pressuremeter model, F_{global} takes the following values:

- $F_{global} = 1.2 \times 2.3 = 2.76$ at permanent and characteristic SLS;
- $F_{global} = 1.2 \times 1.4 = 1.68$ at fundamental ULS;
- $F_{global} = 1.2 \times 1.2 = 1.44$ at accidental ULS;
- $F_{global} = 1.2 \times 1.4 = 1.44$ at seismic ULS (NF P 94 261 - table 9.8.1).

J.2.3.2. Effective supporting surfaces A'

Under a centred load ($M_B = M_L = 0$), the effective supporting surface is taken as being equal to the total foundation surface. Under an off-centred load (M_B and/or $M_L \neq 0$), we adopt the Meyerhof approach which consists in defining a reduced supporting surface A' associated with an average reference ultimate bearing capacity q_{ref} able to guarantee the equilibrium of moments and forces. The formation of an equation for this model leads to the following results:

- Rectangular foundation: $A' = (B - 2e_B).(L - 2e_L)$ with $e_B = \dfrac{M_B}{V}$ and $e_L = \dfrac{M_L}{V}$
- Circular foundation[1]: $A' = \dfrac{B^2}{2}\left(\arccos\left(\dfrac{2e}{B}\right) - \dfrac{2e}{B}\sqrt{1 - \left(\dfrac{2e}{B}\right)^2} \right)$ with $e = \dfrac{M_B}{V}$

[1] NF P 94 261 – Appendix Q

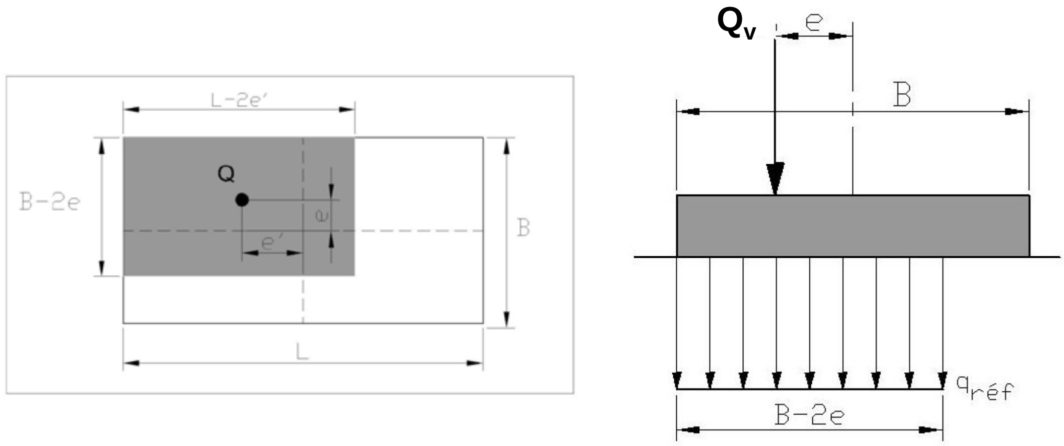


Figure J.2 : Definition of the effective supporting surface in the case of a rectangular foundation

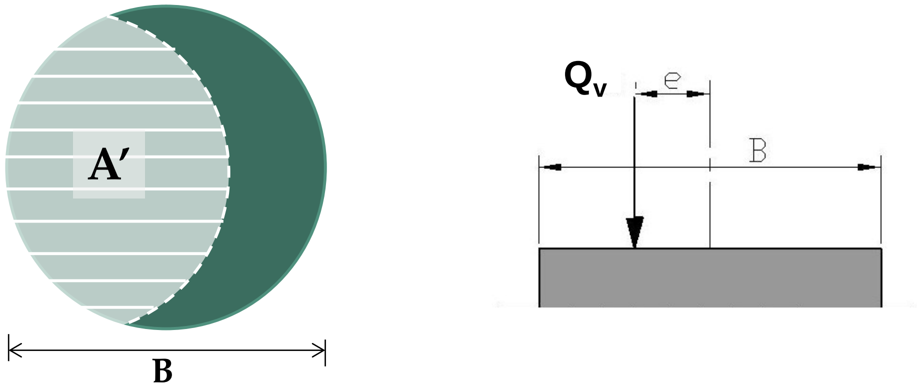


Figure J.3 : Definition of the effective supporting surface in the case of a circular foundation

J.2.3.3. Soil ultimate bearing capacity (pressuremeter method)

The soil ultimate bearing capacity q_u is expressed as the product of the equivalent net limit pressure p_{le}^* multiplied by a pressuremeter bearing factor (k_p):

$$q_u = k_p p_{le}^*$$

- **Equivalent net limit pressure p_{le}***: this is calculated as the geometrical mean of the net limit pressures measured at a depth H_r under the base of the foundation:

$$\log\left(p_{le}^*\right) = \frac{1}{H_r}\int_D^{D+H_r} \log\left(p_l^*(z)\right)dz$$

The value of H_r depends on the load combination and is taken as being equal to:

- o H_r = 1.50 B at SLS (permanent and characteristic);
- o H_r = min (1.50 B, H_{eff}) at ULS (fundamental, seismic and accidental).

With H_{eff} a function of the load eccentricities: $e_B = \dfrac{M_B}{V}$ and $e_L = \dfrac{M_L}{V}$

- o Continuous foundation: $H_{eff} = 3B - 6e_B$
- o Circular foundation: $H_{eff} = \dfrac{8B - 16e_B}{3}$
- o Rectangular foundation: $H_{eff} = \min\left(3B - 6e_B ; 3B - 6e_L\right)$

- **Equivalent embedment depth D_e:** the calculation of the pressuremeter bearing capacity factor k_p requires prior evaluation of the equivalent embedment depth of the foundation calculated using the following equation:

$$D_e = \min\left(D; \frac{1}{p_{le}^*} \int_0^D p_l^*(z)dz \right)$$

With p_{le}* here calculated for H_r = 1.5 B.

- **Pressuremeter bearing factor k_p**: this is expressed in accordance with the following formula

$$k_p = k_p^1 \left(1 - \frac{B}{L}\right) + k_p^2 \frac{B}{L}$$

With k_p^1 and k_p^2 being respectively the bearing factors for continuous and square footings for which the values can be obtained analytically using the following equation:

$$k_p^{1 \text{ or } 2} = k_{p0} + \left(a + b\frac{D_e}{B}\right)\!.\left(1 - e^{-c\frac{D_e}{B}}\right)$$

The values of k_{p0}, a, b and c are specified in the following table. The value of k_p is capped as of D_e/B = 2.0.

Soil category – Bearing factor variation curve		Expression of k_p			
		a	b	c	K_{p0}
Clay and silts	Continuous footing – Q1	0.2	0.02	1.3	0.8
	Square footing – Q2	0.3	0.02	1.5	0.8
Sands and gravels	Continuous footing – Q3	0.3	0.05	2	1
	Square footing – Q4	0.22	0.18	5	1
Chalks	Continuous footing – Q5	0.28	0.22	2.8	0.8
	Square footing – Q6	0.35	0.31	3	0.8
Marl and marly limestones	Continuous footing – Q7	0.2	0.2	3	0.8
Weathered rocks	Square footing – Q8	0.2	0.3	3	0.8

Table J.1 : Parameters for calculating the pressuremeter bearing factor

J.2.3.4. Integration of load angle

The case of an angled load ($Q_h \neq 0$) is dealt with by applying a reduction factor i_δ to the soil ultimate bearing capacity q_u:

$$q_u = i_\delta k_p p_{le}^*$$

The value of i_δ depends on the frictional/cohesive nature of the foundation soil as well as the angle δ = atan(Q_v/Q_h) of the load applied to the foundation. There are three different situations:

- Situation 1: case of a soil with perfectly cohesive behaviour(φ =0);
- Situation 2: case of a soil with perfectly frictional behaviour (c =0);
- Situation 3: case of a soil with intermediate behaviour (c $\neq$ 0 and φ $\neq$ 0).

The expression of i_δ in the three situations is given below (NF P 94 261):

- Situation 1: $$i_\delta = \Phi_1(\delta) = \left(1 - \frac{2\delta}{\pi}\right)^2$$
- Situation 2: $$i_\delta = \Phi_2(\delta) = \begin{cases} \Phi_1(\delta) - \dfrac{4\delta}{\pi}\left(1 - \dfrac{3\delta}{\pi}\right)\exp\left(-\dfrac{D_e}{B}\right) & \delta \le \dfrac{\pi}{4} \\ \Phi_1(\delta)\left(1 - \exp\left(-\dfrac{D_e}{B}\right)\right) & \delta \ge \dfrac{\pi}{4} \end{cases}$$
- Situation 3: $$i_\delta = \Phi_2(\delta) + (\Phi_1(\delta) - \Phi_2(\delta))\left(1 - \exp\left(-\frac{0.6c}{\gamma B \tan\varphi}\right)\right)$$

With γ the average unit weight of the foundation soil.

Note: The choice of a reduction factor corresponding to a cohesive soil implies that the soil will remain cohesive for the loading combinations studied. This assumption is thus mainly intended for the justification of structures in temporary design situations.

J.2.3.5. Proximity of an embankment

The presence of an embankment close to a vertically loaded foundation is dealt with by applying a reduction factor i_β to the soil's ultimate bearing capacity q_u:

$$q_u = i_\beta k_p p_{le}^*$$

The value of i_β depends on the frictional/cohesive nature of the soil, the distance "d" between the edge of the foundation and the embankment and the slope "β" of the embankment. The formulas applied are as follows:

- Case of cohesive soil (φ=0) $$i_\beta = \psi_1(\beta) = 1 - \frac{\beta}{\pi}\left(1 - \frac{d}{8B}\right)^2$$
- Case of frictional soil (c=0) $$i_\beta = \psi_2(\beta) = 1 - 0{,}9\tan\beta(2 - \tan\beta)\left(1 - \frac{d + \dfrac{D_e}{\tan\beta}}{8B}\right)^2$$
- Case of intermediate soil $$i_\beta = \psi_2(\beta) + (\psi_1(\beta) - \psi_2(\beta))\left(1 - \exp\left(-\frac{0.6c}{\gamma B \tan\varphi}\right)\right)$$

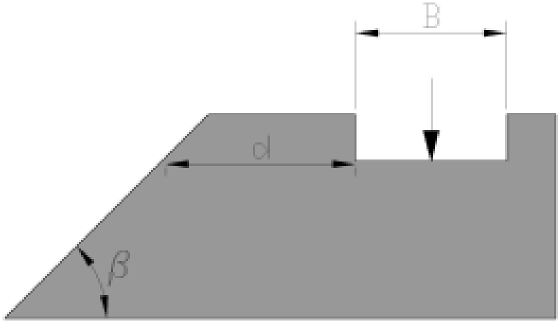


Figure J.4 : Presence of an embankment close to the footing – notations

Note: The choice of a reduction coefficient corresponding to a cohesive soil implies that the soil will remain cohesive for the loading combinations studied. This assumption is thus mainly intended for the justification of structures in temporary design situations.

J.2.3.6. Combination of i_δ and i_β

We now look at the case of a foundation situated close to an embankment and subjected to an angled load. This is dealt with by applying a reduction factor $i_{\delta\beta}$ to the soil ultimate bearing capacity:

$$q_u = i_{\delta\beta} k_p p_{le}^*$$

To calculate $i_{\delta\beta}$, we differentiate between two situations (see figure below):

- load directed towards the exterior of the embankment ($\delta > 0$): $i_{\delta\beta} = i_\delta i_\beta$
- load directed towards the interior of the embankment ($\delta < 0$): $i_{\delta\beta} = \min\left(\frac{i_\beta}{i_\delta}, i_\delta\right)$

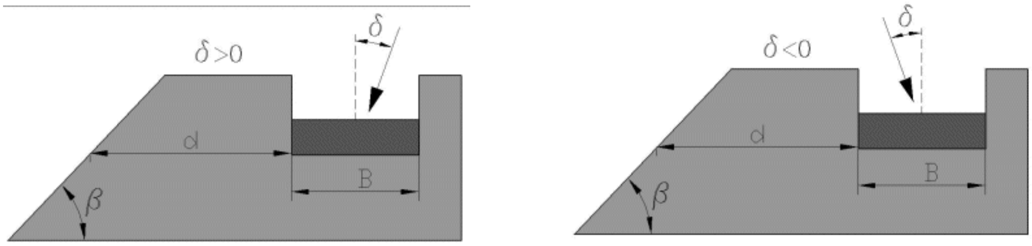


Figure J.5 : Proximity of an embankment and angled load – sign conventions

J.2.4. Tilting stability

The tilting stability is justified by ensuring compression of the supporting soil under the foundation over at least:

- 100% of the total supporting surface at permanent SLS;
- 75% of the total supporting surface at characteristic SLS;
- 10% of the total supporting surface at ULS (fundamental, accidental and seismic).

These thresholds may be translated into load maximum eccentricity criteria. This is summarised in the following table.

Compressed surface / Supporting surface	Continuous foundation of width B	Circular foundation of diameter B	Rectangular foundation of section B x L
= 100%	(1-2e/B) ≥ 2/3	(1-2e/B) ≥ 3/4	$(1-2e_B/B).(1-2e_L/L) \geq 2/3$
≥ 75%	(1-2e/B) ≥ 1/2	(1-2e/B) ≥ 9/16	$(1-2e_B/B).(1-2e_L/L) \geq 1/2$
≥ 10%	(1-2e/B) ≥ 1/15	(1-2e/B) ≥ 3/40	$(1-2e_B/B).(1-2e_L/L) \geq 1/15$

Table J.2 : Tilting stability criteria

J.2.5. Estimation of settlements with pressuremeter method

The settlement under the footing can be estimated with SLS combinations using the pressuremeter method:

$$s = \frac{q - q_0}{9}\left(\frac{\lambda_c B \alpha}{E_c} + 2\frac{B_0}{E_d}\left(\frac{\lambda_d B}{B_0}\right)^\alpha\right)$$

Where:

- q: average stress transmitted to the soil (Q_v / total supporting surface);
- q_0: total vertical stress before works at the base of the foundation;
- α rheological coefficient (see Table J.3);
- λ_c and λ_d form correction factors (see Table J.4);

- E_c and E_d equivalent pressuremeter moduli in the spherical (volumetric deformations) and deviatoric (shear deformations) zones respectively. They are calculated as follows:

$$E_c = E_1 \qquad E_d = \frac{1}{\frac{0{,}25}{E_1} + \frac{0{,}30}{E_2} + \frac{0{,}25}{E_{3,5}} + \frac{0{,}10}{E_{6,8}} + \frac{0{,}10}{E_{9,16}}}$$

With:
- o E_i harmonic mean of the moduli measured between (i-1).B/2 and i.B/2
- o $E_{i,j}$ harmonic mean of the moduli measured between (i-1).B/2 and j.B/2

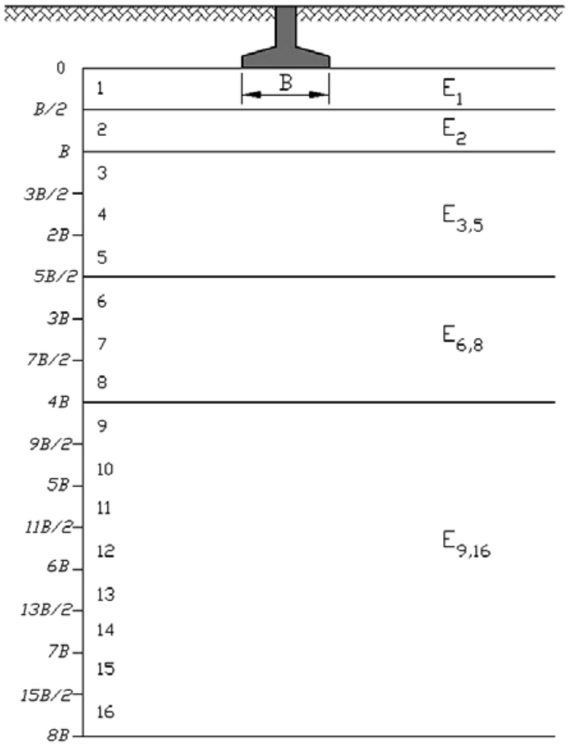


Figure J.6 : Definition of moduli for estimation of settlements using the pressuremeter method

Nature of soil	Peat	Clay		Silt		Sand		Sand and gravel		Type	Rock
	α	E_M/P_l	α	E_M/P_l	α	E_M/P_l	a	E_M/P_l	α		α
Over-consolidated or very tight		*> 16*	*1*	*> 14*	*2/3*	*> 12*	*1/2*	*> 10*	*1/3*	Very slight fracturing	*2/3*
Normally consolidated	1	*9 à 16*	*2/3*	*8 à 14*	*1/2*	*7 à 12*	*1/3*	*6 à 10*	*1/4*	Normal	*1/2*
Under-consolidated altered and disturbed or loose		*7 à 9*	*1/2*	*5 à 8*	*1/2*	*5 à 7*	*1/3*	--		Significant fracturing Significant weathering	*1/3 - 2/3*

Table J.3 : Indications for the choice of rheological coefficient

L/b	Circle	1	2	3	5	20
λ_c	1.00	1.10	1.20	1.30	1.40	1.50
λ_d	1.00	1.12	1.53	1.78	2.14	2.65

Table J.4 : Indications for the choice of form factors

J.3. User's guide

This chapter presents the parameters needed for a Fondsup calculation, as well as the results provided by this module.

The Fondsup module window comprises 3 tabs. All the tabs are visible.

To make a Fondsup calculation, a certain number of parameters need to be filled in and they are specified as and when necessary (certain input zones can only take data with a particular physical meaning).

This chapter does not describe the actual user interface and its operations in detail (buttons, menus, etc.): these aspects are dealt with in part C of the guide.

J.3.1. "Parameters" tab

This first tab comprises four separate frames.

