



Foxta v3

Part F: TASPIE+ MODULE

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F.1. Introduction

Taspie+ module is used to simulate the behaviour of all types of single deep foundations, under axial loads, taking account or not of the surrounding soil volume, when this element belongs to a group or a network. This deep foundation element is called pile to simplify matters.

The calculation is based on the transfer function notion (laws establishing the relation between, on the one hand, the shaft friction and the displacement of the pile and, on the other hand, the base resistance and the displacement). The transfer function notion was originally presented by Coyle and Reese (ASCE, 1966). It is generalised in Taspie+ considering both:

- The relative pile-soil displacement instead of the absolute displacement of the pile both for the friction and for the base reaction which especially enlarges its field of application,
- Its extension to soil prisms of same section, placed above pile head or under its base.

F.2. Theoretical aspects

F.2.1. Notations

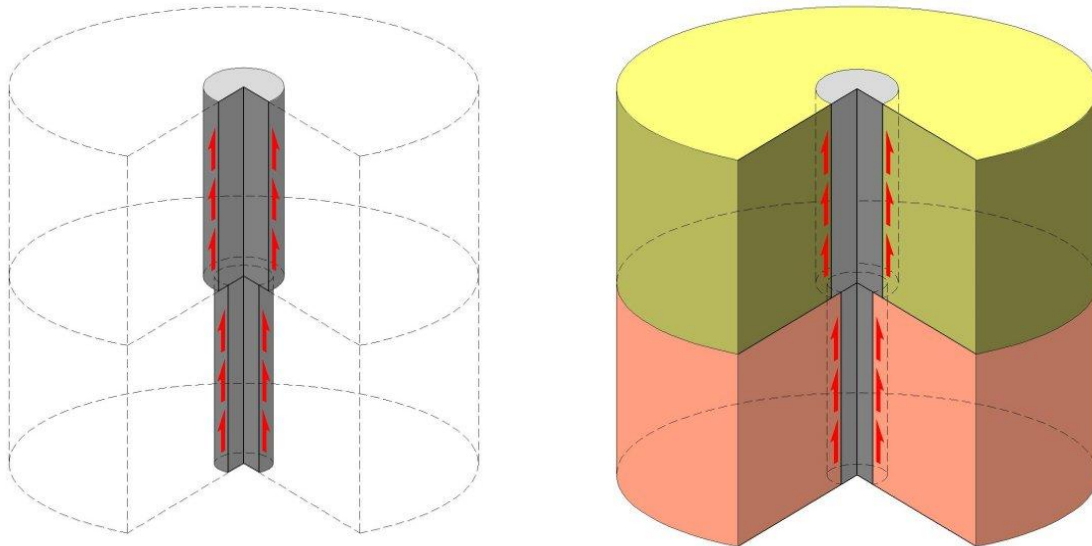
Below, the following notations are used:

C_R	Relaxation coefficient used in a backfill type calculation
D_s	Equivalent diameter of foundation from a perimeter point of view
D_p	Equivalent diameter of pile from section point of view
E_M	Pressuremeter modulus of layer
E_p	Young's modulus of pile
E_{QP}	Fraction of total load applied to head of model which is directly supported by pile head
E_s	Strain modulus representative of soil
H, H_i	Height of a model layer (soil and pile characteristics constant)
P	Pile perimeter
q_s	Pile-soil unit shaft friction (called q_{sl} in Taspie+ users' interface)
q_p	Limit stress under pile base
$Q_p(z)$	Normal force in pile at depth z
$Q_s(z)$	Load vertical resultant transmitted to soil at depth z
S	Section of computational domain ($S = S_p(z) + S_s(z)$) for all z values
$S_p(z)$	Pile section at depth z
$S_s(z)$	Additional soil section at depth S
$y_p(z)$	Pile settlement at depth (z)
$y_s(z)$	<u>Average</u> settlement of soil at depth z
$w(z)$	Relative displacement: $w(z) = y_p(z) - y_s(z)$
τ	Shear against pile
γ_p	Pile unit weight
γ_s	Soil unit weight
ΣH	Total height of computational domain

F.2.2. Principle of model

Two calculation models can be adopted (Figure F.1):

- Model limited to the deep foundation element (1a): the interaction with the surrounding soil is assumed to be entirely described by the chosen transfer laws. However, a settlement of the soil around the pile can be taken into account in the form of an imposed settlement profile which remains independent of the calculation result. The pile axis can have any orientation;
- Model containing the deep foundation element and the associated soil elementary mesh (1b). The interaction between these two domains is taken into account which means that the pile behaviour is affected by the settlement of the surrounding soil and that the soil settlement also depends on the distribution of the forces in the pile. The pile axis is necessarily vertical.



1a: Pile model alone

1b: Pile model and associated soil cylinder

Figure F.1 : Model of pile alone and model of pile and associated soil cylinder

Model 1a can be used to establish:

- The loading curve of a single pile in a medium where the settlements are neglected;
- The loading curve of a single pile when the soil settlement profile in the pile axis is assumed known and independent of the load applied to the pile. This case be that:
 - of a pile made from the bottom of an excavation which passes through layers submitted to extension;
 - a pile passing through layers submitted to a swelling phenomenon;
 - a pile installed in a soil medium which settles under the action of external factors (loads on surface or drawdown).

Model 1b is used to study the behaviour of a periodic pattern within a group of identical piles. This applies notably:

- to The study of an elementary mesh of the reinforcement of a soil by vertical rigid inclusions:
 - under a slab in association with an intermediary layer acting as load transfer platform; the loading conditions at head can often be compared in first approximation to an imposed displacement condition (the internal strains of the slab being negligible compared with the absolute settlements, the settlement on underside of slab being considered uniform over mesh width);
 - under a backfill. This case is that of backfills on piles ("piled embankment"). The loading conditions at head are generally those of a uniform imposed stress at mesh head.
- to The study of the elementary pattern of a mixed foundation associating a slab and piles directly connected to it.
 - Taspie+ model applies in a privileged manner to piles placed in the central part of the work if the centre-to-centre distance in the two directions remains near to an average value;
 - it can also apply to peripheral piles provided certain simplification assumptions are made.

F.2.3. Formulation

The formulation of the equations of the problem is explained in the most general case of model 1b: pile and associated soil volume.

F.2.3.1 General assumptions

- Only the axial loads in the pile are considered;
- The geometry of the problem is assumed at radial symmetry: the pile and the associated soil elementary volume are compared to cylinders of equivalent geometry;
- The load is also assumed at radial symmetry;
- The loads applied to the model are represented by the total load applied at head and the weight of added layers (not present in initial state);
- The model is assumed periodic which means that shear is null on the outer vertical faces;
- The studied mesh is defined by its dimensions in two orthogonal directions;
- The geometry of the pile (and of any associated soil upper and lower volumes) is defined by horizontal layers (diameter for a circular section or section and perimeter for an irregular section).

F.2.3.2 Equations governing model equilibrium

The equilibrium equations express the conservation of the forces in all model horizontal sections (origin of depths is fixed at top of model).

Note:

- The notation is lightened for all the input data which is defined per layer (deletion of identification index of each layer);
- "Pile" indifferently designates the deep foundation element and the upper or lower soil volumes possibly extending it.

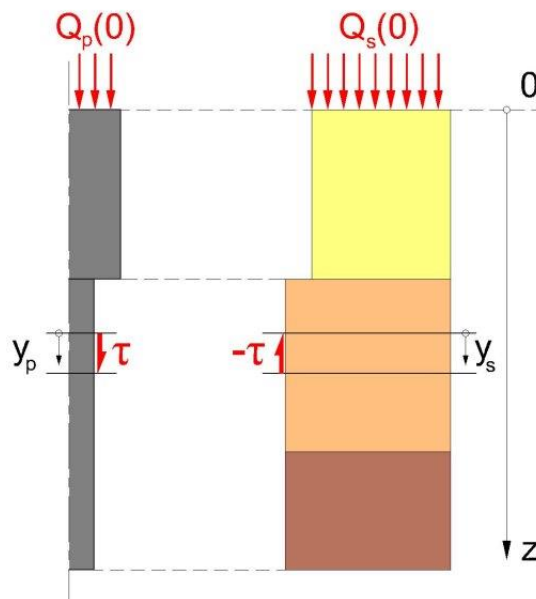


Figure F.2 : Interaction between the two domains of model 1b (pile and associated soil cylinder)

In pile:

$$dQ_p(z) = (\tau p + \gamma_p s_p) dz \quad (1)$$

In soil:

$$dQ_s(z) = (-\tau p + \gamma_s s_s) dz \quad (2)$$

τ represents the shear developed at pile-soil interface by interaction of the two domains.
 γ_s designates the unit weight of the layers which did not exist in initial state and participate in the loading of the model.

Equations (1) and (2) lead to the conversation of the forces in the complete model:

$$dQ_p(z) + dQ_s(z) = (\gamma_p s_p + \gamma_s s_s) dz \quad (3)$$

The pile settlement and the average soil settlement meet the following additional equations:

$$dy_p(z) = \frac{Q_p(z)}{s_p E_p} dz \quad (4)$$

$$dy_s(z) = \frac{Q_s(z)}{s_s E_s} dz \quad (5)$$

$E_p(z)$ is Young's modulus of the material constituting the pile.

$E_s(z)$ designates the apparent strain modulus of the soil for an applied loading level. Taking the model periodicity assumption into account, this modulus can be compared to an oedometric modulus in the case of compressible soils (null lateral strains at model edges).

Equation (5) showing the vertical resultant of the loads applied to the soil enables an estimation of the average soil settlement at depth z .

The interaction between the two domains (pile and additional soil volume) is assumed as entirely described in each layer by a transfer function expressing the dependency of shear τ with the relative displacement between the two domains:

$$\tau = f(y_p - y_s) \quad (6)$$

F.2.4. Transfer functions

The transfer functions relevant to shear can be defined in any way by the user in the form of a set of value pairs (w_i, τ_i) or with reference to semi-empirical formulations based on pressuremeter modulus E_M and shaft friction q_s which have been proposed by Frank and Zhao (1982) or Monnet (2000).

F.2.4.1 According to Frank and Zhao (1982)

A transfer law for the friction and a law for the stress under the base are defined.

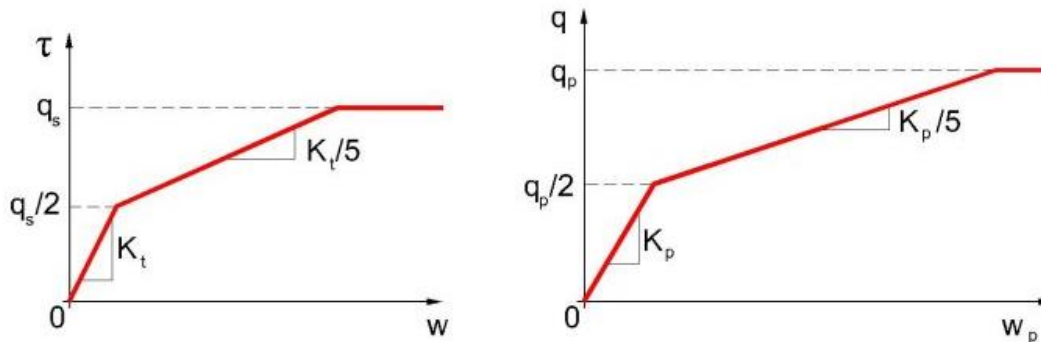


Figure F.3 : Friction and base resistance mobilisation laws (Frank and Zhao, 1982)

For bored piles in fine soils:

$$K_t = \frac{2E_M}{D_s} \quad \text{and} \quad K_p = \frac{11E_M}{D_p} \quad (7)$$

For bored piles in granular soils:

$$K_t = \frac{0.8E_M}{D_s} \quad \text{and} \quad K_p = \frac{4.8E_M}{D_p} \quad (8)$$

If there is no specific experimental data, the same rules are retained for driven piles in fine or granular soils.

F.2.4.2 According to Monnet (2000)

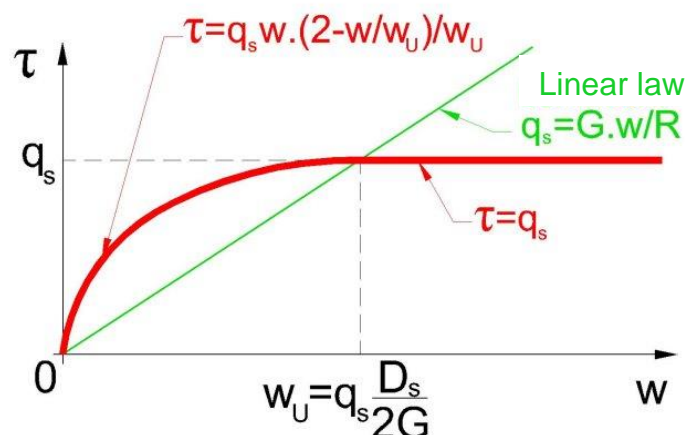


Figure F.4 : Friction mobilisation laws (Monnet, 2000)

$$\tau = q_s w \frac{\left(2 - \frac{w}{w_u}\right)}{w_u} \tag{9}$$

Where

$$w_u = q_s \frac{1.5\alpha}{E_M} D_s \tag{10}$$

This formulation is obtained by comparing the shear modulus G of the soil to $E_M/3\alpha$.

F.2.4.3 Negative friction case

In Taspie+, the transfer function notion is applied to relative displacement $w = (y_p - y_s)$ rather than to absolute displacement.

When soil settlement y_s is higher than pile settlement y_p , friction is negative.

The negative friction mobilisation as a function of the relative settlement is the same as in the positive domain, to within weighting coefficient γ , defined by the user, which is applied not only to the friction but also to the displacement. As Figure F.5 shows, the limit points are displaced according to a homothety of factor γ but the slope of the straight lines is unchanged.

When weighting coefficient is taken as equal to 1, the mobilisation curves $\tau(w)$ are symmetrical with respect to the origin.

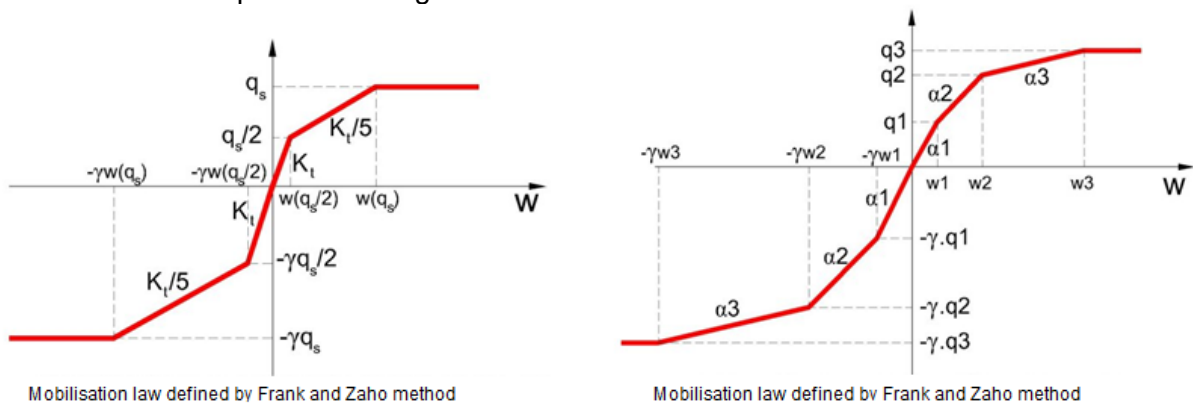


Figure F.5 : Extension of friction mobilisation laws for negative relative displacements

F.2.5. Resolution

F.2.5.1 General resolution method

To solve the nonlinear system constituted by equations (1), (2), (4), (5) and (6), Taspie+ module is provided with two additional calculation kernels:

- Main kernel: matrix resolution by finite elements;
- Secondary kernel: step-by-step resolution by finite differences.

The main kernel (matrix resolution) applies to configurations where the transfer curve corresponds to an increasing monotone function with a single plastification plateau (last plateau). This covers most cases.

In cases where the transfer curve includes one or more decreasing plateaux (degradation, fatigue...), the matrix formulation of the main kernel is no longer valid and the secondary kernel (step-by-step resolution) is automatically used.

F.2.5.2 Single pile model (model 1a)

The equation system (1), (2), (4), (5) and (6) is completed by the following boundary conditions:

- Value $Q_p(0)$ of load applied at pile head;
- Mobilisation curve of stress under pile base;
- Possible definition of an imposed settlement profile $y_s(z)$ around the pile.

The solution obtained guarantees the compatibility of the settlements with the mobilised friction and the load taken at base.

The calculation gives the distribution of the normal force at all points, the settlement and the shaft friction for the load applied. The results are completed by the loading (or extraction) curve of pile at head (load-displacement) up to failure.

F.2.5.3 Pile + associated soil model (model 1b) – calculation at imposed stresses (backfill type)

The equation system (1), (2), (4), (5) and (6) is completed by the following conditions:

- Value $Q(0)$ of total load applied at top of model;
- Fraction of total load supported directly by head of pile domain (factor E_{QP});
- Mobilisation curve of stress under base of pile (domain);
- Null settlement condition at base of soil domain.

The loading studied also includes the weights of the layers of the profile declared added with respect to the original state. These layers (total thickness ΣH_i) are at the origin of the volumic forces which increase the total resultant of the forces applied to the quantity model ($\Sigma H_i \gamma_i$). S_i designating here only the added layers and S the section of the model (studied elementary mesh surface).

The solution obtained guarantees compatibility at all points of the pile/soil settlement differential with the mobilised friction and the load taken at base.

The calculation gives, for the studied loading condition, the distribution at all points of the normal force and of the settlement developing in the two pile and soil domains and the shaft friction distribution at the interface of the two domains.

F.2.5.4 Pile + associated soil model (model 1b) – calculation at imposed strains (slab type)

The equation system (1), (2), (4), (5) and (6) is completed by the following conditions:

- Value $Q(0)$ of the total load applied at top of model;
- Pile settlement equality condition and soil settlement at model head: $y_p(0) = y_s(0)$;
- Mobilisation curve of stress under base of pile (domain);
- Null settlement condition at base of soil domain.

The slab type calculation is different from that of backfill type by the fact that load transfer at head of model between pile and soil, represented by factor E_{QP} , is a result and not problem data. This factor is automatically sought to meet the head settlement equality condition. Thus, a slab type calculation corresponds to several "backfill" type calculations done according to a dichotomic search process.

The loading studied also includes the weight of the profile layers which are declared added by the user with respect to the original state. These layers (total thickness ΣH_i) are at the origin of the volumic forces which increase the total resultant of the forces applied to the quantity model ($\Sigma H_i \gamma_i$). S_i designating here only the added layers and S the section of the model (studied elementary mesh surface).

In a slab type calculation, the load transfer platform is generally to be processed as an added layer unless a previous backfill was done.

The solution obtained guarantees, on the one hand, the equality of pile settlement and of soil average settlement at model head and, on the other hand, the compatibility, at all points, of the pile/soil settlement differential with the mobilised friction and the load taken at base.

The calculation gives, for the total loading condition studied, the distribution at all points of the normal force and of the settlement developing in the two pile and soil domains and the shaft friction distribution at the interface of the two domains.

F.2.6. Validity domain

F.2.6.1 Validity of choice of maximum friction values

The maximum friction values are defined by the user for each layer.

Generally, for piles or inclusions, these maximum values must be chosen with reference to the maximum values deduced from pile axial loading tests conducted according to an identical methodology in layers with comparable geotechnical properties. If there are no direct experimental references, the values generally adopted are those of the French application standard for Eurocode 7 relating to deep foundations (NF P 94 – 262).

In applications addressing reinforcement under a backfill or load transfer layer, the pile element is assumed extended by a cylinder of section identical to the pile head to which the backfill or load transfer layer properties are assigned (E modulus, unit weight γ). It must be checked that the max value q_s adopted for this layer remains compatible with the state of the stresses around the pile. It is therefore recommended to compare the q_s values of the maximum friction and τ of the mobilised friction on the elements of the fictive pile with the average vertical stress values between inclusions.

It is suggested that the maximum value $q_s(z) = \sigma_s(z)$ is adopted along the pile; this assumption is indeed equivalent to the choice of recommended value $K \tan \delta = 1$ to process by the Combarieu negative friction theory the cases of backfills above piles or inclusions.

In applications processing soil reinforcement, the consistency of the maximum friction values q_s introduced with the stress state in the soil must be checked in the part submitted to negative friction. This leads to checking that the following condition is met:

$$q_s \leq K \tan \delta \sigma'_s \quad (11)$$

where:

- $K \tan \delta$: negative friction coefficient applicable to the considered layer
- σ'_s : vertical stress in the soil calculated at same level

A graphic wizard facilitates this data consistency check.

F.2.6.2 Validity of choice of strain modulus E_s values

Modulus E_s defined for each soil layer is a secant modulus which expresses the relation between the average additional vertical stress in the soil and the settlement of this layer:

$$\frac{\Delta y_s}{\Delta z} = \frac{\Delta \sigma_s}{E_s} \quad (12)$$

Generally, the validity of modulus E_s must be assessed with regard to strain level ε_z of each layer when a more sophisticated behaviour law is known. In the compressible layers and on account of the conditions imposed on the outer faces of the studied volume, the stress/strain relation can be described directly from an oedometric law:

$$\frac{\Delta y_s}{\Delta z} = \frac{C_s}{(1+e_0)} \log\left(\frac{\sigma'_p}{\sigma'_{v0}}\right) + \frac{C_s}{(1+e_0)} \log\left(\frac{\sigma'_{v0} + \Delta \sigma_s}{\sigma'_p}\right) \quad (13)$$

Over the height of the load transfer platform or the backfill above the pile, the strain conditions can be compared to oedometric conditions: especially near to the head of the inclusions where shear mobilisation τ causes a substantial rotation of the stresses. As these layers are generally less compressible than the underlying soils, the distinction between Young's modulus and oedometric modulus can however most often be ignored with regard to the respective settlement values expected on the height of the platform and the height of the compressible soil.

The concentration of stresses above the pile head can also lead to differentiate between the value of the attributed module, over the height of a backfill layer, in the soil domain (low value σ_s) and in the pile domain (high value σ_s) when the material concerned reveals a marked dependency of the strain module with the stress level.

F.2.6.3 Check of consistency of stress state in platform

In compliance with ASIRI recommendations, the consistency of the stresses calculated on inclusion head and the soil at same level must be checked with regard to the shear characteristics assigned to the load transfer layer (or the backfill, if there is no specific load transfer layer).

$$\sigma'_{inc} \leq N_q \sigma'_{soil} + c' N_c \quad (14)$$

Where:

- σ'_{inc} : stress on inclusion head
- σ'_{soil} : mean stress on soil at head level
- c' : possible intergranular cohesion of the material constituting the platform

N_q and N_c , Prandtl bearing coefficients, must be evaluated for the friction angle value of the blanket in critical state.

When this check does not give satisfactory results, the load transfer layer modulus in line with the inclusion must be reduced (without modifying the one assigned to the same layer, between the inclusions) until compatible constraints σ'_{inc} and σ'_{soil} are obtained.

This iterative procedure consists in defining a secant modulus of the platform, above the inclusions, compatible with the plasticity criterion which is expressed by relation (14).

F.2.7. Extension of model 1b under pile base

For a soil reinforcement (use of model 1b), it may be recommended to choose a geometry for the pile domain such that its equivalent diameter is practically null (very low non-null value) in the sections located at more than $1.5 D_p$ under the pile base (D_p equivalent diameter at pile base). These arrangements, based on the ratio existing between the mobilisation curves of base and of friction, according to Frank and Zhao, in effect ensure that the mobilised force at pile base is integrally transmitted to the soil domain at more than $1.5 D_p$ under the pile base and that under this depth the section of the soil domain becomes equal to that of the calculation mesh.

It is necessary to assign to the pile domain section located less than $1.5 D_p$ under the real base of the pile a negative friction q_s^* such that the maximum resultant on the cylinder of height $1.5 D_p$ is equal to the maximum resultant under the inclusion base $[(\pi D_p^2/4) \times q_p]$. This condition is achieved with: $q_s^* = q_p/6$.

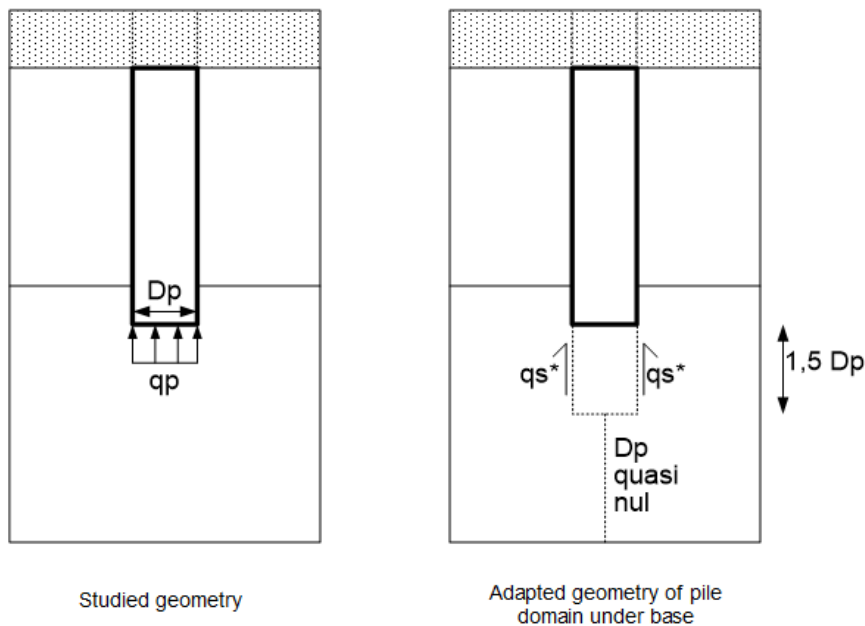


Figure F.6 : Extension of model under pile base

F.2.8. Bearing capacity calculations

In all cases, the program calculates the following regulatory bearing capacity values (according to standard NF P 94 262):

- Maximum values of ultimate loads of friction and of base (without weighting);
- Maximum value of critical creep load (without weighting);
- The allowable loads at SLS (in quasi-permanent and characteristic combinations) and at ULS (in fundamental and accidental combinations).

These calculations are done for the complete length of the pile (all soil layers are taken into account).

For a pile and associated soil medium type calculation, the program searches for the elevation where the load in the pile is maximum (neutral plane), calculates the ultimate load and the maximum creep load (according to the rules of standard NF P 94 -262) for the pile section placed under this elevation and displays the overall safety available with respect to the maximum load obtained.

F.2.9. Estimation of stiffnesses at pile head

For a "single pile" type calculation, a calculation of equivalent stiffness at pile head is done both for the service load applied at head and for a load equal to 70% of the maximum creep load. The latter is used by default as input parameter for pile group calculation in Groupie+ module. The stiffness is expressed as the ratio of load at pile head and corresponding displacement.

For a pile and soil cylinder associated with soil type calculation, the equivalent surface stiffnesses are estimated for load $Q(0)$ defined by the user. The surface stiffness at the pile is obtained by dividing the stress at head of the pile domain by the displacement at head of the pile domain and the surface stiffness at the soil domain by dividing the average vertical stress applied at head of the ground domain by the average settlement at this level.

The ASIRI recommendations explain how to exploit the surface stiffnesses thus obtained to establish a simplified equivalent stiffness distribution around each inclusion and between the inclusions capable of supplying a representative estimation of the moments in the slab. This equivalent surface stiffness distribution can be used in a Tasplaq model of the slab to establish the loads to which it is submitted under the applied loading.

F.2.10. Estimation of additional loads in slab (model 1b)

The results of the Taspie+ model can be used to evaluate the additional loads in the slab due to the presence of inclusions. These are to be combined with those obtained from a slab calculation on equivalent homogenised soil.

The calculation principle consists in comparing the behaviour of the slab in standard section to the behaviour of an equivalent circular plate clamped at edge (by symmetry) and submitted to the application of an overload q_0 on its upper face and to the reactions of the reinforced medium (σ_p , σ_s) on its lower face as shown on the figure below.

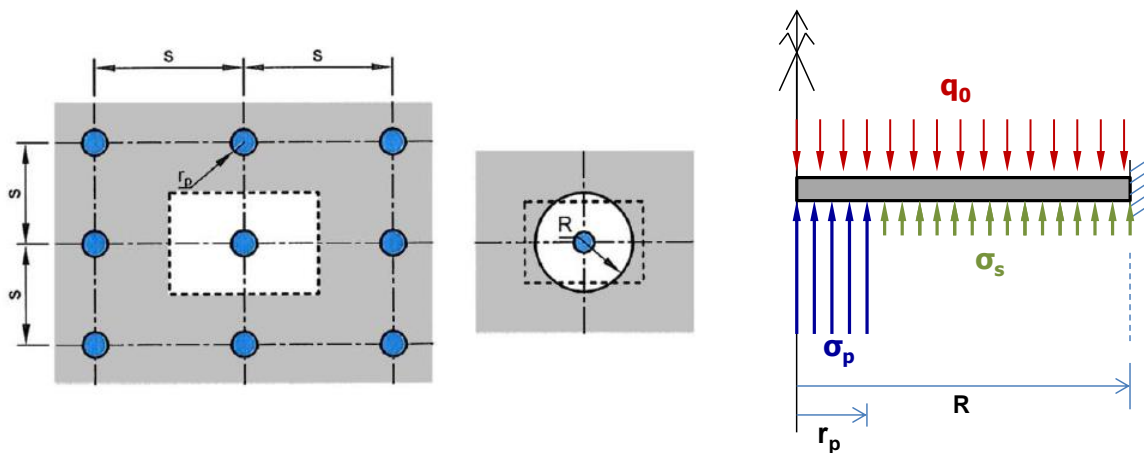


Figure F.7 : Result of outside forces applied to slab

The equivalent radius of the plate representative of the slab in an elementary mesh is directly related to the mesh pitch in each direction "a":

$$R = a / \pi^{1/2}$$

The reactions of the reinforced medium on underside of slab are broken down into two parts:

- Reaction at inclusions σ_p , assumed to develop on an impact radius " r_p ", usually calculated considering a distribution of the stresses at $1h/5v$ in the platform body from the inclusion head to the slab underside;
- Reactions between inclusions σ_s taken as equal to the stress applied to the soil obtained from Taspie+ model.

The load conservation equation allows value of σ_p to be obtained:

$$\sigma_p \times r_p^2 + \sigma_s \times (R^2 - r_p^2) = q_0 \times R^2$$

The equilibrium is then solved by applying the plate theory. For this, refer to the analytical formulas given in the "Engineer's Techniques C0265 – 5 and 6". The calculation of these loads is covered by a "slab moment" wizard described in F.3.9.4.

F.2.11. Bibliographical reference

- Eurocode 7
- NF P94-262 (french norme)
- ASIRI
- Frank, 1982
- Cuira/Simon (Alexandrie 2009)
- Cuira/Simon (Paris 2013)
- Dias/Simon (Paris 2013)
- Simon JNGG (2012)
- Simon (Edinburg)

F.3. USER'S MANUAL

In this chapter, we give:

- The Taspie+ module input parameters.
Certain zones can receive only data with a physical signification (for example, a soil strain modulus E_{soil} must always be strictly positive).

The Taspie+ calculation parameter input window includes 6 tabs. The data to be completed in each tab depends sometimes on certain choices made by the user: for example, the data to be completed for a "single pile with or without imposed soil settlement" calculation is not the same as for a "pile + associated soil mesh" calculation.

Note: It is possible, in the Taspie+ model, to process a single pile, or several piles corresponding to different pile configurations for a given project (see chapter F.3.1 below).

- The results supplied by Taspie+ module. Here again, they depend in part on the data entered by the user and, especially, the calculation type.

This chapter does not detail the user interface itself and its handling operations (buttons, menus, etc.): these aspects are addressed in part C of the manual.

F.3.1. Pile management

Taspie+ module allows one or more piles to be processed within the framework of a given Foxta project but the user can work on only one of these piles at a time: the "active" pile is displayed above the tabs of the data input window.

- When Taspie+ module is first opened for a given project, the module includes only one pile (Pile 1/1). The user must therefore complete this first pile and can then, if necessary, create additional piles (see below);
- When an already completed Taspie+ module is opened, the pile displayed by default is pile 1/n (n being the total number of piles already created in the module). It is then possible to select another pile, add piles or delete piles.

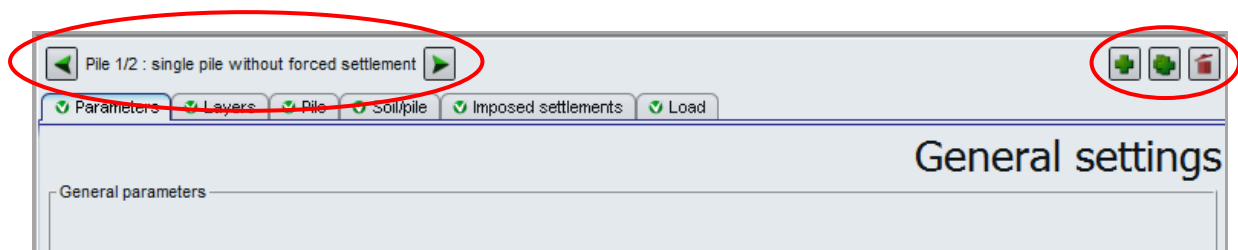







Figure F.8 : Pile management in Taspie+ module

The operations which can be done on piles in Taspie+ module are as follows:

- Add a pile: click  button: Foxta adds a new pile to the project, independent of the previous one, with the same input fields. Its number will be automatically incremented;
- To duplicate current pile, click  button: Foxta adds a pile identical to current pile to the project. The data is duplicated in this new pile but remains modifiable;
- To delete current pile, click  button;
- To display next pile or previous pile, click  or  button.

As stated previously, work can be done only on one pile at a time: the procedure is therefore to select the required pile, complete/modify its data, start the calculation then display the results for this pile. The user can then select another existing pile or create another pile and repeat these steps.

The chapters below describe the use of Taspie+ for a given pile.

F.3.2. "Parameters" tab

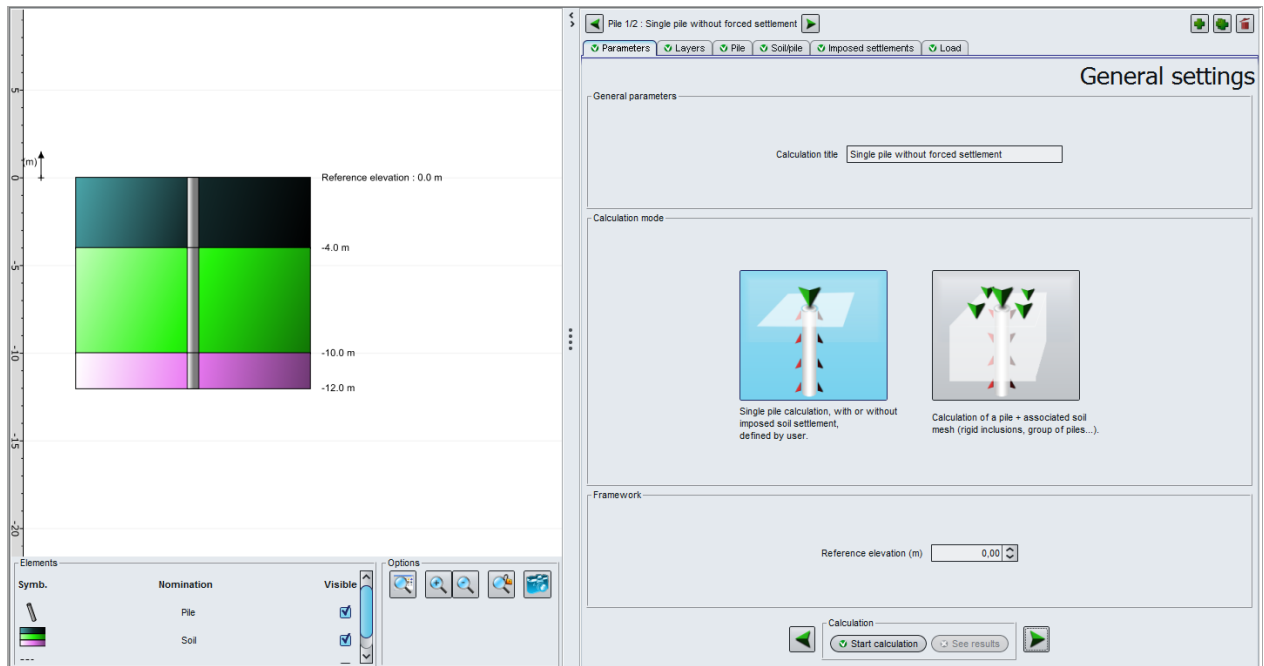


Figure F.9 : "Parameters" tab

F.3.2.1 "General parameters" box

Give calculation title.