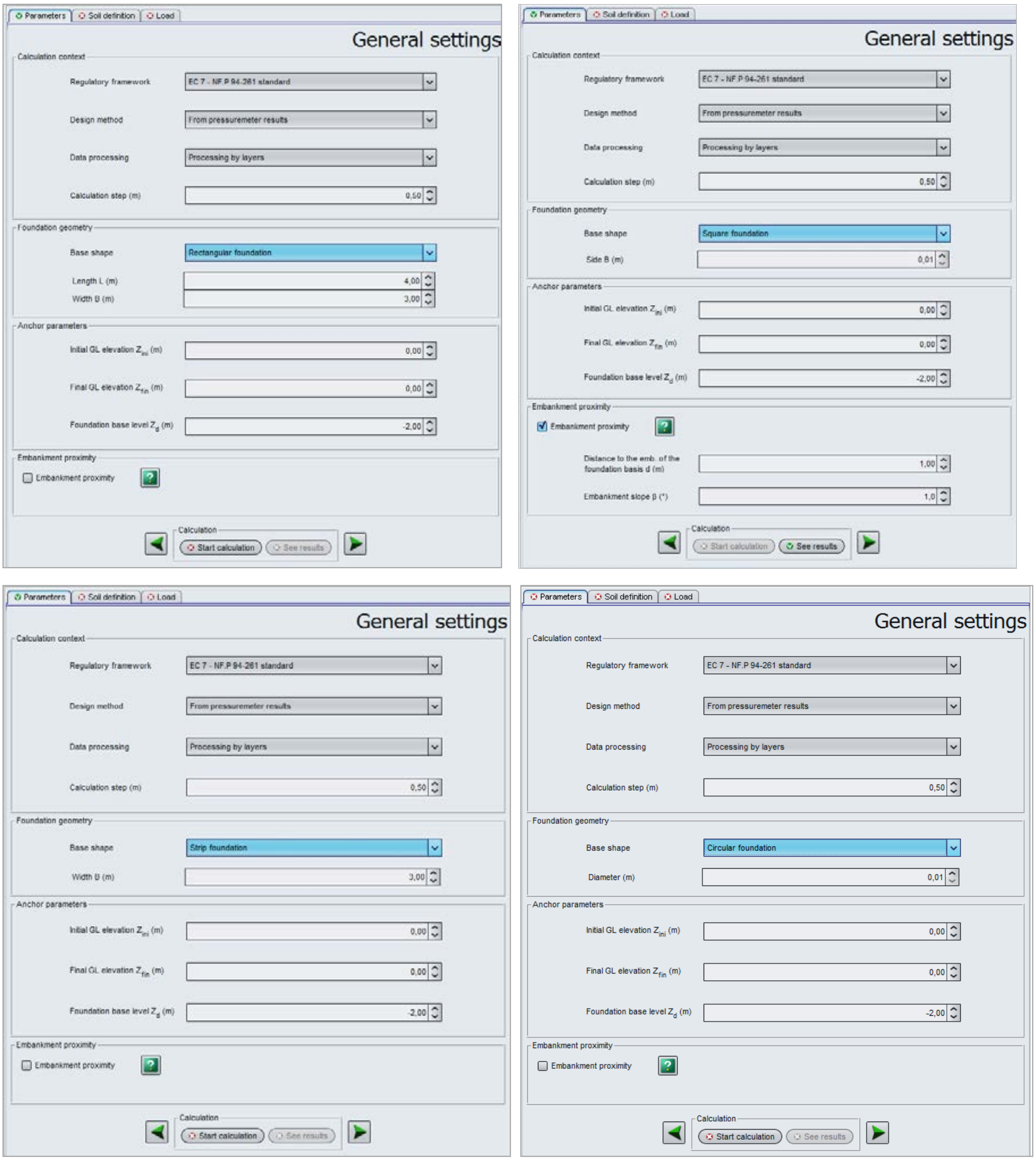


Figure J.7 : "Parameters" tab – Examples of input zones

These different input fields depending on:

- the shape of the base in the "Foundation geometry" frame
- the tick box in the "Embankment proximity" frame

J.3.1.1. "Calculation context" frame

J.3.1.1.1. Data to be defined in this frame

This frame is used to define:

- the regulatory framework. The possible choices are as follows:
    - EC7 – Standard NF.P 94-261 (default selection)
    - "Fascicule 62"
- the design method. The possible choices are as follows:
    - from pressuremeter results (default choice)
    - from penetrometer results
- data processing:
    - by layers (default choice)
    - by measurements
- the calculation step (m)

If CPT data are available, one has to define the design method as *From penetrometer results*.

J.3.1.1.2. Data processing by layers / measurements

The option of "processing by layers" presupposes the prior definition of a "geotechnical" model, with a set of characteristic values (E_M, Pl*) assumed to be homogeneous for each layer (following figure).

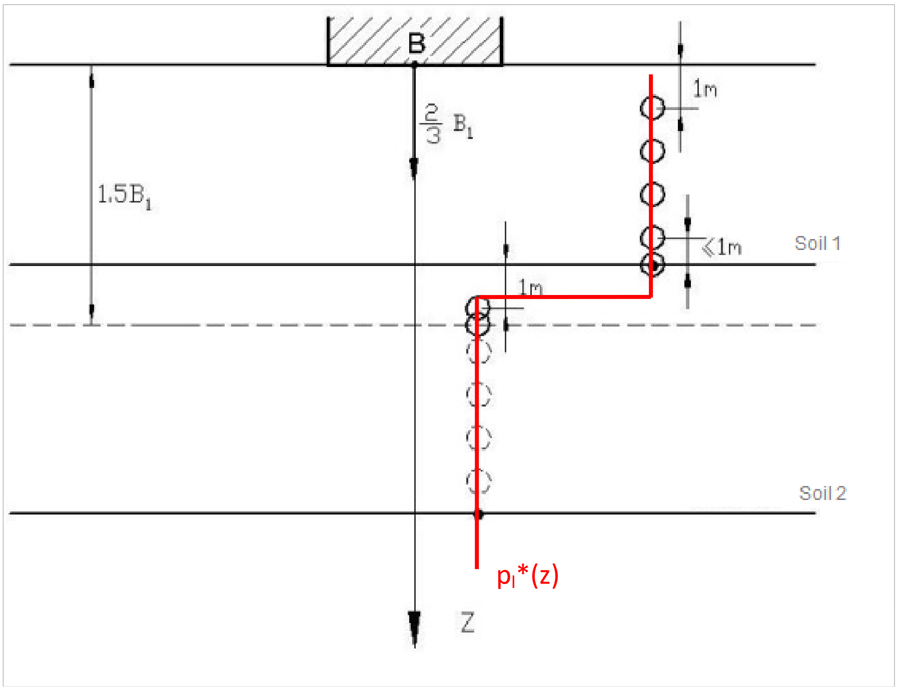


Figure J.8 : Data processing by layers

In the case of processing by measurements, the limit pressure is obtained by interpolation between the measurements input. This method is suited to a calculation based directly on raw pressuremeter data available for the footing (with measurements every metre for example).

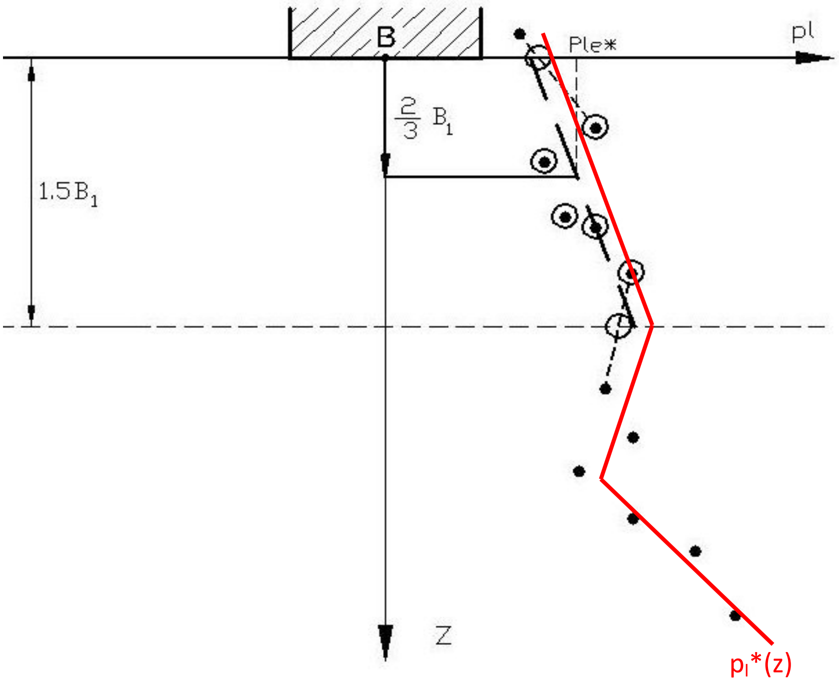


Figure J.9 : Data processing by measurements

If CPT data is available, we recommend to process by measurements.

J.3.1.2. "Foundation geometry" frame

This frame is used to define the shape of the foundation base:

- rectangular,
- square,
- continuous,
- or circular.

Depending on the choice made, the data to be input below vary:

Base shape	Length L (m)	Width B (m)	Side B (m)	Diameter (m)
Rectangular	Yes	Yes	No	No
Square	No	No	Yes	No
Continuous	No	Yes	No	No
Circular	No	No	No	Yes

Table J.5 : Foundation geometry

Note: in the case of a rectangular base, by convention B should be less than or equal to L.

J.3.1.3. "Embedment parameters" frame

This frame is used to define the following elevations:

- the initial groundlevel before foundation works Z_{ini} (m);
- the final groundlevel after foundation works Z_{fin} (m);
- the elevation of the foundation base Z_d (m).

J.3.1.4. "Embankment proximity" frame

If the foundation is close to an embankment, the "Embankment proximity" box should be ticked. The following additional input fields must then be filled out:

- the distance d between the foundation base and the embankment (m);
- the slope of the embankment β (°).

A help figure is available by clicking the  button:

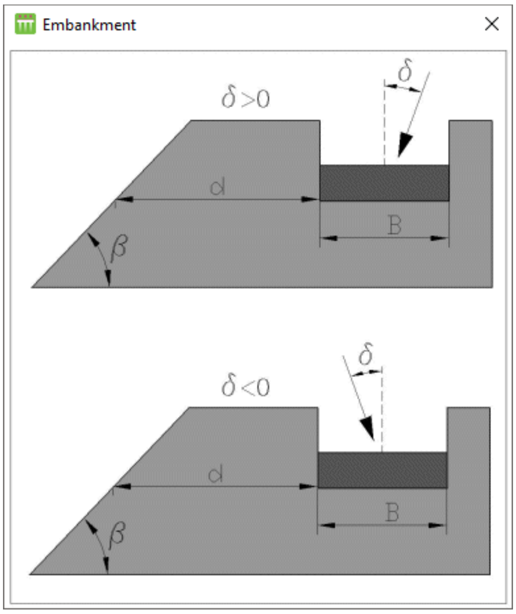


Figure J.10 : Help figure: embankment proximity

J.3.2. "Soil definition" tab

This second tab is used to define the soil behaviour parameters. The number and type of columns vary as a function of the regulatory framework and the design method entered in the "Parameters" tab.

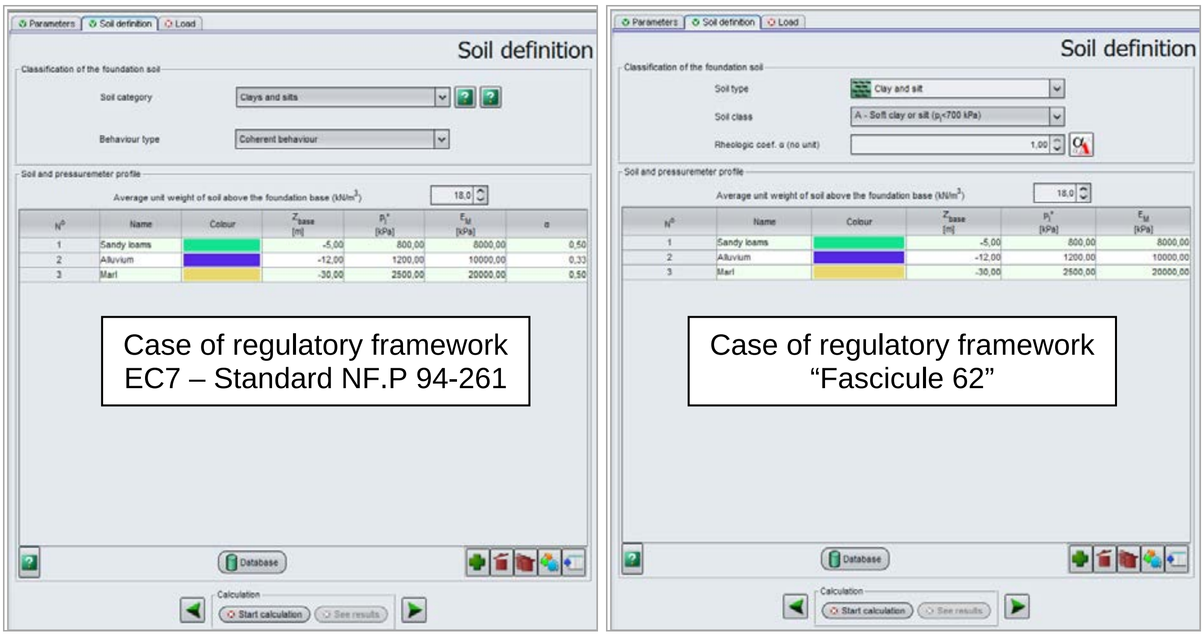


Figure J.11 : "Soil definition" tab

If CPT data is available, one may define q_c values (tip resistance [kPa]).

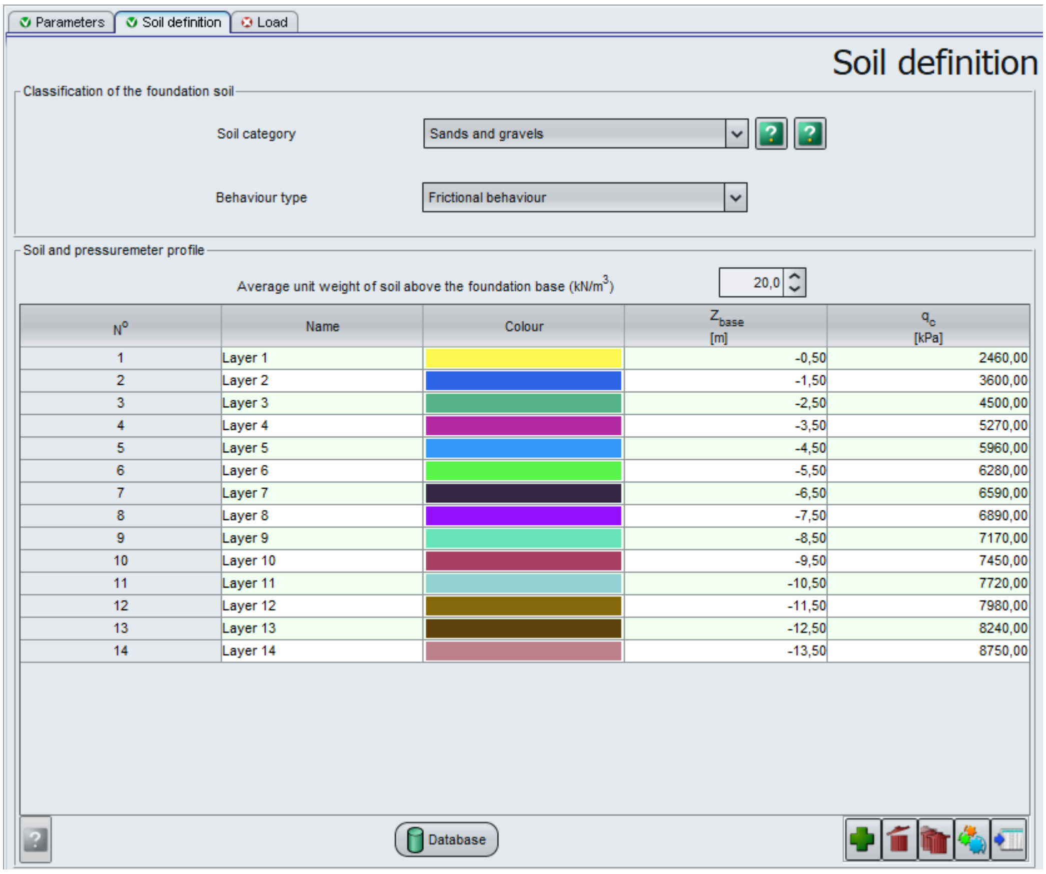


Figure J.12 : Soil definition from CPT data

The import wizard allows for the import a lot of data from clipboard (button *Import*). For example, one may define all values in an Excel spreadsheet, select the range of data and then copy to clipboard.

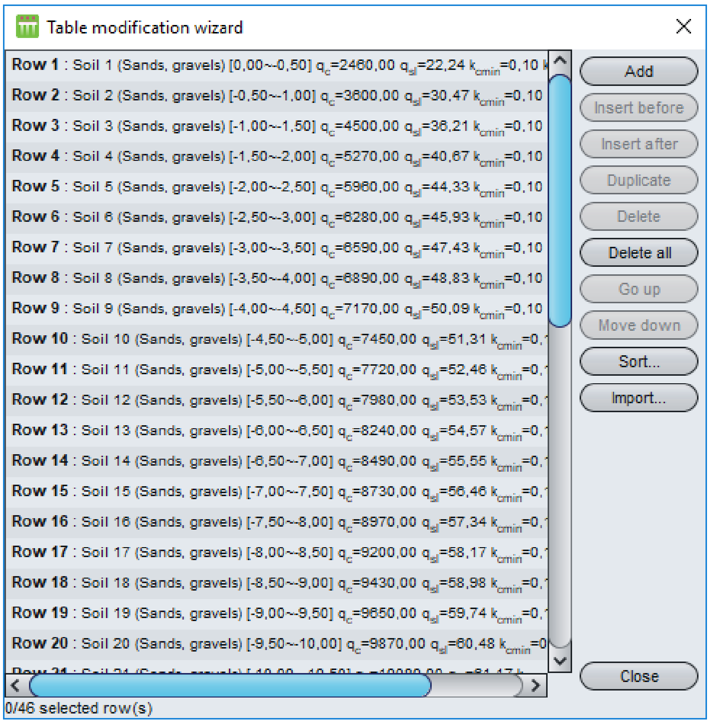


Figure J.13 : Import wizard for soil data

J.3.2.1. "Classification of the foundation soil" frame

The aim here is to define certain characteristics of the soil at the base of the foundation.

J.3.2.1.1. Case of regulatory framework 'EC7 – Standard NF.P 94-261'

2 drop-down lists must be filled out:

- "Soil category": 4 choices are available:
  - ✓ Clays and silts;
  - ✓ Sands, gravels;
  - ✓ Chalk;
  - ✓ Marl, weathered rocks.
- "Behaviour type": 3 choices are available
  - ✓ Frictional (selected by default);
  - ✓ Cohesive;
  - ✓ Intermediate.

  In the case of an "intermediate" behaviour type, additional data must be input:
  - ✓ the cohesion c (kPa);
  - ✓ the friction angle (°);
  - ✓ the unit weight (kN/m^3).

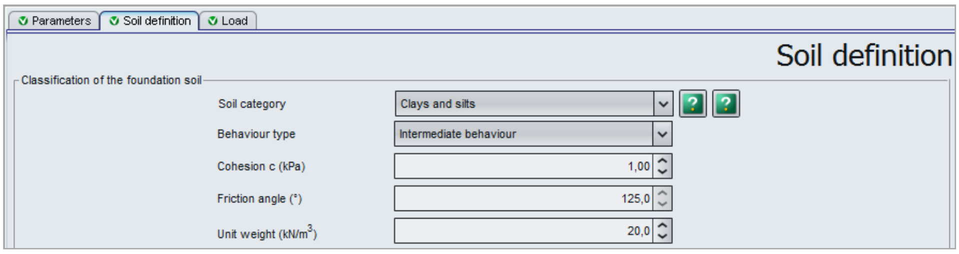


Figure J.14 : Regulatory framework EC7 – Intermediate behaviour type

Two help diagrams are available via the [?] buttons:

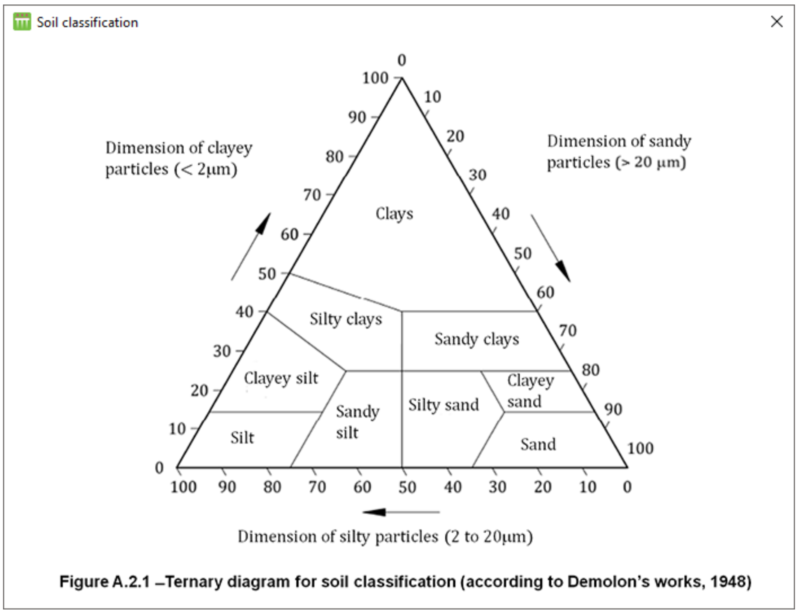


Figure J.15 : Help diagram – Soil classification: ternary diagram for soil classification

Soil classification

Table A.2.2 – Cohesive soil nature – Calcium carbonate $CaCO_3$ content

$CaCO_3$ CONTENT [a]	SOIL CLASS
0 – 10 %	Clay and silt
10 – 30 %	Marly clay or marly silt
30 – 70 %	Marl
70 – 90 %	Marly limestone
90 – 100 %	Limestone (or chalk [b])

a $CaCO_3$ content, according to the NF P 94-048 standard
b chalk term refers to a light coloured sedimentary formation, usually whitish to yellowish, porous and light. Chalk can be identified thanks to specific laboratory tests such as Atterberg limits.

Figure J.16 : Help diagram – Soil classification: cohesive soil nature – CaCO3 content

J.3.2.1.2. Case of regulatory framework "Fascicule 62"

The following drop-down lists should be filled out:

- Type of soil:
  - Clays and silts;
  - Sands, gravels;
  - Marls and marly limestones;
  - Chalk;
  - Weathered rocks.
- Soil class: the various soil classes appear as a function of the type of soil chosen (a diagram is available);

Soil classification

Conventional soil classification

Soil class		Pressuremeter p_l (MPa)	Penetrometer q_c (MPa)
Clays , silts	A – Loose clays and silts	< 0,7	< 3,0
	B – Firm clays and silts	1,2 à 2,0	3,0 à 6,0
	C – Very firm to stiff clays	> 2,5	> 6,0
Sands, gravels	A – Loose	< 0,5	< 5
	B – Moderately compact	1,0 à 2,0	8,0 à 15,0
	C – Compact	> 2,5	> 20,0
Chalks	A – Loose	< 0,7	< 5,0
	B – Weathered	1,0 à 2,5	> 5,0
	C – Compact	> 3,0	
Marls, marly limestones	A – Soft	1,5 à 4,0	
	B – Compact	> 4,5	
Rocks	A – Weathered	2,5 à 4,0	
	B – Fragmented	> 4,5	

Figure J.17 : "Fascicule 62" – Soil classification

- Rheological coefficient (a wizard is available, see below).

  The rheological coefficient wizard is available by clicking the button.

  The values proposed in the "Soil state" drop-down list vary as a function of the type of soil selected. The following table specifies the various possible soil type choices and the corresponding soil state values available.

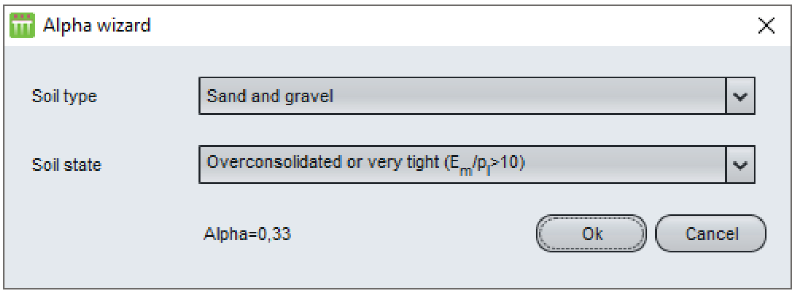


Figure J.18 : Rheological α wizard

The rheological coefficient α is automatically calculated and displayed in the wizard window. Click the OK button to transfer the value to your project.

J.3.2.2. "Soil and pressuremeter profile" frame

This frame is used to define the parameters of the various soil layers in the project.

The Z_{base} level to be input corresponds to the level of the soil testing, which will be handled as the base of the layer .

First of all, one enters the average unit weight of the soil above the foundation base, in kN/m^3. This value is used to calculate the initial stress at the base of the foundation before and after works, which affects calculation of settlement and of bearing capacity.

To add a soil layer, click the button.

The table proposed must then be filled out.

The following table describes the soil parameters to be defined for each layer:

Designation	**Unit**	**Default value**	**Display condition**	**Mandatory value**	**Local checks**
Name of the layer	-	"Layer i"	Always	Yes	-
Colour of the layer	-	Default colour	Always	Yes	-
$\mathbf{Z_{base}}$: level of layer base	m	1 m under the base of the above layer	Always	Yes	Strictly descending values
$\mathbf{P_l}$*****: net limit pressure of layer	kPa	0.00	Always	Yes	> 0
$\mathbf{E_M}$: average pressuremeter modulus of the layer	kPa	0.00	Always	Yes	> 0
α: Ménard's rheological coefficient	-	0.00	EC7 – Standard NF.P 94-261	Yes	$0 < \alpha \leq 1$

Table J.6 : Soil layer data

In the case of regulatory framework 'EC7 – Standard NF.P 94-261', a help table for the choice of the α rheological coefficient is available:

Soil rheologic coefficient selection

SOIL NATURE	Peat	Clay		Silt		Sand		Gravel		Type	Rock
	α	E_M/p_l	α	E_M/p_l	α	E_M/p_l	α	E_M/p_l	α		α
Overconsolidated or very tight		> 16	1	> 14	2/3	> 12	1/2	> 10	1/3	Very slightly fractured	2/3
Normally consolidated	1	9 to 16	2/3	8 to 14	1/2	7 to 12	1/3	6 to 10	1/4	Normal	1/2
Underconsolidated weathered and disturbed or loose		7 to 9	1/2	5 to 8	1/2	5 to 7	1/3	--		Very fractured – Very weathered	1/3 - 2/3

Figure J.19 : EC7 – Standard NF.P 94-261 – Choice of soil rheological coefficient

J.3.2.3. Data import

The Fondsup module enables to import soil layer data from the Windows® clipboard.

J.3.2.3.1. Data import procedure

These soil "layer" data are imported as follows:

- prepare/recover an Excel® spreadsheet containing the data to be imported;
- open this spreadsheet and copy the data into the Windows® clipboard;
- open the "Table Modification wizard" and click the Import... button;
  - in this wizard, specify the range of rows to be imported. If the first row on the spreadsheet contains column headers, it should be ignored (and import should therefore start on row 2).

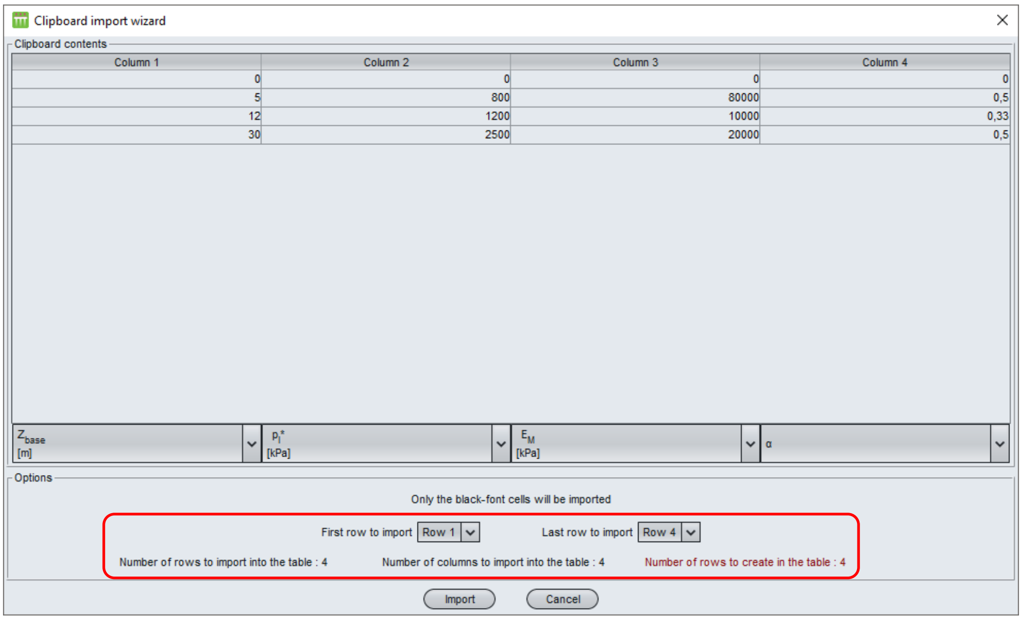


Figure J.20 : Data import wizard

  - click the Import... button;
  - the table modification wizard then displays the imported data. Click the Close button: the imported soil layers were created with a default name and the values of the parameters imported from the spreadsheet.

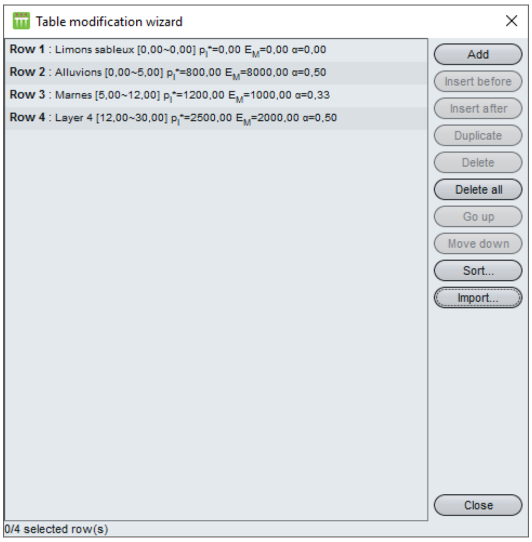


Figure J.21 : Table modification wizard

J.3.2.3.2. Format of spreadsheets to be imported

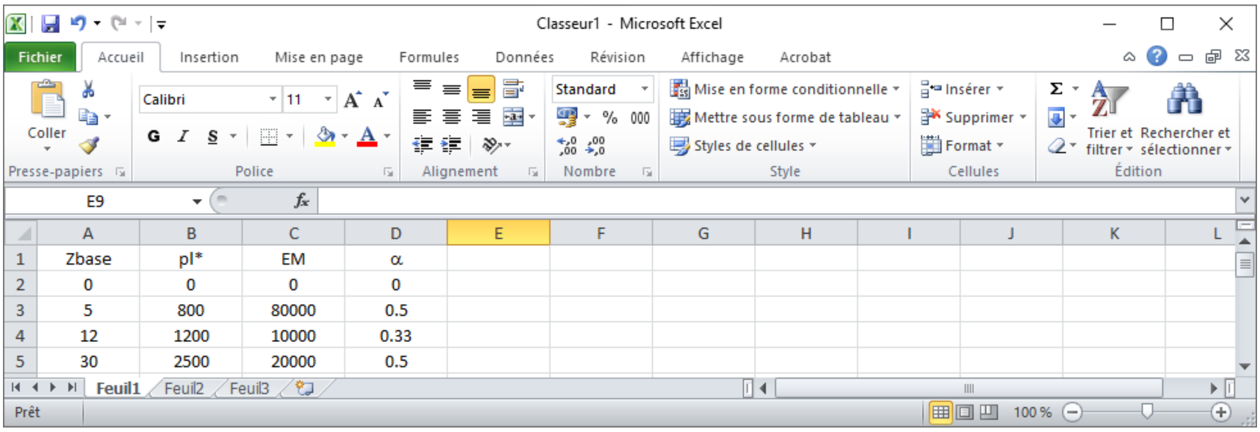
Examples of the spreadsheet formats to be used are given below.

For the two cases mentioned below, the screenshot illustrates the data specific to Fondsup as a function of the regulatory framework, following the order given in the "Soil definition" tab of the application.

Note: not all the data columns have to be filled out (but the Z_{base} data, however, is mandatory).

<u>Regulatory framework EC7</u>:

Imported data: Z_{base}, p_{l*}, E_M and α.

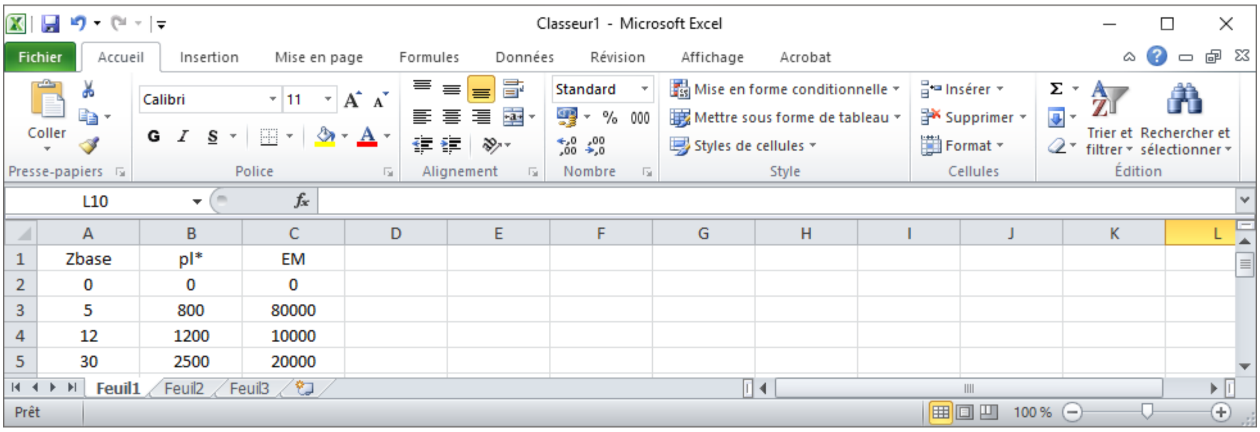


	A	B	C	D
1	Zbase	pl*	EM	α
2	0	0	0	0
3	5	800	80000	0.5
4	12	1200	10000	0.33
5	30	2500	20000	0.5

Figure J.22 : Format of spreadsheet to be imported (regulatory framework EC7)

Regulatory framework "Fascicule 62":

Imported data: Z_{base}, p_{l^*} and E_M.



	A	B	C
1	Zbase	pl*	EM
2	0	0	0
3	5	800	80000
4	12	1200	10000
5	30	2500	20000

Figure J.23 : Format of spreadsheet to be imported (regulatory framework "Fascicule 62")

The data checks are the same as those mentioned in Table J.8.

In certain cases, if the imported values do not correspond to the checks (P_l* and E_M strictly positive or α between 0 excluded and 1 included), Fondsup will display the tab with a red cross [Soil definition] to warn the user that the imported data do not correspond to the values expected by the application.

J.3.3. "Load" tab

This tab is used to input the various load cases applied to the foundation.

The global forces and moments applied to the footing for each load case must be expressed at the centre of the base of the footing.