F.3.2.2 "Calculation mode" box

Select:

- Either "Single pile calculation, with or without imposed soil settlement, defined by user";
- Or "Calculation of a pile + associated soil mesh (rigid inclusions, group of piles, ...).

F.3.2.3 "Framework" box

Give the reference elevation (m).

A summary table of the general parameters is given below:

Designation	Units	Default value	Display condition	Mandatory value
Title	-	-	Always	Yes
Calculation mode	-	Single pile	Always	Yes
Reference elevation	m	0,0	Always	Yes

Table F.1 : General parameters summary

F.3.3. "Layers" tab

This tab is used to define layers: the characteristics to be completed in the table vary with the type of calculation chosen: see subchapters F.3.3.1 and F.3.3.2.

IMPORTANT: by Taspie+ convention, the bottom of the pile is assumed to be at the level of the bottom of the last soil layer defined. Therefore, the soil cross section must be stopped at bottom of pile (except in certain "pile + associated mesh" cases which require an extension of the model under the toe of the piles, also check chapter F.2.7).

Foxta offers the possibility of recording the soil layers in the project soil database and/or in the soil global database by clicking  button.

This allows soil layers to be recorded with their parameters and avoids having to input them again when creating a new pile in Piecoef+ module or another Foxta project.

Use of soil database is described in detail in part C of the manual.

F.3.3.1 Calculation of a single pile (with or without imposed soil settlement)

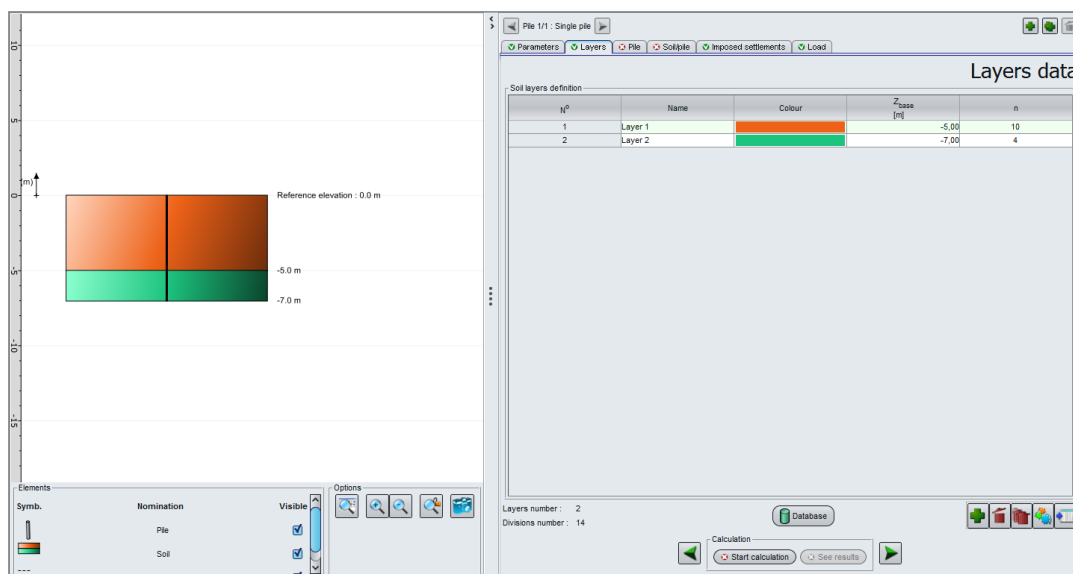


Figure F.10 : "Layer" tab for a calculation of a single pile with or without imposed soil settlement

A summary table of the layer definition parameters is given below:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
Name of layer	-	"Layer i"	Always	Yes	-
Colour of layer	-	Default colour	Always	Yes	-
Z: layer base elevation	m	1 m lower than layer base above	Always	Yes	Values strictly decreasing with depth
n: number of layer subdivisions	-	10	Always	Yes	> 0

Table F.2 : Summary of parameters required for soil definition - "Single pile" type calculation

F.3.3.2 Calculation of a pile + associated soil mesh

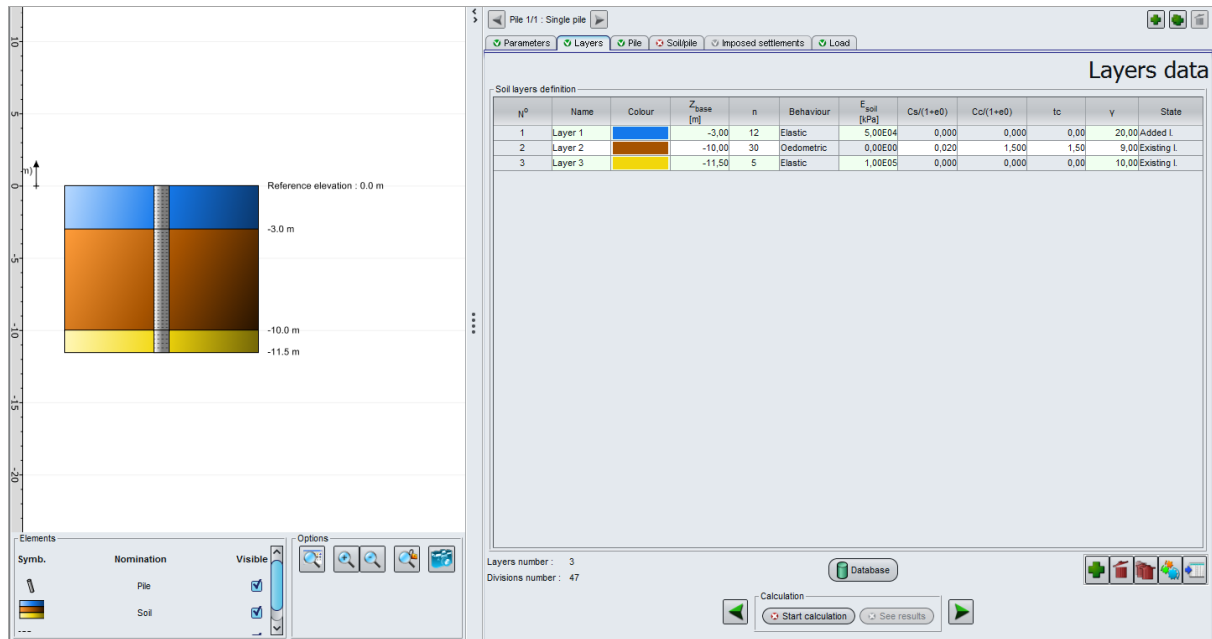


Figure F.11 : "Layer" tab for a calculation of a pile + associated soil mesh

The data defined for the single pile is also required here (see Table F.2).

The following additional data is also required for this type of calculation:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
Soil behaviour:	-	Elastic	Always	Yes	Possible values: elastic or oedometric
E _{soil} : layer strain modulus	kPa	-	If elastic behaviour		> 0
C _s /(1+e ₀): Swelling ratio	-	0	If oedometric behaviour		≥ 0
C _c /(1+e ₀): Consolidation ratio	-	0	If oedometric behaviour		≥ 0
t _c : Overconsolidation parameter	No units if >0, in kPa if <0	0	If oedometric behaviour		-
γ (or γ'): net unit weight of layer	kN/m ³	-	Always	Yes	> 0
State of layer (see chapter F.2.5)	-	Existing	Always	Yes	Possible values: given or existing

Table F.3 : Summary of parameters required for soil definition - "Pile + associated mesh" type calculation

The "net" unit weight of the layer is to be input as a function of the position of the ground water table:

- Input total unit weight in case where layer is located above ground water table;
- Input buoyant unit weight in case where layer is located under at top of ground water table.

The layer strain modulus must be chosen with reference to the stress path which can be anticipated: in particular, in compressible layers, choice of an "oedometric" type behaviour seems more suitable.

By convention, for an oedometric behaviour, the over-consolidation parameter t_c is interpreted as follows:

- $t_c = \frac{\sigma'_p}{\sigma'_{v0}}$ if input value is positive ($t_c > 0$);
- $t_c = -(\sigma'_p - \sigma'_{v0})$ if input value is negative ($t_c < 0$).

F.3.4. "Pile" tab

This tab allows the definition of the pile itself: geometry, implementation mode and strain modulus. The choice of certain characteristics conditions the type of data required.

F.3.4.1 "Pile type" box

Details of possible selections are given below (see screen copies in chapter F.3.4.2).

Designation	Units	Default value	Display condition	Mandatory value	Local checks
Implementation mode of pile	-	Without displacement	Always	Yes	Possible values: with or without displacement
Type of pile section	-	Circular section	Always	Yes	Possible values: circular or irregular section

Figure F.12 : Summary of parameters required in "Pile type" box

F.3.4.2 "Pile parameters" and "Pile definition in each layer" boxes

2 screen copy examples are given below illustrating various combinations of circular/irregular section and constant modulus/diameter or not along the pile.

In a circular section case, the section is assumed "solid" and the diameter alone is sufficient to define the exact geometry of the pile in each layer (that is to calculate the perimeter and section).

For an irregular section, give the pile perimeter which will be used for the calculation of the force due to shaft friction and the pile section which will be used for the pile axial stiffness calculation (ES) and for the base resistance.

Also, pile inclination in "Pile parameters" box can be modified only for a "Single pile" type calculation. For a "Pile + associated mesh" type calculation, the inclination is automatically fixed at 0° (vertical pile only).

For parameters given as constant along the pile by the user in "Pile parameters" box, define their values in this box and the value is automatically transferred (not modifiable) into the table below (as shown on Figure F.14).

However, for parameters not ticked as constants along the pile, the user must complete the parameter value for each soil layer (Taspie+ automatically takes the list of layers defined in previous tab, as shown on Figure F.13).

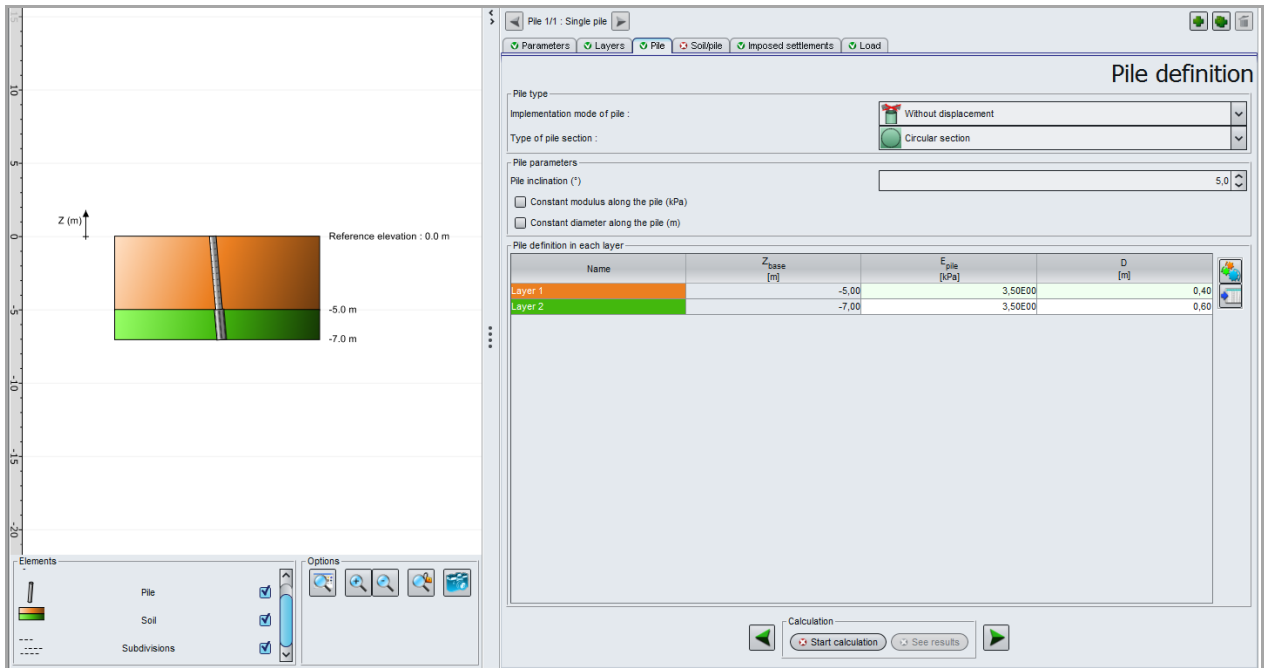


Figure F.13 : "Pile" tab for a circular section single pile, variable modulus along the pile calculation

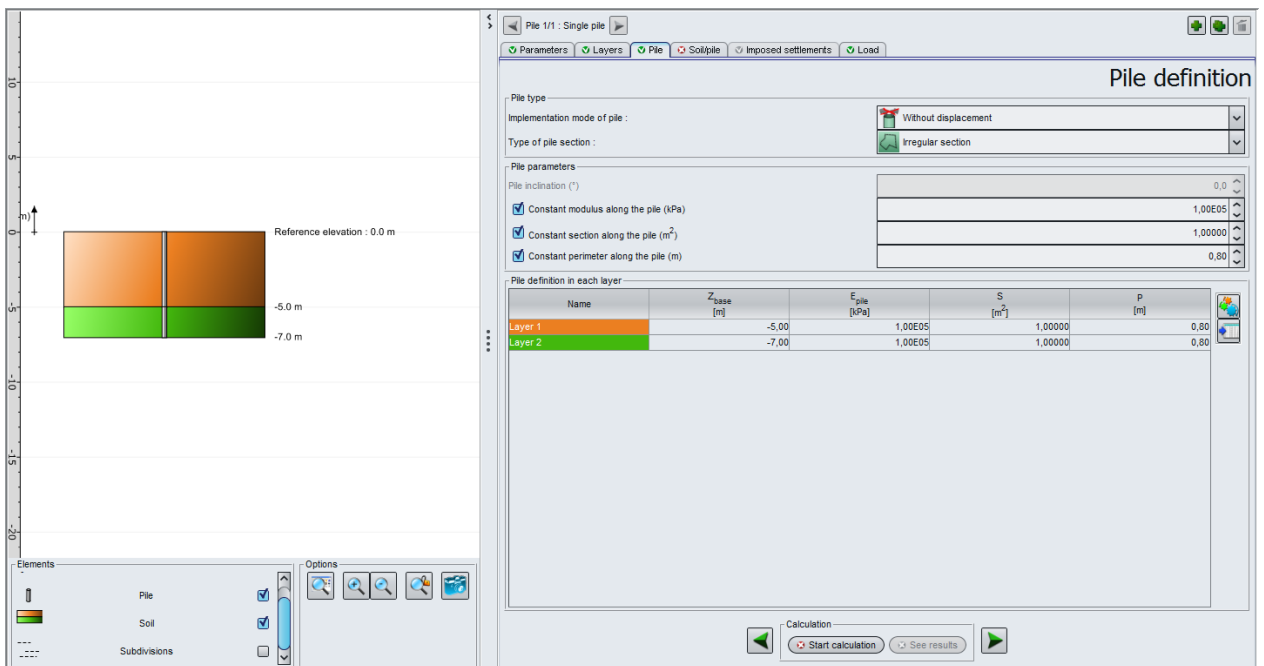


Figure F.14 : "Pile" tab for a "pile + associated mesh" calculation with an irregular section pile and constant characteristics along the pile

The table below summarises the pile definition parameters as a function of selected section type (circular or irregular) and calculation type:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
Pile inclination	°	0	Always	Yes	Modifiable only for "single pile" type calculations -90 ° < incl < 90°
E_{pile} : Young's modulus of pile	kPa	-	Always	Yes	> 0
D: section diameter	m	-	If circular section	Yes	> 0
P: section perimeter	m	-	If irregular section	Yes	> 0
S: section	m ²	-	If irregular section	Yes	> 0

Table F.4 : Summary of parameters required for pile definition

Tip: It is possible to first tick the "Constant modulus along the pile" box, enter the value most often used, then untick said box and modify only the layers with different values.

F.3.5. "Soil/pile" tab

This tab is used to define the shaft friction mobilisation laws and the base resistance term. It has three different boxes.

F.3.5.1 "Mobilisation law for the shaft friction of the soil and the base resistance" box

In the drop-down list, select one of the mobilisation laws proposed:

- From pressuremeter values (Frank and Zhao law). Also see chapter F.2.4.1;
- From pressuremeter values (Monnet law). Also see chapter F.2.4.2;
- Point by point input.

This choice will apply both for the shaft friction and for the base resistance term and will condition the data displayed in the 2 boxes below.

Subchapters F.3.5.2 and F.3.5.3 describe the data to be input according to the chosen mobilisation laws.

Whatever the chosen behavioural law, the graphical part represents either the shaft friction mobilisation law (cf. Figure F.15) or the mobilisation law of base resistance (cf. Figure F.16), or the 2 (cf. Figure F.17).

The default display corresponds to the active frame (for example, when working in the "Definition of the mobilisation law of the base resistance" frame, the mobilisation curve of base pressure is displayed), but it is possible to force the display on the required curve or curves thanks to the tick boxes located under the curves.

For the shaft friction mobilisation curves, the curve displayed corresponds to selected layer (the legend under the curve confirms the concerned layer, see Figure F.15).

Also, the curves are displayed only when the corresponding data is completely input and valid.

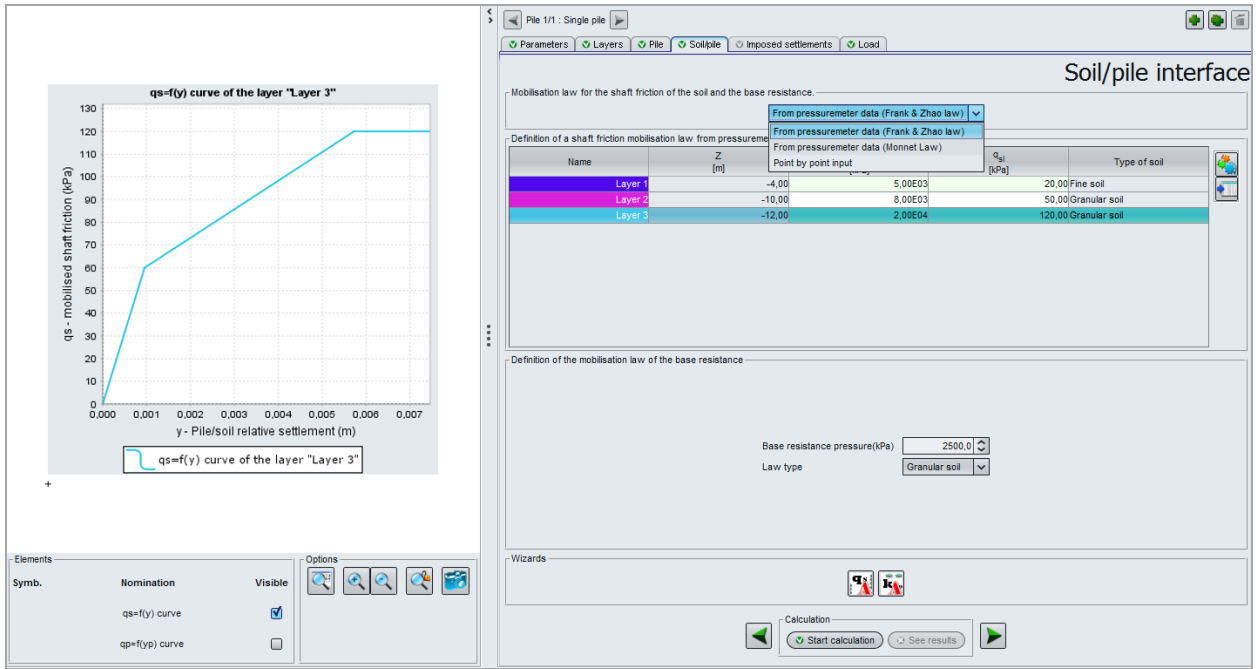


Figure F.15 : "Soil/pile" tab

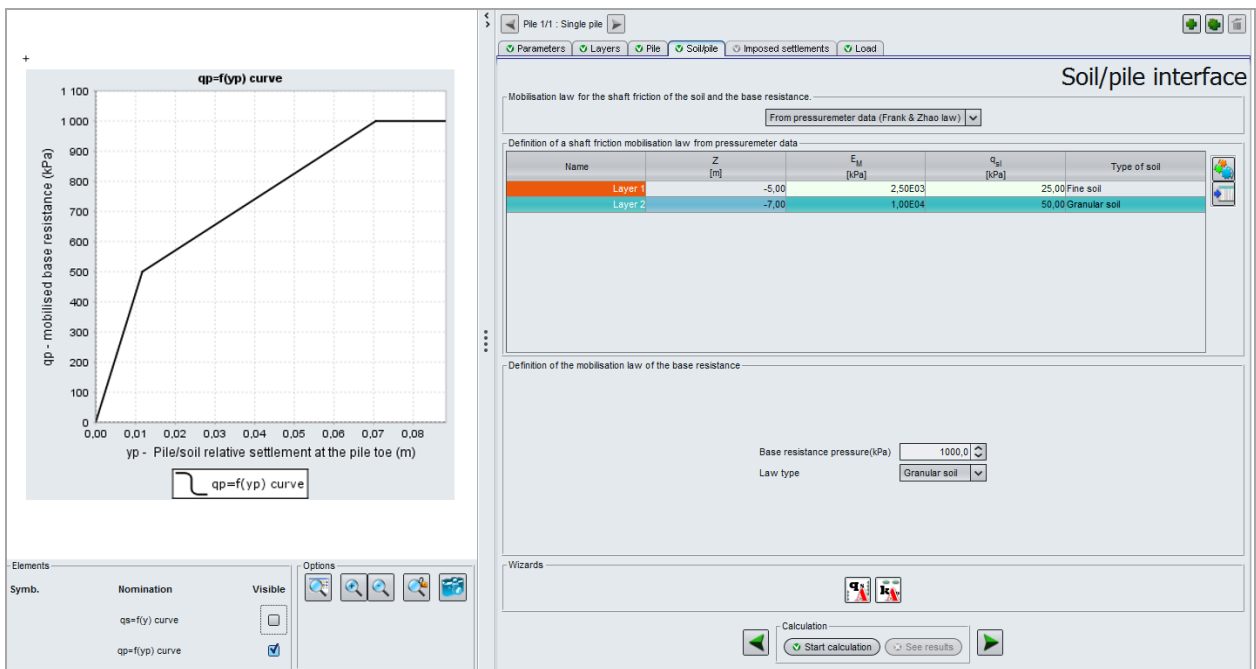


Figure F.16 : "Soil/pile" tab: display of $q_p = f(y_p)$ curve

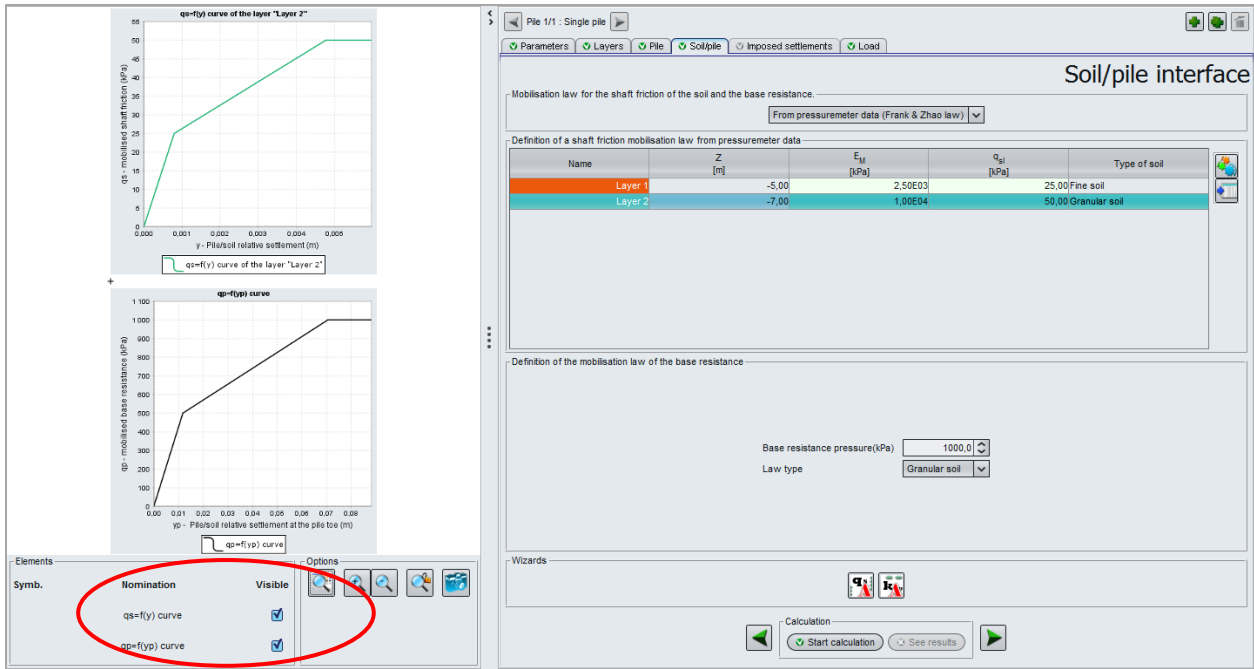


Figure F.17 : "Soil/pile" tab: display of 2 curves $q_s=f(y)$ and $q_p=f(y_p)$

F.3.5.2 Shaft friction mobilisation law

Also see chapter F.2.4.

F.3.5.2.1 Frank and Zhao law

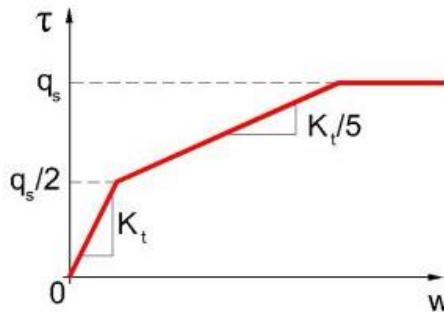


Figure F.18 : Frank and Zhao friction mobilisation law

For this law, the shaft friction mobilisation is defined in the "Definition of shaft friction mobilisation law" box.

The first 2 columns of the table of this box are precompleted as a function of the definition of the layers done previously. The number of lines is limited to the number of layers declared in the "Layers" tab.

Definition of a shaft friction mobilisation law from pressuremeter data				
Name	Z [m]	E_M [kPa]	q_{s1} [kPa]	Type of soil
Layer 1	-5,00	2,50E03	25,00	Fine soil
Layer 2	-7,00	1,00E04	50,00	Granular soil

Figure F.19 : "Definition of shaft friction mobilisation law" box – Frank & Zhao law

The table below summarises the friction parameters to be completed for the Frank & Zhao law:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
N°	-	-	Always	Yes	Automatically completed
Z: bottom level of the layer	m	-	Always	Yes	
E _M : pressuremeter modulus	kPa	-	Always	Yes	> 0
q _{sl} : unit shaft friction	kPa	-	Always	Yes	> 0
Soil type	-	Fine soil	Always	Yes	Possible choices: fine soil or granular soil

Table F.5 : Summary of parameters required for friction definition (Frank & Zhao law)

F.3.5.2.2 Monnet law

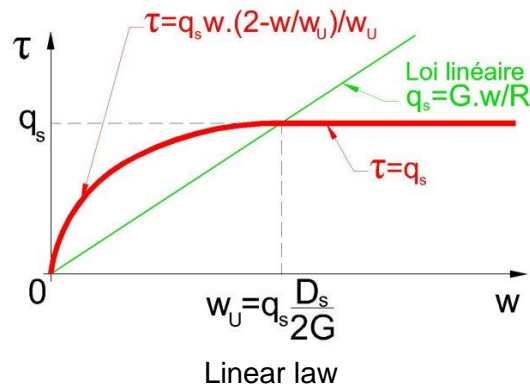


Figure F.20 : Monnet friction mobilisation law

For this law also, the shaft friction mobilisation is defined in the "Definition of a shaft friction mobilisation law" box.

As above, the first 2 columns of the table of this box are pre-completed as a function of the definition of the layers done previously. The number of lines is limited to the number of layers declared in "Layers" tab.

Name	Z [m]	E _M [kPa]	q _{sl} [kPa]	α
Layer 1	-5,00	2,50E03	25,00	0,30
Layer 2	-7,00	1,00E04	50,00	0,25

Figure F.21 : "Definition of a shaft friction mobilisation law" box – Monnet law

A summary table of the friction parameters for the Monnet law is given below:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
N°	-	-	Always	Yes	Automatically completed
Z: bottom level of layer	m	-	Always	Yes	
E _M : pressuremeter modulus	kPa	-	Always	Yes	> 0
q _{sl} : unit shaft friction	kPa	-	Always	Yes	> 0
α: Menard's rheologic coefficient	-	-	Always	Yes	0 < α ≤ 1

Table F.6 : Summary of parameters required for friction definition (Monnet law)

F.3.5.2.3 Point by point input mobilisation laws

In this case, the parameters are input via the "Point by point definition of a shaft friction mobilisation law" box.

Input a set of value pairs (y = pile/soil relative settlement; q_{sl} = mobilised unit friction) for each layer defined.

"Layers reminder" box:

- Select a layer (from those previously defined) to define the q_s = f(y) law for this layer.
Note: A q_s = f(y) law must be defined for each layer.

"q_s = f(y) law" box:


- Input required set of value pairs (y; q_{sl}).
Note: Click  button to add a line to the table.



Figure F.22 : "Shaft friction mobilisation law definition" box – Point by point input

A summary table of the friction parameters is given below:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
y: pile/soil relative settlement	m	-	Always	Yes	≥ 0 and strictly increasing values
q _s : mobilised unit friction	kPa	-	Always	Yes	≥ 0

Table F.7: Summary of parameters required for friction definition – Point by point input

For each layer, the $q_s = f(y)$ law must include at least one point different from the origin.

Reminder: If the shaft friction mobilisation law for at least one of the layers includes a decreasing or constant intermediary plateau, Taspie+ will automatically change to step-by-step calculation mode (see chapter F.3.8).

F.3.5.3 Mobilisation law of base resistance

The mobilisation law of base resistance is defined in the "Definition of the mobilisation law of the base resistance" box.

F.3.5.3.1 Frank and Zhao and Monnet laws

For these 2 laws, Taspie+ automatically generates a law with three plateaux of Frank and Zhao type (Figure F.3) the construction of which is controlled by four parameters (see chapter F.2.4.1):

- Pressuremeter modulus considered for the **last** layer of the model;
- Equivalent diameter of pile section in the **last** layer of the model;
- Base resistance pressure q_{pl} to be defined by the user;
- Soil type to be considered for the base behaviour to be chosen by the user.

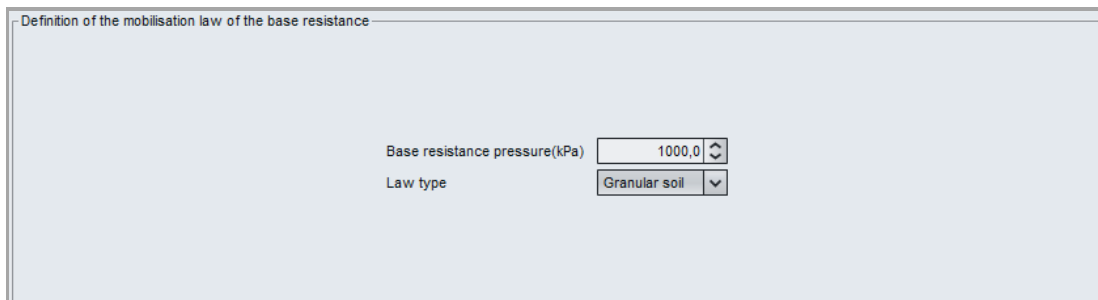


Figure F.23: "Definition of the mobilisation law of base resistance" box – Frank & Zhao or Monnet laws

A summary table of the parameters required is given below:

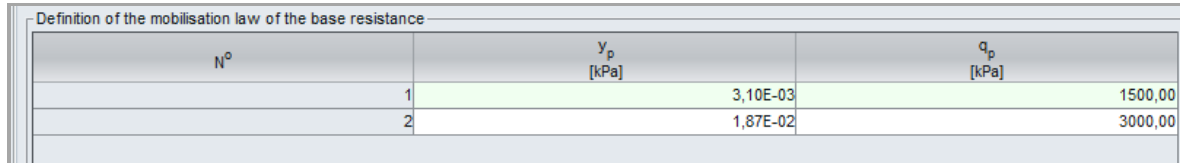
Designation	Units	Default value	Display condition	Mandatory value	Local checks
Base resistance pressure q_{pl}	kPa	-	Always	Yes	> 0
Law type	-	Granular soil	Always	Yes	Possible choices: granular soil or fine soil

Table F.8: Summary of parameters required for definition of mobilisation law of base resistance (Frank & Zhao or Monnet laws)

Note: For a characterisation from pressuremeter (resp. penetrometer) values, the base resistance pressure q_{pl} is taken as equal to $k_p \times pl_e$ (resp. $k_c \times q_{ce}$), where k_p (resp. k_c) is the pressuremeter (resp. penetrometer) bearing factor and pl_e (resp. q_{ce}) is the net equivalent boundary pressure (resp. base resistance) under the foundation base in the sense given in standard NF P 94 262.

F.3.5.3.2 Point by point input mobilisation laws

If the base resistance mobilisation law is input point by point $q_p = f(y)$, the user inputs the mobilisation curve values according to the same principle as for shaft friction (see chapter F.3.5.2.3).



N°	y_p [kPa]	q_p [kPa]
1	3,10E-03	1500,00
2	1,87E-02	3000,00

Figure F.24 : "Definition of mobilisation law of base resistance" box – Point by point input

A summary table of the parameters required for the calculation is given below:

Designation	Units	Default value	Display condition	Mandatory value	Local checks
y_p : relative pile/soil settlement at base	m	-	Always	Yes	≥ 0 and strictly increasing values
q_p : base resistance pressure	kPa	-	Always	Yes	≥ 0

Table F.9 : Summary of parameters required for definition of mobilisation law of base resistance (point by point input)

$q_p = f(y)$ law must include at least one point different from the origin.

Reminder: If the mobilisation law of base resistance includes an decreasing or constant intermediary plateau, Taspie+ will automatically change to step-by-step calculation mode (see chapter F.3.8).

F.3.6. "Imposed settlements" tab

This tab is accessible only for a "Single pile" type calculation.

- Tick the box if you want to "Activate defined settlement".

If a imposed settlement is defined, the soil/pile shaft friction and the base resistance are not functions of the pile settlement alone but of the relative pile/soil settlement.

F.3.6.1 "Soil imposed settlement profile" box

This box is only accessible if "Activate imposed settlement" tick box has been activated.

The soil imposed settlement values to be defined by default at elevations representative of the head of the various layers and at the bottom of the model (that is $n+1$ where n designates the total number of layers).

By convention, the settlement is taken as positive downwards.