In the case of regulatory framework EC7 – Standard NF.P 94-261, one must define whether the load case is defined by (design values):

- Q_d and δ_d or
- $Q_{v,d}$ and $Q_{h,d}$.

In the case of regulatory framework "Fascicule 62", one must define whether the load case is defined by:

- Q and δ or
- Q_v and Q_h.

The data to be input vary according to the type of load case chosen, as well as the regulatory framework. It is necessary to input at least one load case (with at least one force or moment value other than zero).

For each load case, the values of (Q_d, $M_{B,d}$, $M_{L,d}$, $Q_{v,d}$, $Q_{h,d}$) for regulatory framework EC7, or the values of (Q, M_B, and M_L) for regulatory framework "Fascicule 62", shall meet the following criteria:

- for each load case, the division of M_B (and M_L in the case of a square or rectangular foundation) by the vertical resultant of the load shall be strictly less than the half-length, the half-width or the half-diameter of the foundation (depending on the shape of the foundation).
- for each load case, either the values of Q, Q_v and Q_h are other than zero, or the values of M_B or M_L are other than zero.

Designation	**Unit**	**Default value**	**Display condition**	**Mandatory value**	**Local checks**
$\mathbf{Q_d}$ (EC7) or **Q** ("Fascicule 62"): Resultant force expressed at centre of foundation base (design value)	kN or kN/ml if continuous foundation	0.0	Load case "With Q_d and δ_d"	Yes	-
δ_d (EC7) or δ ("Fascicule 62"): Angle of the load to the vertical (design value)	°	0.0	Load case "With Q_d and δ_d"	Yes	-
$\mathbf{Q_{v,d}}$ (EC7) or $\mathbf{Q_v}$ ("Fascicule 62"): vertical force expressed at centre of foundation base (design value)	kN or kN/ml if continuous foundation	0.0	Load case "With $Q_{v,d}$ and $Q_{h,d}$"	Yes	-
$\mathbf{Q_{h,d}}$ (EC7) or $\mathbf{Q_h}$ ("Fascicule 62"): horizontal force expressed at centre of foundation base (design value)	kN or kN/ml if continuous foundation	0.0	Load case "With $Q_{v,d}$ and $Q_{h,d}$"	Yes	-
$\mathbf{M_{B,d}}$ (EC7) or $\mathbf{M_B}$ ("Fascicule 62"): value of moment along the width of foundation, expressed at foundation base (design value)	kN.m or kN.m/ml if continuous foundation	0.0		Yes	-
$\mathbf{M_{L,d}}$ (EC7) or $\mathbf{M_L}$ ("Fascicule 62"): value of moment along the length of foundation, expressed at foundation base (design value)	kN.m	0.0	Square or rectangular foundation	Yes	-
Combination of load cases	-	-	EC7 – Standard NF.P 94-261	Yes (1)	-

Table J.7 : Data concerning load cases

(1) The possible combinations are as follows:

- SLS – Quasi-permanent;
- SLS – Characteristic;
- ULS – Fundamental;
- ULS – Accidental;
- ULS - Seismic.

A help diagram is available by clicking the  button:

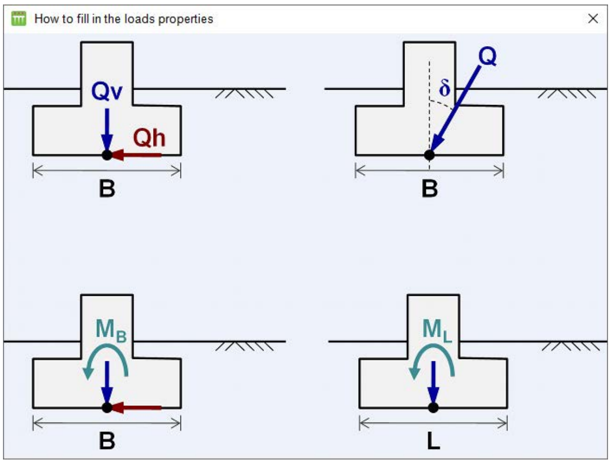


Figure J.24 : Help diagram: How to fill in the loads properties

J.3.4. Calculations and results

J.3.4.1. Calculation

The calculation can be started from any tab, provided that the tabs have been correctly filled out, that is when they are all marked with a green tick (for example: Soil definition).

They are displayed with a red cross (for example: Soil definition) until they are correctly filled out (data missing or not conforming to the expected values).

To start the calculation, click the Start calculation button.

To display the calculation results, click the See results button.

J.3.4.2. Results

The following window can be used to choose the type of results to be displayed. Fondsup provides numerical results only:

- formatted results;
- results table.

Figure J.25 : Results window

J.3.4.2.1. Formatted numerical results

The formatted numerical results contain:

- a reminder of the data: design options, general parameters, soil layer characteristics, geometry of the foundation, embedment parameters, soil characteristics and foundation soil class;
- the results values for each load case: equivalent embedment depth D_e (m) and bearing capacity factor k_p;
- for each load case, in the case of regulatory framework EC7:
  - a reminder of the loads values
  - the verification of the bearing capacity and tilting, with the following intermediate design values:
    - eccentricity of the load along B (and as applicable along L) (m);
    - effective supporting surface A' (m^2);
    - equivalent limit pressure p_{le} (kPa);
    - calculation height Hr (m);
    - reduction coefficient idb (=$i_{\delta\beta}$);
    - initial stress q_0 at the base of the foundation (kPa);
    - net ultimate stress q_u (kPa);
    - Regulatory framework EC7:
      - global weighting factor F;
      - the resultant of the initial stress under the foundation R_0 (kN);
      - the design value for the net soil resistance design value $R_{v,d}$ (kN);
      - verification of the bearing capacity. This is satisfactory if the following condition is met: $Q_{v,d} – R_0 < R_{v,d}$
      - verification of tilting. This consists in checking that the "compressed" surface under the footing remains greater than or equal to:
        - ✓ 100% for the SLS-QP combinations;
        - ✓ 75% for the SLS-CARAC combinations;
        - ✓ 10% for the ULS combinations.
    - Regulatory framework "Fascicule 62":
      - Reference stress q_{ref} (kPa);
      - For comparison: the allowable stresses at ULS and SLS.
  - calculation of settlements (only for the SLS-QP combinations in regulatory framework EC7), with the following intermediate design values:
    - the lambda_c and lambda_d form factors;
    - the equivalent moduli E_1, E_2, $E_{3,5}$, $E_{6,8}$, $E_{9,16}$ and the E_c and E_d (kPa) moduli;
    - the initial stress at the base of the foundation s_{v0} (kPa);
    - the volumetric part of the settlement s_c (mm);
    - the deviatoric part of the settlement s_d (mm);
    - the total settlement at 10 years (mm).

Copy all   Copy only the selection

```
Programme FondSup v2.1.0                    (c) TERRASOL 2016

File :  Z:\Logiciel TS\02 - Foxta\Example\EXAMPLE 1\Example 1[FS].resu

Calcul réalisé le :    29/09/2016  à 17h03
               by :  Terrasol

Paramètres de calcul :
    - calcul basé sur des paramètres issus du pressiomètre de Ménard
    - calcul selon la norme NF P 94 261 - EC7
    - profils de pl* et EM définis par couche

 Base de la fondation Zd          -2.00

 Toit du terrain initial Zini      0.00
 Toit du terrain final Zfin        0.00

 Fondation rectangulaire :
         largeur B                 3.00
         longueur L                4.00

Caractéristiques du sol (données utilisateur)

    Classe du sol de fondation : Argiles et limons
    Type de comportement       : parfaitement cohérent

    Poids volumique moyen du sol au dessus de Zd    18.00
    Coefficient rheologique du sol de fondation      0.45

    Couche     base        pl*          EM
    ------------------------------------------
      01       -5.00      800.00      8000.00
      02      -12.00     1200.00     10000.00
      03      -30.00     2500.00     20000.00

Discrétisation des couches (Paramètres du calcul)

    Pas du calcul    0.50

couche    point        cote         pl*          EM
-----------------------------------------------------------
  01        1          0.00       800.00       8000.00
  01        2         -0.50       800.00       8000.00
  01        3         -1.00       800.00       8000.00
  01        4         -1.50       800.00       8000.00
```

License : Terrasol   Project : Formation / Portance d'une semelle superficielle

```
                 RESULTATS DU CALCUL

Valeurs valables pour tous les cas de charge :

      Hauteur d'encastrement equivalente De        1.75
      Facteur de portance kp                       0.96

==============================================================
    Cas de charge n° :   001  - Combinaison ELS-QP
==============================================================

        Charge verticale V,d      3500.00
        Charge horizontale H,d       0.00
        Moment Mb,d                  0.00
        Moment Ml,d                  0.00

          ---------------------------
            PORTANCE ET RENVERSEMENT
          ---------------------------

    Excentricité de la charge selon B       0.00
    Excentricité de la charge selon L       0.00
    Surface d'assise effective A'          12.00

    Pression limite équiv. Ple            915.77
    Hauteur de calcul Hr                    4.50

    Coefficient réducteur idb               1.00

    Contrainte initiale q0                 36.00
    Contrainte ultime nette qu            883.04

    Facteur de pondération global F         2.76

    Résultante de la contrainte
    intiale sous la fondation R0          432.00

    Valeur de calcul de l'effort de
    résistance nette du terrain Rv,d     3839.30

    Portance     : V,d - R0 < Rv,d          =>  OK!
    Excentricité : Surface comprimée = 100% =>  OK!

          -------------------------
                 TASSEMENTS
          -------------------------

    Coefficients de forme :
         Coefficient Lambda_c               1.13
         Coefficient Lambda_d               1.26

    Modules équivalents :
```

Case of regulatory framework
EC7 – Standard NF.P 94-261

```
            Cas de charge n° :      003
==============================================================

        Charge verticale V          4700.00
        Charge horizontale H         400.00
        Moment Mb                    600.00
        Moment Ml :                  600.00

          ---------------------------
           CONTRAINTES ADMISSIBLES
          ---------------------------

    Excentricité de la charge selon B       0.13
    Excentricité de la charge selon L       0.13
    Surface d'assise effective A'          10.28

    Pression limite équiv. Ple            915.77
    Hauteur de calcul Hr                    4.50

    Coefficient réducteur idb               0.89

    Contrainte initiale q0                 36.00
    Contrainte ultime nette qu            777.46

    Contrainte de référence qréf          457.29

    A comparer à :
             Contrainte adm ELU           406.73
             Contrainte adm ELS           283.15

          -------------------------
                 TASSEMENTS
          -------------------------

    Coefficients de forme :
         Coefficient Lambda_c               1.13
         Coefficient Lambda_d               1.26

    Modules équivalents :
                   Module E1             8000.00
                   Module E2             8000.00
                   Module E3,5          10000.00
                   Module E6,8          12857.14
                   Module E9,16         20000.00

                   Module Ec             8000.00
                   Module Ed             9387.22

    Contrainte initiale sv0                36.00

    Tassements (mm):

         Part volumique sc                  5.04
         Part déviatorique sd               8.77
         Tassement total 10 ans            13.81
```

Case of regulatory framework
"Fascicule 62"

Figure J.26 :   Formatted results

J.3.4.2.2. Results table

The results table displays the same results as those detailed for the formatted results in the previous chapter (although with fewer intermediate results visible).

<u>For regulatory framework EC7</u>:

- The load case number;
- The load combination;
- $Q_{v,d}$: design value of the vertical component of the applied load (kN);
- δ_d: design value of the angle of the applied load with respect to the vertical (°);
- $e_{B,d}$: design value of the eccentricity of the load along B with respect to the centre of the foundation (m);
- $e_{L,d}$: design value of the eccentricity of the load along L with respect to the centre of the foundation (m);
- $R_{v,d}$: design value of net soil resistance under the foundation (kN);
- R_0: value of the weight of the volume of soil situated above the base of the foundation after the works (kN);
- Verification of bearing capacity (using the formula indicated in the previous chapter);
- Verification of tilting (using the criteria indicated in the previous chapter);
- Total settlement at 10 years in mm (calculated only for SLS-QP type combinations).

Export | Back to the index

Results

Number of the load case	Combination	$Q_{v,d}$ [kN]	δ_d [°]	$e_{B,d}$ [m]	$e_{L,d}$ [m]	$R_{v,d}$ [kN]	R_0 [kN]	Punching	Tilting	Settlement
1	SLS-Quasi-per...	3500,00	0,00	0,00	0,00	3840,00	432,00	Ok	Ok	13.7
2	SLS-Character...	3000,00	4,76	0,17	0,17	2810,00	432,00	Ok	Ok	-
3	ULS-Fundame...	4700,00	4,86	0,13	0,13	4830,00	432,00	Ok	Ok	-
4	ULS-Accidental	4700,00	7,28	0,21	0,21	4770,00	432,00	Ok	Ok	-
5	ULS-Seismic	4700,00	9,66	0,26	0,26	3640,00	432,00	Invalid	Ok	-

Figure J.27 : Results table – Regulatory framework EC7

<u>For regulatory framework "Fascicule 62"</u>:

- The load case number;
- q_{ref}: reference stress under the foundation (kPa);
- q_{ULS}: allowable stress at ULS (kPa);
- q_{SLS}: allowable stress at SLS (kPa);
- Settlement under q_{ref} in mm.

Export | Back to the index

Results

Number of the load case	q_{ref} [kPa]	q_{ULS} [kPa]	q_{SLS} [kPa]	Settlement [mm]
1	2,920E02	4,500E02	3,120E02	9,920E00
2	3,070E02	4,080E02	2,840E02	8,310E00
3	4,570E02	4,070E02	2,830E02	1,380E01
4	5,110E02	3,860E02	2,690E02	1,380E01
5	5,410E02	3,660E02	2,560E02	1,380E01

Figure J.28 : Results table – Regulatory framework "Fascicule 62"

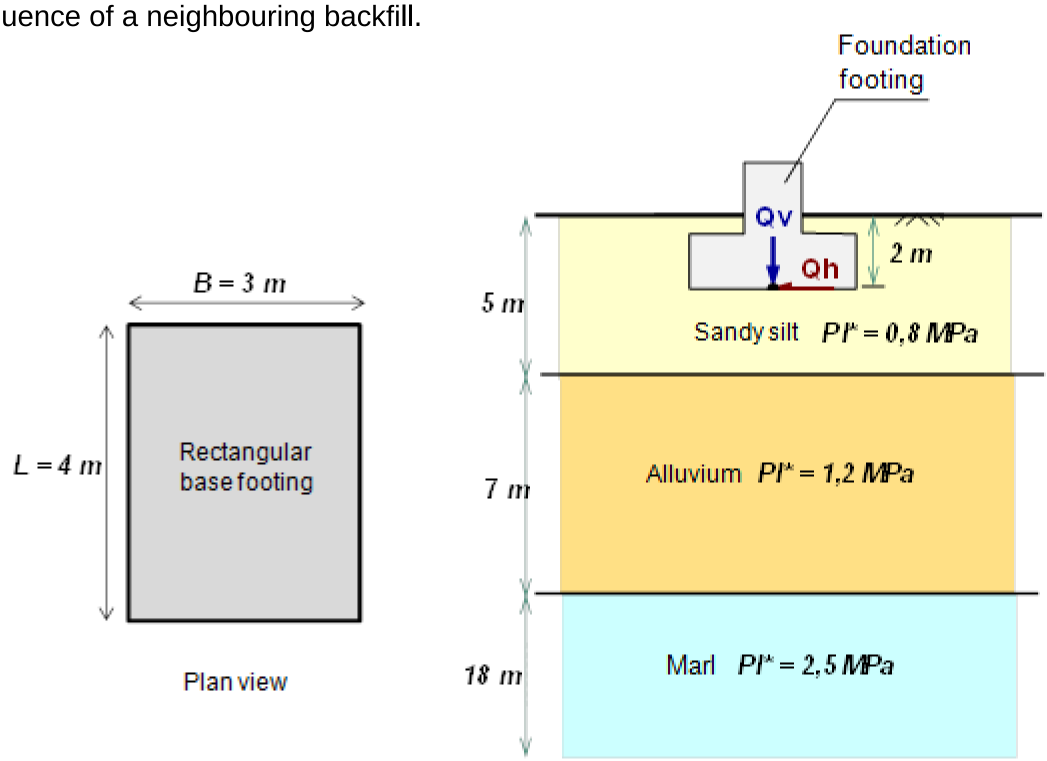
J.4. Calculation example: bearing capacity and settlement of a foundation footing

This example deals with the case of a 3 m x 4 m shallow rectangular foundation resting on a multilayer soil. It aims at illustrating:

- the verification of bearing capacity and tilting of the footing under various load combinations;
- the calculation of settlements under permanent loading.

We will first of all use the Fondsup module, which can meet the objectives of the exercise by direct application of standard NF P 94 261, which is the implementation standard of Eurocode 7 for shallow foundations.

Subsequently, we will use the TASPLAQ module which, in addition to calculating settlement, can handle more complex situations, such as interaction between neighbouring footings or the influence of a neighbouring backfill.



J.4.1. Processing with the Fondsup module

Double-click the Foxta icon to start the programme, choose the type of login and the required language then click the OK button.

J.4.1.1. Data input

When the application opens, Foxta proposes:

- o creating a new project;
- o opening an existing project;
- o automatically opening your latest project used.

In the case of this example:

- o select creation of a new project with the New project radio-button;
- o click the OK button.

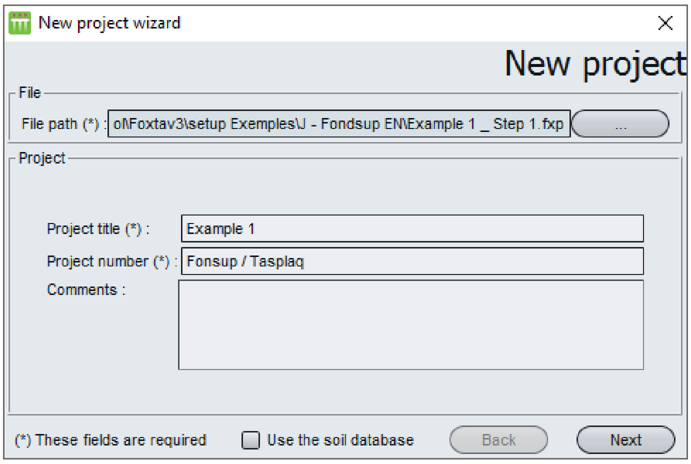
New project wizard

"File" frame

- o Fill out the project path by clicking the ... button.
- o Give the project a name and save it.

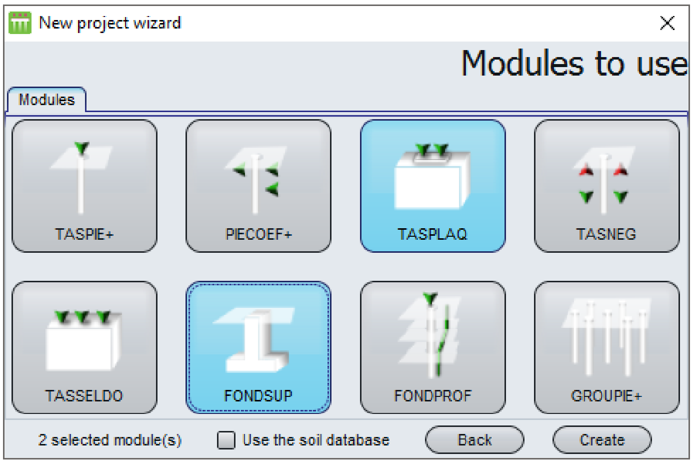
"Project" frame

- o Give the project a title.
- o Enter a project number.
- o Complete with a comment if necessary.
- o Leave the "Use the soil database" box unticked (we will not use the database in this example) and click the Next button.



New project wizard: choice of modules

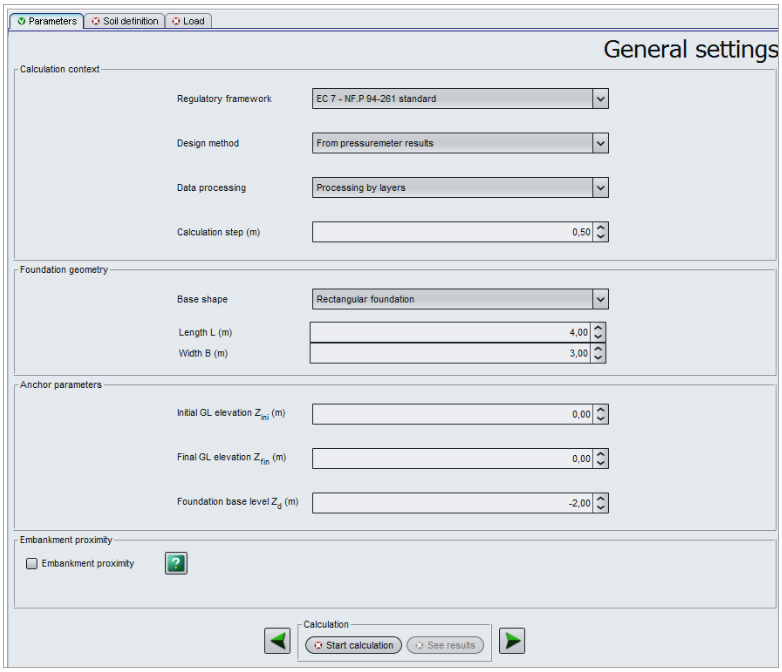
Select the Fondsup and Tasplaq modules, then click the Create button.



The Tasplaq data input window then appears. This module will only be used in the second part of the calculations. First of all switch to the Fondsup module by clicking the corresponding icon in the top-right of the window 
.

J.4.1.2. "Parameters" tab

This tab concerns the general calculation parameters.



<u>"Calculation context" frame</u>

- Regulatory framework: EC 7 – Standard NF P 94-261.
- Design method: From pressuremeter results.
- Data processing: Processing by layers.
- Calculation step (m): 0.50 m.

Note: Processing by layers presupposes prior definition of a "geotechnical" model with a set of characteristic values (E_M, Pl*) assumed to be homogeneous for each layer (see chapter J.3.1.1.2).

<u>"Foundation geometry" frame</u>

- Base shape: Rectangular foundation.
- Length L (m): 4.00 m.
- Length B (m): 3.00 m.

<u>"Anchor parameters" frame</u>

- Initial groundlevel Z_{ini} (m): 0.00.
- Final groundlevel Z_{fin} (m): 0.00.
- Foundation base level Z_d (m): -2.00.

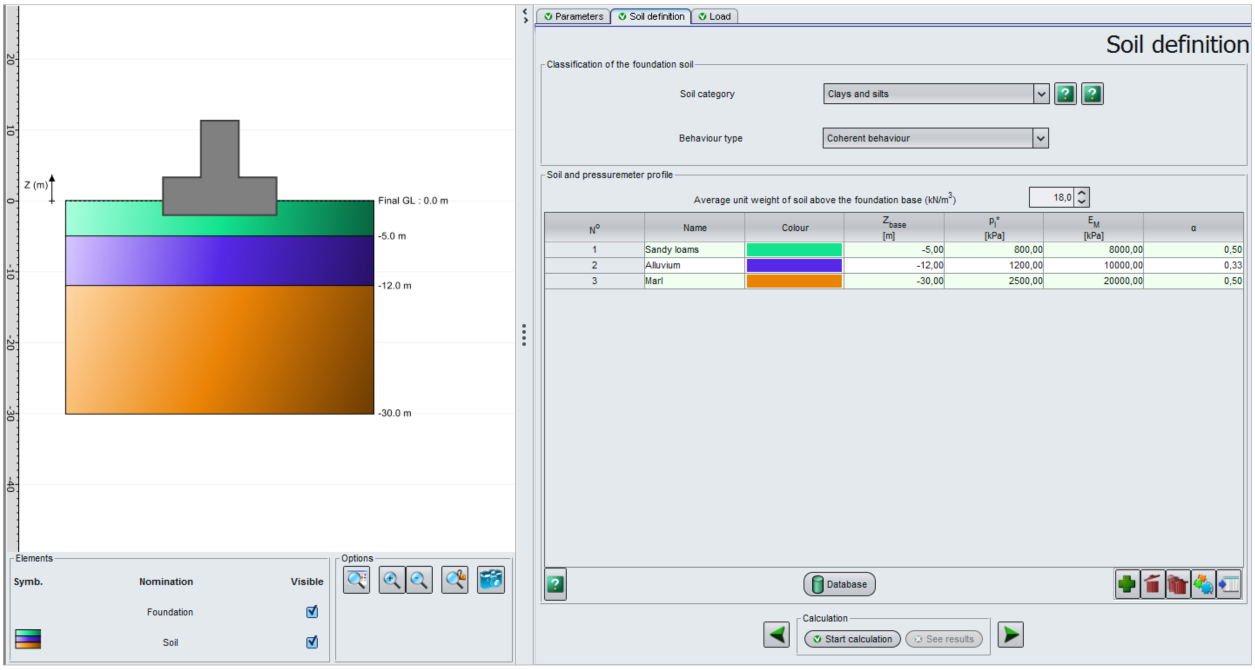
<u>"Embankment proximity" frame</u>

There is no embankment in proximity to the foundation in this example. Leave the corresponding box "unticked".

To move to the next tab, either click the name of the "Soil definition" tab, or the button.

J.4.1.3. "Soil definition" tab

This tab concerns the definition of the soil layers.



"Classification of the foundation soil" frame

Here the conventional foundation soil category is filled out. In the case of a heterogeneous soil, the user must choose the "dominant" category of the soil in which the foundation is embedded. This choice affects the calculation of the bearing capacity coefficient k_p (or k_c in the case of a calculation using static penetrometer tests). In this example, the chosen category is "Clays and silts".

- Soil category: Clays and silts
- Behaviour type: Cohesive behaviour

"Soil and pressuremeter profile" frame

First of all, the value of the average unit weight of the soil above the foundation base must be filled in. This value is used to calculate the initial stress at the base of the foundation before and after works, which affects the settlement and bearing capacity calculation. In this example, the proposed value is 18 kN/m^3.

Then click the button to create each of the layers.

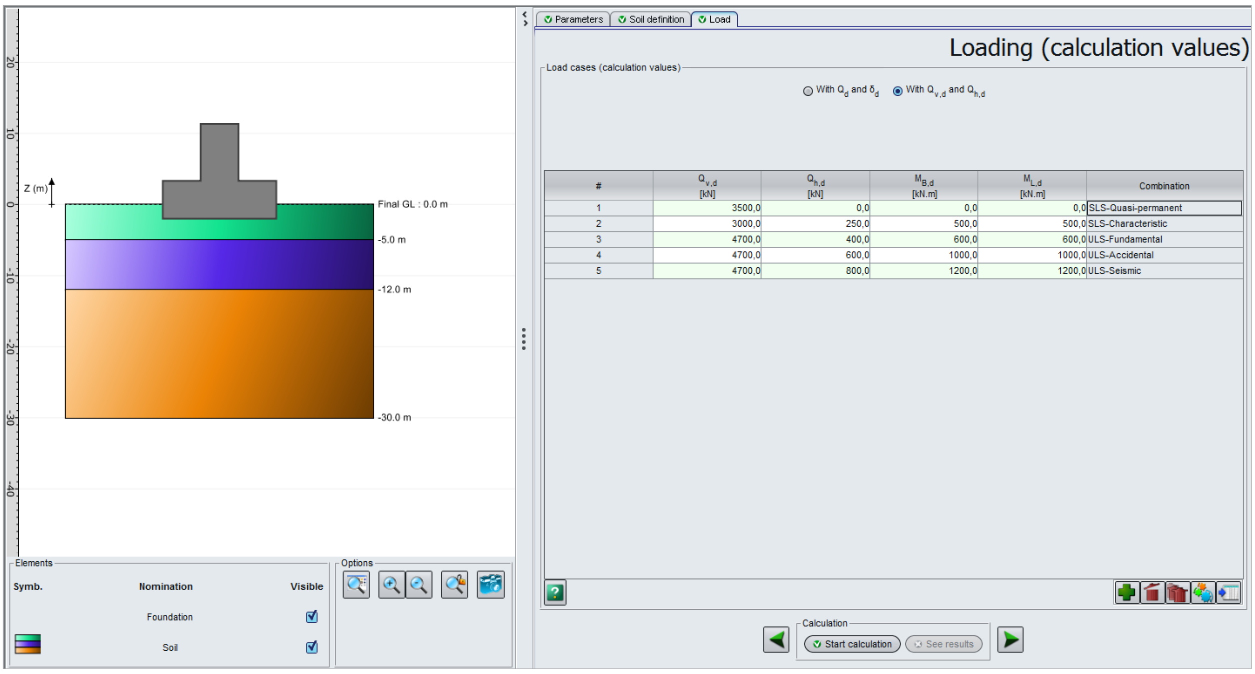
For the various soil layers, input:

- Base level of layer Z_{base} (m).
- Average limit pressure value p_l* (kPa).
- Average pressuremeter modulus value E_M (kPa).
- Average rheological coefficient value α (no unit).

Name	Z_{base} (m)	p_l* (kPa)	E_M (kPa)	α (-)
Sandy silt	-5	800	8000	0.50
Alluvium	-12	1200	10000	0.33
Marls	-30	2500	20000	0.50

J.4.1.4. "Loading" tab

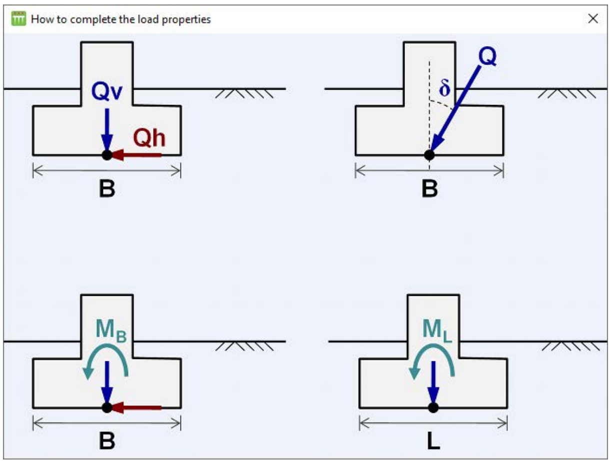
This tab is used to fill out all the load cases applied to the footing.



Tick the box "with $Q_{v,d}$ and $Q_{h,d}$": this means that the load applied to the footing must be broken down, for each load case, into the vertical and horizontal components.

The loads are to be entered as "design values" as defined in the Eurocodes. In other words, the loads to be input are assumed to be already weighted.

Caution: the global forces and moments applied to the footing must be expressed at the centre of the base of the footing.



For each load case, the following should be filled out:

- Design value of the vertical force $Q_{v,d}$ (kN);
- Design value of the horizontal force $Q_{h,d}$ (kN);
- Design value of the moment along B $M_{B,d}$ (kN.m);
- Design value of the moment along L $M_{L,d}$ (kN.m);
- Type of design combination: SLS-QP, SLS-CARAC, ULS-FOND, ULS-ACC or ULS-SEISMIC.

The first row is created automatically by Fondsup. Click the button to create each additional load case.

Case n°	**$Q_{v,d}$ (kN)**	**$Q_{h,d}$ (kN)**	**$M_{B,d}$ (kN.m)**	**$M_{L,d}$ (kN.m)**	**Combination**
1	3500	0	0	0	SLS-QP
2	3000	250	500	500	SLS-CARAC
3	4700	400	600	600	ULS-FOND
4	4700	600	1000	1000	ULS-ACC
5	4700	800	1200	1200	ULS-SISMIQUE

J.4.1.5. Calculation and results

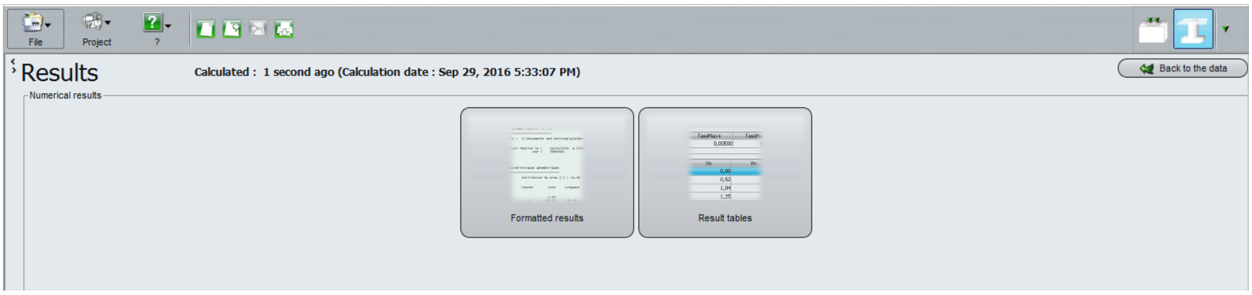
J.4.1.5.1. Calculation

Until the tabs are correctly filled out, the button used to start the calculation is shown with a red cross: Start calculation.

Once all the data have been correctly input, the Start calculation button becomes active and is available from all the tabs. Clicking this button will start the calculation.

J.4.1.5.2. Results

To access the results, click the See results button.



<u>Formatted numerical results</u>

This file reports the calculation data and details all the intermediate parameters used in the calculation, according to the rules and conventions of the regulatory framework chosen (here standard NF P 94 261).


```
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 Programme FondSup v2.1.0                    (c) TERRASOL 2016

 File :  Z:\Logiciel TS\02 - Foxta\Example\EXAMPLE 1\Example 1[FS].resu

 Calcul réalisé le :    29/09/2016  à 17h44
                by :   Terrasol

Paramètres de calcul :
    - calcul basé sur des paramètres issus du pressiomètre de Ménard
    - calcul selon la norme NF P 94 261 - EC7
    - profils de pl* et EM définis par couche

 Base de la fondation Zd           -2.00

 Toit du terrain initial Zini       0.00
 Toit du terrain final Zfin         0.00

 Fondation rectangulaire :
         largeur B                  3.00
         longueur L                 4.00

Caractéristiques du sol (données utilisateur)

    Classe du sol de fondation : Argiles et limons
    Type de comportement       : parfaitement cohérent

    Poids volumique moyen du sol au dessus de Zd    18.00
    Coefficient rheologique du sol de fondation      0.45

    Couche     base         pl*          EM
    ------------------------------------------
      01       -5.00      800.00      8000.00
      02      -12.00     1200.00     10000.00
      03      -30.00     2500.00     20000.00

Discrétisation des couches (Paramètres du calcul)

    Pas du calcul    0.50

couche    point        cote         pl*          EM
-----------------------------------------------------
  01        1          0.00       800.00      8000.00
  01        2         -0.50       800.00      8000.00
  01        3         -1.00       800.00      8000.00
```

```
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    Hauteur de calcul Hr                   4.50

    Coefficient réducteur idb              0.84

    Contrainte initiale q0                36.00
    Contrainte ultime nette qu           746.05
    ______________________________________________

    Facteur de pondération global F        1.44

    Résultante de la contrainte
    intiale sous la fondation R0         432.00

    Valeur de calcul de l'effort de
    résistance nette du terrain Rv,d    4767.65

    Portance     : V,d - R0 < Rv,d         =>  OK!
    Excentricité : Surface comprimée > 10%  =>  OK!

=====================================================
    Cas de charge n° :   005  - Combinaison ELU-SISM
=====================================================

         Charge verticale V,d      4700.00
         Charge horizontale H,d     800.00
         Moment Mb,d               1200.00
         Moment Ml,d               1200.00

          --------------------------
           PORTANCE ET RENVERSEMENT
          --------------------------

    Excentricité de la charge selon B      0.26
    Excentricité de la charge selon L      0.26
    Surface d'assise effective A'          8.69

    Pression limite équiv. Ple           915.77
    Hauteur de calcul Hr                   4.50

    Coefficient réducteur idb              0.80

    Contrainte initiale q0                36.00
    Contrainte ultime nette qu           703.65
    ______________________________________________

    Facteur de pondération global F        1.68

    Résultante de la contrainte
    intiale sous la fondation R0         432.00

    Valeur de calcul de l'effort de
    résistance nette du terrain Rv,d    3638.18

    Portance     : V,d - R0 > Rv,d         =>  Non justifiée!
    Excentricité : Surface comprimée > 10%  =>  OK!
```

Results tables

This table gives a summary of the main calculation results to be used for the design of the footing.