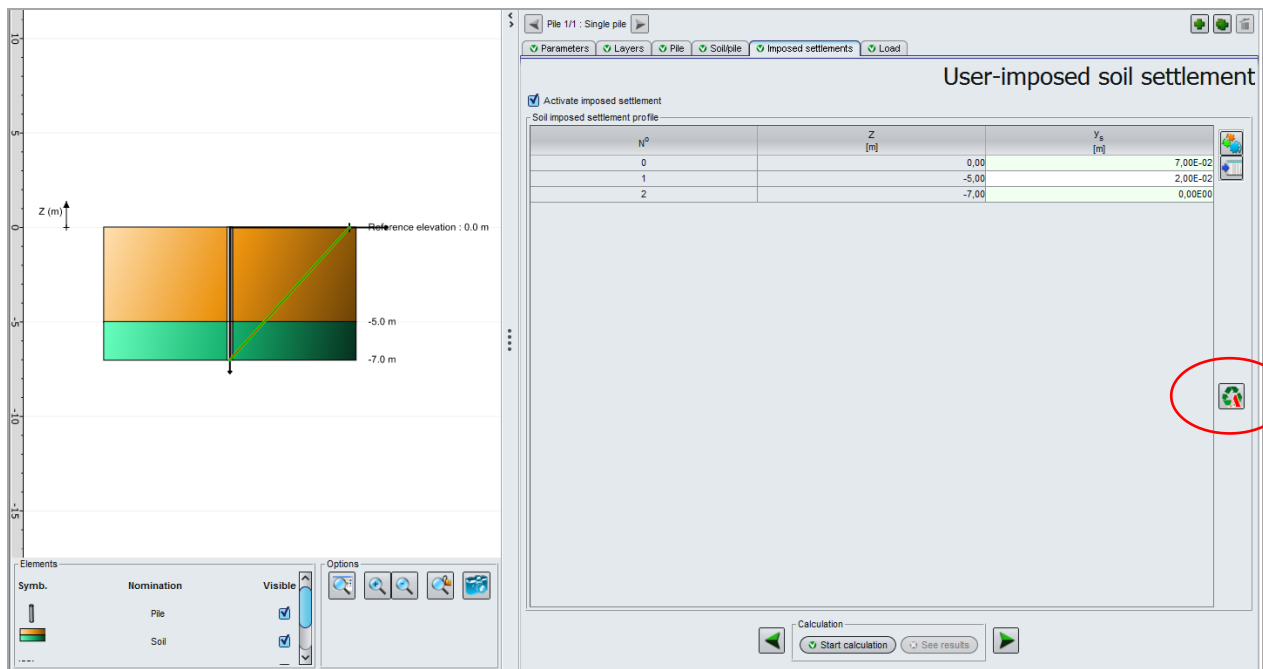


Figure F.25 : Example of user-imposed soil settlement

A table summarising the parameters to be completed is given below:

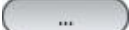
Designation	Units	Default value	Display condition	Mandatory value	Local checks
N°	-	-	Always	Yes	Automatically completed
Z: elevation of calculation point	m	-	Always	Yes	
y _s : imposed soil settlement at this elevation	m	-	Always	Yes	-

Table F.10 : Summary of parameters required for definition of imposed soil settlement

F.3.6.2 Imposed soil settlement import wizard

Taspie+ module allows soil imposed settlement profiles to be imported from a Taspie+, Tasseldo or Tasnég calculation by clicking  button.

"Import directory" box:

By default, when the wizard is opened, Foxta tries to find a file to be imported in the directory where current project is found. If this directory does not contain the file required, click Browse  button.

"Import from Taspie+" tab:

In the left-hand box, select the file to be imported.

The following are displayed on the right:

- Calculation date (as a reminder);
- Pairs (z; y_s): elevations/settlements to be imported.

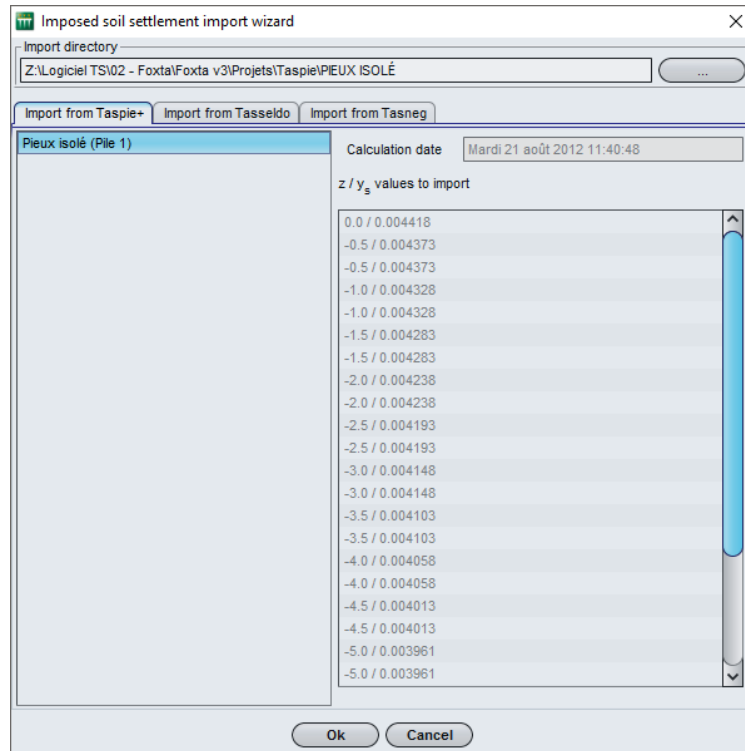


Figure F.26 : Imposed soil settlement import wizard from Taspie+

"Import from Tasseldo" tab:

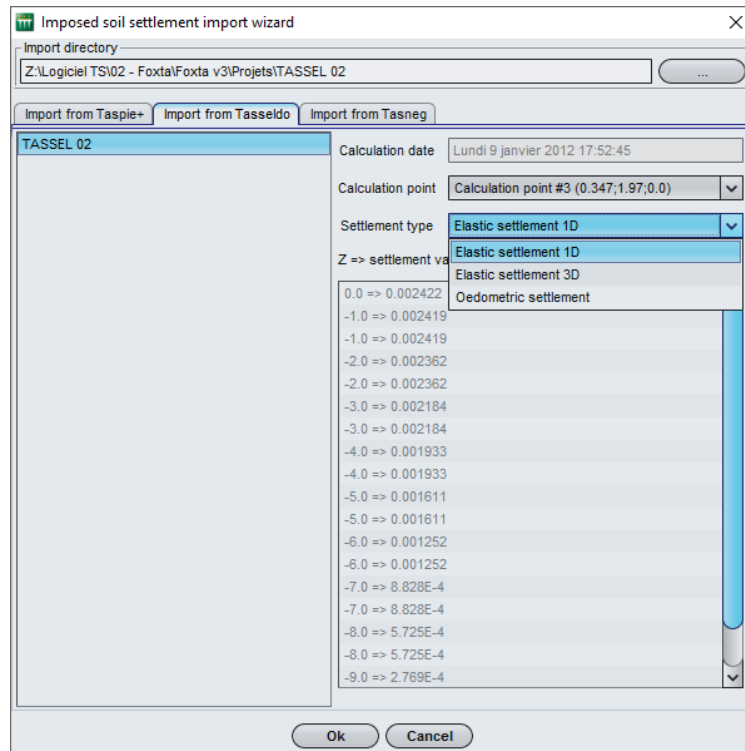


Figure F.27 : Imposed soil settlement import wizard from Tasseldo

In the left-hand box, select the file to be imported.

The following are displayed on the right:

- Calculation date (as a reminder);

- The Tasseldo calculation points available in selected file: select required calculation point in drop-down list;
- Settlement type: in drop-down list, select the settlement values to be imported: elastic 1D, elastic 3D or oedometric;
- Pairs (Z; y): elevations/settlements to be imported.

"Import from Tasneg" tab:

In the left-hand box, select the file to be imported.

The following are displayed on the right:

- Calculation date (as a reminder);
- Pairs (Z; y): elevations/settlements to be imported.

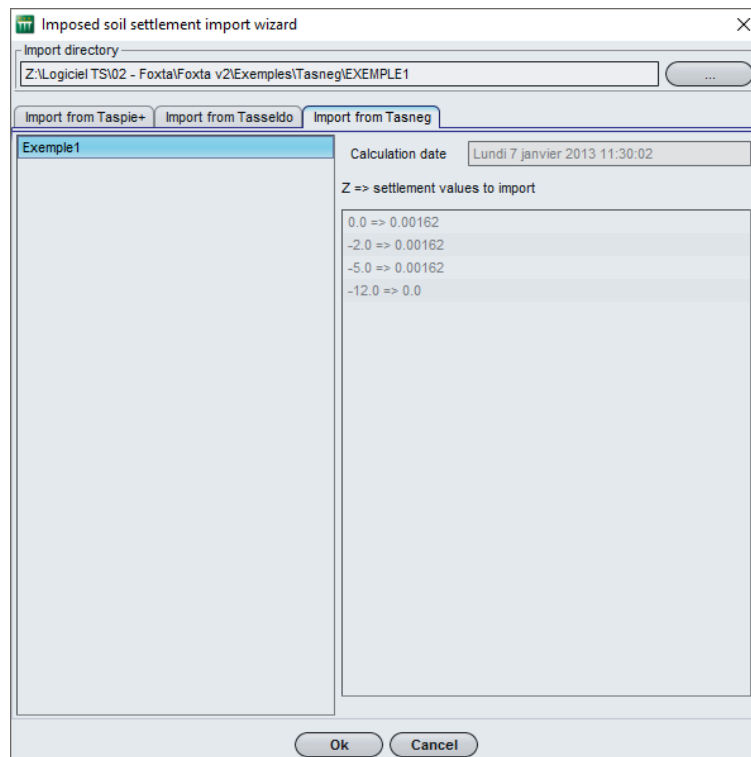


Figure F.28 : Imposed soil settlement import wizard from Tasneg

F.3.7. "Load" tab

F.3.7.1 For a "Single pile" type calculation

F.3.7.1.1 Definition of top load

- Enter the load applied at pile head (kN). This load is taken as positive towards the bottom (compression). A negative load can be defined. This corresponds to a calculation of a pile submitted to tensile loads (at head).

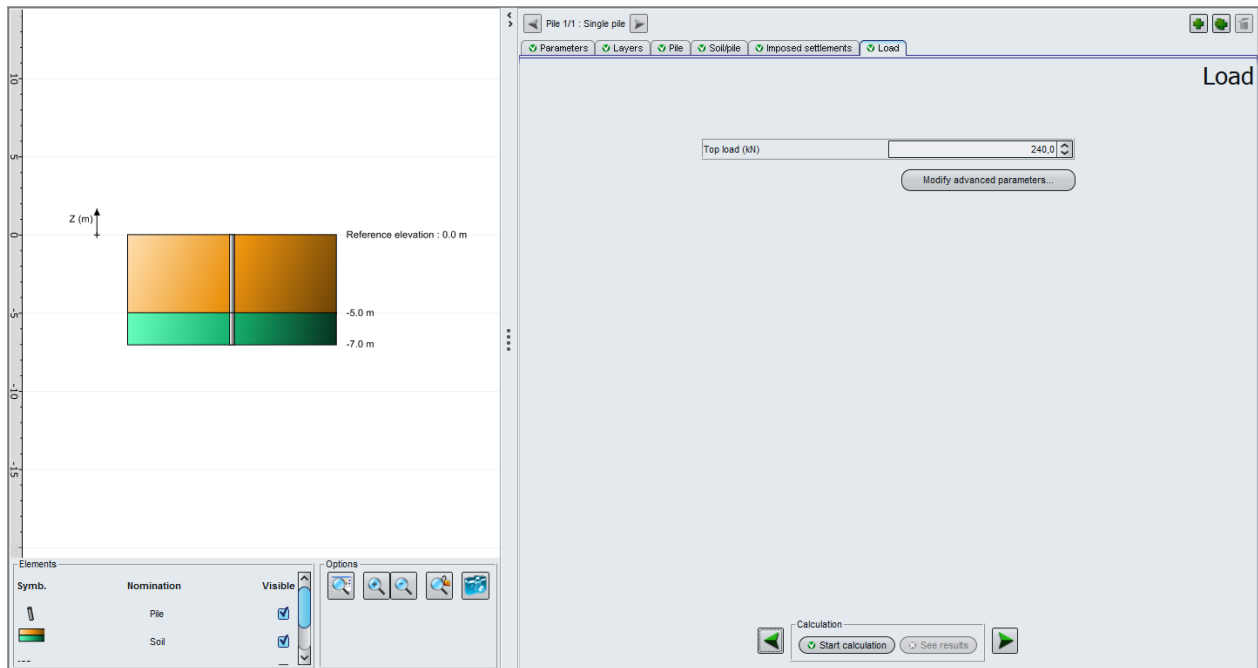


Figure F.29 : "Load" tab for a Single pile calculation

F.3.7.1.2 Advanced parameters

The "Modify advanced parameters..." button allows the following parameters to be controlled:

- Tolerance: this parameter controls the relative accuracy of the iterative process managing the nonlinearity of the mobilisation laws;
- Steps number: this parameter controls the number of points comprising the load curve;
- Negative skin friction coefficient: this weighting factor, by default equal to 1.00, is applied in zones where friction is negative (see chapter F.2.4.3).

The default values proposed are to be conserved in most cases (and a button allows the advanced parameters to be reinitialised at default values if necessary):

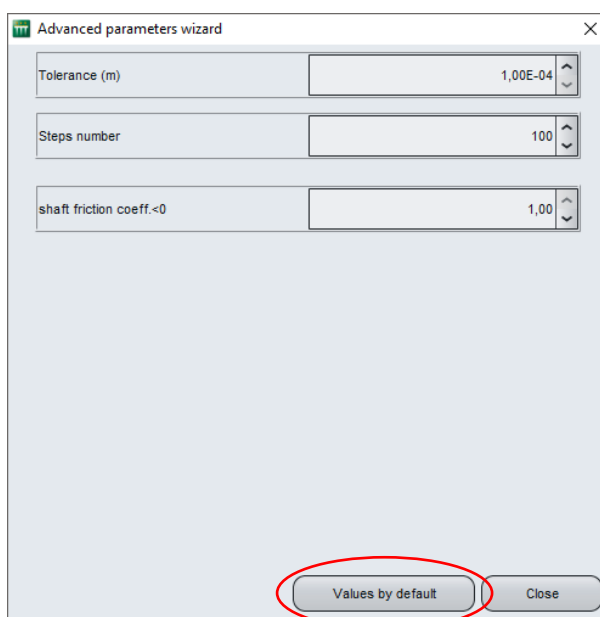


Figure F.30 : Advanced parameters wizard for a "Single pile" calculation

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
Tolerance (or relative accuracy of calculations)	m	1,0E-04	Always	Yes	-
Steps number	-	100	Always	Yes	$1 \leq x \leq 1000$
Shaft friction coeff.<0: negative skin friction weighting coefficient (also see chapter F.2.4.3)	-	1,0	Always	Yes	Coeff > 0

Table F.11 : Advanced parameters, single pile case

F.3.7.2 "Pile + associated soil mesh" calculation case

F.3.7.2.1 "Mesh parameters" box

The data to be defined is as follows:

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
Mesh element dimension along X	m	1,0	Always	Yes	> 0
Mesh element dimension along Y	m	1,0	Always	Yes	> 0
Mesh element load	kPa	0,0	Always	Yes	≥ 0

Table F.12 : Mesh parameters ("pile + associated mesh" calculation case)

F.3.7.2.2 Calculation type: Slab

In an "Imposed strain (slab type)" type calculation, settlement is assumed as uniform at top of mesh (case of a slab on rigid inclusions for example). Taspie+ in this case allows the distribution of the stresses between pile and soil to be determined (also see chapters F.2.2 and F.2.5.4).

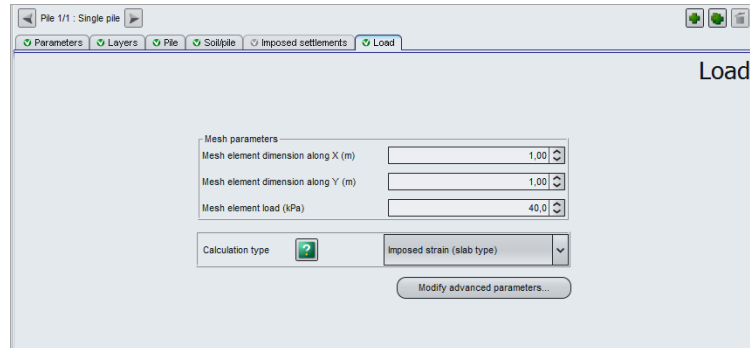



Figure F.31 : "Load" tab of a pile + associated soil mesh type calculation of Slab type

A help figure is available to explain calculation type choice by clicking associated  button:

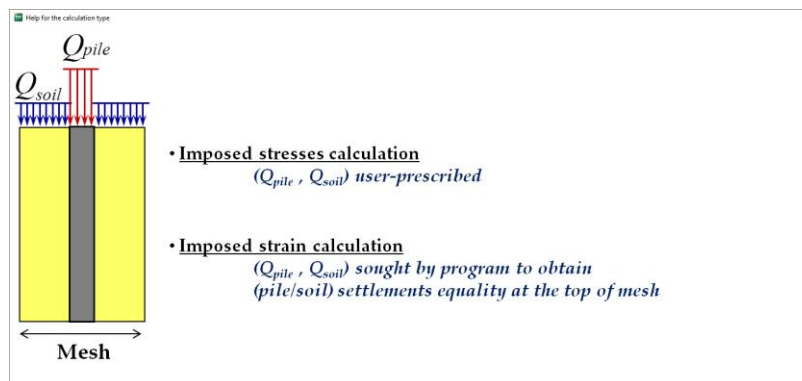


Figure F.32 : Help figure – Choice of Slab/Backfill calculation type

F.3.7.2.3 Calculation type: Backfill

In an "Imposed stress (backfill type)" type calculation, the user imposes the distribution of the stresses at top of mesh (also see chapters F.2.2 and F.2.5.3).

For the backfill type calculation, additional data must be defined, that is the $e_{Q_{pile}}$ parameter:

- $e_{Q_{pile}}$: Fraction of total load on mesh applied at pile head. This fraction is a decimal number between 0 and 1 included.

The value proposed by default is $e_{Q_{pile}} = \text{pile section}/\text{mesh section}$. This corresponds to a uniform loading condition at top of mesh.

The $e_{Q_{pile}}$ value can be modified to meet specific situations: in this case, choose "Manual entry". For example:

- $e_{Q_{pile}} = 1$: indicates that complete load applied will be transmitted to the pile;
- $e_{Q_{pile}} = 0$: translates the fact that the pile is not loaded at head. The complete load applied is taken by the soil.

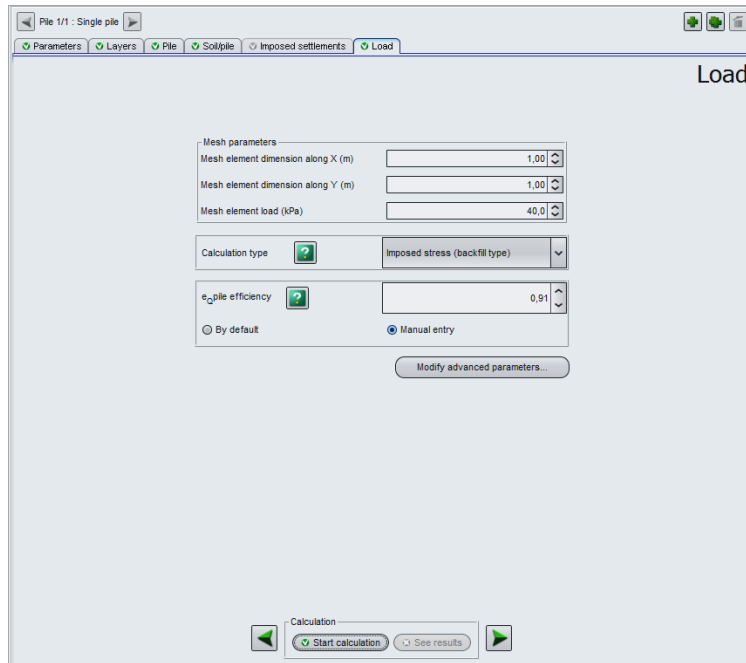



Figure F.33 : "Load" tab of a Pile + associated soil mesh calculation of Backfill type

A help figure is available to explain the meaning of the e_{qpile} parameter by clicking the associated  button:

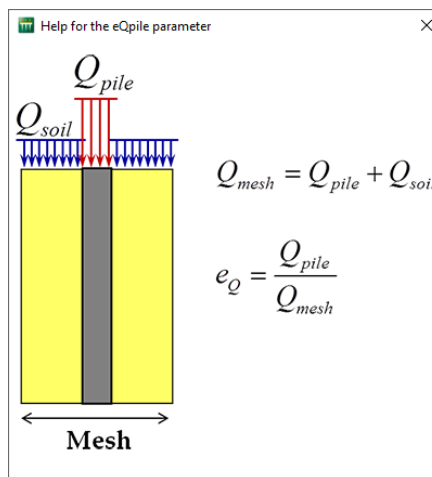
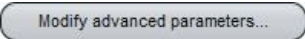


Figure F.34 : Help figure – Meaning of e_{qpile} parameter

F.3.7.2.4 Advanced parameters

The advanced parameters are accessible by clicking  button.

A table summarising the advanced parameters for a "pile + associated soil mesh" calculation is given below:

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
Tolerance (or convergence criterion)	m	1E-04	Always	Yes	-
Steps number	-	100	Always	Yes	$1 \leq x \leq 1000$

Table F.13 : Summary of advanced parameters for a "pile + associated soil mesh" calculation

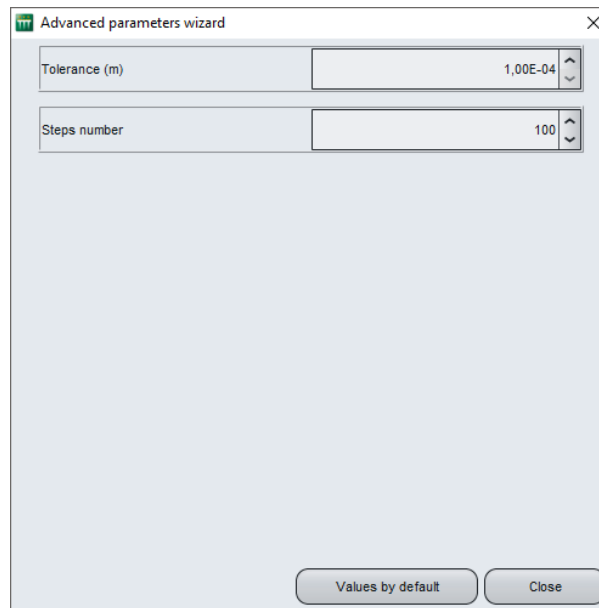


Figure F.35 : Advanced parameters wizard for a "pile + associated soil mesh" calculation

F.3.8. Standard calculation/Step-by-step calculation

As stated in chapter F.2.5.1, Taspie+ has 2 additional calculation engines.

The choice between the 2 calculation engines is done automatically by Taspie+ as a function of the input data.

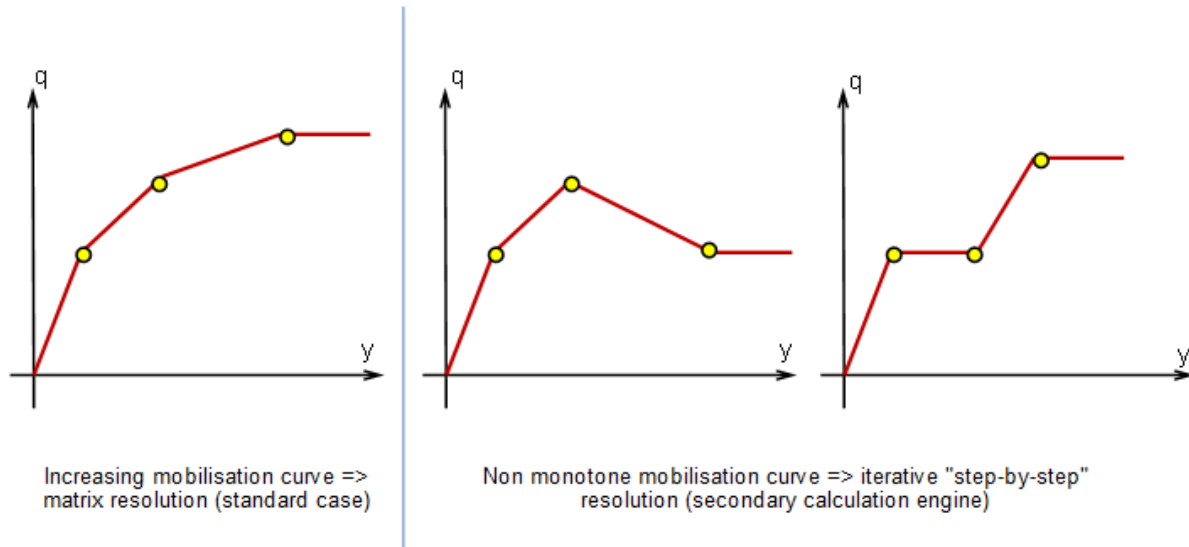
In most cases, the main calculation engine (matrix solving by finite elements) is the one used. Here, we will refer to this situation by the term "standard case".

However, in the case where the transfer curve includes one or more decreasing plateaux, the secondary calculation engine will be used. This case occurs in the case where the user:

- chooses point-by-point input mobilisation laws;
- and defines at least one of the mobilisation laws (shaft friction for one of the layers or base resistance) as being not strictly increasing: e.g. a constant intermediary plateau or a decreasing plateau as shown on figure below.

Here, we will refer to this situation by the term "step-by-step calculation". When Taspie+ identifies this situation, certain additional parameters are required (mainly in the advanced parameters of the "Load" tab).

The specificities of the parameters for a "step-by-step" calculation are defined in the following subchapters.



F.3.8.1 "Parameters" tab - Printing type

For step-by-step calculations, the "General parameters" box includes additional data: printing type.

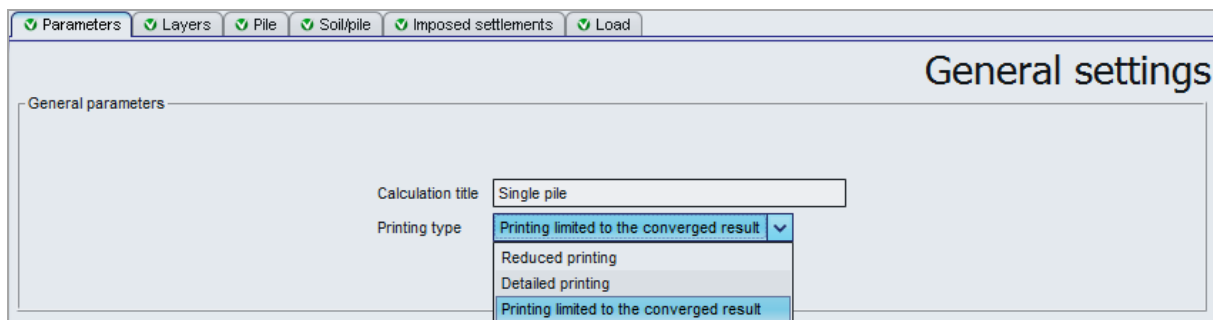


Figure F.36 : "Parameters" tab – "Step-by-step" calculation case

Possible choices for printing type are shown on the figure above. The choice proposed by default is printing limited to the converged result.

F.3.8.2 "Layers" tab - Limitations

For a step-by-step calculation, the following limitations are to be taken into account:

- Total number of layers must be 25 maximum;
- Total number of subdivisions along the pile must be 500 maximum.

However, for the "standard" calculation case, there is no limit on the total number of layers or subdivisions.

F.3.8.3 "Soil/pile" tab - Limitations

For a step-by-step calculation, the base resistance pressure must be strictly higher than zero. Put a numerically low value (0.1 kPa for example) in situations where the total base resistance can be neglected.

F.3.8.4 "Load" tab

For step-by-step calculations, the advanced parameters window includes additional parameters with respect to the standard case described previously:

F.3.8.4.1 Single pile case – Tensile load case

For a step-by-step calculation, the program does not automatically cancel the total base resistance for a pile submitted to tensile loads. In this case, the user must enter a numerically very low base resistance pressure (0.1 kPa for example).

F.3.8.4.2 Single pile case – Advanced parameters

The additional advanced parameters displayed are those of the "Calculation range" box. They are detailed below:

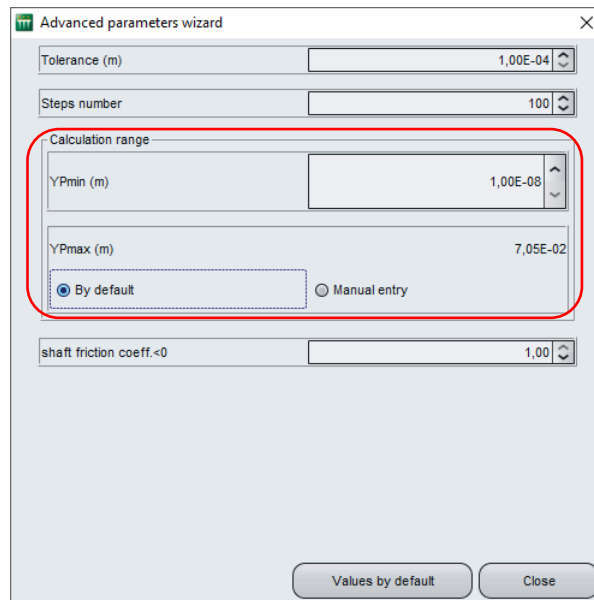


Figure F.37 : Advanced parameters wizard – Step-by-step calculation (single pile)

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
YPmin : minimal value of the tip displacement to take care of	m	1.0E-08	Always	Yes	> 0
YPmax : maximal value of the tip displacement to observe	m	Last value of mobilisation curve of base resistance	Always	Yes	> YPmin

Table F.14 : Parameters of Advanced parameters wizard – Step-by-step calculation (single pile)

F.3.8.4.3 "Pile + associated mesh" of slab type calculation case – Advanced parameters

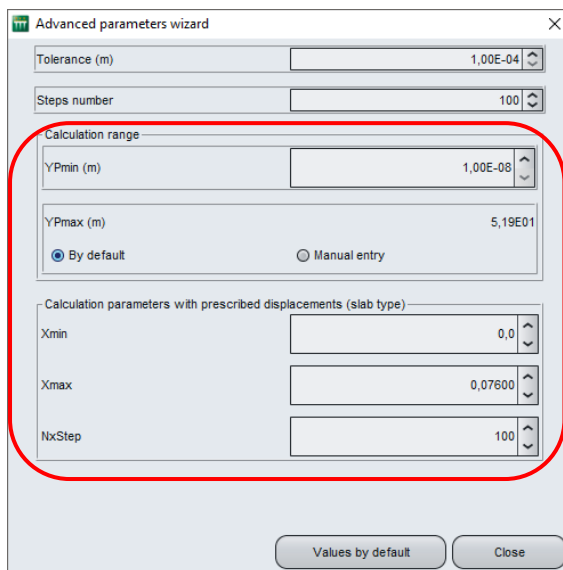


Figure F.38 : Advanced parameters wizard – Step-by-step calculation (pile + associated mesh - slab type)

The additional parameters of the "Calculation range" box are the same as those described above for the single pile (chapter F.3.8.4.1).

The additional parameters of the "Calculation parameters with prescribed displacements (slab type)" box are as follows:

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
YPmin : minimal value of the tip displacement to take care of	m	1.0E-08	Always	Yes	>0
YPmax : maximal value of the tip displacement to observe	m	Settlement calculated for soil without pile under stress q_{mesh}	Always	Yes	> YPmin
Xmin : lower bound of the slab settlement range to be studied	m	0	Always	Yes	-
Xmax : upper bound of the slab settlement range to be studied	m	= YPmax	Always	Yes	> Xmin
NxStep : number of calculation steps	-	100	Always	Yes	$0 < \text{Nxstep} \leq 10^5$

Table F.15 : Parameters of Advanced parameters wizard – Step-by-step calculation (pile + associated mesh, slab type)

F.3.8.4.4 "Pile + associated mesh" calculation case of backfill type – Advanced parameters

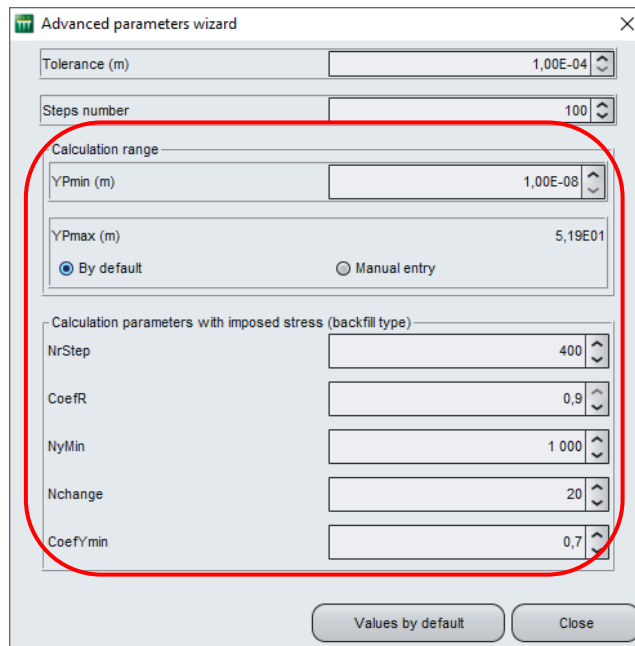


Figure F.39 : Advanced parameters wizard – Step-by-step calculation (pile + associated mesh - backfill type)

The additional parameters of the "Calculation range" box are the same as those described above for the single pile (chapter F.3.8.4.1).

The additional parameters of the "Calculation parameters with imposed stress (backfill type)" box are as follows:

Designation of parameters	Units	Default value	Display condition	Mandatory value	Local checks
YPmin: minimal value of the tip displacement to take care of	m	1.0E-08	Always	Yes	>0
YPmax: maximal value of the tip displacement to observe	m	Settlement calculated for soil without pile under stress q_{mesh}	Always	Yes	> YPmin
NrStep: maximal number of iterations to calculate the settlement of soil cylinder	-	400	Always	Yes	$0 < Nrstep \leq 1000$
CoefR: relaxation coefficient. Defines the convergence of successive imposed settlement profiles around pile (*)	-	0.9	Always	Yes	$0 < CoefR < 1$

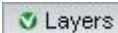
Nymin: number of steps adopted from iteration 2 and following to scan the interval of displacements at bottom	-	1000	Always	Yes	$0 < Nymin \leq 10^5$
Nchange: number of iteration from which the scan interval is redefined as a function of choice of CoefYmin and the divisions number becomes Nymin	-	20	Always	Yes	$0 < Nchange \leq 1000$
CoefYmin	m	0.7	Always	Yes	$0 < CoefYmin < 1$

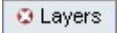
(*) Imposed settlement (n+1) = CoefR x imposed settlement (n) + (1-CoefR)*calculated settlement (n)

Table F.16 : Parameters of Advanced parameters wizard – Step-by-step calculation
(pile + associated mesh, backfill type)

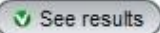
F.3.9. Calculation and results

F.3.9.1 Calculation

The calculation can be started from any tab provided the tabs are correctly completed, that is when they are all marked by a green tick (for example: ).

The tabs are marked by a red cross (for example: ) until correctly completed (missing or nonconforming data with expected values).

To start the calculation, click  button.

To display the calculation results, click  button.

The window below is then displayed and proposes various types of results accessible after a Taspie+ calculation:

- 2 types of numerical results: formatted results and result tables;
- 3 types of graphical results: loading curve, main results and complementary results.
Note: The loading curve is accessible only for "Single pile" type calculations.
- 1 calculation wizard for evaluation of loads in slab (this is accessible only for a "pile + associated soil mesh" type calculation).

IMPORTANT: The results are given along the pile in the **local** coordinate system of the pile (on abscissa with respect to pile head) and not in elevations.