Export | Back to the index

Results

Number of the load case	Combination	$Q_{v,d}$ [kN]	δ_d [°]	$e_{B,d}$ [m]	$e_{L,d}$ [m]	$R_{v,d}$ [kN]	R_0 [kN]	Punching	Tilting	Settlement
1	SLS-Quasi-permanent	3500,00	0,00	0,00	0,00	3840,00	432,00	Ok	Ok	13.7
2	SLS-Characteristic	3000,00	4,76	0,17	0,17	2810,00	432,00	Ok	Ok	-
3	ULS-Fundamental	4700,00	4,86	0,13	0,13	4830,00	432,00	Ok	Ok	-
4	ULS-Accidental	4700,00	7,28	0,21	0,21	4770,00	432,00	Ok	Ok	-
5	ULS-Seismic	4700,00	9,66	0,26	0,26	3640,00	432,00	Invalid	Ok	-

This example shows the following results:

- ⇨ Settlement of 13.7 mm under load SLS-QP;
- ⇨ Tilting checked for all load cases;
- ⇨ Bearing capacity checked for load cases 1 to 4.
- ⇨ For case n°5, the bearing capacity is not checked (insufficient soil resistance).

The result obtained for load case 5 leads to propose an increase:

- ⇨ Of the footing dimensions;
- ⇨ and/or of the embedment depth.

J.4.2. Processing in TASPLAQ

We now propose repeating the previous calculation for the SLS-QP and SLS-CARAC calculations using the TASPLAQ module.

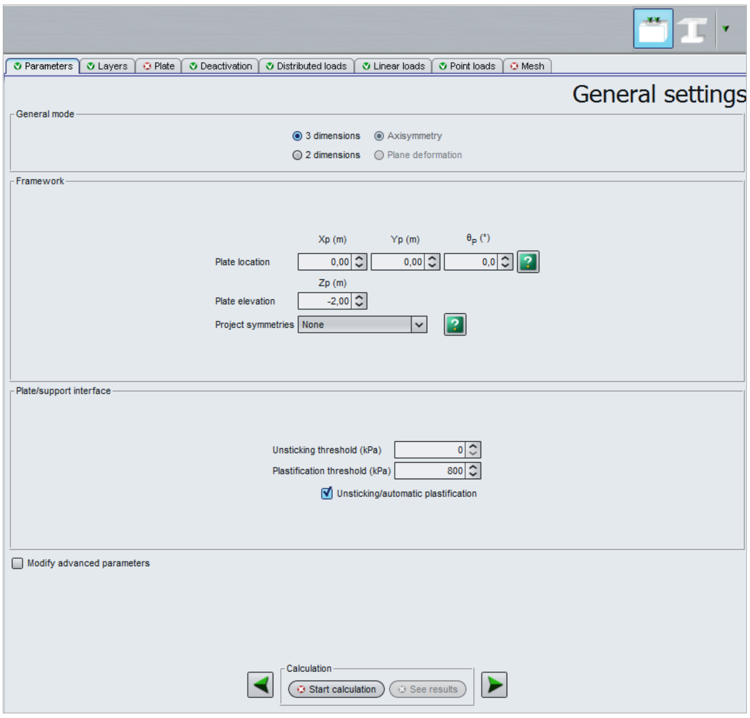
Open the TASPLAQ module by clicking the 

button.

J.4.2.1. Calculation under SLS-QP load

J.4.2.1.1. "Parameters" tab

This tab contains 4 different frames. Input the data shown on the following screenshot.



<u>"General mode" frame</u>:

As the model studied is three-dimensional,

- Click the "3 dimensions" radio-button.

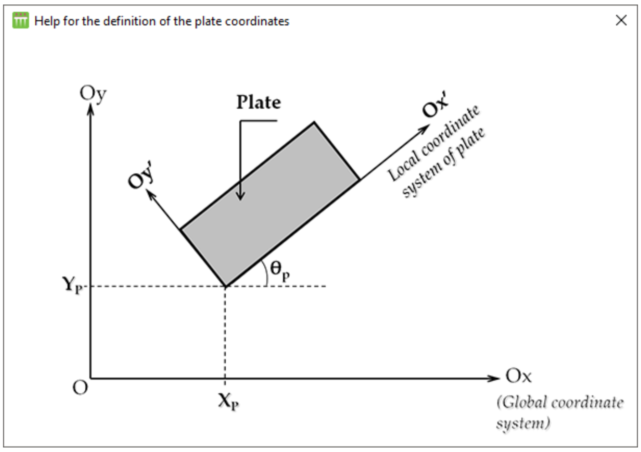
<u>"Framework" frame</u>:

In this example, the local coordinates system for the plate representative of the footing is considered to be identical to the global coordinates system of the model. The point (0,0) represents the "bottom-left" corner of the model.

- Position of the plate:

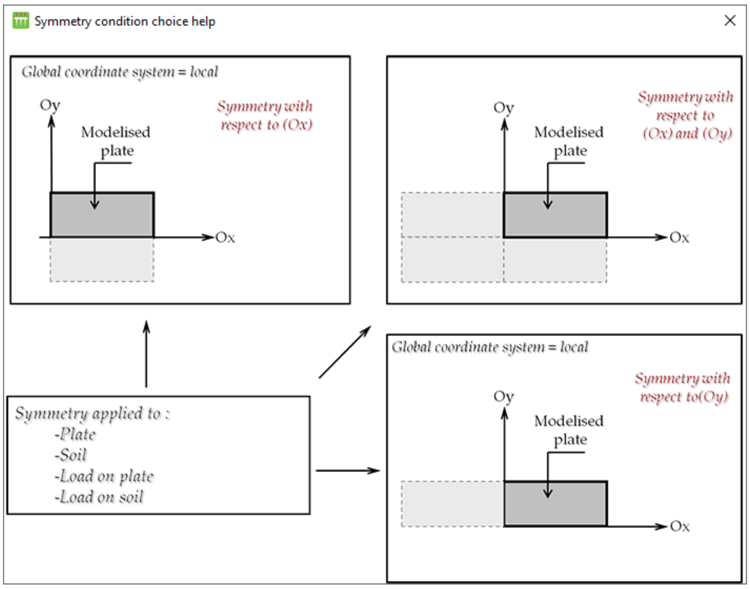
X_p (m)	Y_p (m)	θ_p (°)
0.00	0.00	0.00

It is possible to place and tilt the geometrical coordinates system of the model in any way (following help diagram).



- Plate elevation: Z_p (m) = -2.00 (reference level = level of the base of the footing).
- Project symmetry: None

In Tasplaq, it is possible to define axes of symmetry in order to simplify certain modelling operations (which could have been the case here, but we chose not to use them).



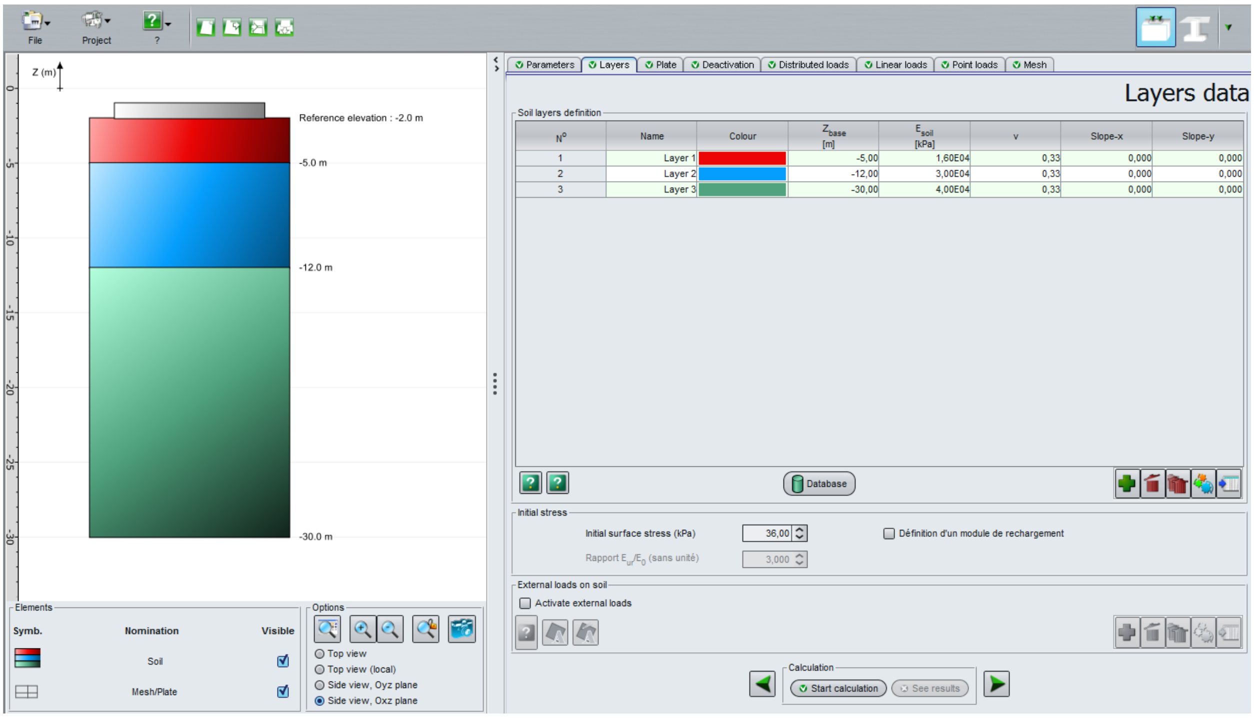
<u>"Plate/support interface" frame</u>:

This frame is used to activate automatic management of the unsticking and plastification criteria with user-defined criteria. The following values are proposed.

Unsticking threshold (kPa)	0
Plastification threshold (kPa)	800
Unsticking/automatic plastification	Ticked

To move to the next tab, click either the name of the "Layers" tab, or the button.

J.4.2.1.2. "Layers" tab



<u>"Soil layers definition" frame</u>:

Click the button to create each soil layer.

The data to be input are specified below. The deformation modules proposed were chosen from the correlation E = k x E_M/α, with k =1 as an initial approach. The subject of this part of the exercise is precisely to adjust the value of "k" to obtain settlements comparable to those calculated previously with the Fondsup module.

Name	Z_{base} (m)	E_{soil} (kPa)	ν	Slope-x	Slope-y
Layer 1	-5.0	1.60E+04	0.33	0	0
Layer 2	-12.0	3.00E+04	0.33	0	0
Layer 3	-30.0	4.00E+04	0.33	0	0

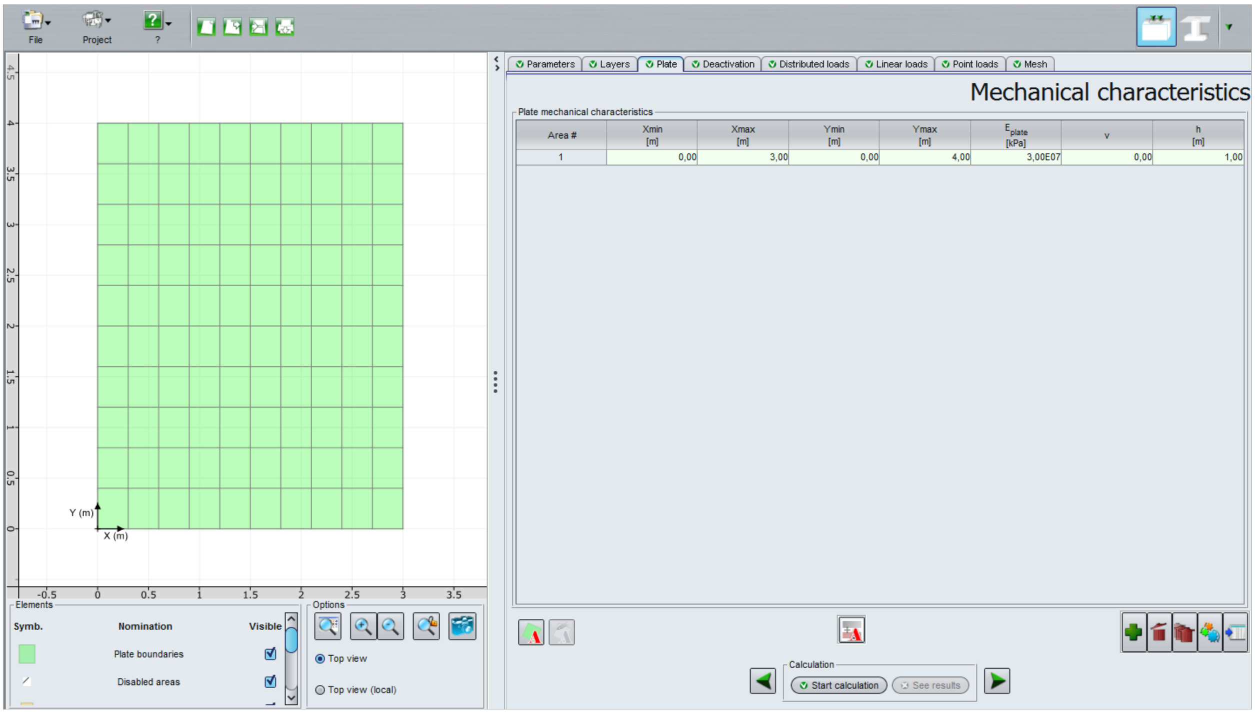
- Initial stress at surface: 36 kPa (corresponding to the unit weight of the soil of 18 kN/m^3 above the base of the foundation).

<u>"External loads on soil" frame</u>:

- Activate external loads: unticked.

J.4.2.1.3. "Plate" tab

In this example, we only model the base of the footing, which is homogeneous and continuous. To define its characteristics, one just has to define a single zone covering the entire model: i.e. from Xmin = 0 to Xmax = 3 m along Ox and from Ymin = 0 to Ymax = 4 m along Oy.



<u>"Plate mechanical characteristics" frame</u>:

The base of the footing is assumed to be 1 m thick.

Group	Xmin (m)	Xmax (m)	Ymin (m)	Ymax (m)	E_{plate} (kPa)	ν	h (m)
1	0	3	0	4	3.00E+07	0.00	1.00

The choice of a nil Poisson's ratio is explained by the hypothesis of a footing made of reinforced concrete. In reality, as we are only here interested in the displacement calculations, the choice of the value of the Poisson's ratio has little influence on the result.

J.4.2.1.4. "Deactivation" tab

In this example, there are no elements to be deactivated, as the plate representative of the footing is solid and rectangular.

J.4.2.1.5. "Distributed loads" tab

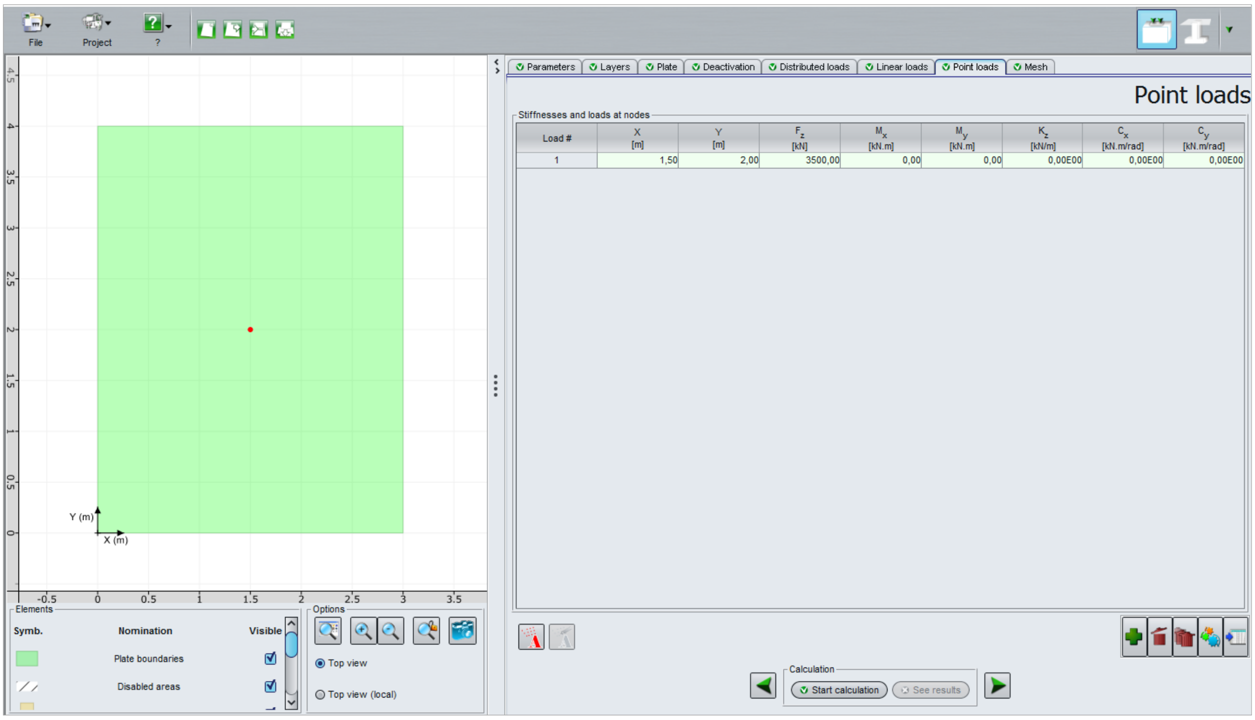
There are no distributed loads to be defined in this step.

J.4.2.1.6. "Linear loads" tab

There are no linear loads to be defined in this step.