Figure F.40 : Results window

F.3.9.2 Numerical results

F.3.9.2.1 Formatted numerical results – Case of a "Single pile" type calculation

```

Programme Taspie+ v2.4.1 (c) TERRASOL 2014
File : R:\Logiciels\Foxta\Foxta v3\Manuels et exemples\Manuels Foxta v3\F - Taspie+\Traduction ENG\exemples VBE\TASPIE+ EXEMPLE 1\Taspie+ exemple 1[TP]-1.b11
Calcul réalisé le : 13/06/2016 à 16h07
by : Terrasol
Calculation title : Pieu isolé sans tassement imposé

Caractéristiques géométriques
Inclinaison du pieu (°) : 0.00

Couche Cote Longueur éléments Diametre Diametre Section Perimetre
(section) (perimetre)
1 0.00
2 -4.00 4.00 10 0.600 0.600 0.283 1.885
3 -10.00 6.00 20 0.600 0.600 0.283 1.885
3 -12.00 2.00 10 0.600 0.600 0.283 1.885
-----
12.00
Mise en place sans refoulement

Caractéristiques mécaniques
Couche Cote Prottement Module Module Paramètres oedométriques
limite du pieu du sol Cs/(1+e0) Cc/(1+e0) tc G ou G' IG
1 0.00 20.00 0.100E+08 0.100E+11
2 -4.00 50.00 0.100E+08 0.100E+11 0.00 0
3 -10.00 120.00 0.100E+08 0.100E+11 0.00 0
3 -12.00
-----
qp1 = 2500.00

Lois de mobilisation
Couche 1 cotes : 0.000 à -4.000
Em = 5000. qs1 = 20.00
mobilisation frottement y qs *** Frank et Zhao (sol fin foré)
    
```

Figure F.41 : Formatted numerical results (reminder of data)

The formatted results contain:

- A reminder of the data (Figure F.41): geometrical characteristics, characteristics of soil layers, details of mobilisation laws.
- The bearing capacity calculations (Figure F.42, also see chapter F.2.8), with the following regulatory values (according to standard NF P 94 262):
 - ✓ Limit values of total shaft resistance and total base resistance (without weighting);
 - ✓ Limit value of critical creep load (without weighting);
 - ✓ Allowable loads at SLS (in quasi-permanent and characteristic combinations) and at ULS (in fundamental and accidental combinations).

These calculations are done over the complete length of the pile (all soil layers are taken into account).

CAPACITE PORTANTE			
Capacité ultime du pieu	q _{lim} =	549.78	
frottement	q _{s1} =	353.43	
pointe	q _{p1} =	196.35	
Charge de fluage du pieu	Q _c =	345.58	
---- CHARGES ADMISSIBLES SELON LA NORME NF P 94 262 ----			
A partir de la méthode pressiométrique			
	(1)	(2)	(3)
ELU-FOND	395.10	324.54	227.18
ELU-ACCI	434.61	357.00	249.90
ELS-PERM	248.35	204.00	142.80
ELS-CARA	303.54	249.33	174.53
A partir de la méthode pénétrométrique			
	(1)	(2)	(3)
ELU-FOND	385.05	313.35	227.18
ELU-ACCI	423.56	344.69	249.90
ELS-PERM	242.03	196.97	142.80
ELS-CARA	295.82	240.74	174.53
(1) : Pieux non ancrés dans la craie			
(2) : Pieux ancrés dans la craie			
(3) : Pieux de catégorie 10,15,17,18,19 et 20			

Figure F.42 : Formatted numerical results – Bearing capacity

- For each calculation elevation, the results table details (Figure F.43):
 - ✓ Pile settlement (m);
 - ✓ Soil settlement (m);
 - ✓ Force in pile (kN);
 - ✓ Additional force taken by soil (kN) (with respect to state of initial stresses);
 - ✓ Mobilised shaft friction (kPa);
 - ✓ $\Delta\sigma_{pile}$ (kPa): stress in pile (force/section);
 - ✓ $\Delta\sigma_{soil}$ (kPa): additional stress in soil with respect to initial vertical stress.

Taspie+ also displays the maximum value (max+) and minimum value (max-) for each column at bottom of table.


```

Maille élémentaire 2.000 m x 2.000 m
-----
Surface 4.000 Rayon équivalent 1.128
Contrainte /maille 80.000 Charge totale 320.000

Calcul à déformations imposées

Tolérance des calculs : 0.10E-02
Pondération frottement négatif : 1.000

*****
****SOLUTION****
*****

EQpieu trouvé : 0.723 au bout de 014 iterations
Ecart relatif |yp(0)-ys(0)|/|yp(0)|= 0.4E-03

```

Figure F.44 : Formatted numerical results – Pile + associated mesh, slab type (information related to mesh)

- At end of file, the "Equivalent stiffnesses" section has been replaced by the section shown on Figure F.45. We find:
 - ✓ The unreinforced soil settlement;
 - ✓ For the pile: the settlement at pile head (m), the load at pile head (in kN and in proportion with respect to the total load, moreover, we find for the proportion the value of EQpile), the corresponding stress at pile head and the corresponding surface stiffness (kPa/m, see chapter F.2.9);
 - ✓ For the soil: the average settlement at surface (m), the load taken by the soil (in kN and in proportion with respect to the total load), the average corresponding stress on surface and the corresponding surface stiffness (kPa/m, see chapter F.2.9);
 - ✓ A summary of the loads in the pile (or the inclusion):
 - maximum stress S_{max} (kPa) reached in the inclusion;
 - elevation $z(m)$ at which S_{max} is reached (critical point);
 - maximum load Q_{max} (kN) reached in the inclusion;
 - safety with respect to creep load $Q_c(z)$: value $Q_c(z)$ (kN) and safety factor $F = Q_c(z) / Q_{max}$;
 - safety with respect to breaking load $Q_l(z)$: value $Q_l(z)$ (kN) and safety factor $F = Q_l(z) / Q_{max}$.

The values of $Q_c(z)$ and $Q_l(z)$ are calculated below the critical point.

The equivalent surface stiffnesses are estimated for load $Q(0)$ defined by the user. The surface stiffness at the pile is obtained by dividing the stress at pile head of the pile domain by the displacement at pile head of the pile domain and the surface stiffness at the soil domain by dividing the average vertical stress applied to the pile head of the soil domain by the average settlement at this level.

The ASIRI recommendations explain how to use the surface stiffnesses thus obtained to establish an equivalent simplified stiffness distribution, around each inclusion and between the inclusions, capable of giving a representative estimation of the moments in the slab. This equivalent surface stiffness distribution can be used in the Tasplaq model of the slab to establish the loads to which it is submitted under the loading applied.

068	-5.800	0.710E-02	0.120E-02	0.265E+03	0.946E+02	0.200E+02	0.211E+04	0.244E+02
069	-5.800	0.710E-02	0.120E-02	0.265E+03	0.946E+02	0.200E+02	0.211E+04	0.244E+02
069	-5.900	0.708E-02	0.709E-03	0.263E+03	0.971E+02	0.200E+02	0.209E+04	0.251E+02
070	-5.900	0.708E-02	0.709E-03	0.263E+03	0.971E+02	0.200E+02	0.209E+04	0.251E+02
070	-6.000	0.706E-02	0.201E-03	0.260E+03	0.996E+02	0.200E+02	0.207E+04	0.257E+02
071	-6.000	0.706E-02	0.201E-03	0.260E+03	0.996E+02	0.800E+02	0.207E+04	0.257E+02
071	-6.100	0.704E-02	0.167E-03	0.250E+03	0.110E+03	0.800E+02	0.199E+04	0.283E+02
072	-6.100	0.704E-02	0.167E-03	0.250E+03	0.110E+03	0.800E+02	0.199E+04	0.283E+02
072	-6.200	0.702E-02	0.130E-03	0.240E+03	0.120E+03	0.800E+02	0.191E+04	0.309E+02
073	-6.200	0.702E-02	0.130E-03	0.240E+03	0.120E+03	0.800E+02	0.191E+04	0.309E+02
073	-6.300	0.700E-02	0.902E-04	0.230E+03	0.130E+03	0.800E+02	0.183E+04	0.335E+02
074	-6.300	0.700E-02	0.902E-04	0.230E+03	0.130E+03	0.800E+02	0.183E+04	0.335E+02
074	-6.400	0.698E-02	0.467E-04	0.220E+03	0.140E+03	0.800E+02	0.175E+04	0.361E+02
075	-6.400	0.698E-02	0.467E-04	0.220E+03	0.140E+03	0.800E+02	0.175E+04	0.361E+02
075	-6.500	0.697E-02	0.150E-07	0.210E+03	0.150E+03	0.800E+02	0.167E+04	0.387E+02
		tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	dsigma pieu	dsigma sol
max+		0.274E-01	0.274E-01	0.293E+03	0.150E+03	0.800E+02	0.233E+04	0.387E+02
max-		0.697E-02	0.150E-07	0.210E+03	0.673E+02	-0.260E+02	0.167E+04	0.174E+02

	y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)
Sans renforcement	0.1094				
Avec renforcement					
Pieu	0.0274	231.375	0.723	1841.224	67128.6
Sol (moyenne)	0.0274	88.625	0.277	22.875	833.7
Maille		320.000	1.000	80.000	

sollicitations dans l'inclusion

- contrainte maximale S_max = 2329.4
- atteinte à cote Z = -4.300
- charge maximale Qmax = 292.7
- sécurité par rapport à Qc(Z) = 417.0 F= 1.42
- sécurité par rapport à Ql(Z) = 595.6 F= 2.03

Figure F.45 : Formatted numerical results (solution) for a pile + mesh Slab type calculation

F.3.9.2.3 Formatted numerical results – "Pile + associated mesh" calculation case – Backfill type calculation

The formatted results displayed for a backfill type calculation are almost identical to those of a slab type calculation (see chapter F.3.9.2.2), except for the section concerning the mesh and the calculation type.

Indeed, for a backfill type calculation, we find the "calculation at imposed stresses" indication, and the reminder of the EQpile value (imposed by the user) and the corresponding load distribution: average stress applied to the soil (kPa) and load applied at pile head (kN).

Maille élémentaire	3.000 m	x	3.000 m
Surface	9.000	Rayon équivalent	1.693
Contrainte /maille	100.000	Charge totale	900.000
Calcul à contraintes imposées			
EQpieu	0.196		
Contrainte /sol	82.157	Charge sur pieu	176.715

Figure F.46 : Formatted numerical results – Pile + associated mesh, backfill type (information related to mesh)

F.3.9.2.4 Numerical results – Results table

The content of the results table is identical for the 3 calculation types (single pile, pile + associated mesh/slab type and pile + associated mesh/backfill type).

Note: Mouse over the column header to obtain the meaning and the units of each term in a tool tip.

We find, in the first columns of the table, the same results as those detailed for the formatted results of chapter F.3.9.2.1 (part of the detailed results table), but also find additional information for each calculation elevation:

- $Q_{s_{lim}}$ (kPa): unit shaft friction at soil/pile interface;
- ΔQ_{mesh} (kN): total added in mesh (addition with respect to the initial stress state);
- Q_{mesh} (kN): total force in mesh (pile + soil);
- σ_{v0} (kPa): initial vertical stress;

- σ_{mesh} (kPa): average stress in mesh (= $Q_{\text{mesh}}/\text{mesh section}$).

However, this display includes neither the data reminder part nor certain results (especially equivalent stiffnesses and bearing).

X [m]	ypile [m]	ysoil [m]	Qpile [kN]	qsmob [kPa]	opile [kPa]	Qsoil [kN]	osol [kPa]	qslm [kPa]	ΔQ_{mesh} [kN]	Qmesh [kN]	ov0 [kPa]	omesh [kPa]
0,00	0,0201	0,0239	1499,0	-28,65	2982	141,00	40,33	30	1640,0	1640,00	0,00	410,00
0,30	0,0201	0,0232	1520,0	-26,44	3023	120,30	40,39	30	1640,0	1664,00	6,00	416,00
0,30	0,0201	0,0232	1520,0	-26,44	3023	120,30	40,39	30	1640,0	1664,00	6,00	416,00
0,60	0,02	0,0226	1538,0	-23,19	3061	101,60	41,05	30	1640,0	1688,00	12,00	422,00
0,60	0,02	0,0226	1538,0	-23,19	3061	101,60	41,05	30	1640,0	1688,00	12,00	422,00
0,90	0,02	0,022	1555,0	-19,99	3093	85,30	42,39	30	1640,0	1712,00	18,00	428,00
0,90	0,02	0,022	1555,0	-19,99	3093	85,30	42,39	30	1640,0	1712,00	18,00	428,00
1,20	0,0199	0,0216	1569,0	-16,82	3121	71,40	44,42	30	1640,0	1736,00	24,00	434,00
1,20	0,0199	0,0216	1569,0	-16,82	3121	71,40	44,42	30	1640,0	1736,00	24,00	434,00
1,50	0,0199	0,0212	1580,0	-14,09	3144	59,71	47,07	30	1640,0	1760,00	30,00	440,00
1,50	0,0199	0,0212	1580,0	-14,09	3144	59,71	47,07	30	1640,0	1760,00	30,00	440,00
1,80	0,0198	0,0209	1590,0	-11,58	3163	50,08	50,32	30	1640,0	1784,00	36,00	446,00
1,80	0,0198	0,0209	1590,0	-11,58	3163	50,08	50,32	30	1640,0	1784,00	36,00	446,00
2,10	0,0198	0,0206	1598,0	-9,35	3179	42,18	54,06	30	1640,0	1808,00	42,00	452,00
2,10	0,0198	0,0206	1598,0	-9,35	3179	42,18	54,06	30	1640,0	1808,00	42,00	452,00
2,40	0,0198	0,0204	1604,0	-7,50	3191	35,82	58,24	30	1640,0	1832,00	48,00	458,00
2,40	0,0198	0,0204	1604,0	-7,50	3191	35,82	58,24	30	1640,0	1832,00	48,00	458,00
2,70	0,0197	0,0202	1609,0	-6,02	3202	30,73	62,79	30	1640,0	1856,00	54,00	464,00
2,70	0,0197	0,0202	1609,0	-6,02	3202	30,73	62,79	30	1640,0	1856,00	54,00	464,00
3,00	0,0197	0,02	1613,0	-4,67	3210	26,69	67,63	30	1640,0	1880,00	60,00	470,00
3,00	0,0197	0,02	1613,0	-4,67	3210	26,69	67,63	30	1640,0	1880,00	60,00	470,00
3,30	0,0196	0,0199	1616,0	-3,55	3216	23,59	72,75	30	1640,0	1904,00	66,00	476,00
3,30	0,0196	0,0199	1616,0	-3,55	3216	23,59	72,75	30	1640,0	1904,00	66,00	476,00
3,60	0,0196	0,0198	1619,0	-2,81	3220	21,27	78,08	30	1640,0	1928,00	72,00	482,00
3,60	0,0196	0,0198	1619,0	-2,81	3220	21,27	78,08	30	1640,0	1928,00	72,00	482,00
3,90	0,0195	0,0197	1620,0	-1,80	3224	19,61	83,61	30	1640,0	1952,00	78,00	488,00
3,90	0,0195	0,0197	1620,0	-1,80	3224	19,61	83,61	30	1640,0	1952,00	78,00	488,00
4,20	0,0195	0,0196	1621,0	-1,09	3226	18,52	89,30	30	1640,0	1976,00	84,00	494,00
4,20	0,0195	0,0196	1621,0	-1,09	3226	18,52	89,30	30	1640,0	1976,00	84,00	494,00
4,50	0,0194	0,0194	1622,0	-0,43	3227	17,95	95,13	30	1640,0	2000,00	90,00	500,00
4,50	0,0194	0,0194	1622,0	-0,43	3227	17,95	95,13	30	1640,0	2000,00	90,00	500,00
4,80	0,0194	0,0193	1622,0	0,21	3227	17,86	101,10	30	1640,0	2024,00	96,00	506,00
4,80	0,0194	0,0193	1622,0	0,21	3227	17,86	101,10	30	1640,0	2024,00	96,00	506,00
5,10	0,0193	0,0192	1622,0	0,85	3226	18,26	107,20	30	1640,0	2048,00	102,00	512,00
5,10	0,0193	0,0192	1622,0	0,85	3226	18,26	107,20	30	1640,0	2048,00	102,00	512,00
5,40	0,0193	0,0191	1621,0	1,54	3225	19,17	113,50	30	1640,0	2072,00	108,00	518,00
5,40	0,0193	0,0191	1621,0	1,54	3225	19,17	113,50	30	1640,0	2072,00	108,00	518,00
5,70	0,0192	0,019	1619,0	2,31	3222	20,62	119,90	30	1640,0	2096,00	114,00	524,00
5,70	0,0192	0,019	1619,0	2,31	3222	20,62	119,90	30	1640,0	2096,00	114,00	524,00

Figure F.47 : Numerical results – Results table

F.3.9.3 Graphical results

F.3.9.3.1 Loading curve

The loading curve is accessible only for a single pile calculation.

It represents the settlement of pile at top (m) as a function of the load applied at pile head (kN).

It is constructed automatically by Taspie+: the first point corresponds to a null load applied at pile head. The last point corresponds to the application of 95% of the breaking load.

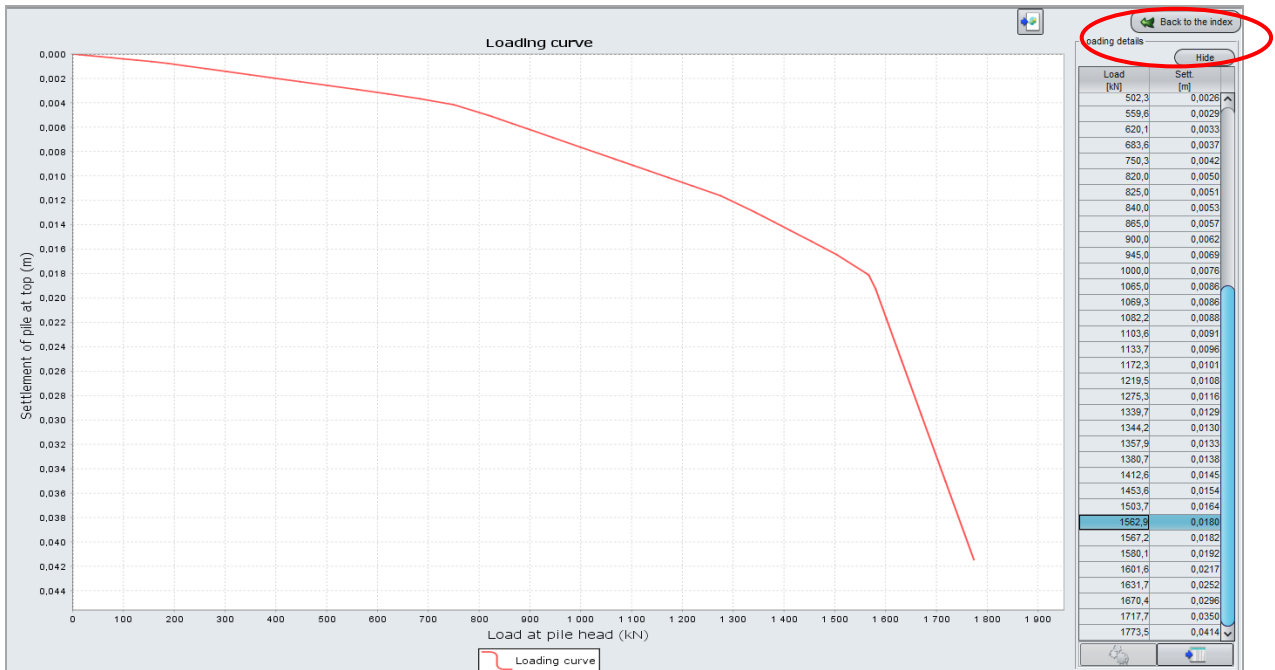


Figure F.48 : Graphical results – Loading curves (single pile calculation)

By default, only the curve is displayed. A Show/Mask button on top right of the window shows or masks the table of points calculated by Taspie+ to construct the loading curve.

F.3.9.3.2 Main results

The curves shown are almost identical for the 3 calculation types (single pile, pile + associated mesh slab type and pile + associated mesh backfill type).

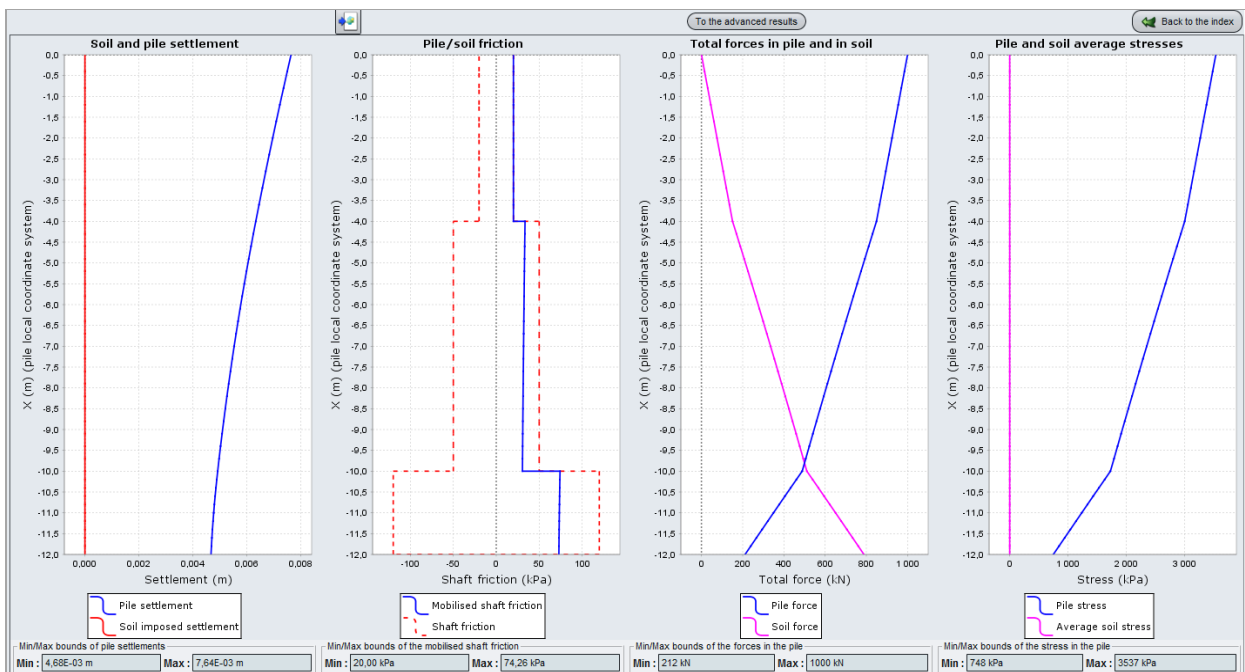


Figure F.49 : Graphical results – Main results (single pile)

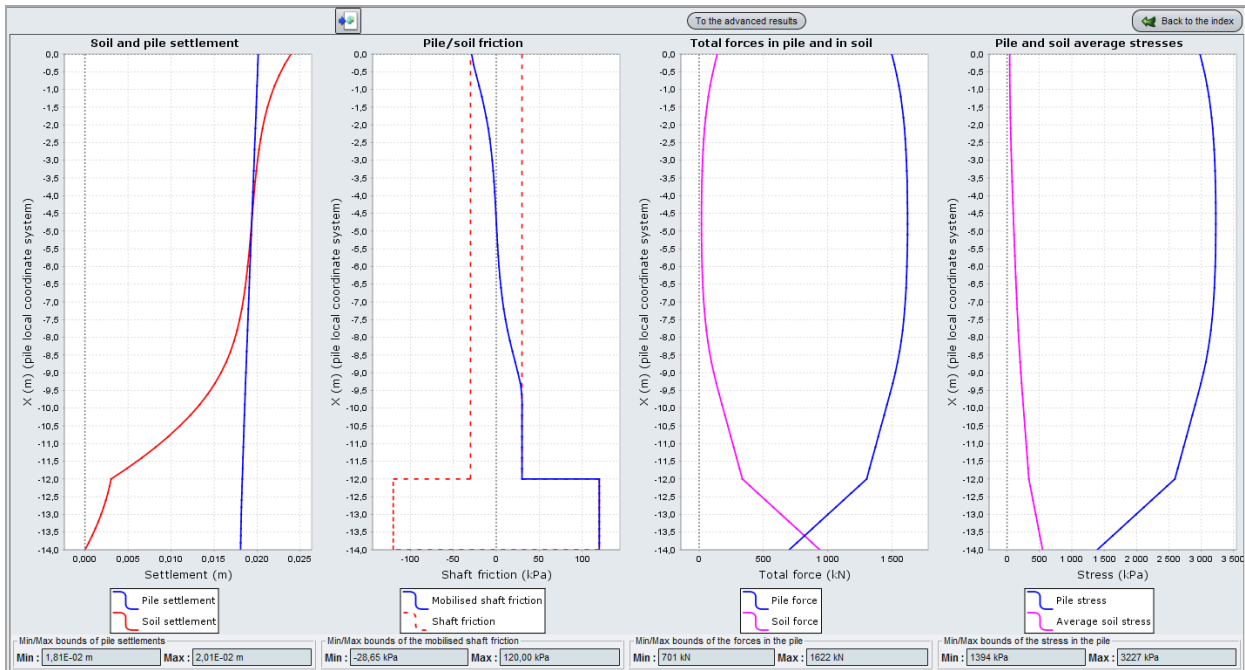


Figure F.50 : Graphical results – Main results (pile + associated mesh)

The main curves present the graphical display of 4 types of results as a function of the local abscissa of the pile x(m):

- The settlements (m): pile settlement resulting from Taspie+ calculation and soil settlement. Concerning the soil settlement, these are:
 - ✓ The imposed soil settlement as defined in the data for a "single pile" type calculation;
 - ✓ The average soil settlement resulting from Taspie+ calculation for a pile + associated mesh type calculation.
- The pile/soil frictions (kPa): mobilised friction resulting from Taspie+ calculation and shaft friction as defined in the data;
- The total forces (kN): force in the pile and force taken by the soil;
- The stresses (kPa): stress in the pile (force/section) and average vertical stress in the soil between the piles (this is not calculated for a single pile type calculation).

The minimum and maximum values of the quantities represented are given under each curve.

F.3.9.3.3 Additional results

Clicking **To the advanced results** button displays the additional results. These are also directly accessible from the result type choice window:

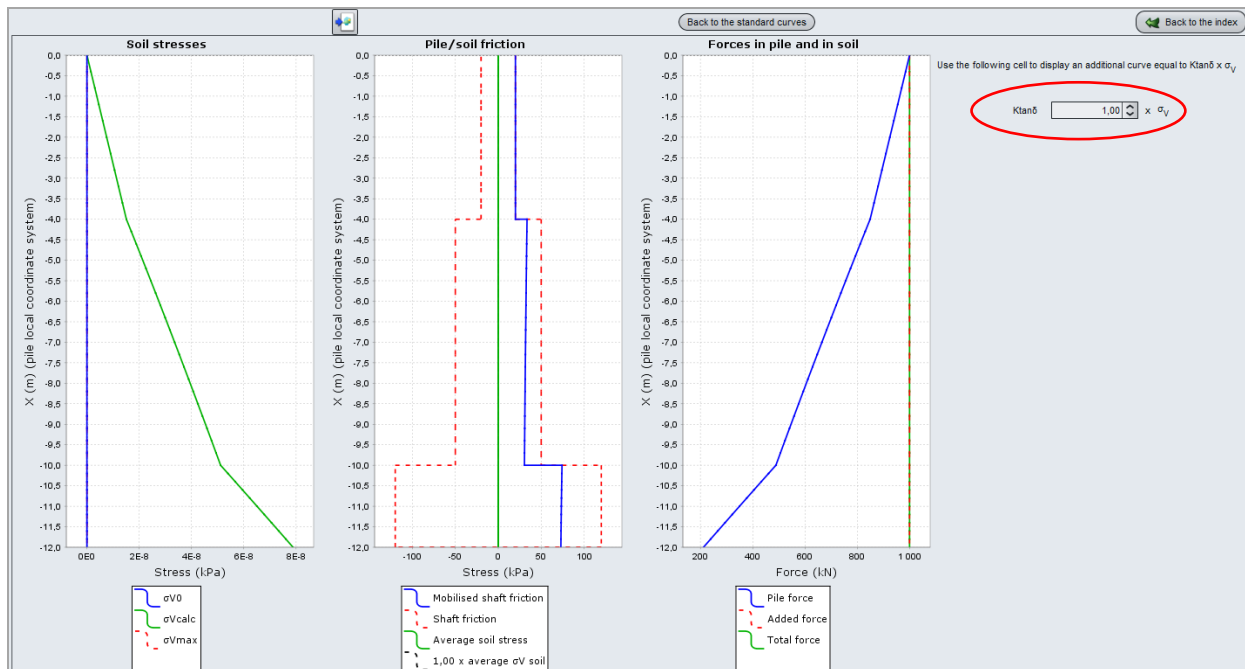


Figure F.51 : Graphical results – Additional results

The main curves present the graphical display of 3 types of results as a function of the local abscissa of the pile $x(m)$:

- The stresses in the soil (kPa):
 - ✓ σ_{v0} : initial vertical stress in soil;
 - ✓ σ_{vcalc} : final stress in soil resulting from Taspie+ calculation (corresponding to σ_{soil} column of results table);
 - ✓ σ_{vmax} : average final stress in mesh (corresponding to σ_{mesh} column of results table).
- The pile/soil frictions (kPa):
 - ✓ Mobilised friction: mobilised soil/pile friction resulting from Taspie+ calculation;
 - ✓ Limit friction: limit unit friction as defined by the user;
 - ✓ Average soil stress: final stress in the soil (corresponding to σ_{soil} column of results table);
 - ✓ Soil average $Ktan\delta \times \sigma_v$: previous curve multiplied by the $Ktan\delta$ value that the user can modify on top right of window (default value equal to 1,0). Also see chapter F.2.6.1 and example 4 of chapter F.4.4.
- The forces in pile and soil (kN):
 - ✓ Force in pile (Q_{pile});
 - ✓ Added force on mesh (corresponding to ΔQ_{mesh} column of results table);
 - ✓ Total force in mesh (corresponding to Q_{mesh} column of results table).

F.3.9.4 "Additional loads" in slab wizard

The results of Taspie+ model can be used to evaluate the additional loads in the slab due to the presence of inclusions. These additional loads can be calculated by means of the "slab moment wizard" accessible from the results window (external wizard):

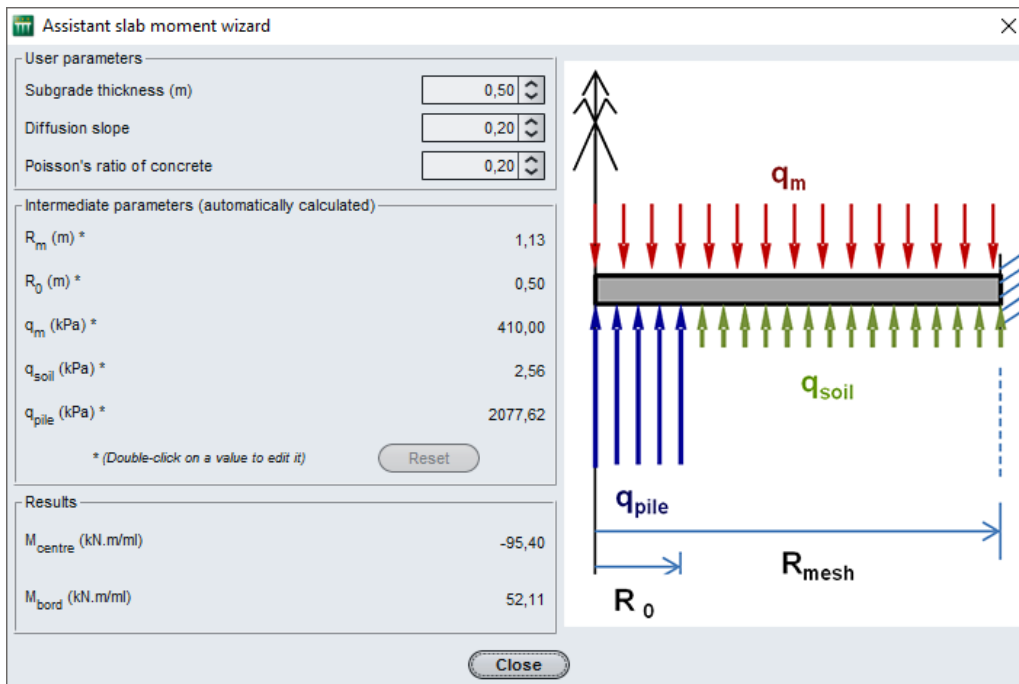


Figure F.52 : Slab moment wizard

Upper part of the wizard window: additional data

Input (once more) the following additional data:

- Subgrade thickness (that is, here, the load transfer platform), by default taken as equal to thickness of first layer of model;
- Diffusion slope (stresses in body of platform), taken by default as equal to 0,2 (1H/5V);
- Poisson's ratio of concrete (between 0 and 0,2).

Centre part of the wizard window: intermediary calculation parameters (see chapter F.2.10). These parameters are automatically precalculated by the interface but can be modified by a double click:

- R_m : equivalent radius of elementary cell, directly related to the mesh pitch in each direction;
- R_0 : "impact" radius under slab at inclusions, calculated taking diffusion slope in platform body into account;
- q_m : average stress applied to elementary cell (on slab surface), obtained from input data;
- q_{soil} : average stress transmitted to soil (on slab under face);
- q_{pile} : average stress (additional) applied at inclusions at slab under face (distributed on impact radius R_0).

Lower part of wizard window: results

These values are calculated as a function of previously input values (and cannot be modified).

- M_{centre} : moment in centre of elementary mesh;
- M_{edge} : moment on edge of elementary mesh.

These two values (centre moment and edge moment) constitute an envelope [M_{lower} , M_{upper}] corresponding to the "mb" term in the sense of the calculation rules explained in the ASIRI guide. These additional moments are to be combined with a slab calculation on homogenised soil.

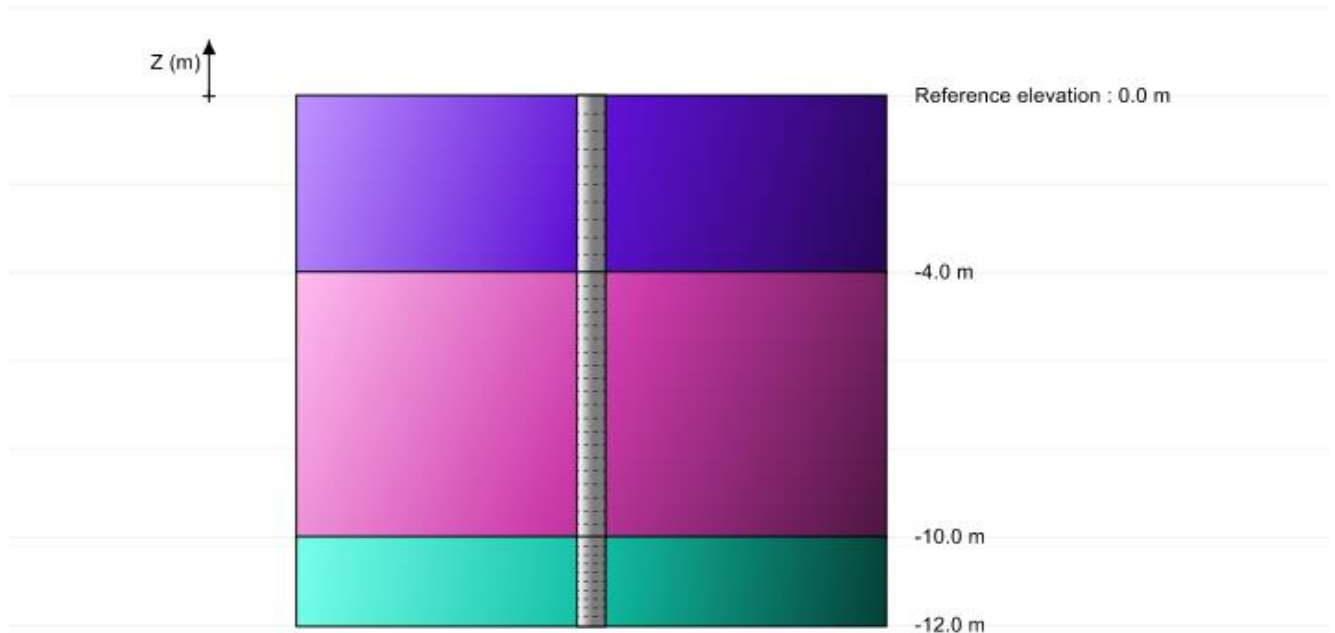
Note: The moments are taken as positive when the lower fibre is under traction.

F.4. Taspie+ calculation examples

F.4.1. Example 1: Single pile

This first example deals with a cast-in-place single pile of 0.6 m in diameter and subjected, in a first step, to a load of 1000 kN.

In a second step, we will proceed to a calculation where the pile is also subjected to the settlement of the surrounding ground.



F.4.1.1 Step 1: Single pile

F.4.1.2 Data input

- Create a new project by clicking on the Layers radio-button;
- Click on the button.

If Foxta is already open, click on "File", then "New project".

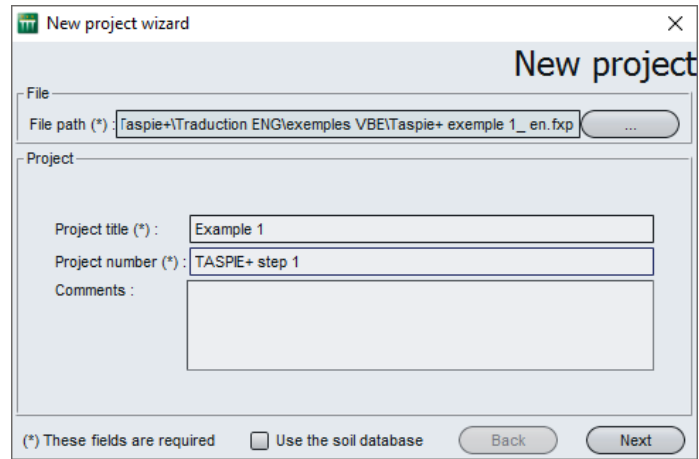
F.4.1.2.1 New project wizard

"File" frame

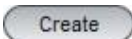
- Click on the button to choose the work directory;
- Name and save the file.

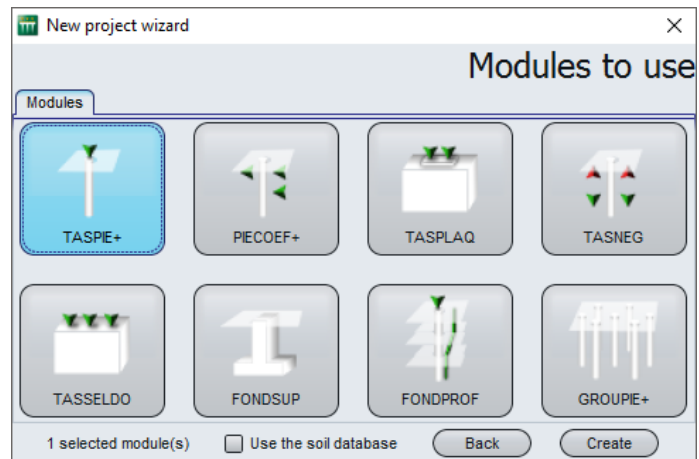
"Project" frame

- Define a title for the project;
- Define a project number;
- Complete comments if necessary;
- Leave the "Use the soil database" box unchecked (for this example we will not use the soil database), and click on the button.

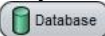


F.4.1.2.2 New project wizard: Module selection

- In the "Modules to use" window, select the Taspie+ module and click on the  button.

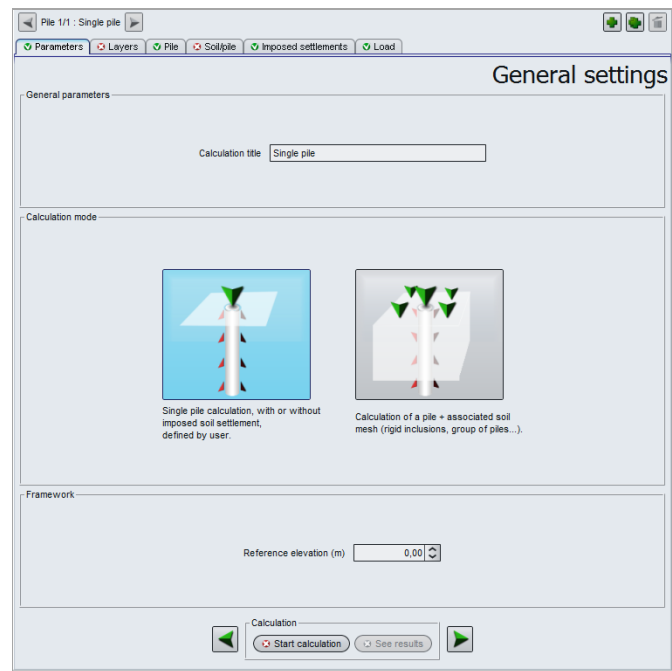


Note:

Foxta allows the save of soil layers in the soil database of the project and/or in the global soil database by clicking on the  button.

This allows the user to save the soil layer parameters to reuse them without retyping again in another module of the same project or in a new Foxta project.

The database will not be used in this example, but its use is described in detail in the section C of the user's manual.

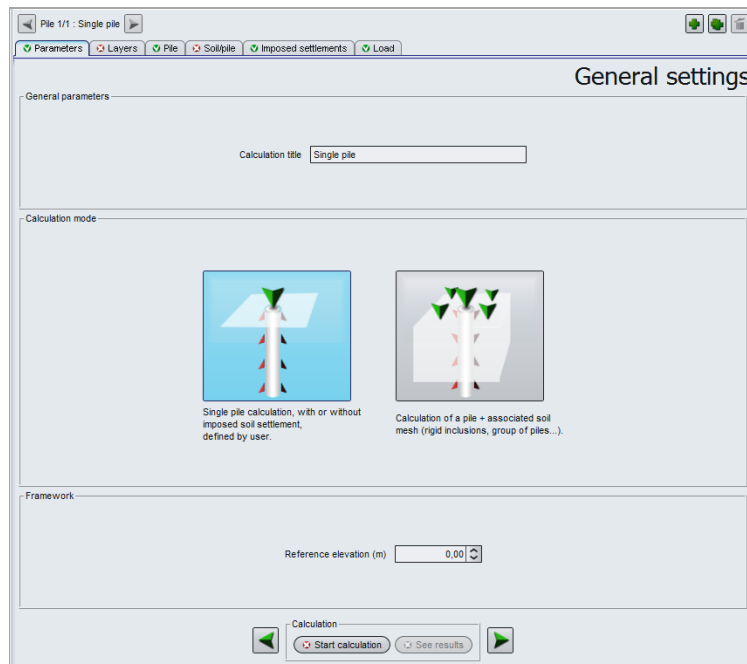


The input data window of Taspie+ is now displayed.

All data tabs should be now completed in the right zone of the screen.

F.4.1.2.3 “Parameters” tab

Definition of the general parameters:



“General parameters” frame:


- Calculation title: Name it “single pile” for example.

“Calculation mode” frame:

- Select the calculation type by clicking on the adequate button. In this example: “Single pile calculation”.

“Framework” frame:

- Reference elevation: 0.00 m (head of the pile).

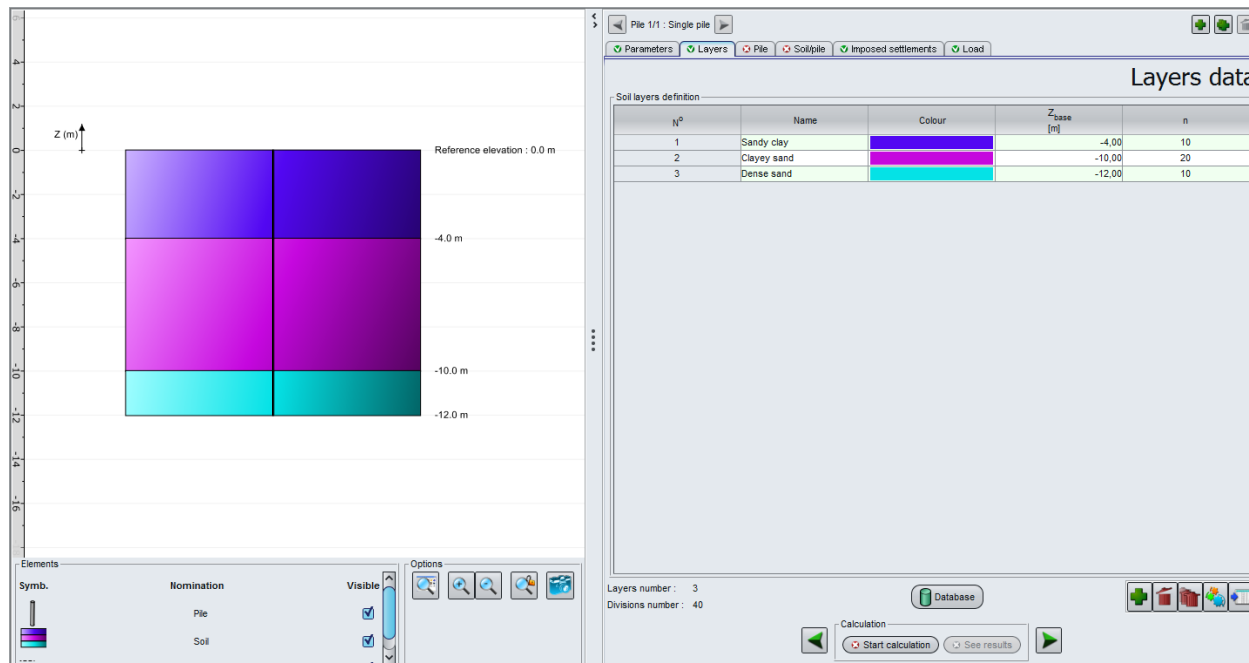
To shift to the next tab, click either on the name of the tab “Layers”, or on the  button.

F.4.1.2.4 "Layers" tab

This tab allows the definition of the soil layer characteristics:

- The elevation of the base of each soil layer Z_{base} (m);
- The number of subdivisions n of each layer.

IMPORTANT: by Taspie+ convention, the bottom of the pile is assumed to be at the level of the bottom of the last soil layer defined. Therefore, the soil cross section must be stopped at bottom of pile (except in certain "pile + associated mesh" cases which require an extension of the model under the toe of the piles, also check chapter F.2.7).



The input to use in this section is the following:

Layer	Name	Z_{base} (m)	n
1	Sandy clay	-4.00	10
2	Clayey sand	-10.00	20
3	Dense sand	-12.00	10

Note: in this case, the n values of discretisation correspond to a slicing of each soil layer into calculation slices of 20 to 40 cm thick.

F.4.1.2.5 "Pile" tab

Via this tab, we will define the type of the pile and its parameters: in this example, the pile characteristics (Young's modulus E_{pile} and diameter D) are constant along the whole length of the pile.

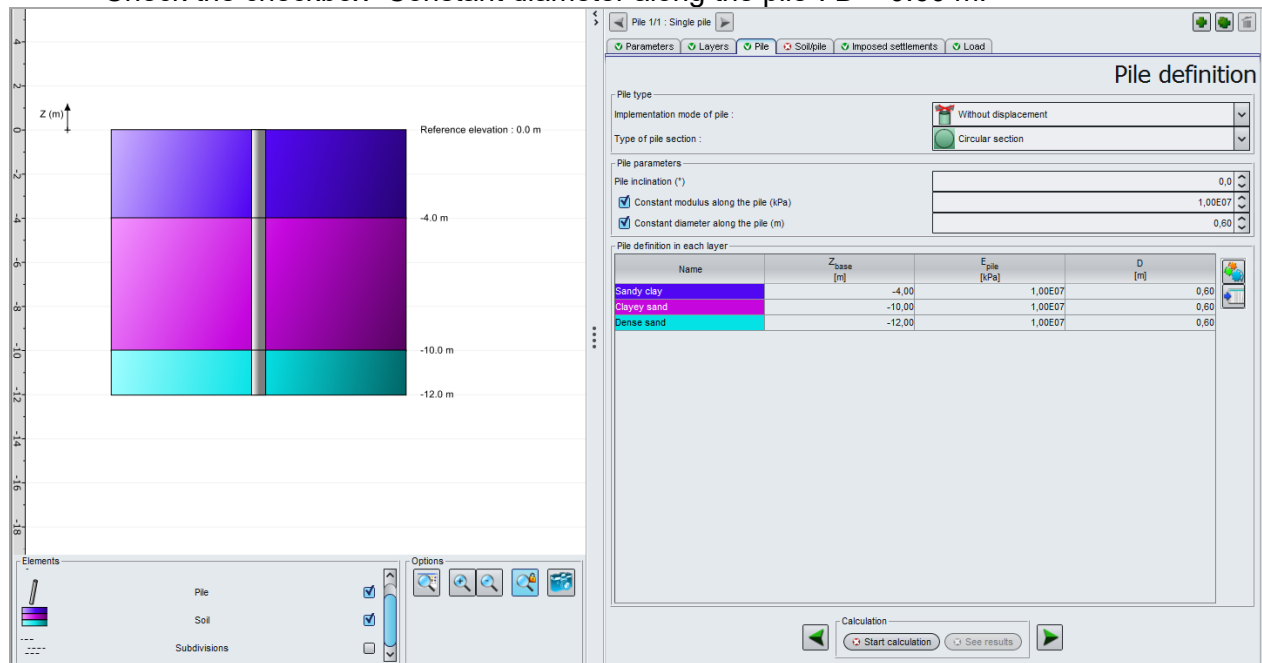
"Pile type" frame:

- Implementation mode of pile: chose "Without displacement" (bored pile);
- Type of pile section: chose "Circular section".

"Pile parameters" frame:

- Pile inclination: 0° (vertical pile);

- Check the checkbox “Constant modulus along the pile (kPa)”: $E_{pile} = 1.0E^{07}$ kPa (concrete, long term case);
- Check the checkbox “Constant diameter along the pile”: $D = 0.60$ m.



“Pile definition in each layer” frame:

The table in this tab is automatically filled in with the parameters entered in the previous tab as the soil layers and their Z_{base} , Young’s modulus and diameter of the pile (constant along the pile in this case). Thus, this table is displayed as a reminder of the previous input (however, when the Young’s modulus and/or the diameter are not constant along the pile, it is proposed a manual input for each layer):

Name	Z_{base} (m)	E_{pile} (kPa)	D (m)
Sandy clay	-4.00	1.00E07	0.60
Clayey sand	-10.00	1.00E07	0.60
Dense sand	-12.00	1.00E07	0.60

F.4.1.2.6 “Soil/Pile” tab

This tab allows the definition of the skin friction and base resistance mobilisation laws.

The skin friction mobilisation law we will use in this example is Frank and Zhao law built up from the pressuremeter data. The limit skin friction is 20 kPa in sandy clay, 50 kPa in clayey sand, and 120 kPa in dense sand.

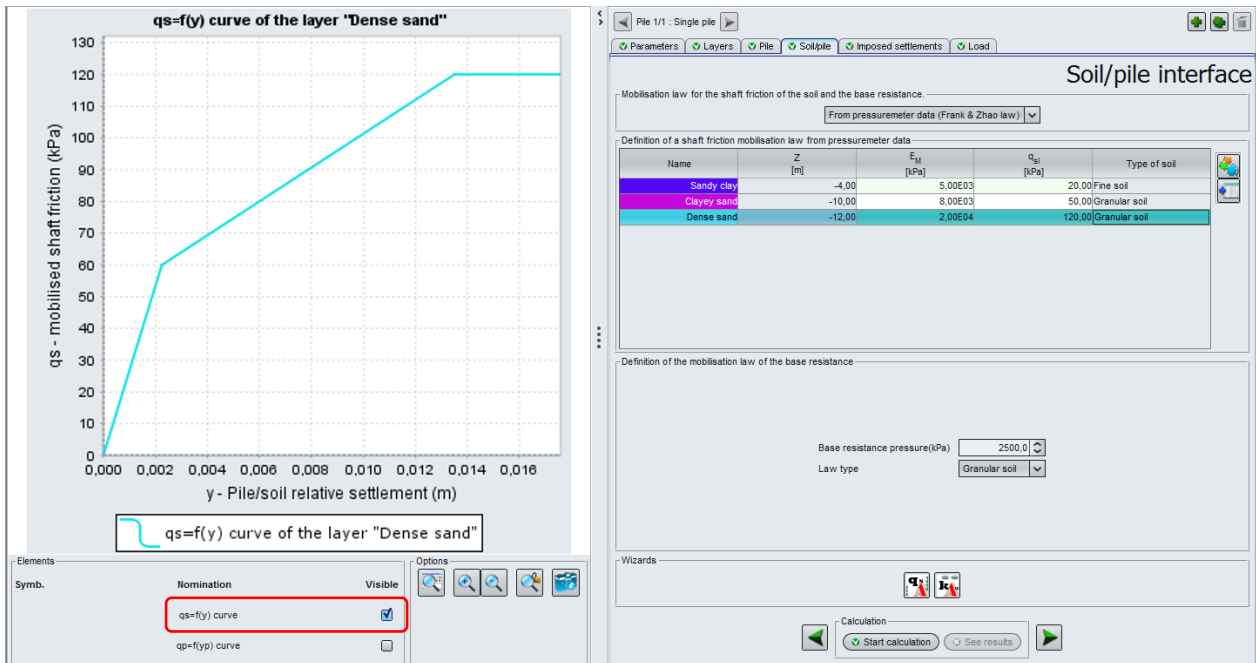
“Mobilisation law for the shaft friction of the soil and the base resistance” frame:

- Within the dropdown list, chose “From pressuremeter data (Frank & Zhao law)”. It is a by default choice.

“Definition of a shaft friction law” frame:

The table is automatically filled in by the soil layers previously defined. The data to complete for each soil layer are the following:

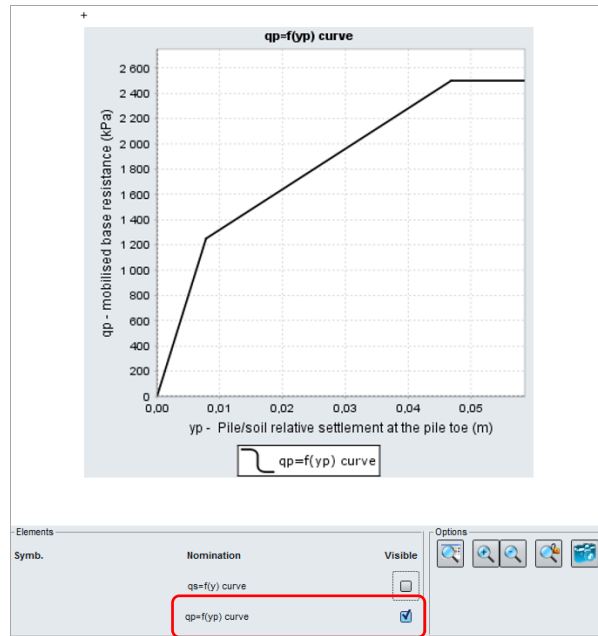
Name	E_M (kPa)	q_{si} (kPa)	Soil type
Sandy clay	5.00E03	20.00	Fine soil
Clayey sand	8.00E03	50.00	Granular soil
Dense sand	2.00E04	120.00	Granular soil



“Definition of the mobilisation law of the base resistance” frame:

The mobilisation law of the base resistance to choose here is Frank and Zhao for granular soil with a limit resistance pressure of 2500 kPa ($k_p \times p_e$):

- Base resistance pressure: 2500 kPa;
- Law type: “Granular soil”.

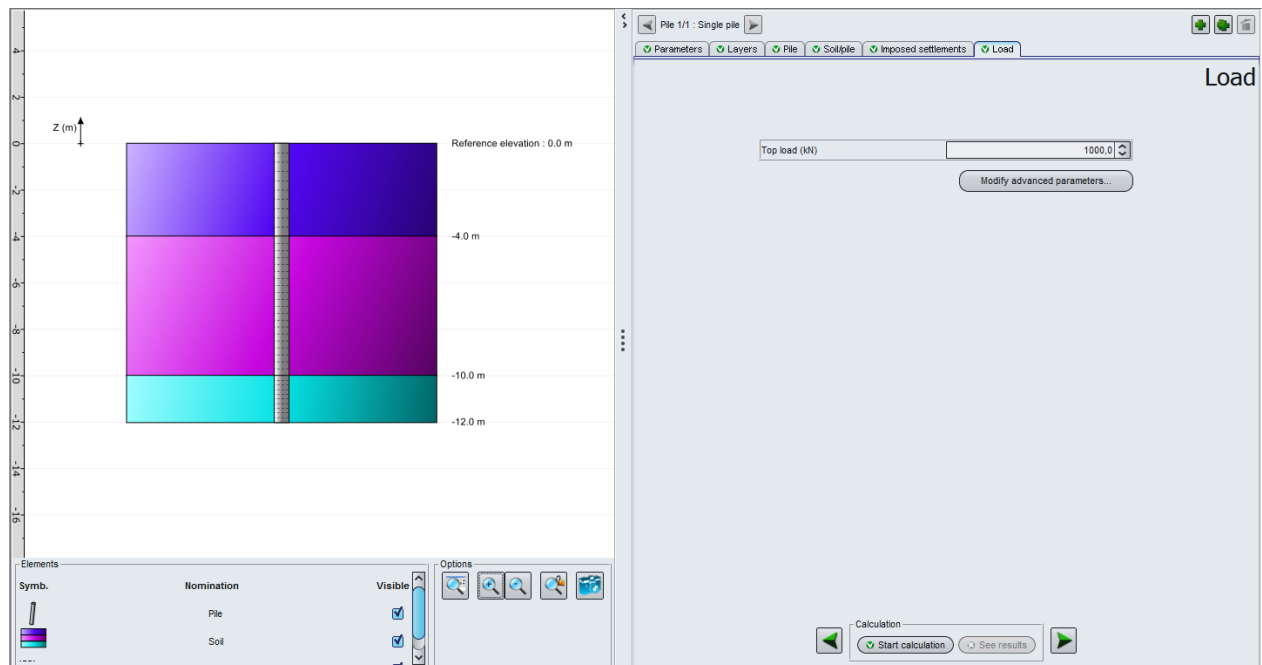


F.4.1.2.7 "Imposed settlement" tab

- Let the checkbox “Activate imposed settlement” unchecked. In this part of the example, we do not want to impose any settlement to the soil in-between the piles.

F.4.1.2.8 “Load” tab

This tab allows the definition of the loading conditions on top of the pile.

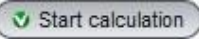



- Top load: enter 1000 kN.

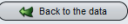
We will not modify the advanced parameters in this example (which means that the default values are conserved).

F.4.1.3 Calculations and results

F.4.1.3.1 Calculation

Click on the  button.

To display the results formatted as tables and graphical views, click on the  button.

Results Calculated : 3 seconds ago (Calculation date : Jun 13, 2016 5:49:23 PM) 

Numerical results



Formatted results



Result tables

Graphical results



Loading curve



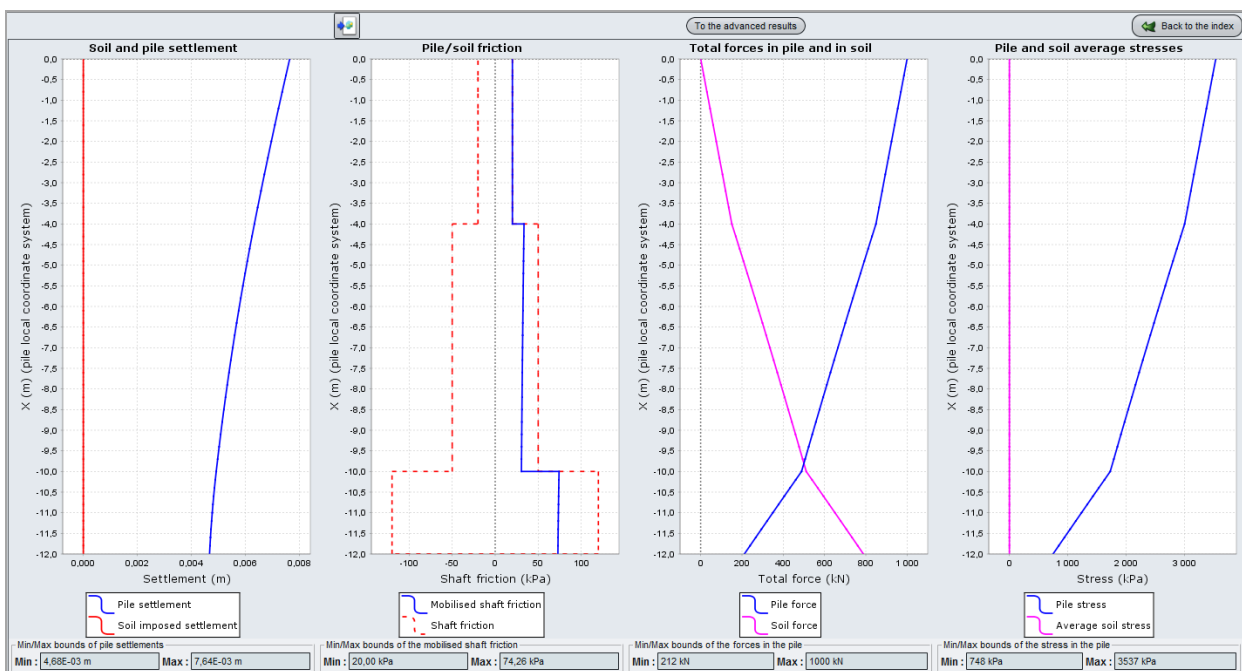
Main results



Complementary results

F.4.1.3.2 Graphical results

Main results

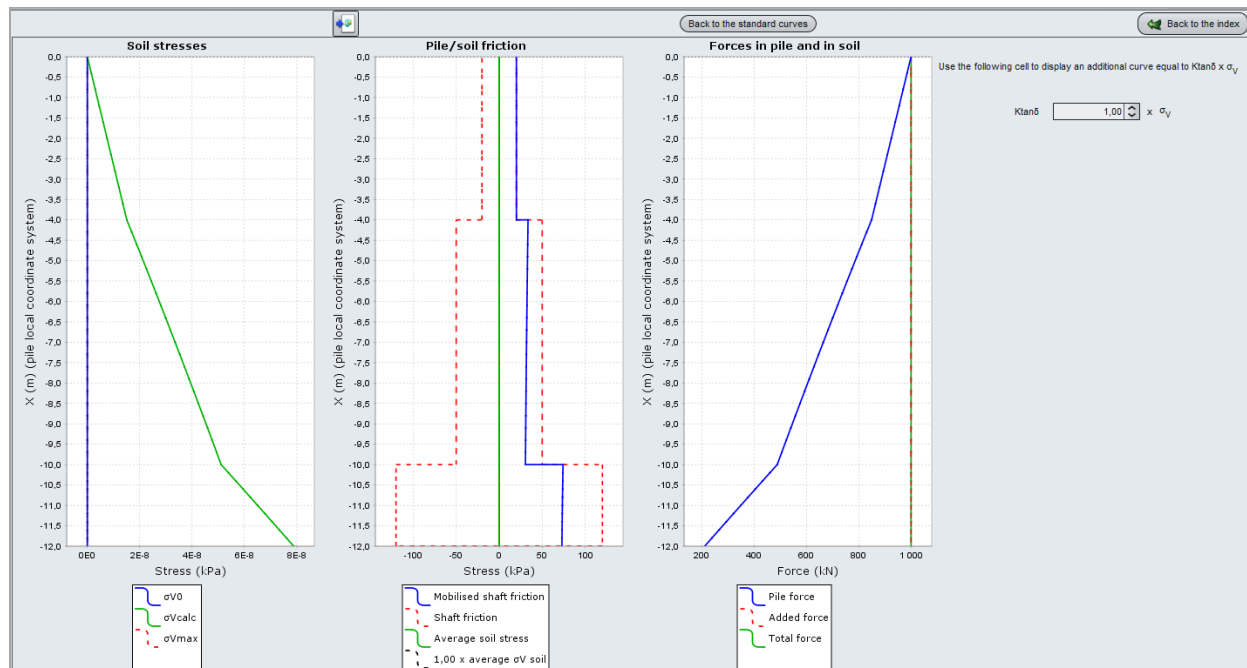


We note that:

- The maximum settlement of the pile is 7.64 mm. This value corresponds to the pile head settlement while the base of the pile settles 4.7 mm. The imposed settlement of the soil is null (as we didn't define any imposed settlement in the input);
- The limit skin friction is entirely mobilised in the sandy clay (down to 4 m deep), and it is partially mobilised within the clayey sand and dense sand.
- The force in the pile is maximum at top and it is equal to 1000 kN (the load applied on top of the pile). This force is dissipated in depth thanks to the lateral skin friction. At the base of the pile, the force in the pile is 212 kN (base load), whereas the force buried by the soil is equal to 788 kN (= 1000-212, sum of the mobilised skin friction along the pile)
- the average stress in the soil is not calculated here ("single pile" calculation type). The stress in the pile is equal to the force in the pile divided by its section: thus it decreases by depth (3537 kPa at the top and 748 kPa at the base).

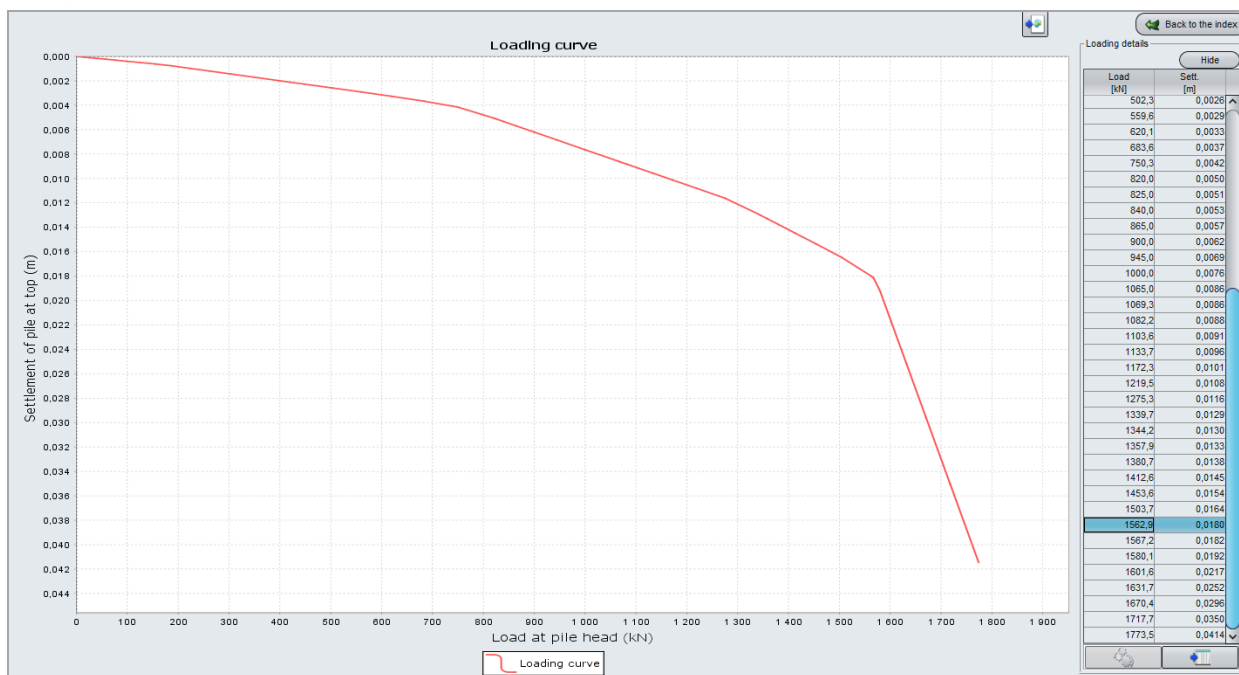
Clicking on the [To the advanced results](#) button leads to display the stress curves in the soil, pile/soil skin friction, and pile and soil forces:

In the case of our example of a single pile, the advanced results do not provide any additional information.



To display the loading curve, click on the [Back to the index](#) button then "Loading curve".

This curve, available only for "single pile", is automatically built up by Taspie+ for a load varying from 0 up to 95% of the ultimate resistance.



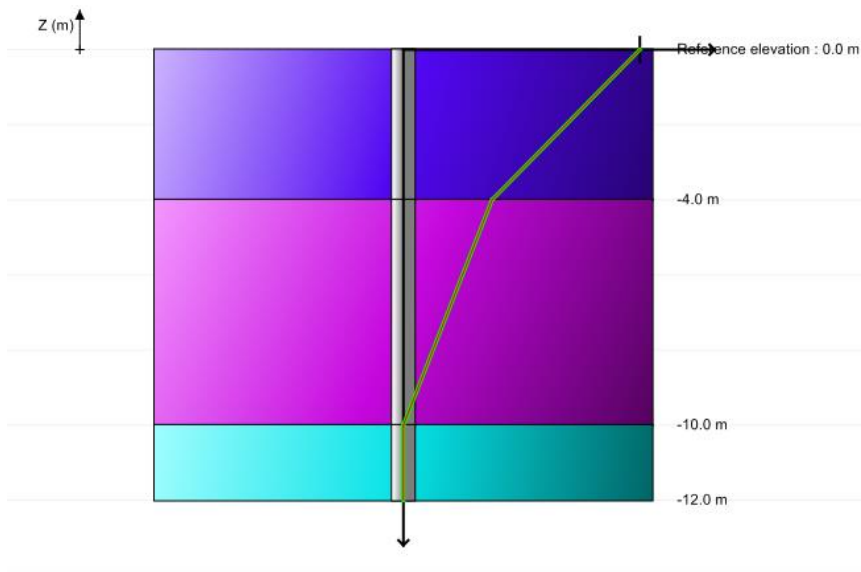
F.4.1.3.3 Numerical results

At the end of this file, the settlement value obtained under 1000 kN, as well as the equivalent stiffness of the pile top can be consulted.

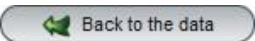
Caractéristiques mécaniques									
Couche	Cote	Frottement limite	Module du pieu	Module du sol	Paramètres oedométriques			G ou G'	ig
					Cs/(1+e0)	Cc/(1+e0)	tc		
1	0.00	20.00	0.100E+08	0.100E+11				0.00	0
2	-4.00	50.00	0.100E+08	0.100E+11				0.00	0
3	-12.00	120.00	0.100E+08	0.100E+11				0.00	0
qp1 = 2500.00									
Lois de mobilisation									
Couche 1 cotes : 0.000 à -4.000									
Em = 5000. qs1 = 20.00									
mobilisation frottement y qs *** Frank et Zhao (sol fin foré)									
0.0006 10.00									
0.0036 20.00									
Couche 2 cotes : -4.000 à -10.000									
Em = 8000. qs1 = 50.00									
mobilisation frottement y qs *** Frank et Zhao (sol granulaire foré)									
0.0023 25.00									
0.0141 50.00									
Couche 3 cotes : -10.000 à -12.000									
Em = 20000. qs1 = 120.00									
mobilisation frottement y qs *** Frank et Zhao (sol granulaire foré)									
0.0022 60.00									
0.0135 120.00									
mobilisation pointe *** Frank et Zhao (sol granulaire foré)									
y qp Qp									
0.0078 1250.00 353.43									
0.0469 2500.00 706.86									
CAPACITE PORTANTE									

F.4.1.4 Step 2: Single pile with imposed settlement of the soil

We start again the same example as previous, but this time we will define an imposed settlement of the surrounding soil.



F.4.1.5 Modification of the input

To modify the input, click on the  button. Then “save your project as” with another name.

Note: it was also possible to duplicate the pile within the same project (see example 2).

F.4.1.5.1 “Parameters” tab

- Change the name of the calculation: “Single pile with imposed settlement of the soil” for example.

F.4.1.5.2 “Imposed settlement” tab

- Check the “Activate imposed settlement” checkbox.