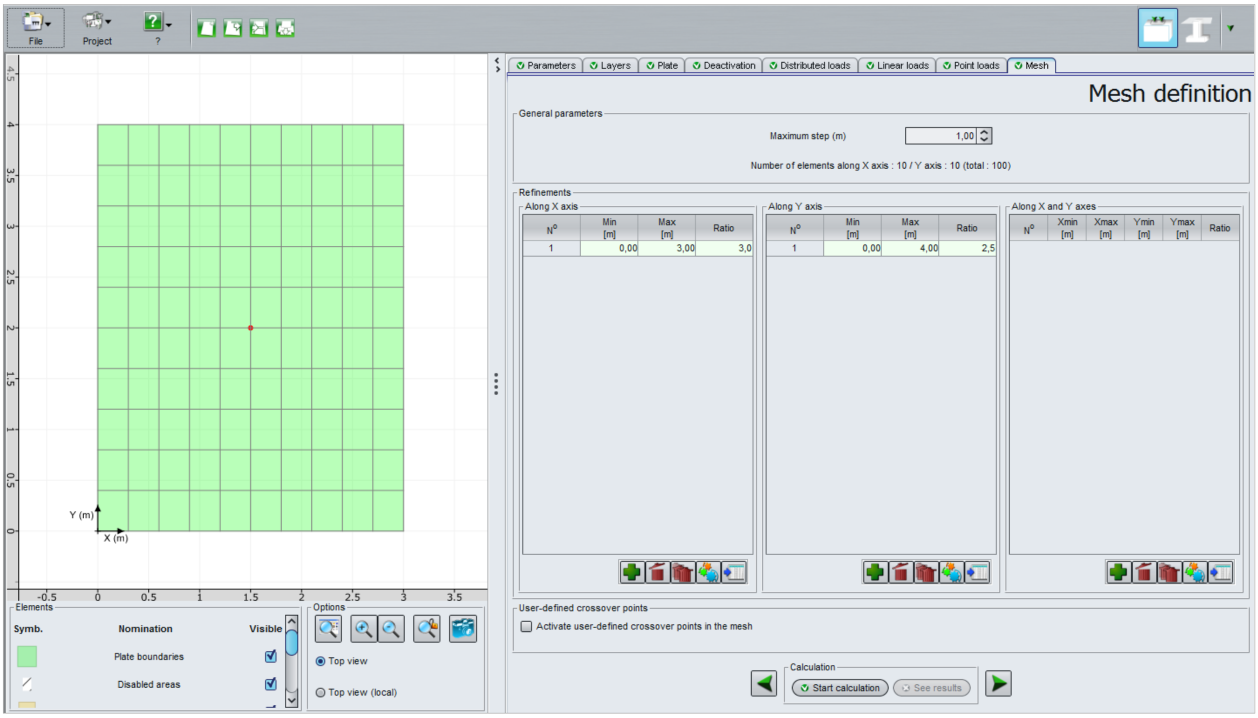
J.4.2.1.7. "Point loads" tab

Here we define the vertical load applied to the footing: Fz = 3500 kN (combination SLS-QP). This is to be applied to the centre of the footing, i.e. at X = 1.50 m and Y = 2.00 m.



J.4.2.1.8. "Mesh" tab

We choose to run the calculation with a mesh of 10 x 10 elements. To do this, we propose choosing a maximum step of 1 m with the definition of two refinement zones along X and Y, enabling a step of 0.3 m to be obtained along X and 0.4 m along Y.



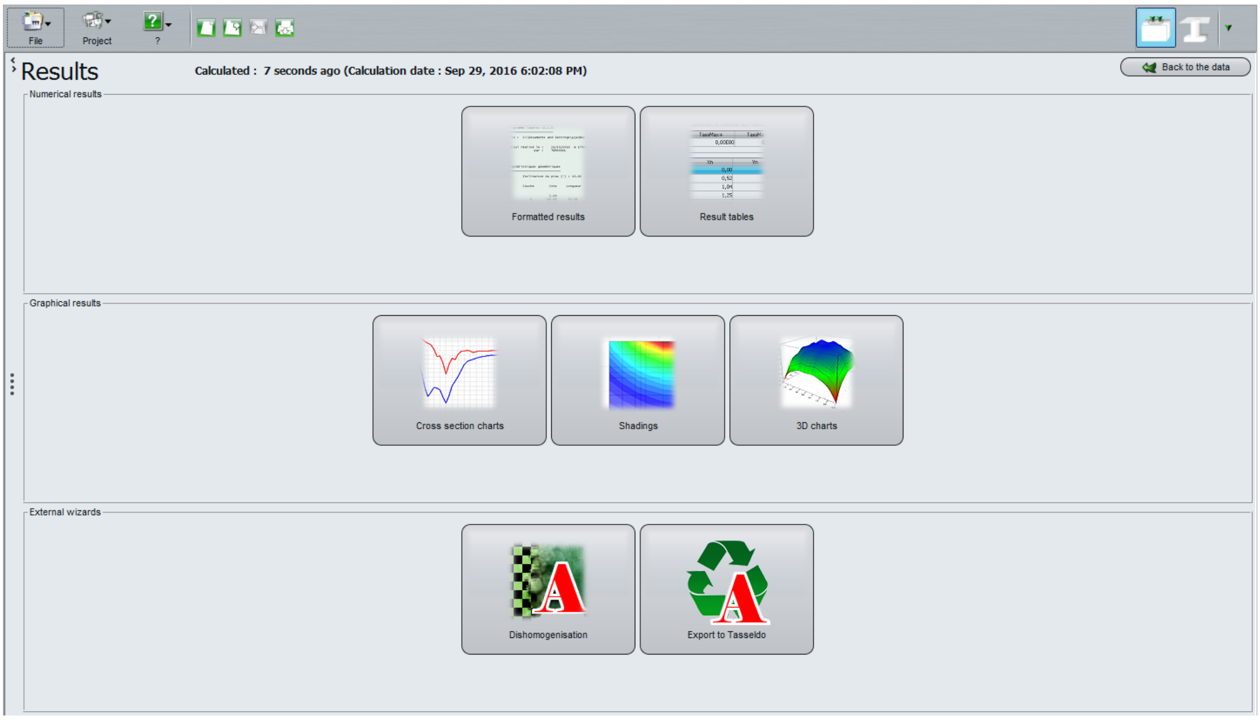
J.4.2.1.9. Calculation and results

Calculation

Click the Start calculation button.

A window shows the progress of the calculation engine. Click the Close button to close this window at the end of the calculation.

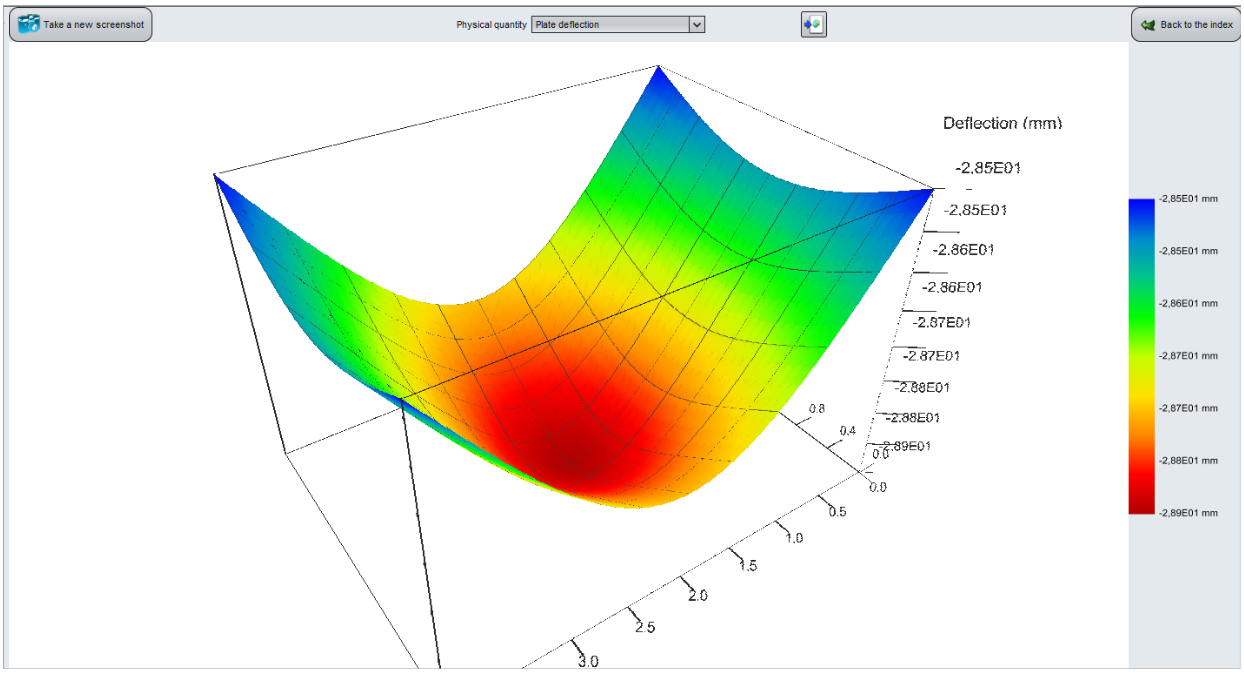
To access the results in the form of tables and graphics, click the See results button:



Results

Graphic results

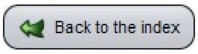
Click the "3D charts" button: by default the deflection of the plate is displayed:



The maximum deflection of the plate (in the centre) is 2.9 cm.

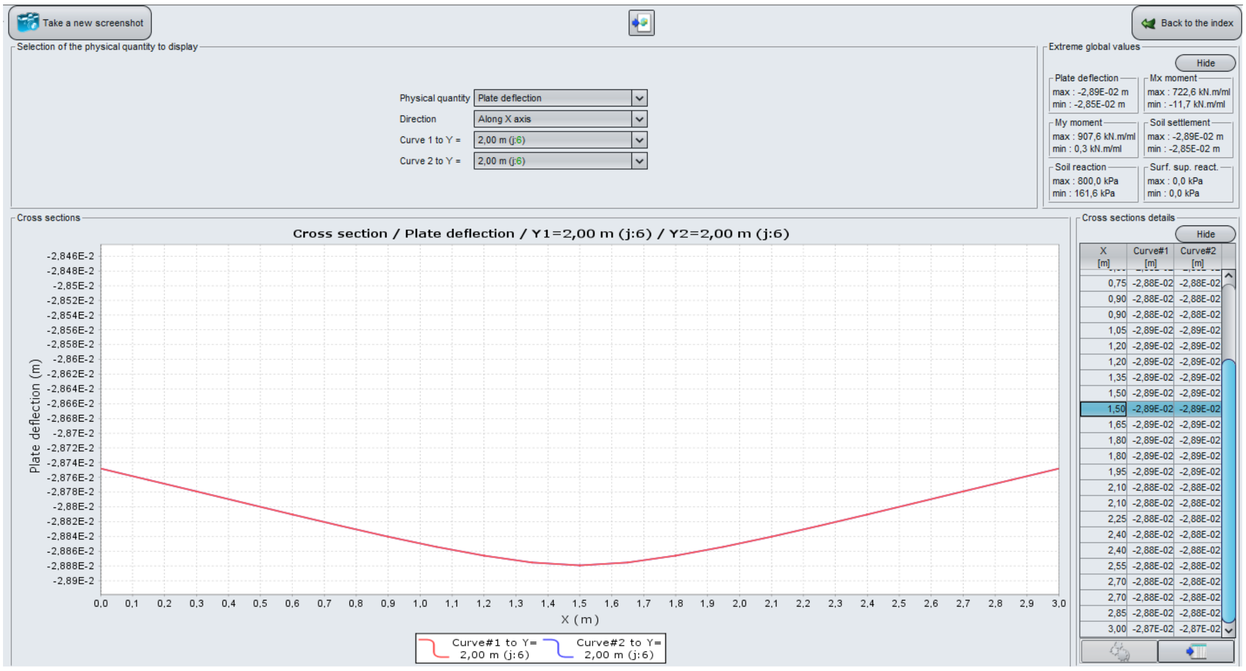
The minimum deflection value (in the corners) is 2.85 cm: plate settlement is therefore virtually uniform over the entire plate (rigid footing).

Note: the deflection of the plate and the settlement of the soil are identical for this example (no separation).

Click the  button and click the "Cross-section charts" button.

"Plate deflection" cross-section along X with:

Section 1 (and 2) at Y = 2.00 m (j: 6): Max. deflection of 2.9 cm at X = 1.50 m

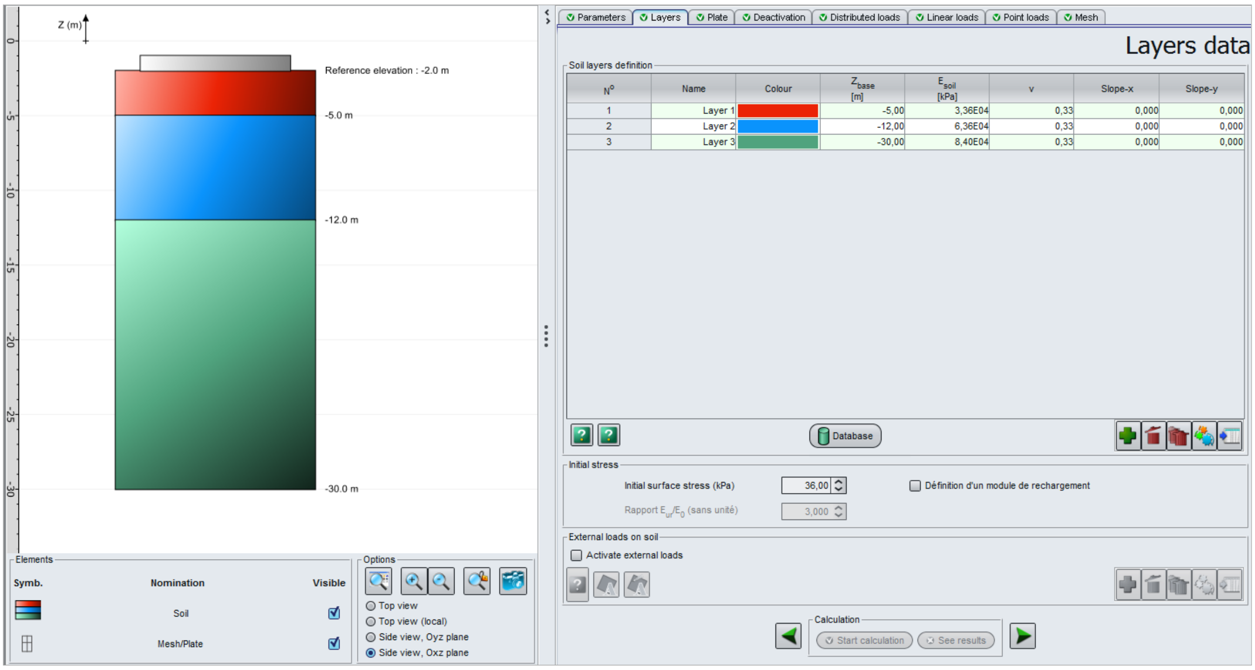


This cross-section confirms the previous observations: virtually uniform deflection, with maximum value in the centre of the plate of 2.9 cm.

The settlement obtained in the Tasplaq module is about 2.1 times higher than that previously calculated by Fondsup. The pressuremeter method used in Fondsup is empirical and gives results closely in line with the settlements actually observed. We will thus adjust the soil moduli E so as to obtain equal settlements between the elastic (Tasplaq) and pressuremeter (Fondsup) methods. For this, we choose k = 2.1 ($E = 2.1 \times E_M/\alpha$).

J.4.2.1.10. Adjustment of soil moduli

"Layers" tab

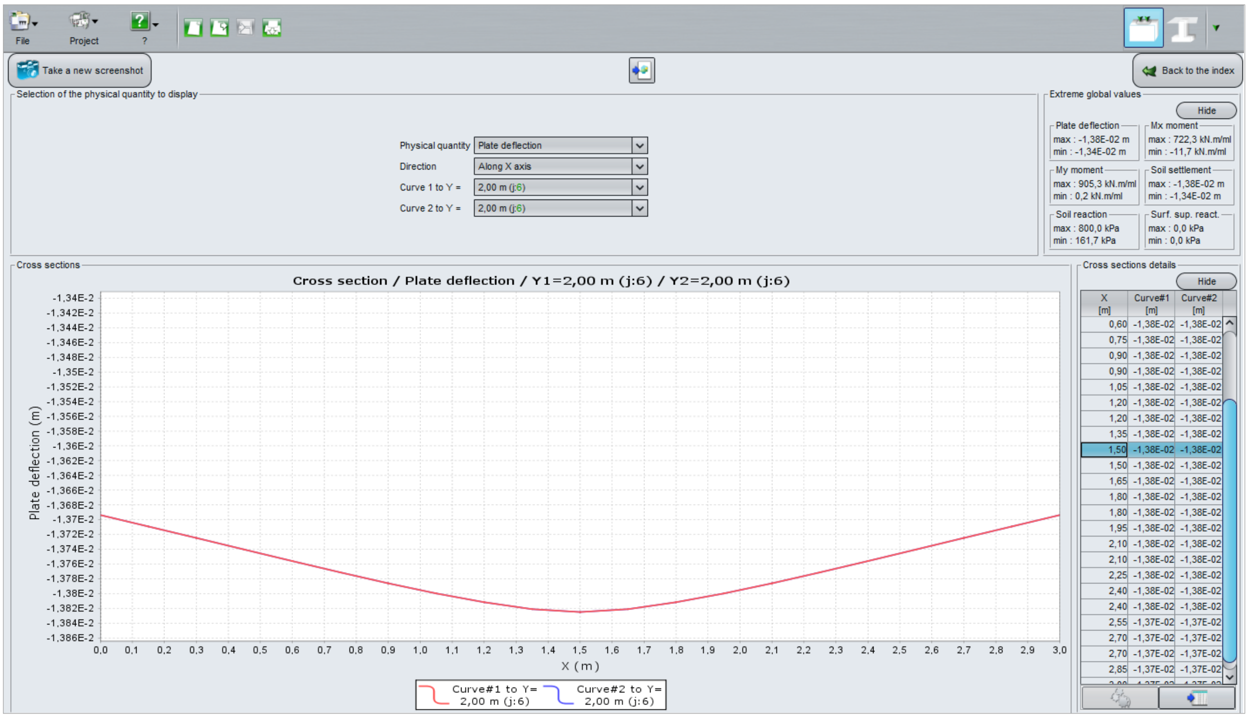


The data to be input (modified modulus values) are as follows:

Name	Z_{base} (m)	E_{soil} (kPa)	ν	Slope-x	Slope-y
Layer 1	-5.0	**3.36E+04**	0.33	0	0
Layer 2	-12.0	**6.36E+04**	0.33	0	0
Layer 3	-30.0	**8.40E+04**	0.33	0	0

Click the "Start calculation" button to run the calculation again and then "See results" to check the results.