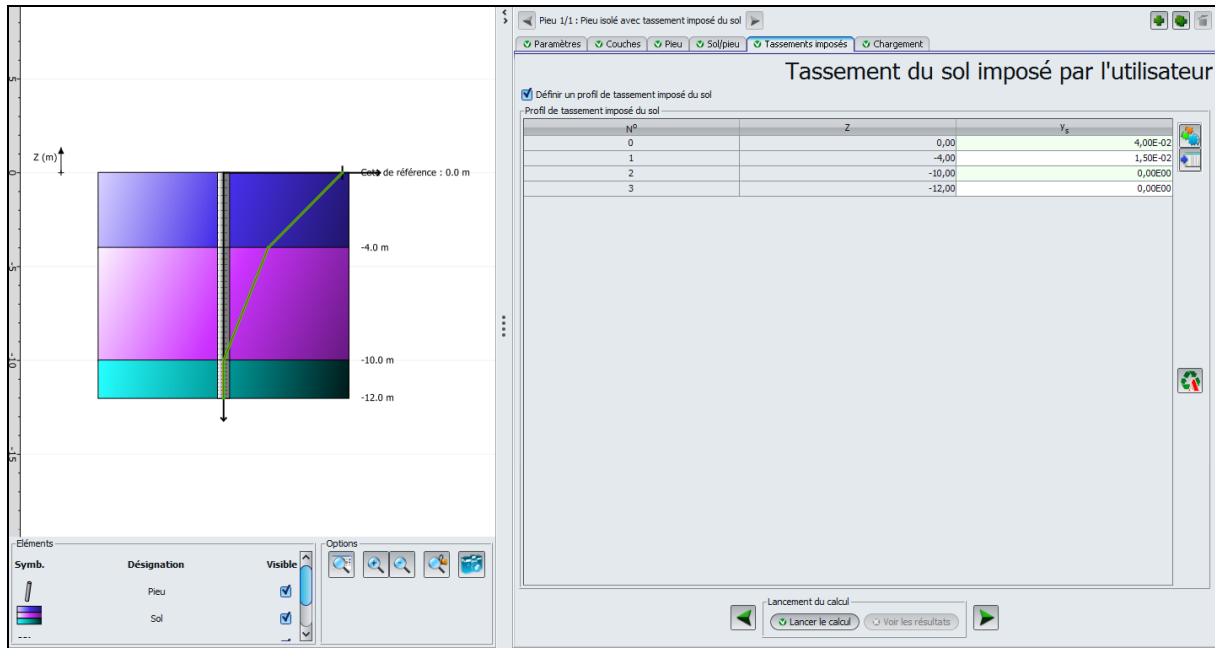
“User-imposed soil settlement” frame

It is proposed, for this example, to define the following profile of soil settlement y_s :

- $y_s = 4$ cm at elevation 0.0 m (at the surface);
- $y_s = 1.5$ cm at elevation -4.0 m (at the base of the first soil layer);
- $y_s = 0$ cm at elevation -10.0 m and below (at the base of the deeper soil layers).

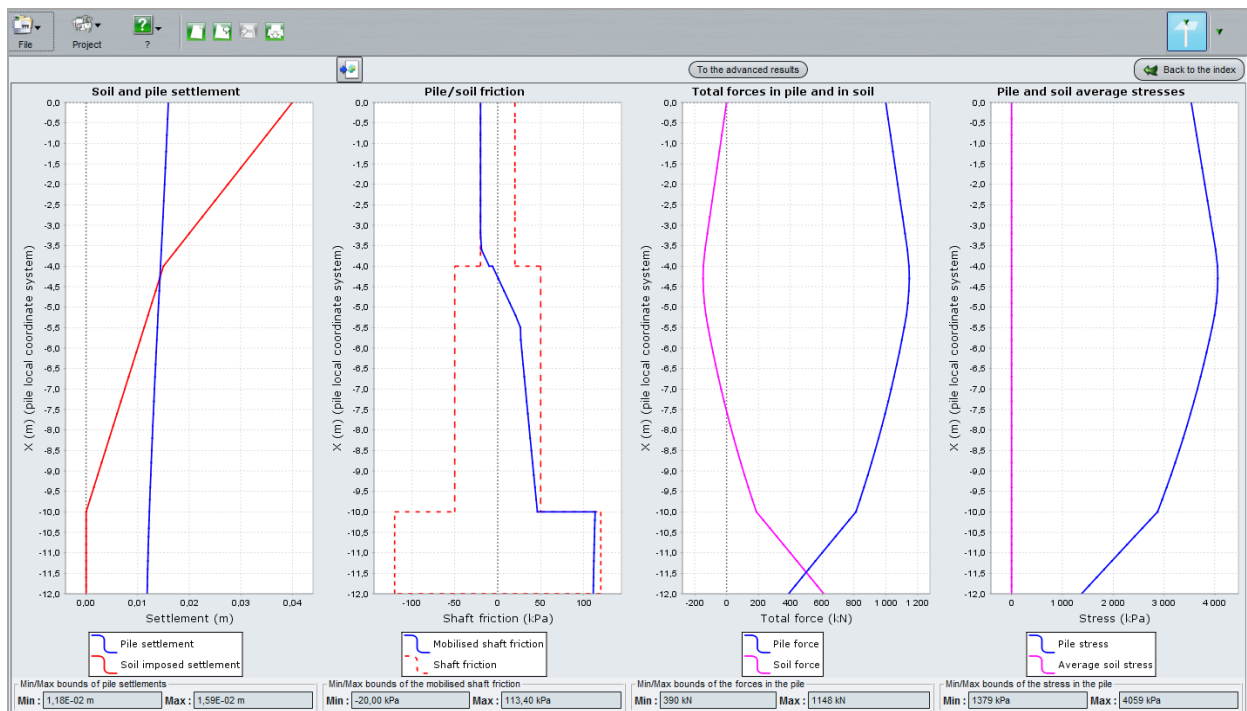
Accordingly, the input data are the following:

N°	Z (m)	y_s (m)
0	0.00	4.00E-02
1	-4.00	1.50E-02
2	-10.00	0.00E00
3	-12.00	0.00E00



F.4.1.6 Calculations and results

Run again the calculation by clicking on the  button.

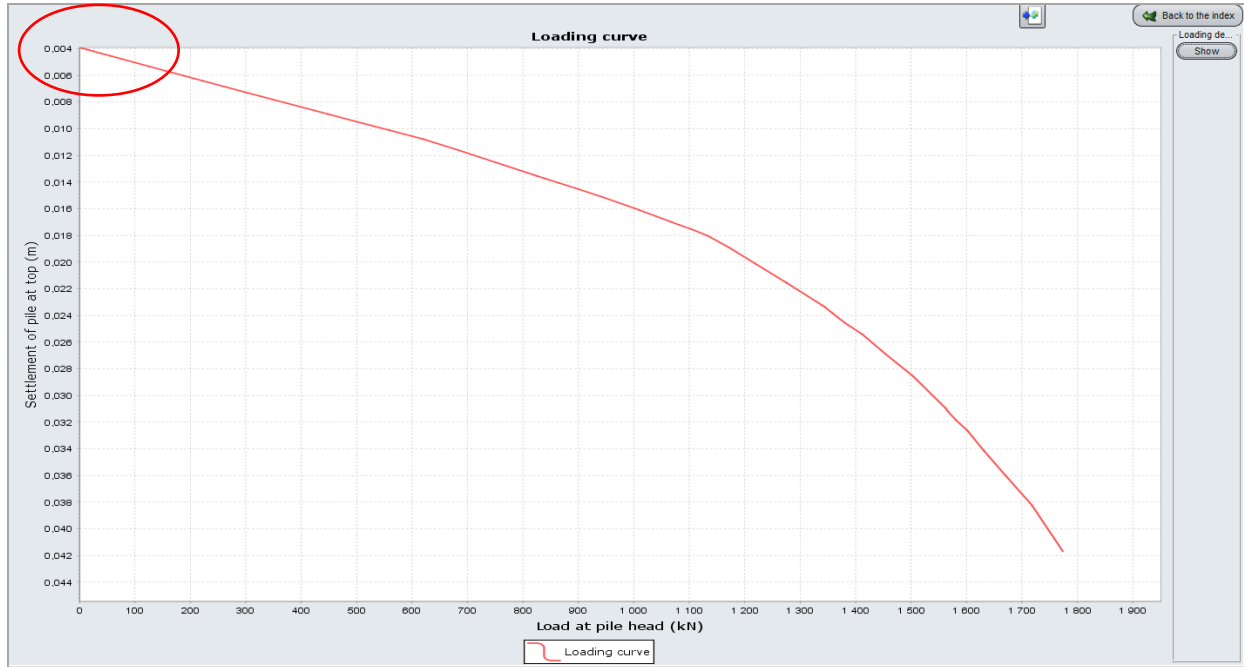


We note that:

- The maximum settlement of the pile is 1.6 cm. It is obtained at the pile top, while the pile base settles 1.2 cm (the settlement values have been doubled comparing to the step 1). The imposed settlement of the soil is not null: it is equal to the imposed settlement value defined as an input;
- Down to 4 m deep, the soil settles more than the pile, consequently a negative friction (hanging effect) appears. From this depth downward, called “Neutral plane”, the pile settles more than the soil and the friction becomes positive. The bearing capacity of the pile shall be verified starting from the neutral plane.

- Maximum force in the pile is not obtained at the pile top but at the level of the neutral plane and is equal to 1148 kN: this value corresponds to the load applied on top (1000 kN) + the sum of the negative friction mobilised above the neutral plane (148).

To display the loading curve, click on the [Back to the index](#) button then on “Loading curve”. Note that for a pile top load equal to zero, the settlement of the pile is different from zero: this is due to the hanging effect of the soil settlement.



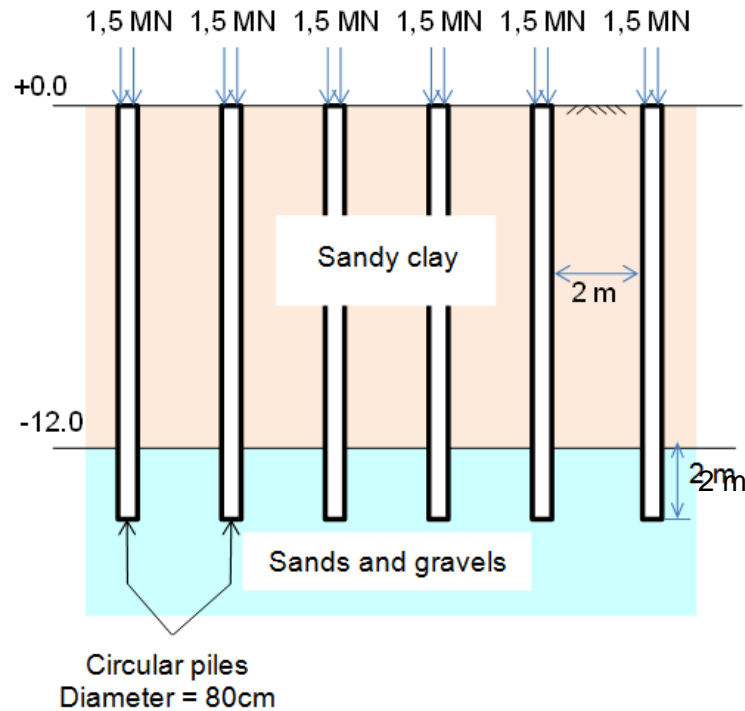
The following table presents a comparison of the results of 2 different calculations (without and with imposed settlement of the soil around the pile):

	Settlement of the pile (cm)		Mobilised skin friction (kPa)		Force in the pile (kN)		Stress in the pile (kPa)	
	Min	Max	Min	Max	Min	Max	Min	Max
Single pile without imposed settlement of the soil	0.47	0.77	20	74	212	1000	748	3537
Single pile with imposed settlement of the soil	1.18	1.60	-20	113	390	1148	1379	4059

F.4.2. Example 2: Pile group and negative skin friction

This example illustrates how to deal with a group of piles submitted to negative skin friction.

The project is illustrated on the below figure. The group of piles is composed of 80 cm diameter and 14 m long piles; they are embedded in a two-layer soil. Piles are placed in a regular mesh of 2 m x 2 m, each pile bears a vertical load of 1500 kN.



The following table shows the available geo-mechanical characteristics:

Layer	Z _{top} (m)	γ (kN/m ³)	E _M (MPa)	P _I * (MPa)	α	q _{sl} (kPa) ^(**)	E (MPa) ^(*)
Sandy clay	+0.00	20	5.0	0.6	0.67	30	15
Sands and gravels	-12.00	20	20	2.0	0.33	120	120

(*) E is the equivalent elastic strain modulus.

(**) q_{sl} is the limit unit skin friction (for a bored pile).

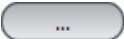
F.4.2.1 Data input

- To create a new project, click on the New project radio-button;
- Click on the button.

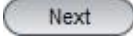
If Foxta is already open, click on “File”, then “New project “.

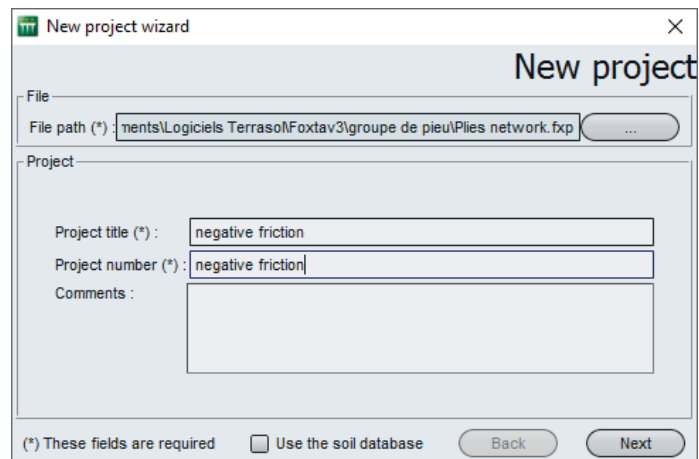
F.4.2.1.1 New project wizard

“File” frame:

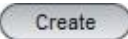
- Click on the  button to choose the work directory;
- Name and save the file.

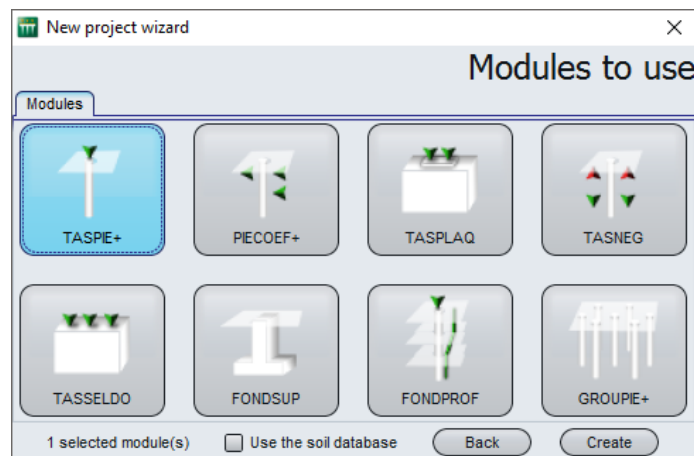
“Project” frame:

- Define a title for the project;
- Define a project number;
- Complete comments if necessary;
- Leave the "Use the soil database" box unchecked (for this example we will not use the soil database), and click on the  button.



F.4.2.1.2 New project wizard: Module selection

- In the "Modules to use" window, select the Taspie+ module and click on the  button.

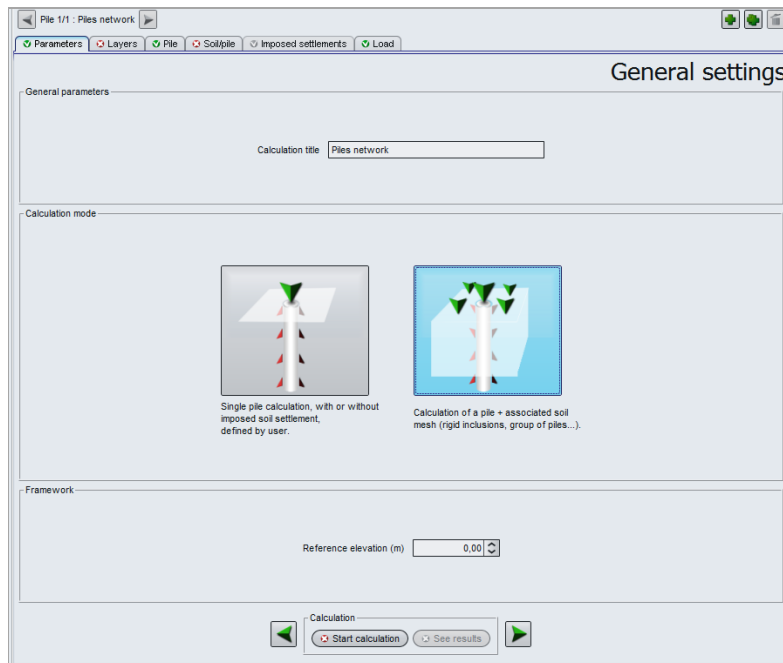


The input data window of Taspie+ is now displayed.

All data tabs should be now completed in the right zone of the screen.

F.4.2.1.3 “Parameters” tab

Chose the "Pile + associated soil mesh" calculation type. The reference elevation is set by default to 0.00m.



“General parameters” frame:

- Calculation title: "Pile group" for example.

“Calculation mode” frame:

- Select "Calculation of a pile + associated soil mesh ".

“Framework” frame:

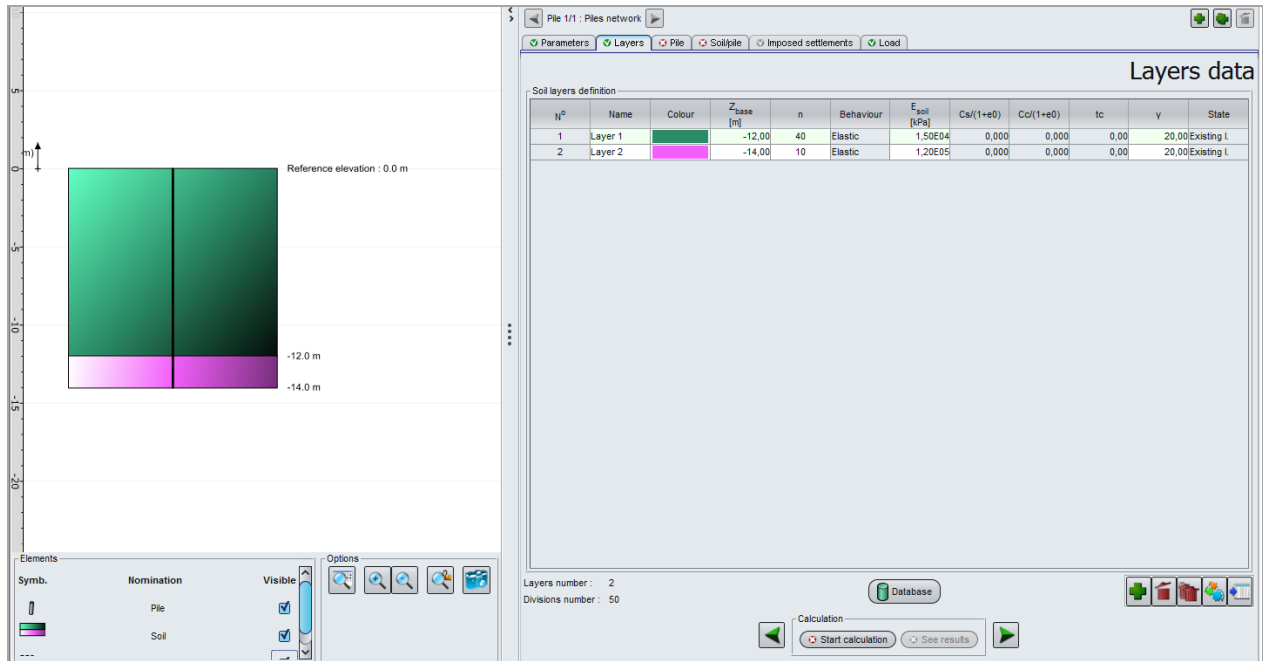
- Reference elevation: 0.00 m.

F.4.2.1.4 "Layers" tab

Create two soil layers and define the corresponding parameters using the information given within the below table.

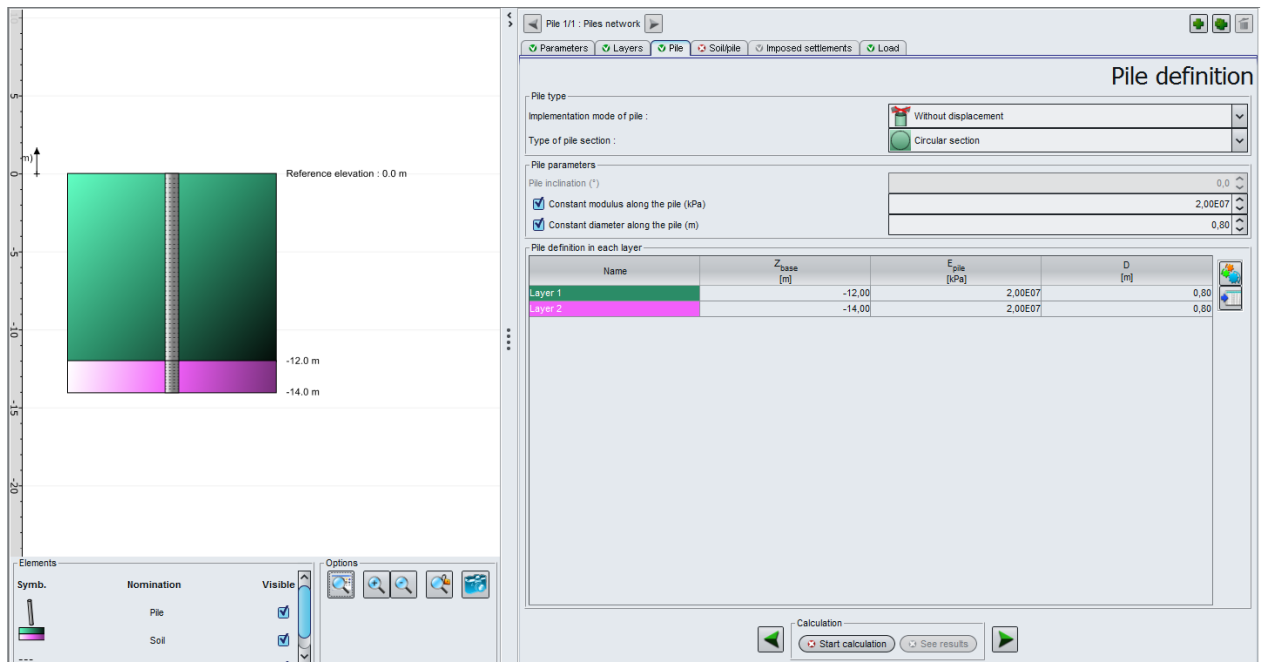
REMINDER: by convention, in Taspie+ the soil model bottom level is defined same as the pile toe level.

Name	Z _{base} (m)	N	Behaviour	E _{soil} (kPa)	γ'(kN/m ³)	State
Sandy clay	-12.00	40	Elastic	1.50E+04	20	Existing I.
Sands and gravels	-14.00	10	Elastic	1.20E+05	20	Existing I.



F.4.2.1.5 "Pile" tab

Piles are installed without displacement of the soil. The piles are circular and they have a constant diameter of 80 cm and a Young's modulus of 20 GPa.



"Pile type" frame:

- Implementation mode of pile: "Without displacement";
- Type of pile section: "Circular section".

"Pile Parameters" frame:

- "Constant modulus along the pile": checked, $E_{pile} = 2.0E^{07}$ kPa;
- "Constant diameter along the pile": checked, $D = 0.80$ m.

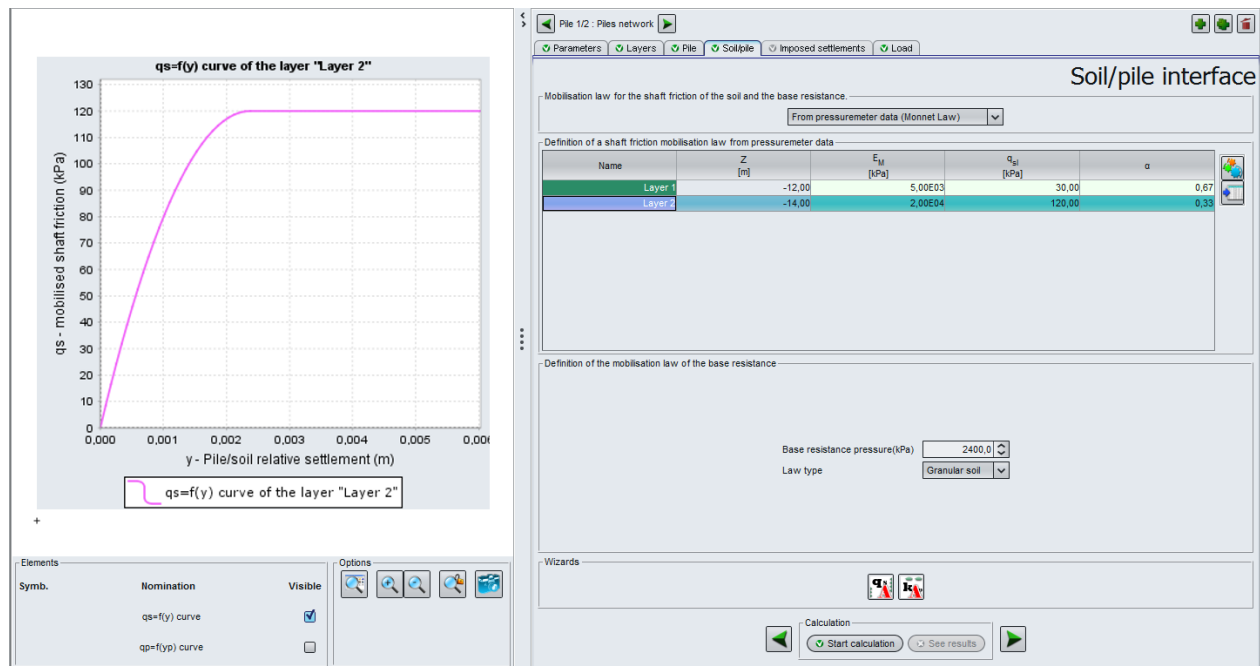
"Pile definition in each layer" frame:

Nothing to do, data are automatically filled in.

F.4.2.1.6 "Soil/Pile" tab

In this example, we choose to characterise the soil/pile friction by using a “Monnet” type mobilisation law. This is a “hyperbolic” law based on the pressuremeter modulus and the rheological coefficient.

The mobilisation of the base resistance pressure is modelled according to Frank & Zhao type law for granular soils with an ultimate stress equal to $1.2 \times 2000 = 2400$ kPa.



"Mobilisation law for the shaft friction of the soil and the toe force" frame:

- Select in the drop-down list: “From pressuremeter data (Monnet law)”.

"Definition of a shaft friction mobilisation law from pressuremeter data" frame:

For different soil layers, input the following:

- Pressuremeter modulus E_M (kPa);
- Unit shaft friction q_{si} (kPa);
- Rheological coefficient α .


Name	E_M (kPa)	q_{si} (kPa)	α
Sandy clay	5,0E+03	30	0,67
Sands and gravels	2.0E+04	120	0,33

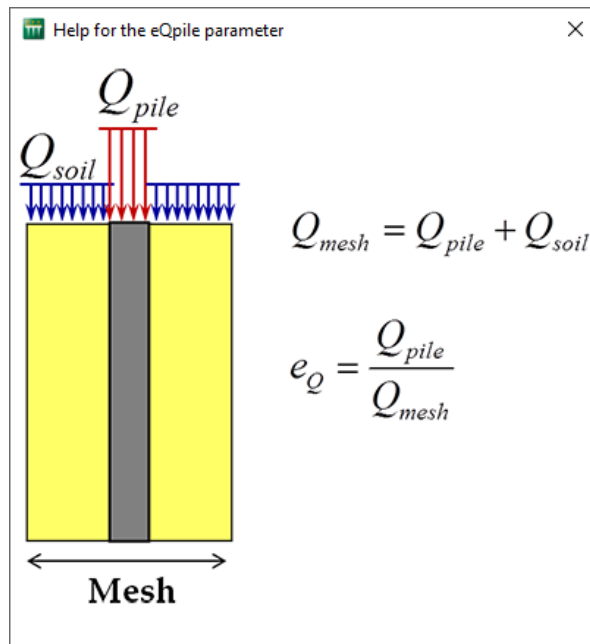
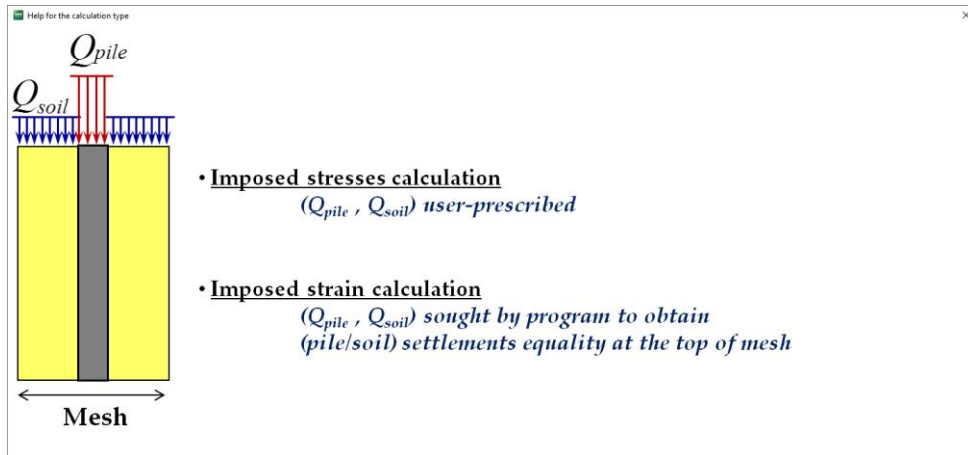
"Definition of the mobilisation law of the base resistance" frame:

- Base resistance pressure: “2400” kPa;
- Law type: “Granular soil”.

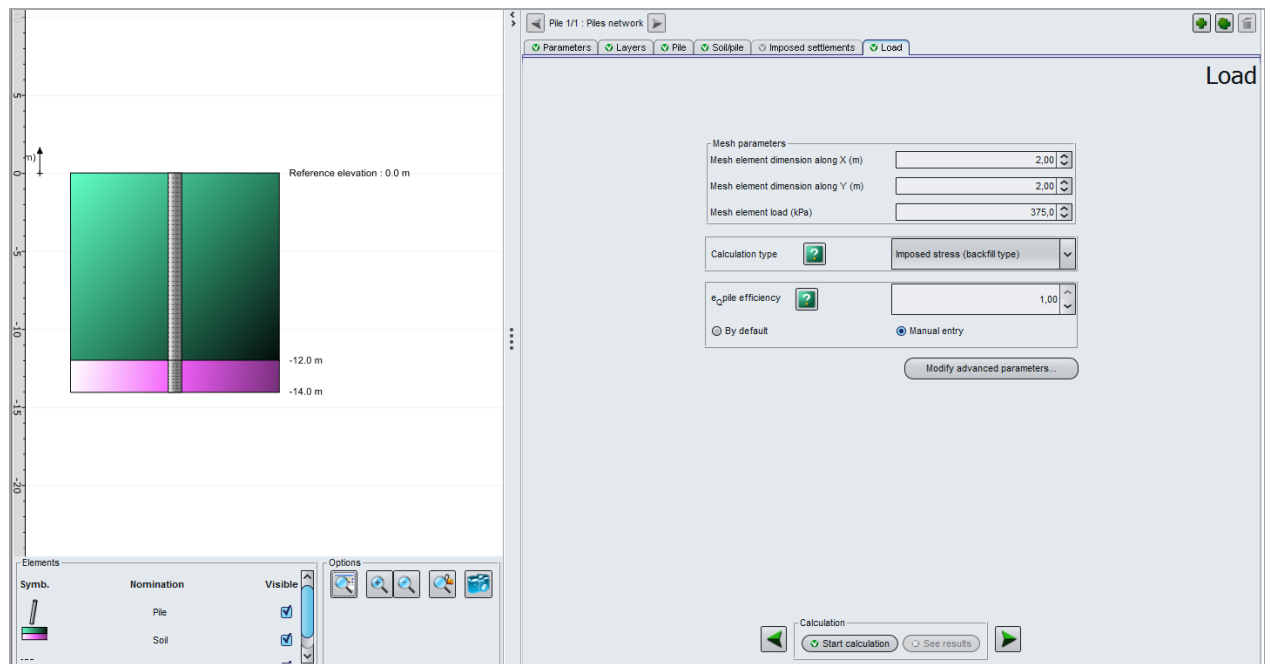
F.4.2.1.7 “Load” tab

This tab allows defining the mesh of the piles and the loading parameters on top of the model. These parameters should be adjusted in a way that the whole load is transferred onto the pile head. Consequently, it should be used an “imposed stress” calculation, combined with $e_{Q_{pile}} = 1$.

Two help pictures are available in this tab by clicking on the  buttons. They illustrate respectively the selection of the calculation type and the $e_{Q_{pile}}$ parameter definition:



The load applied on top of the model should be provided as an average stress: in this case it is calculated as $1500 \text{ kN} / (2 \times 2) = 375 \text{ kPa}$.



“Mesh parameters” frame:

- Mesh element dimension along X: 2.0 m;
- Mesh element dimension along Y: 2.0 m;
- Mesh element load: 375 kPa.

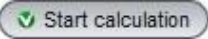
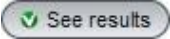
“Calculation type” frame:

- Calculation type: imposed stress (backfill type).

“ $e_{q,pile}$ efficiency” frame:

- $e_{q,pile}$ efficiency: 1.00 (manual entry).

F.4.2.2 Calculations and results

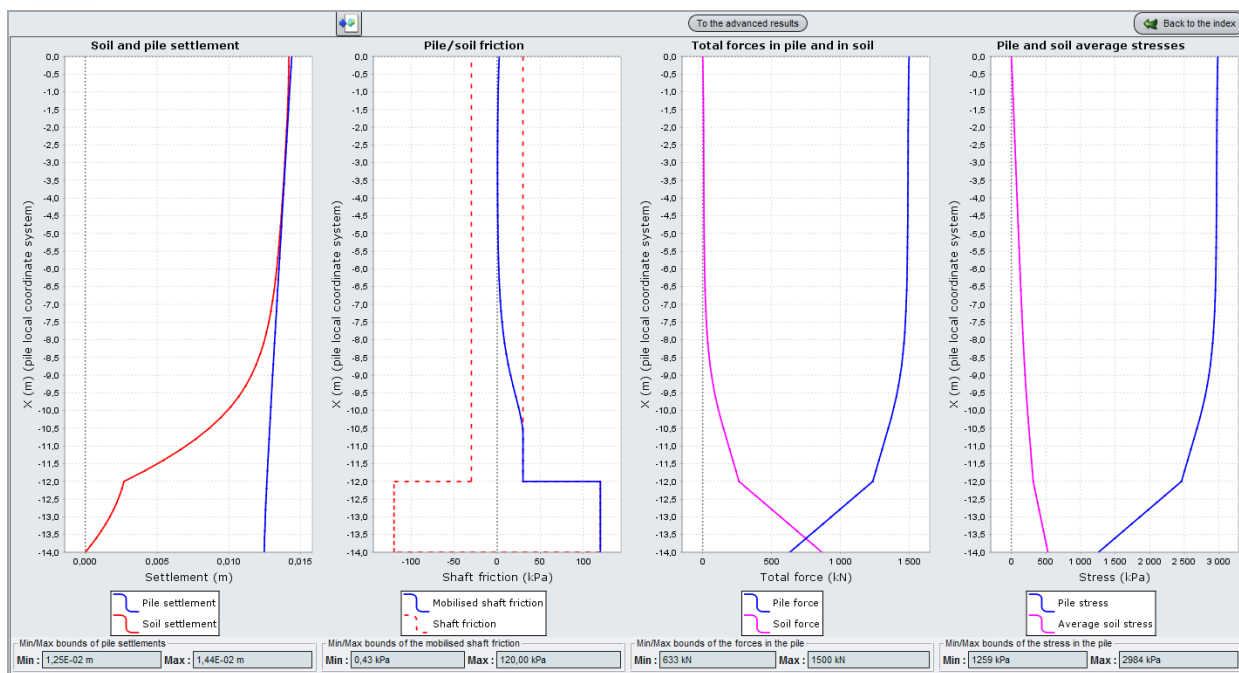
Click on the  button to run the calculations. Then click on the  button to display the results.

Click on “Main results” to display directly the graphical output.

Note that the “Loading curve” graphical option is only available for a “single pile” calculation type.

Based on the results, the following observations can be made:


- The maximal settlement is equal to 1.44 cm, and it is mainly due to the pile toe displacement;
- The soil/pile friction is positive on the whole height of the piles but is only occurred from 6 m deep downwards. This can be explained by a significant driving force undertaken by the soil in between the piles until 6 m deep, which corresponds to the uniform settlement until 6 m deep (soil and pile settlements are equal down to that depth);
- The absence of negative skin friction implies that the stress is maximal at pile head.

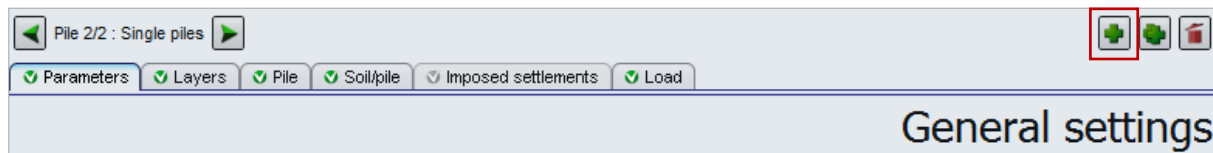


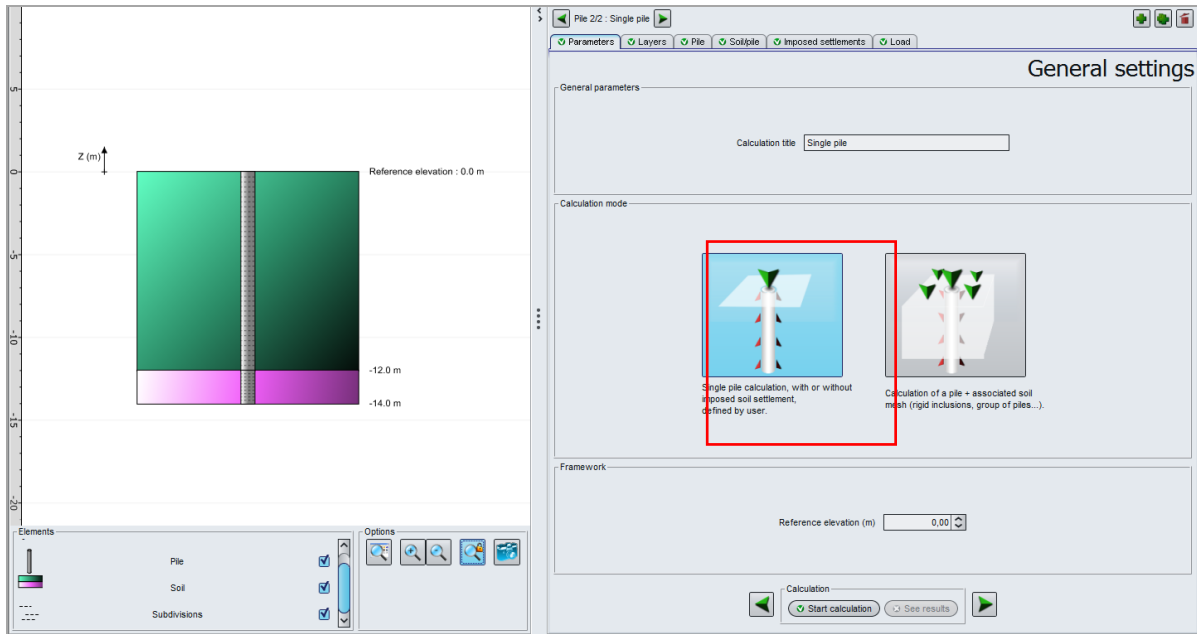
F.4.2.3 Comparison with a single pile

It is interesting to compare the previous results to those that would be obtained for a single pile. For that purpose, return to the data mode by clicking on the [Back to the index](#) button, and then on [Back to the data](#).

F.4.2.3.1 "Parameters" tab

- "Duplicate the current pile" by clicking on ;
- Change the title to "Single pile",
- Change the calculation mode to "Single pile calculation".

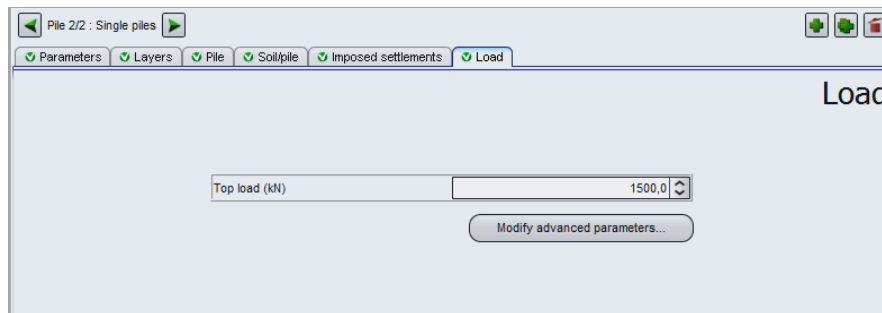




F.4.2.3.2 “Load” tab

- Define the load value applied on pile head: 1500 kN.

The other parameters remain unchanged.



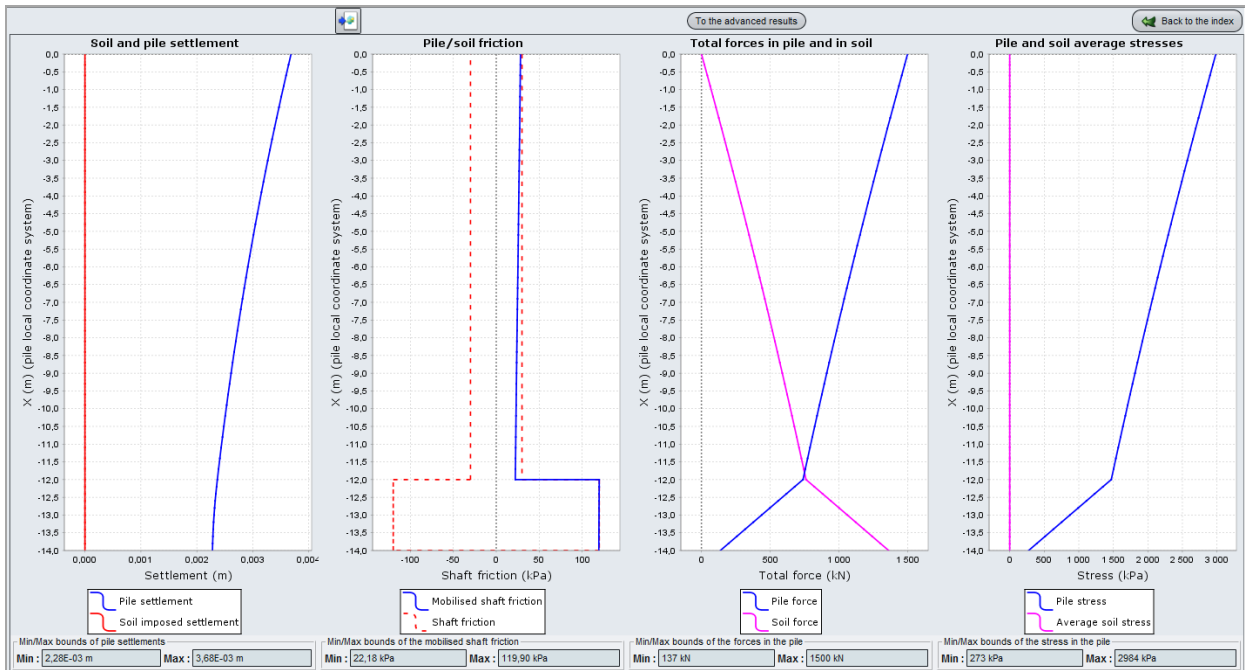
F.4.2.4 Calculations and results

Run the calculation again by clicking on **Start calculation** and then on **See results**.

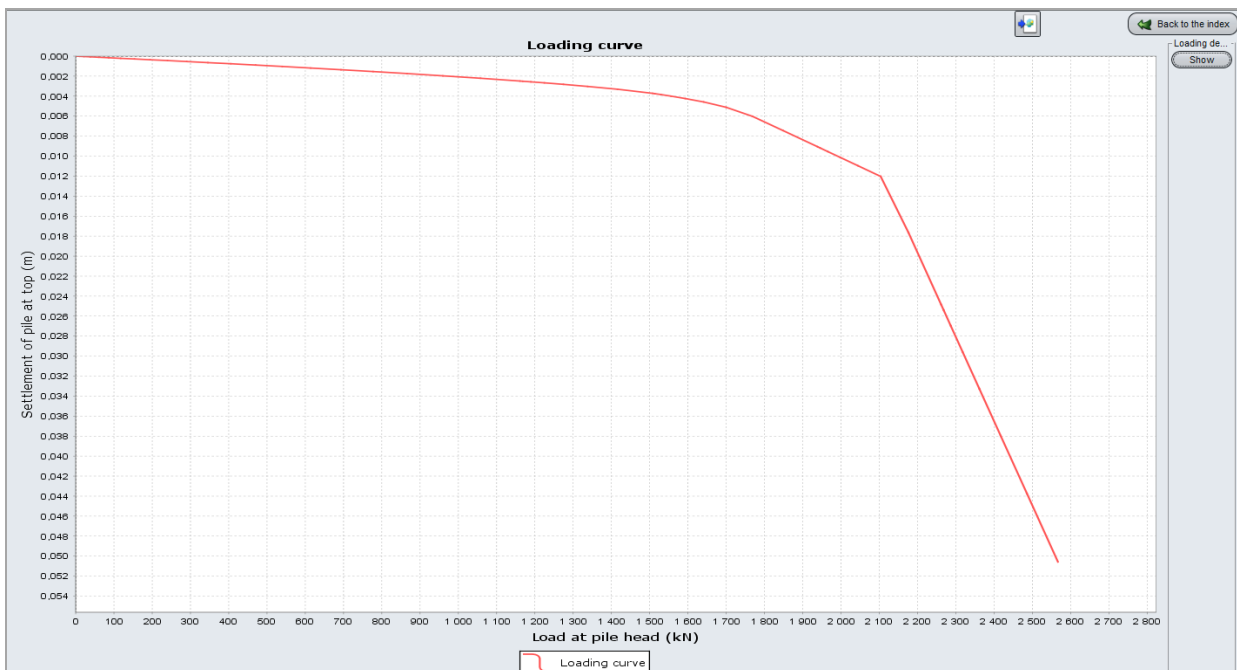
Display the “Main results”.

The results are similar to the behaviour of a single pile with a positive shaft friction occurring from the head downward and a maximum settlement of 4 mm approximately.

The assumption of a single pile conducts to more optimistic results with a settlement value 4 times lower than the one obtained by considering a group effect.

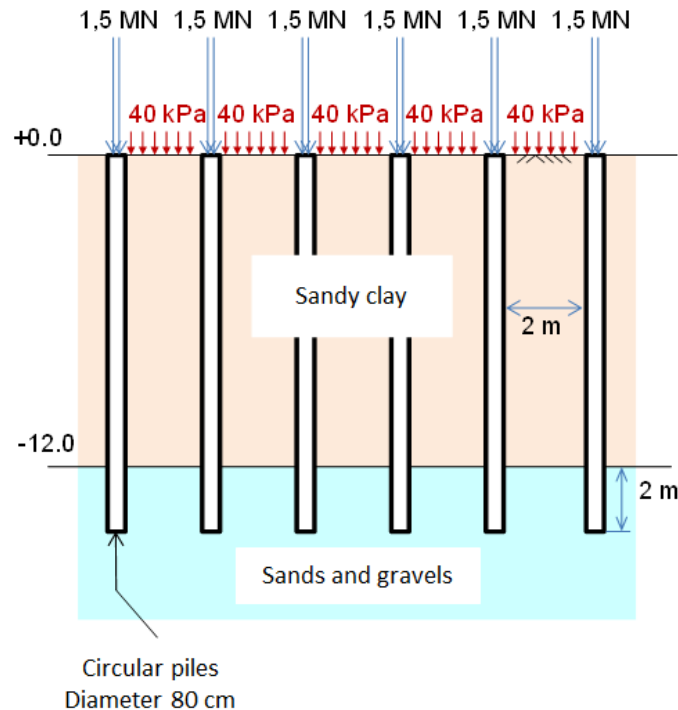


Note that this time, with regards to a “single pile”, Taspie+ built up a loading curve going up to 95% of the ultimate resistance. This value can be displayed by using the “loading curve” button within the results window.



F.4.2.5 Negative skin friction influence

We will now reiterate the previous calculations and this time we will consider a load of 40 kPa applied onto the ground level between the piles.



F.4.2.6 Input data

Start again the previous project by duplicating once again the current pile:

- Change the title to “negative friction”;
- Change the calculation mode to "Pile + associated soil mesh".

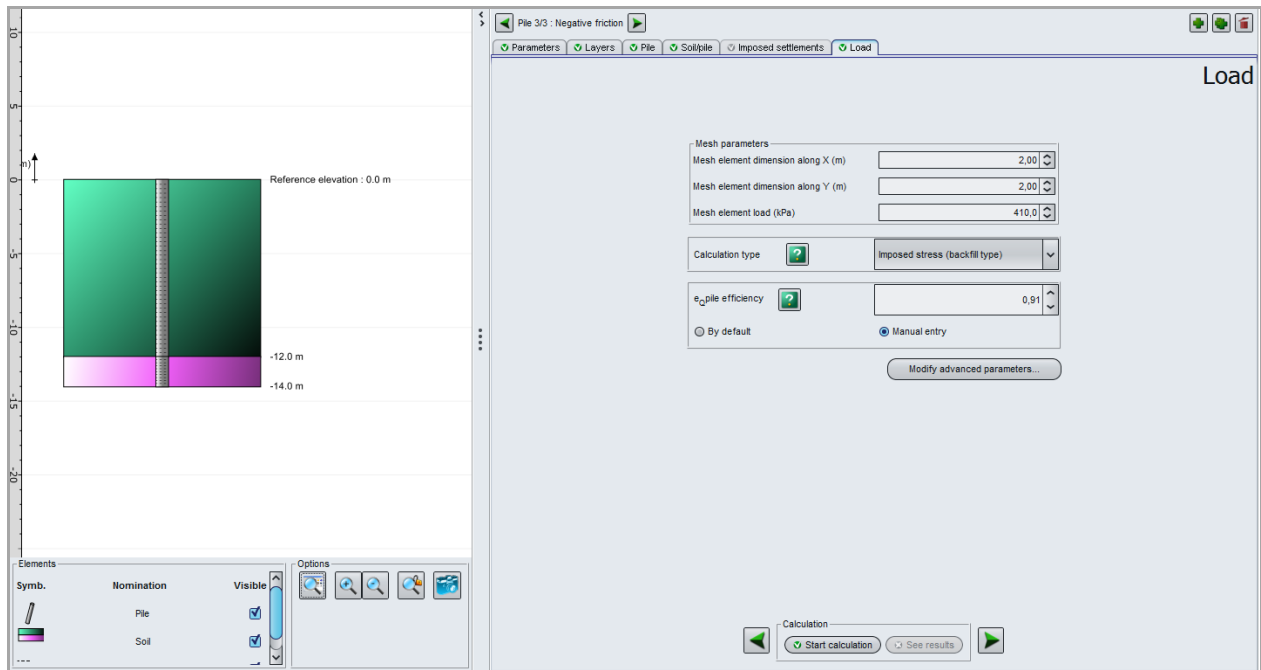
At this stage you may check that Foxta indeed copied the whole data defined in the first part of the example into the new pile. After that, switch to “Load” tab. The (q_{mesh} , e_{Qpile}) parameters should now be adjusted to the new loading conditions:

- The q_{mesh} average stress applied on top of the mesh element can be calculated as follows:

$$q_{\text{mesh}} = (1500 + 40 \times (4 - \pi \times 0.4^2)) / 4 = 410 \text{ kPa}$$

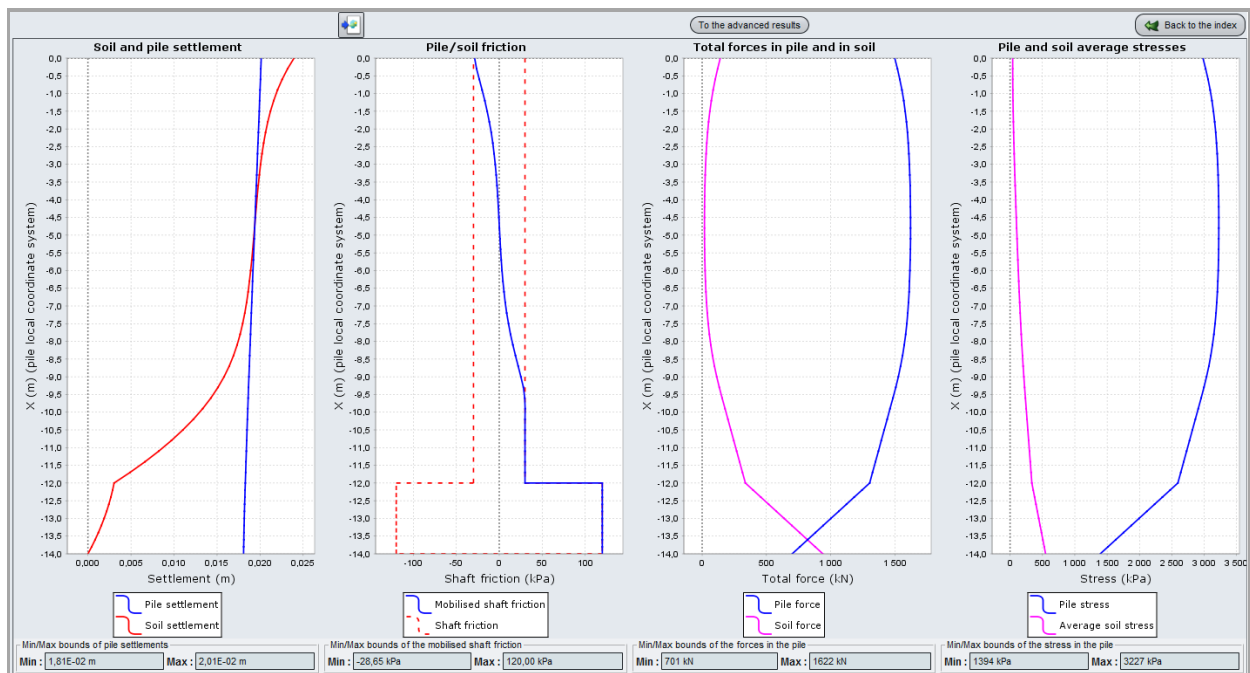
- The " e_{Qpile} " parameter is calculated as the ratio of the force to be transmitted to the pile (1500 kN) and the total load applied on the mesh:

$$e_{\text{Qpile}} = 1500 / (410 \times 4) = 0.914$$



F.4.2.7 Results

After running the calculation, the following results are obtained:



The results hereafter show that the negative friction occurs down to 5m deep approximately. At this depth, an equal settlement plane is obtained. The settlement of the pile is increased by 0.5cm comparing the previous case.

The display of the formatted results points out that the maximal stress in the piles is obtained at 4.8m deep exactly and its value is 3.2 MPa, which is acceptable. However, the factor of safety on the critical creep load is less than 1 and this is not sufficient to ensure the bearing capacity of the foundation for SLS case. This brings us to propose the lengthening of the piles.

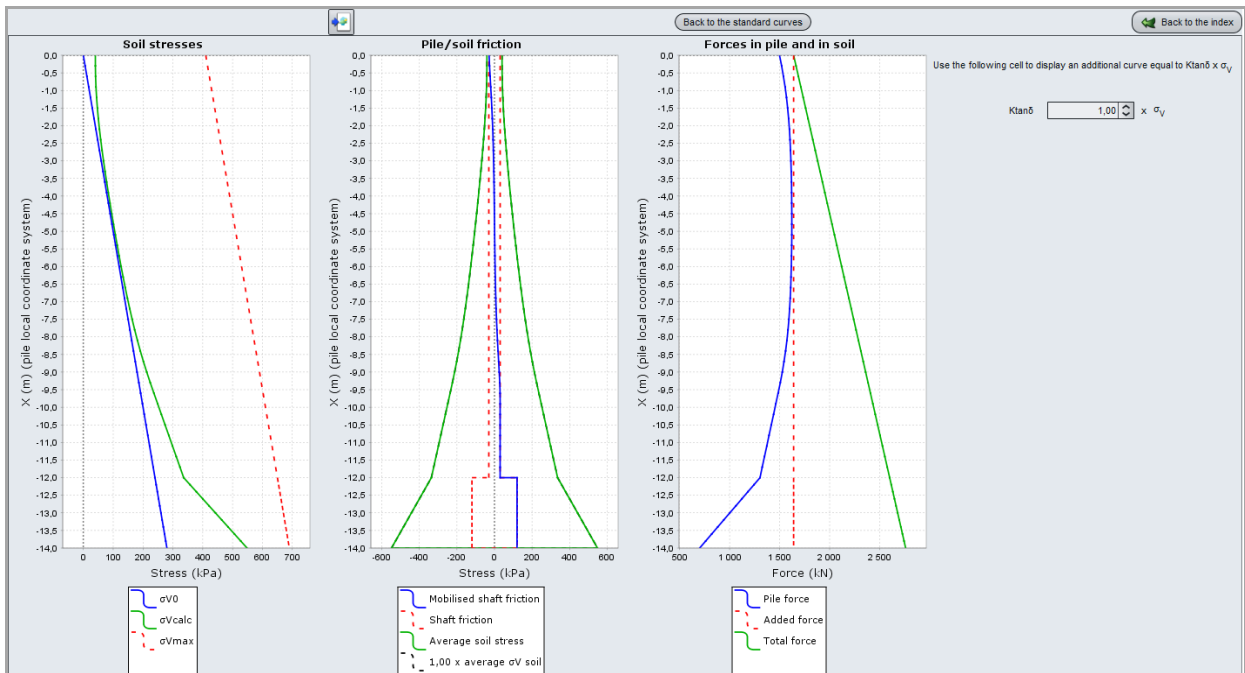
Copy all Copy only the selection Back to the index

037	-11.100	0.184E-01	0.822E-02	0.137E+04	0.268E+03	0.300E+02	0.273E+04	0.767E+02
038	-11.100	0.184E-01	0.822E-02	0.137E+04	0.268E+03	0.300E+02	0.273E+04	0.767E+02
039	-11.400	0.184E-01	0.663E-02	0.135E+04	0.291E+03	0.300E+02	0.268E+04	0.832E+02
040	-11.700	0.183E-01	0.490E-02	0.133E+04	0.314E+03	0.300E+02	0.264E+04	0.897E+02
041	-12.000	0.183E-01	0.304E-02	0.130E+04	0.336E+03	0.300E+02	0.259E+04	0.961E+02
042	-12.200	0.182E-01	0.286E-02	0.124E+04	0.396E+03	0.120E+03	0.247E+04	0.113E+03
043	-12.400	0.182E-01	0.266E-02	0.118E+04	0.457E+03	0.120E+03	0.235E+04	0.131E+03
044	-12.600	0.182E-01	0.243E-02	0.112E+04	0.517E+03	0.120E+03	0.223E+04	0.148E+03
045	-12.800	0.182E-01	0.217E-02	0.106E+04	0.577E+03	0.120E+03	0.211E+04	0.165E+03
046	-13.000	0.182E-01	0.188E-02	0.100E+04	0.638E+03	0.120E+03	0.199E+04	0.182E+03
047	-13.200	0.181E-01	0.156E-02	0.942E+03	0.698E+03	0.120E+03	0.187E+04	0.200E+03
048	-13.400	0.181E-01	0.121E-02	0.882E+03	0.758E+03	0.120E+03	0.175E+04	0.217E+03
049	-13.600	0.181E-01	0.838E-03	0.821E+03	0.818E+03	0.120E+03	0.163E+04	0.234E+03
050	-13.800	0.181E-01	0.433E-03	0.761E+03	0.879E+03	0.120E+03	0.151E+04	0.251E+03
050	-14.000	0.181E-01	0.939E-07	0.701E+03	0.939E+03	0.120E+03	0.139E+04	0.269E+03

		tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	sigma pieu	sigma sol
max+		0.201E-01	0.239E-01	0.162E+04	0.162E+04	0.120E+03	0.282E+04	0.269E+03
max-		0.181E-01	0.939E-07	0.701E+03	0.179E+02	-0.287E+02	0.139E+04	0.511E+01

			y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)	
Sans renforcement								
			0.3348					
Avec renforcement								
		Pieu (moyenne)	0.0201	1498.960	0.914	2982.086	148172.9	
		Sol	0.0239	141.040	0.086	40.328	1684.7	
		Maille		1640.000	1.000	410.000		
Solllicitations dans l'inclusion								
		- contrainte maximale	S _{max} =	3227.1				
		- atteinte à cote	Z =	-4.800				
		- charge maximale	Q _{max} =	1498.960	F = 0.87			
		- sécurité par rapport à Qc(Z)	=	2405.4				
		- sécurité par rapport à Ql(Z)	=	2352.4	F = 1.45			

In addition, advanced graphical results can be displayed to verify the compatibility between the negative skin friction at the surface and the vertical effective stress by using an adequate value for the $k \cdot \tan \delta$ parameter (see examples 3 and 4).



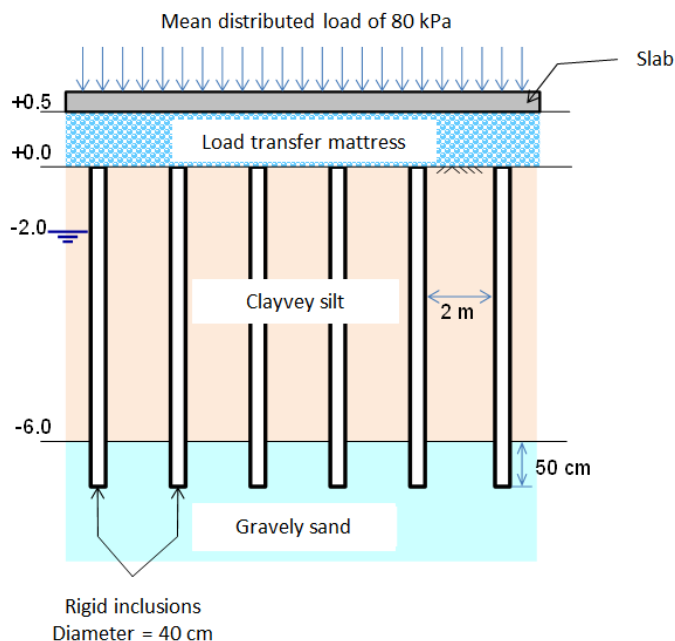
F.4.3. Example 3: Slab on soil reinforced by rigid inclusions

This example deals with the case of a soil volume reinforced by rigid inclusions. We are interested in a reinforcement by rigid inclusions beneath a heavily loaded slab.

The treatment of this exercise is mainly based on the Taspie+ module. A complementary calculation using Taspiaq will be illustrated for the evaluation of the “additional” forces within the slab due to the presence of the inclusions.

F.4.3.1 Project presentation

The figure below illustrates the current study case.



The above figure is to be completed by the following elements:

- The groundlevel is assumed to be at elevation +0.00. Water table is at elevation - 2.00;
- The slab is laid on a granular load transfer mattress of 50 cm thick;
- The inclusions are driven (with the displacement of the surrounding soil), and they are embedded in the gravelly sand (bearing layer);
- The inclusions are placed according to a regular grid of 2.0 x 2.0 m;
- The thickness of the slab is 25 cm. Applied load (80 kPa) corresponds to a SLS load combination (characteristic) and it includes the dead load of the slab;
- The following table summarise the available geomechanical parameters:

Layer	Z _{top} (m)	γ (kN/m ³)	E _M (MPa)	P _I * (MPa)	q _{sl} (kPa) ^(**)	E (MPa) ^(*)
Granular mattress	+0.50	20	15	--	--	50
Clayey silt	+0.00	19	2,5	0.3	20	5
Gravelly sand	-6.00	20	20	2.0	80	80

(*) E is the vertical elastic strain modulus.

(**) q_{sl} is the unit limit skin friction (soil/inclusion).

F.4.3.2 Data input

Double-click on the Foxta icon to run the software, chose the type of connection and the language. Then click on button.

At the beginning, Foxta proposes:

- To create a new project;
- To open an existing project;
- To open recent project.

In the case of this example:

- To create a new project, click on the New project radio-button;
- Click on the button.

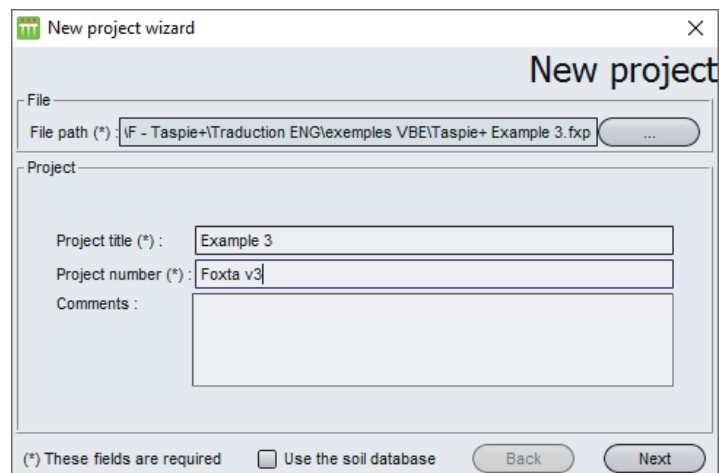
F.4.3.2.1 New project wizard

"File" frame

- Click on the button to choose the work directory;
- Name and save the file.

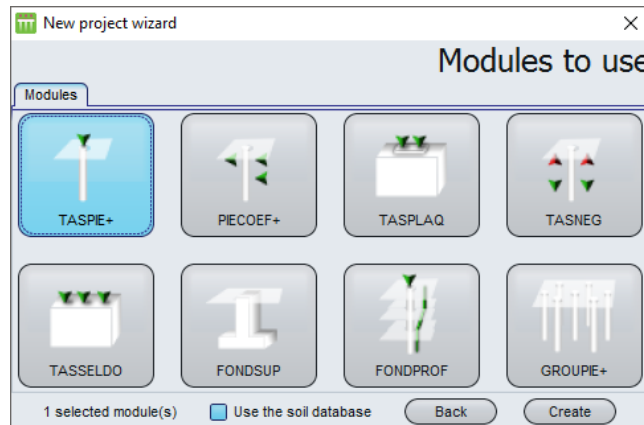
"Project" frame

- Define a title for the project;
- Define a project number;
- Complete comments if necessary;
- Leave the "Use the soil database" box unchecked (for this example we will not use the soil database), and click on the button.



F.4.3.2.2 New project wizard: Module selection

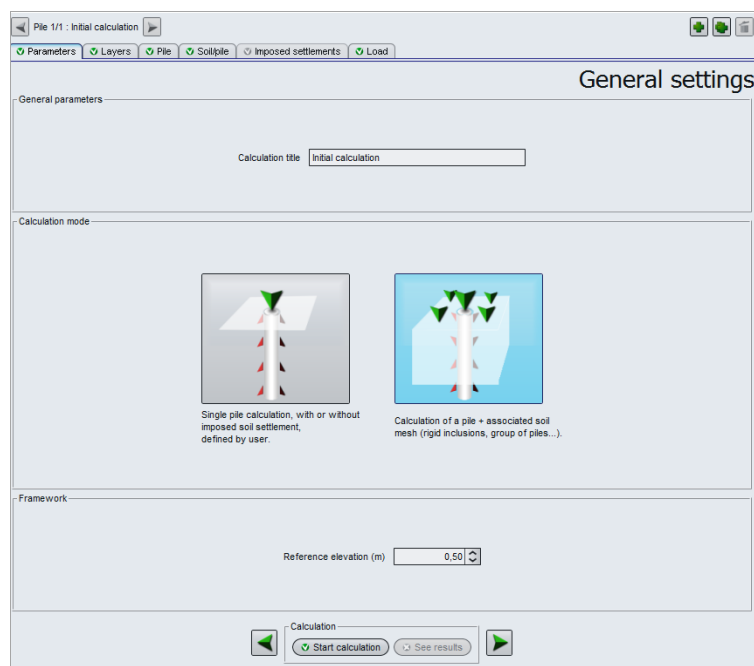
Select the Taspie+ and Tasplaq modules, then click on the **Create** button.



The input data window of Taspie+ is now displayed. All data tabs should be now completed in the right zone of the screen.

F.4.3.2.3 “Parameters” tab

This tab allows the definition of the general parameters of the calculations.



“General parameters” frame

- Calculation title: "Initial calculation" for example.

“Calculation type” frame

- Select "Calculation of a pile + associated soil mesh ".

“Framework” frame

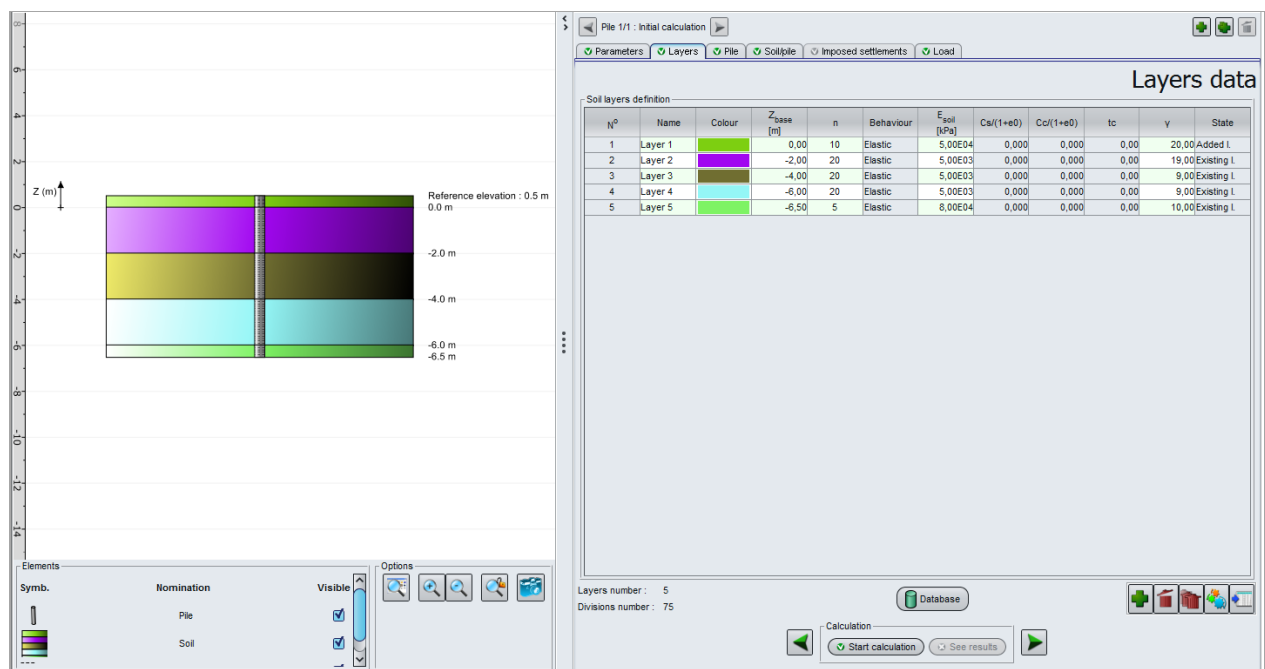
- Reference elevation: +0.50 m. In this case, the reference elevation corresponds to the underside of the slab.

To shift to the next tab, click either on the name of the tab “Layers”, or on the  button.

F.4.3.2.4 "Layers" tab

This tab is for the definition of the soil layers. Silt layer has been divided into 3 sublayers of 2 m thick each, in order to assign some parameters refined by depth. It is also necessary to define a limit at elevation -2 (water table elevation) with the aim of using different unit weight values for the silt layer distinguished between above and under the water table.

IMPORTANT: by Taspie+ convention, the bottom of the pile is assumed to be at the level of the bottom of the last soil layer defined. Therefore, the soil cross section must be stopped at bottom of pile (except in certain "pile + associated mesh" cases which require an extension of the model under the toe of the piles, also check chapter F.2.7).