This time, the settlement obtained (1.38 cm) is very close to that obtained with Fondsup in the first step.



Save your project under a different name before continuing.

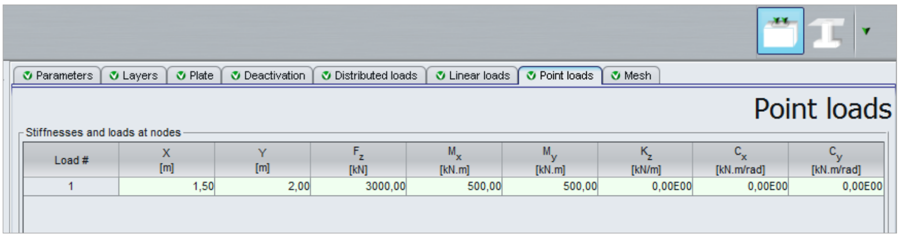
J.4.2.2. Calculation under SLS-CARAC load

Under a SLS-CARAC combination, and in addition to the vertical force of 3000 kN, the footing is also subjected to two bending moments M_x = 500 kN.m and M_y = 500 kN.m.

J.4.2.2.1. "Point loads" tab

As shown in the following screenshot, modify the definition of the point load with the following values:

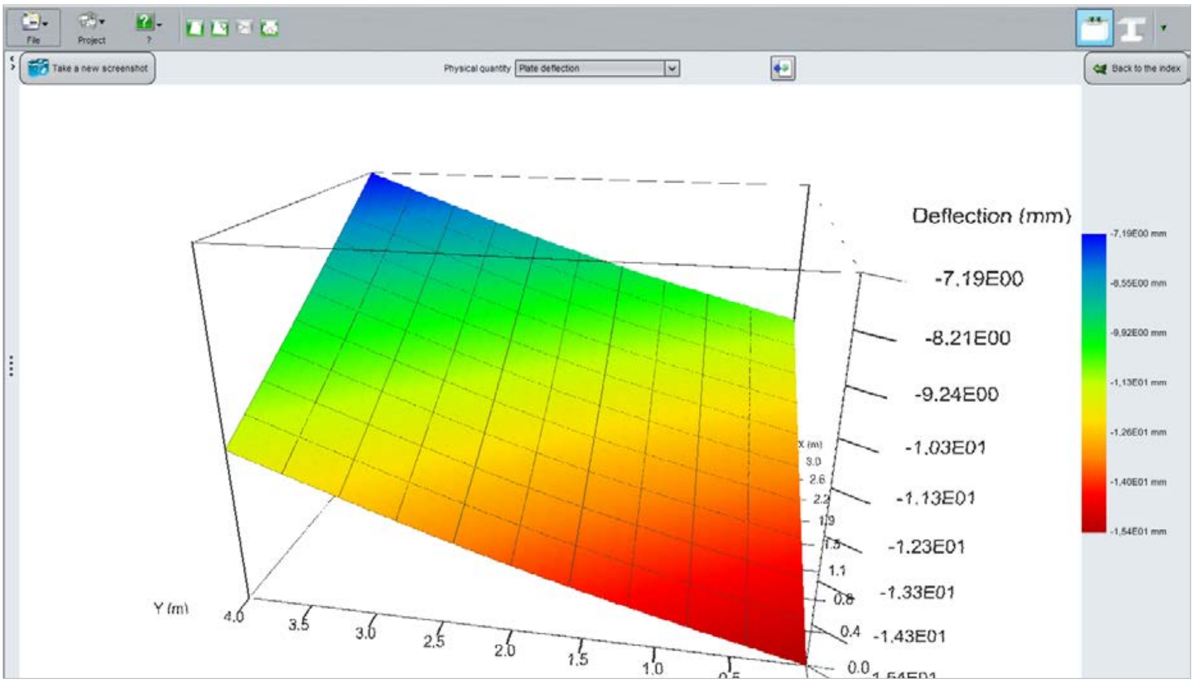
- F_z = 3000 kN
- M_x (moment around axis –Oy) = 500 kN.m
- M_y (moment around axis Ox) = 500 kN.m



Load #	X [m]	Y [m]	F_z [kN]	M_x [kN.m]	M_y [kN.m]	K_z [kN/m]	C_x [kN.m/rad]	C_y [kN.m/rad]
1	1,50	2,00	3000,00	500,00	500,00	0,00E00	0,00E00	0,00E00

J.4.2.2.2. Calculation and results

<u>3D graphic results – Plate deflection</u>



This time, we observe a tilting of the footing, with maximum settlement in the corner most "loaded by the moments" of 1.54 cm, and a minimum settlement in the opposite corner of 0.72 cm. The plate acts as a rigid block.

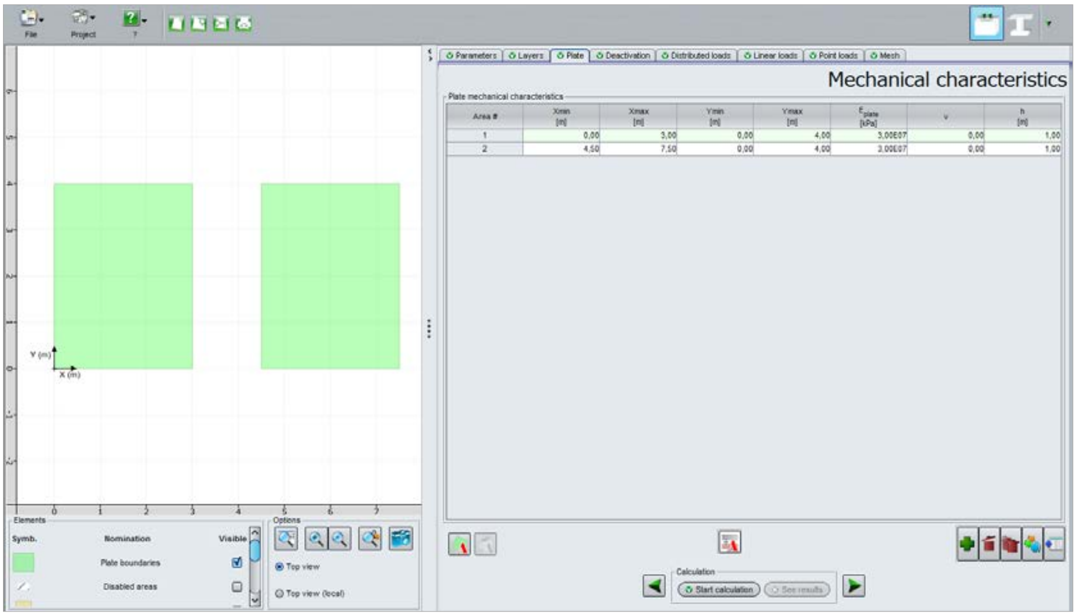
Again save your file under a different name before continuing.

J.4.2.3. Interaction between two neighbouring footings

We will now examine the interaction between two neighbouring identical footings, separated by a distance of 1.5 m. For this, we will extend the mesh along X, to integrate the plate representative of the second footing and then deactivate the central part corresponding to the distance between both footings.

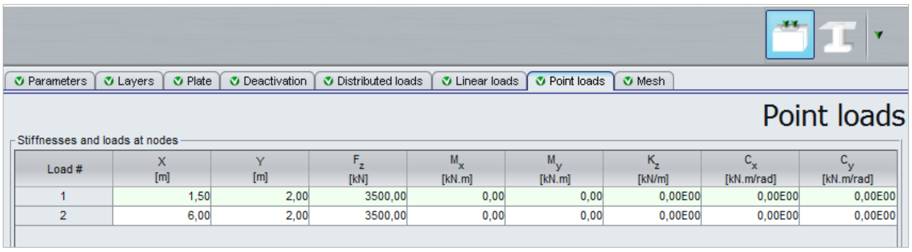
J.4.2.3.1. "Plate" tab

In order to model the second footing, simply declare it in the Plate tab as shown in the figure below. The "empty" zone between the two footings will be automatically considered by the programme to be a "deactivated" zone of the model.



J.4.2.3.2. "Point loads" tab

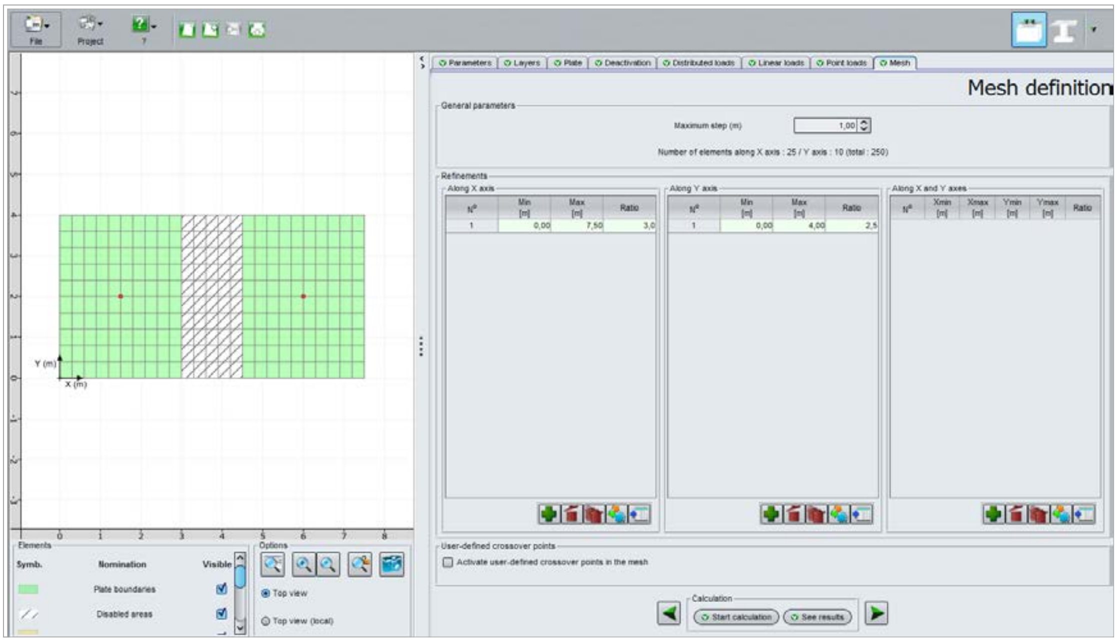
Here we use the load SLS-QP (Fz = 3500 kN), applied to the centre of each of the 2 footings: X = 1.5 m / Y = 2.0 m for footing 1, X = 6.0 m / Y = 2.0 m for footing 2.



Load #	X [m]	Y [m]	F_z [kN]	M_x [kN.m]	M_y [kN.m]	K_z [kN/m]	C_x [kN.m/rad]	C_y [kN.m/rad]
1	1,50	2,00	3500,00	0,00	0,00	0,00E00	0,00E00	0,00E00
2	6,00	2,00	3500,00	0,00	0,00	0,00E00	0,00E00	0,00E00

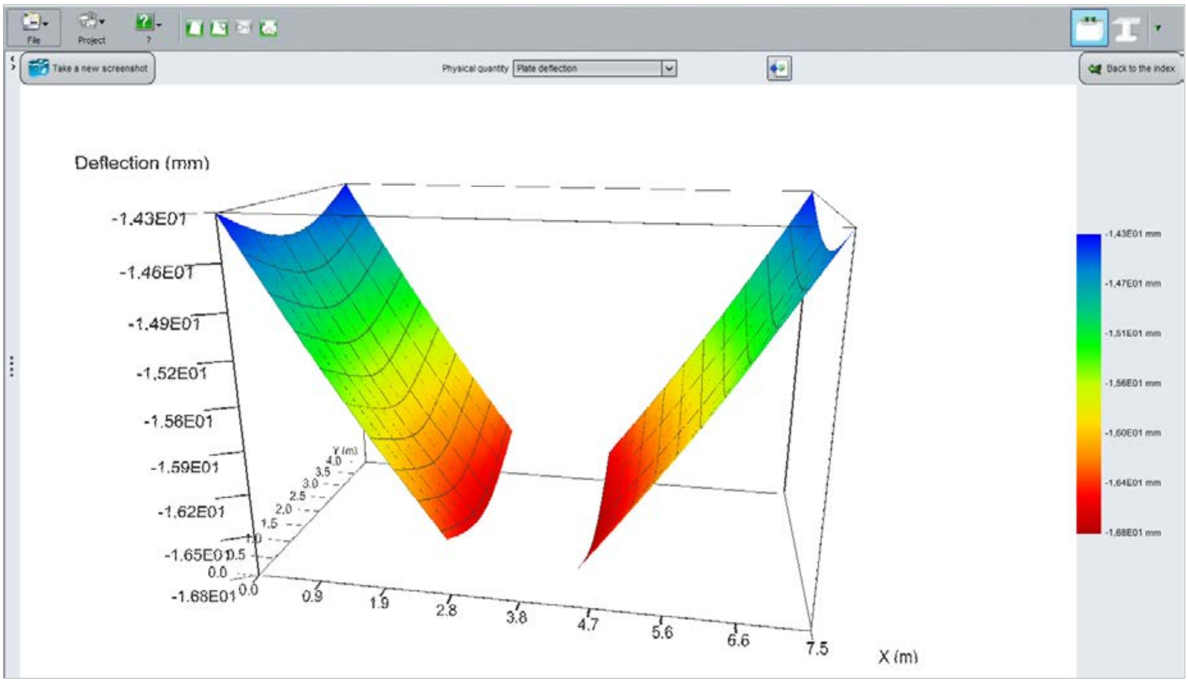
J.4.2.3.3. "Mesh" tab

We use the same mesh as for the case of a single footing: step of 0.3 m along Ox and 0.4 m along Y. To do this, simply follow the indications in the following figure.



J.4.2.3.4. Calculation and results

3D graphic results – Plate deflection



The model is symmetrical and behaves as such.

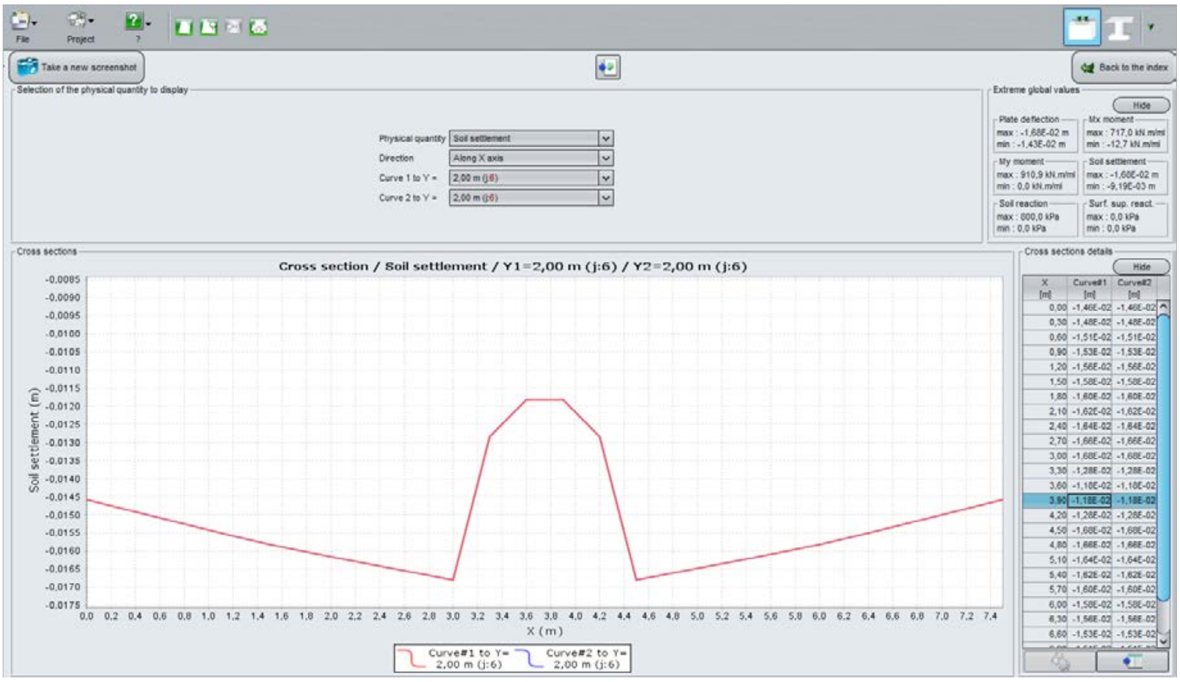
Each footing tilts towards the central zone (under the effect of its own load and the load of the neighbouring plate). This type of behaviour could not have been obtained with a model "on springs".

The maximum deflection of each footing (on the side closest to the other plate) is 1.68 cm. The minimum deflection of each footing ("exterior" side) is 1.43 cm.

The zone between both plates does not appear on the 3D view of plate deflection because the plate was indeed deactivated in the central zone.

Graphic cross-sections – Soil settlement

Section 1 (and 2) along X at Y = 2.00 m (j: 6): Settlement of 1.17 cm at X = 3.75 m



It should be noted that the differential settlement of each footing (edge to edge) is 0.22 cm, i.e. less than 0.1%, which is acceptable.

Note: the soil settlement is displayed continuously, even for the zone in which the plate was deactivated. The shape of each footing can be clearly identified.