Nº	Name	Colour	Z _{base} [m]	n	Behaviour	E _{soil} [kPa]	Cs/(1+e0)	Cc/(1+e0)	tc	γ	State
1	Layer 1		0.00	10	Elastic	5,00E04	0.000	0.000	0.00	20,00	Added I.
2	Layer 2		-2.00	20	Elastic	5,00E03	0.000	0.000	0.00	19,00	Existing I.
3	Layer 3		-4.00	20	Elastic	5,00E03	0.000	0.000	0.00	9,00	Existing I.
4	Layer 4		-6.00	20	Elastic	5,00E03	0.000	0.000	0.00	9,00	Existing I.
5	Layer 5		-6.50	5	Elastic	8,00E04	0.000	0.000	0.00	10,00	Existing I.

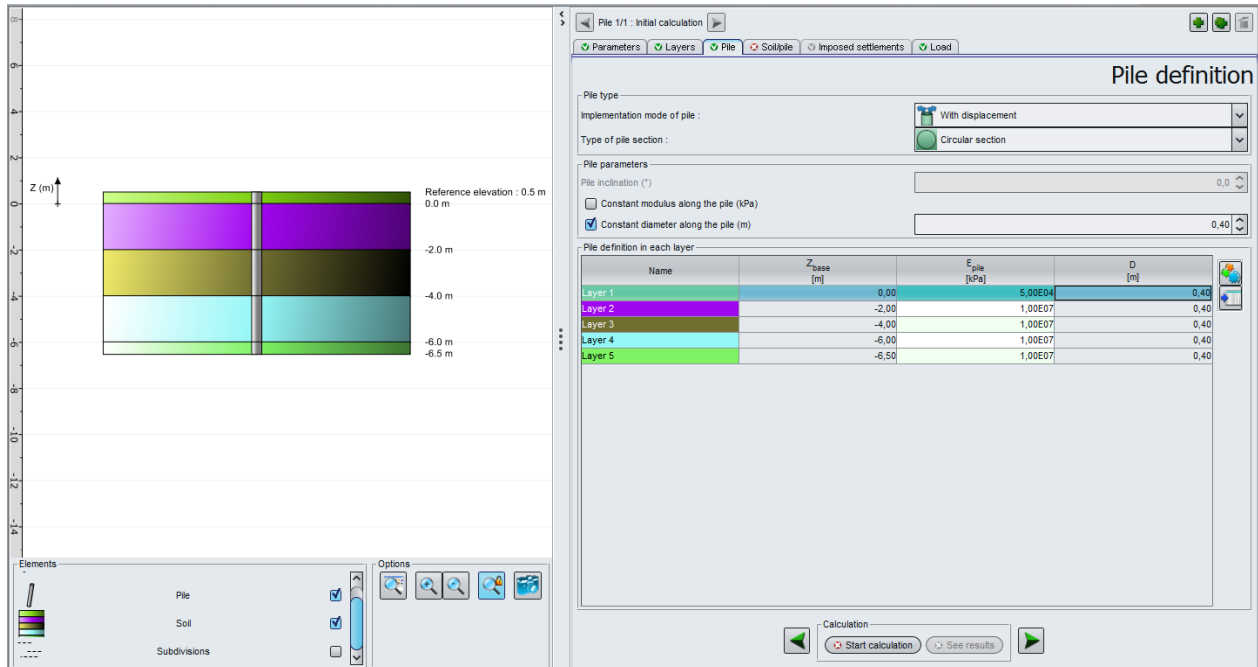
Use the  button under the table to create soil layers one by one.

The input parameters are summarised in the table below:

Name	Z _{base} (m)	n	Behaviour	E _{soil} (kPa)	γ' (kN/m ³)	State
Mattress	0.00	10	Elastic	5.00E+04	20	Added I.
Silt 1	-2.00	20	Elastic	5.00E+03	19	Existing I.
Silt 2	-4.00	20	Elastic	5.00E+03	9	Existing I.
Silt 3	-6.00	20	Elastic	5.00E+03	9	Existing I.
Sand	-6.50	5	Elastic	8.00E+04	10	Existing I.

F.4.3.2.5 “Pile” tab

This tab allows the definition of the “pile domain”. This domain includes the inclusion itself and the soil volume directly above the pile (extended from the pile cap up to the top of the model).



“Pile type” frame:

- Implementation mode of pile: “With displacement”;
- Type of pile section: “Circular section”.

“Pile parameters” frame:

- Pile inclination: 0° (unable to modify: the modification is possible in the case of a single pile only);
- “Constant modulus along the pile”: unchecked;
- “Constant diameter along the pile”: checked, D = 0.4 m.

“Pile definition in each layer” frame:

The strain moduli of the “pile domain” for each layer have to be defined here. These moduli correspond to:

- The modulus of the mattress (50 MPa) in the first layer;
- The modulus of the inclusion’s constitutive concrete down to the base of the model (10 000 MPa).

Note: to save time, it is possible to check “Constant modulus along the pile” option at first, define the modulus value as 10 000 MPa, then uncheck the option and finally modify the modulus value for the first layer only (50 MPa).

F.4.3.2.6 “Soil/Pile” tab

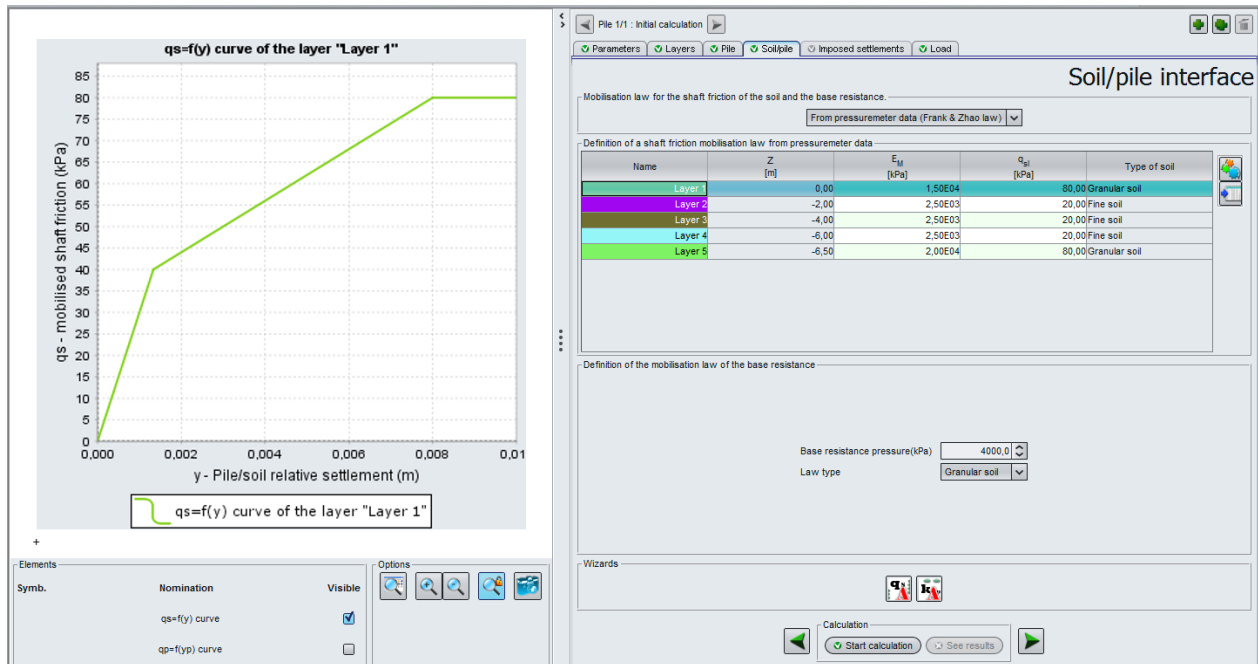
This tab allows the definition of the skin friction and base resistance mobilisation laws.

The skin friction mobilisation law to be use in this example is Frank and Zhao law built up from the pressuremeter data. The limit skin friction is 20 kPa in silt, and 80 kPa in gravely

sand. As the inclusion is virtually extended inside the mattress, the unit skin friction to be defined for this layer corresponds to a “soil/soil” interface. For this layer, we consider a Frank and Zhao law with a limitation at $q_{sl} = k \tan \delta \cdot \sigma_v'$, where σ_v' refers to the vertical effective stress within the layer and $k \tan \delta = 1$. The value of σ_v' is obviously a calculation result and not an input data. For the first iteration, we consider $\sigma_v' = 80$ kPa, which is the mean load applied on top of the slab.

The mobilisation of the base resistance pressure is modelled according to Frank & Zhao type law for granular soils with an ultimate stress equal to $q_{pl} = k_p \times p_l^* = 2.0 \times 2000 = 4000$ kPa.

Please note that these suggested laws are strictly valid for a bored pile. Their use for an inclusion installed with the displacement of the surrounding soil within sand and/or gravel constitutes a pessimistic approach.



"Mobilisation law for the shaft friction of the soil and the toe force" frame:

- Select in the drop-down list: “From pressuremeter data (Frank & Zhao law)”.

"Definition of a shaft friction mobilisation law from pressuremeter data" frame:

For different soil layers, input the following:

- Pressuremeter modulus E_M (kPa);
- Unit shaft friction q_{sl} (kPa);
- Soil type.

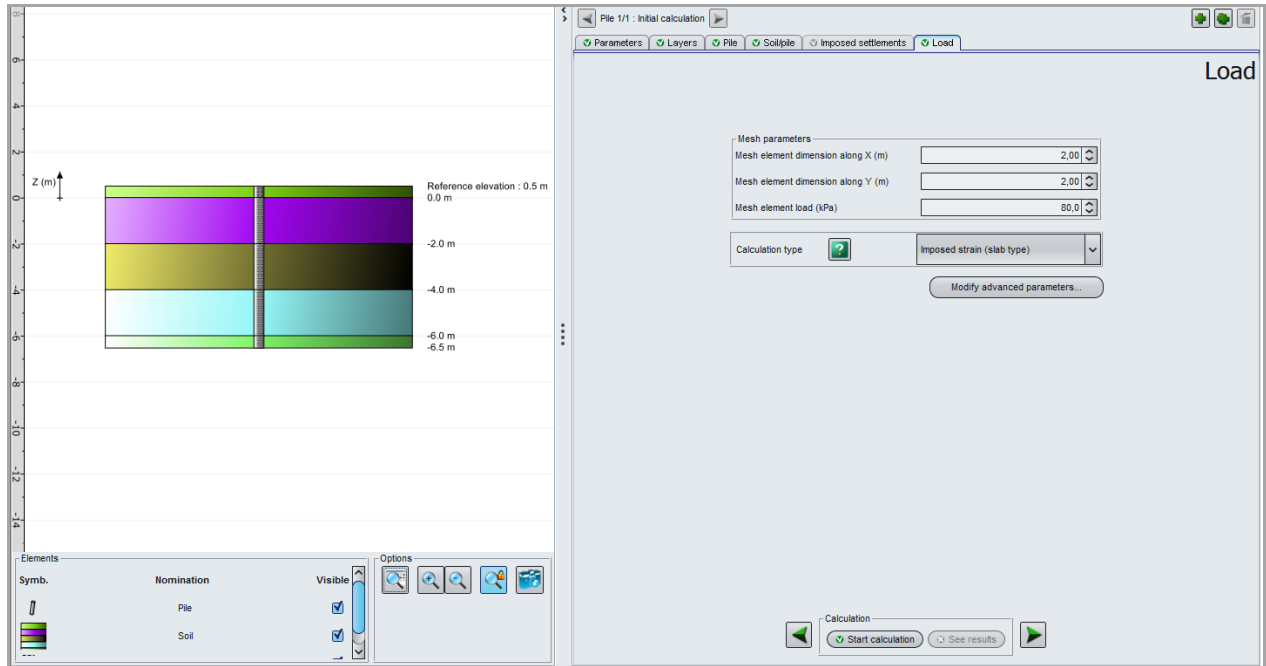
Name	E_M	q_{sl}	Soil type
Mattress	1.50E+04	80.0	Granular soil
Silt 1	2.50E+03	20.0	Fine soil
Silt 2	2.50E+03	20.0	Fine soil
Silt 3	2.50E+03	20.0	Fine soil
Sand	2.00E+04	80.0	Granular soil

"Definition of the mobilisation law of the base resistance" frame:

- Base resistance pressure: “4000” kPa;
- Law type: “Granular soil”.

F.4.3.2.7 “Load” tab

This tab allows defining the mesh of the inclusions and the loading conditions on top of the model.



“Mesh parameters” frame:

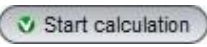
- Mesh element dimension along X: 2.0 m;
- Mesh element dimension along Y: 2.0 m;
- Mesh element load: 80 kPa. This corresponds to the mean stress applied at top of the model.

“Calculation type” frame:

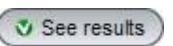
- Calculation type: imposed strain (slab type). Indeed, we are looking for the distribution of the stresses between the “pile” and “soil” domains for the case where the settlement value is equal for both domains.
We will not modify the advanced parameters and keep using the default values.

F.4.3.3 Calculations and results

F.4.3.3.1 Calculation

When the input data are correctly entered, click on the  button to run the calculations. This button is accessible from all tabs.

F.4.3.3.2 Results

To display the results formatted as tables and graphical views, click on the  button.

"Graphical results" frame:

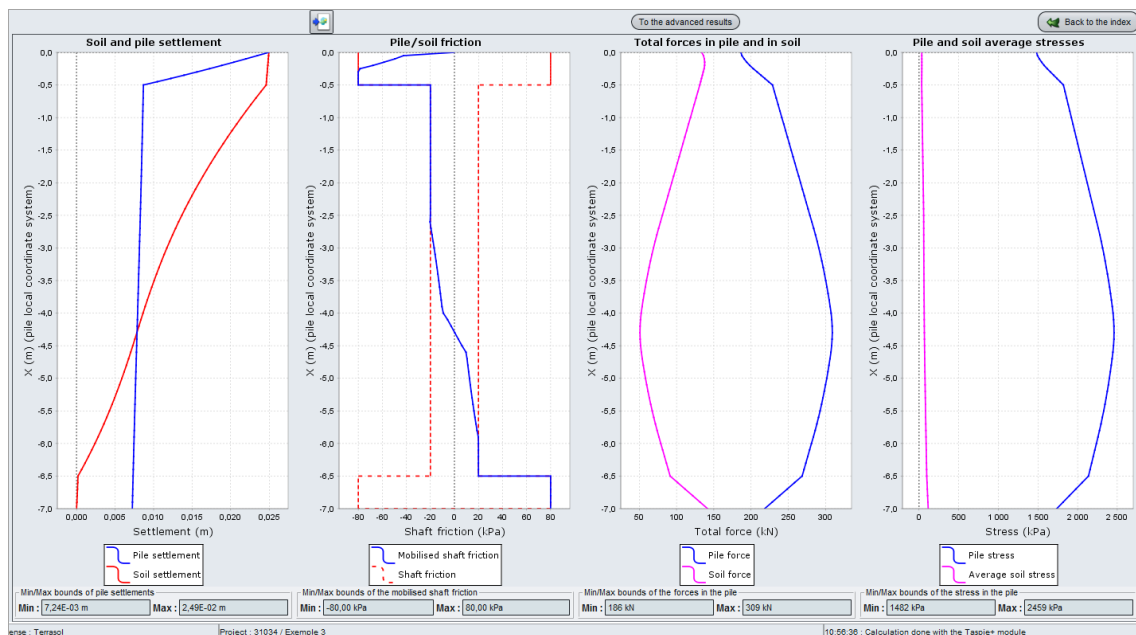
Click on the "Main results" button. This will allow you to access to the settlement curves, skin friction values, forces and stresses for both of the "pile" and "soil" domains

The maximum settlement of the pile domain is 2.5 cm. 1.5 cm of the total settlement occurred within the mattress.

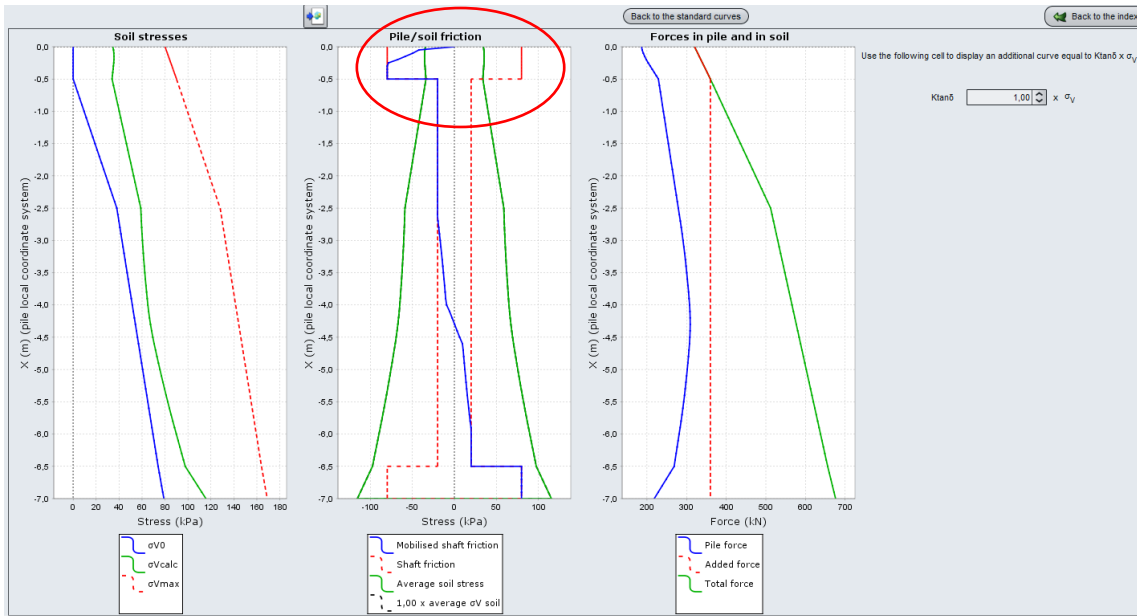
The settlement curves demonstrate the development of two equal settlement planes:

- The first one is obtained at the base of the slab which is an input hypothesis,
- The second one, which is the "neutral plane", is obtained at elevation -3.80 m (this corresponds to -4.30 m in the local coordinates of the pile, used for the display of the curves).

Above the neutral plane, the skin friction is negative and the soil settles more than the inclusion (hanging effect). The elevation of the neutral plane matches also to the elevation where the stress in the inclusion is maximum (2.45 MPa approximately).



Additional results are also available by clicking on the [To the advanced results](#) button.



The graph in the centre presents the superposition of the vertical effective stress in the soil (in between the inclusions), the mobilised skin friction as well as the limit skin friction. In particular, we can note that the concentration of the stresses directly above the inclusion lead to a vertical stress in the soil, at its surface, inferior to 80 kPa applied by the slab.

Again in the mattress, we can see that the actually mobilised vertical shear (blue curve) exceeds, in absolute value, the vertical effective stress (green curve): this is mechanically unacceptable (see chapter F.4.2.6).

Consequently, the skin friction mobilisation law in the mattress should be corrected by using the vertical effective stress obtained at mid-depth of the mattress (35 kPa approximately) as the limit skin friction value.

F.4.3.4 Adjustment of the limit skin friction value in the mattress

Go back to the input by clicking on the button, then on the button.

F.4.3.4.1 "Soil/Pile" tab

- Modify the "q_{sl}" value assigned to the first layer: 35 kPa.

Soil/pile interface

Mobilisation law for the shaft friction of the soil and the base resistance.

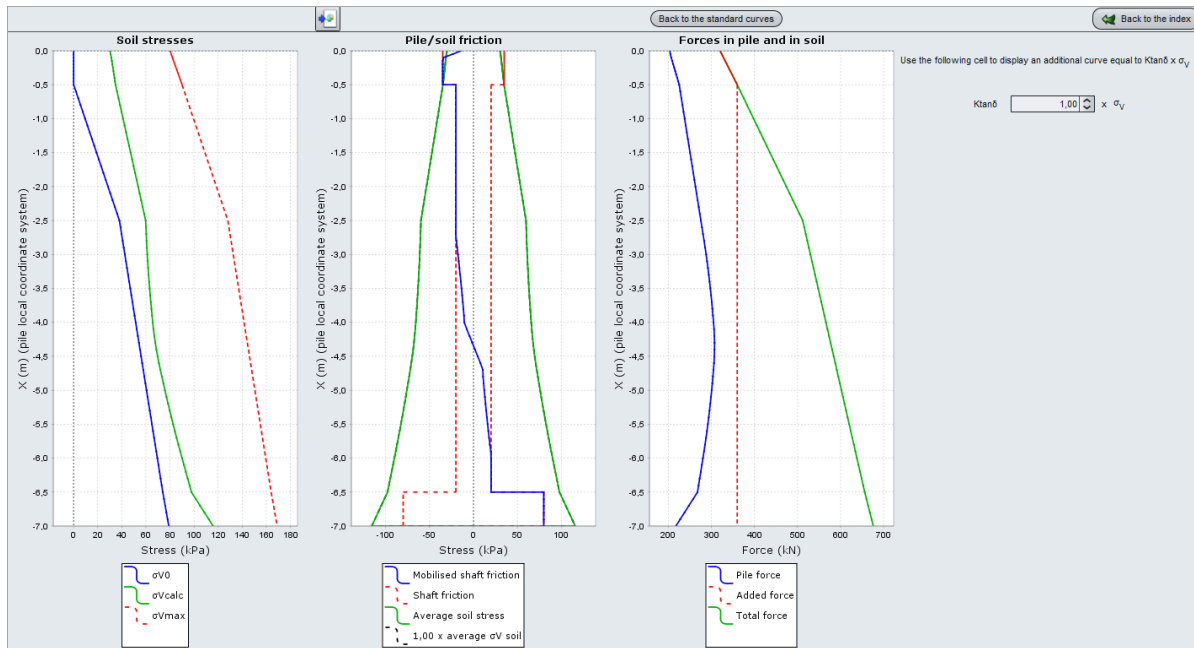
Definition of a shaft friction mobilisation law from pressuremeter data

Name	Z [m]	E _M [kPa]	q _{sl} [kPa]	Type of soil
Layer 1	0,00	1,50E04	35,00	Granular soil
Layer 2	-2,00	2,50E03	20,00	Fine soil
Layer 3	-4,00	2,50E03	20,00	Fine soil
Layer 4	-6,00	2,50E03	20,00	Fine soil
Layer 5	-6,50	2,00E04	80,00	Granular soil

F.4.3.4.2 Calculation

Run the calculations again by clicking on , then on .

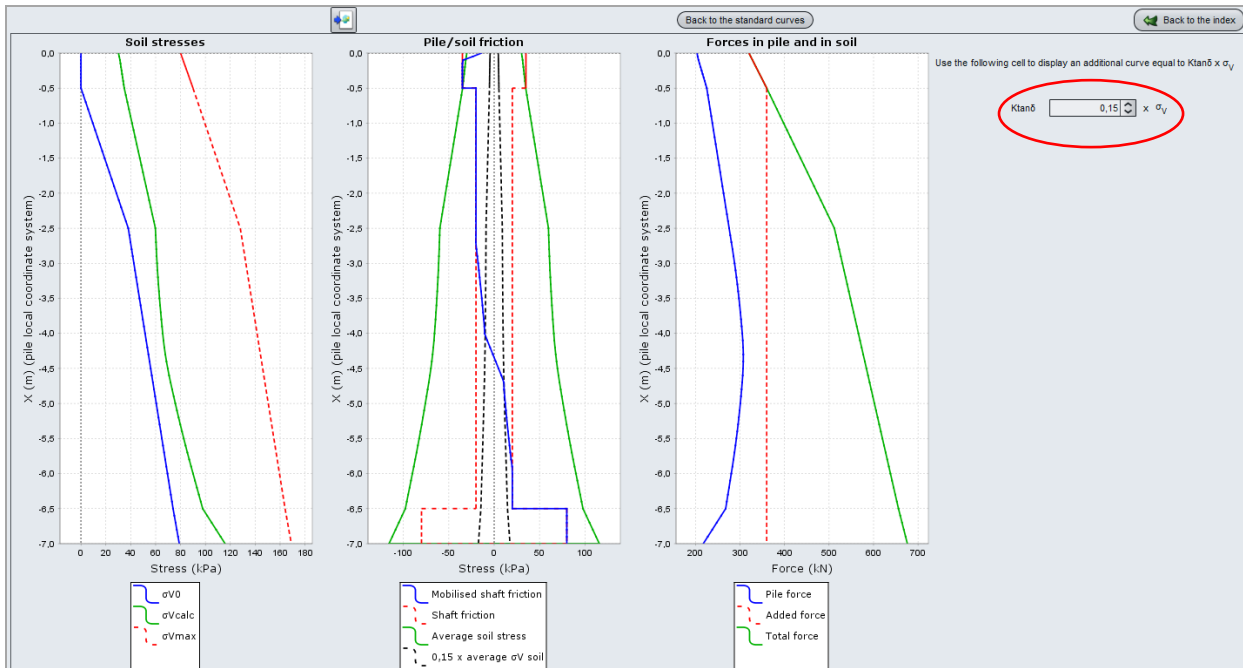
By displaying the additional results, we check that this time the mobilised friction within the mattress is limited to the vertical effective stress in this layer.



Now, we want to examine the mobilised skin friction in the compressible soil layer (silts). This friction is negative down to the elevation -3.80 m, and it is limited to 20 kPa (in absolute value) accordingly to the input data. Strictly speaking, it should be verified that this negative friction is compatible with the vertical stress level σ_v' by checking that its absolute value is lower than $k\tan\delta \cdot \sigma_v'$, with $k\tan\delta = 0.15$ in this case (the $k\tan\delta$ value should be selected, for each case, in function of the pile type, installation method of the pile and the soil type).

- Use the corresponding box to input the $k\tan\delta = 0.15$ value.

This will add a new curve which shows that the $|q_s| \leq k\tan\delta \cdot \sigma_v'$ condition is not respected. The limit negative friction should also be adjusted within the first four top meters of the silt layer. Graphically, the limit to target is about 7.5 kPa in the first two meters and 10 kPa in the two lower meters. Below that, the friction is positive and there is no adjustment to do.



F.4.3.5 Adjustment of the limit skin friction value in silt layers 1 and 2

Go back to the input by clicking on the button, then on the button.

F.4.3.5.1 “Soil/Pile” tab

- Modify the "q_{sl}" values assigned to the silt layers 1 and 2 by using 7.5 and 10.0 kPa respectively.

Pile 1/1 : Initial calculation

Parameters Layers Pile Soil/pile Imposed settlements Load

Soil/pile interface

Mobilisation law for the shaft friction of the soil and the base resistance.

From pressuremeter data (Frank & Zhao law)

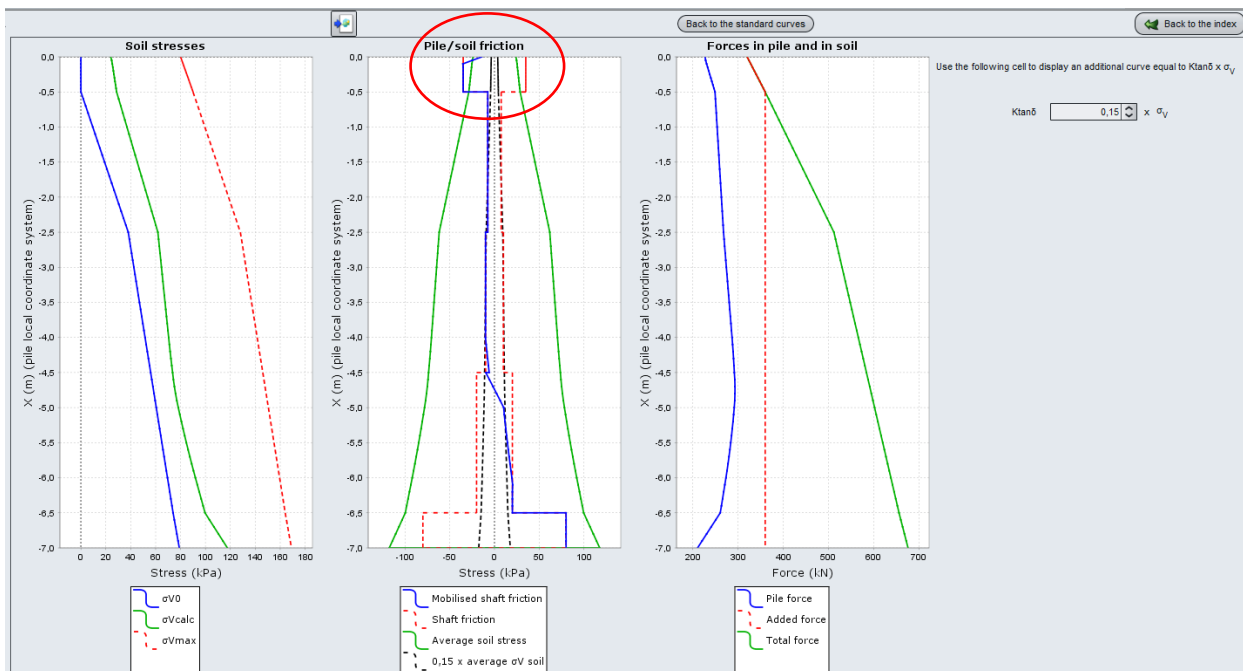
Definition of a shaft friction mobilisation law from pressuremeter data

Name	Z [m]	E _M [kPa]	q _{sl} [kPa]	Type of soil
Layer 1	0,00	1,50E04	35,00	Granular soil
Layer 2	-2,00	2,50E03	7,50	Fine soil
Layer 3	-4,00	2,50E03	10,00	Fine soil
Layer 4	-6,00	2,50E03	20,00	Fine soil
Layer 5	-6,50	2,00E04	80,00	Granular soil

F.4.3.6 Calculations and results

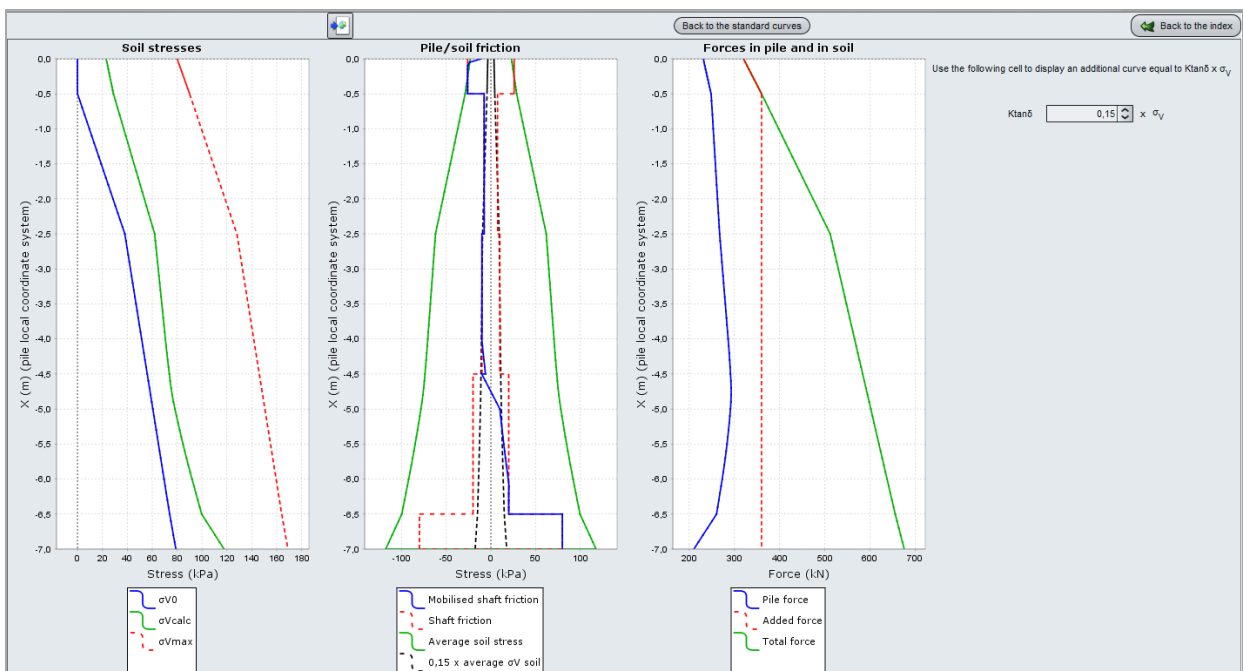
Run again the calculations by clicking on , than on .

By displaying the additional results, we check that the mobilised negative skin friction within the silt layers are now compatible with the vertical effective stress level for $k_{tan}\delta = 0.15$.



- Furthermore, we find out that it is also necessary to readjust the limit friction in the mattress by rectifying it to 26 kPa (value of the vertical effective stress obtained at the mid-depth of the mattress).

This correction leads to the final result presented in the next figure.



Go back to the results window and click on the “Formatted results”. This will show in detail the input and output data as well as a summary of some key values:

Tout copier		Copier uniquement la sélection							Retour
066	-5.600	0.715E-02	0.215E-02	0.270E+03	0.895E+02	0.205E+02	0.215E+04	0.231E+02	
067	-5.600	0.715E-02	0.215E-02	0.270E+03	0.895E+02	0.205E+02	0.215E+04	0.231E+02	
067	-5.700	0.712E-02	0.169E-02	0.268E+03	0.921E+02	0.200E+02	0.213E+04	0.238E+02	
068	-5.700	0.712E-02	0.169E-02	0.268E+03	0.921E+02	0.200E+02	0.213E+04	0.238E+02	
068	-5.800	0.710E-02	0.120E-02	0.265E+03	0.946E+02	0.200E+02	0.211E+04	0.244E+02	
069	-5.800	0.710E-02	0.120E-02	0.265E+03	0.946E+02	0.200E+02	0.211E+04	0.244E+02	
069	-5.900	0.708E-02	0.709E-03	0.263E+03	0.971E+02	0.200E+02	0.209E+04	0.251E+02	
070	-5.900	0.708E-02	0.709E-03	0.263E+03	0.971E+02	0.200E+02	0.209E+04	0.251E+02	
070	-6.000	0.706E-02	0.201E-03	0.260E+03	0.996E+02	0.200E+02	0.207E+04	0.257E+02	
071	-6.000	0.706E-02	0.201E-03	0.260E+03	0.996E+02	0.800E+02	0.207E+04	0.257E+02	
071	-6.100	0.704E-02	0.167E-03	0.250E+03	0.110E+03	0.800E+02	0.199E+04	0.283E+02	
072	-6.100	0.704E-02	0.167E-03	0.250E+03	0.110E+03	0.800E+02	0.199E+04	0.283E+02	
072	-6.200	0.702E-02	0.130E-03	0.240E+03	0.120E+03	0.800E+02	0.191E+04	0.309E+02	
073	-6.200	0.702E-02	0.130E-03	0.240E+03	0.120E+03	0.800E+02	0.191E+04	0.309E+02	
073	-6.300	0.700E-02	0.902E-04	0.230E+03	0.130E+03	0.800E+02	0.183E+04	0.335E+02	
074	-6.300	0.700E-02	0.902E-04	0.230E+03	0.130E+03	0.800E+02	0.183E+04	0.335E+02	
074	-6.400	0.698E-02	0.467E-04	0.220E+03	0.140E+03	0.800E+02	0.175E+04	0.361E+02	
075	-6.400	0.698E-02	0.467E-04	0.220E+03	0.140E+03	0.800E+02	0.175E+04	0.361E+02	
075	-6.500	0.697E-02	0.150E-07	0.210E+03	0.150E+03	0.800E+02	0.167E+04	0.387E+02	
		tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	dsigma pieu	dsigma sol	
max+		0.274E-01	0.274E-01	0.293E+03	0.150E+03	0.800E+02	0.233E+04	0.387E+02	
max-		0.697E-02	0.150E-07	0.210E+03	0.673E+02	-0.260E+02	0.167E+04	0.174E+02	
			y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)		
Sans renforcement			0.1094						
Avec renforcement		Pieu	0.0274	231.375	0.723	1841.224	67128.6		
		Sol (moyenne)	0.0274	88.625	0.277	22.875	833.7		
		Maille		320.000	1.000	80.000			
sollicitations dans l'inclusion									
- contrainte maximale		S_max =	2329.4						
- atteinte à cote		Z =	-4.300						
- charge maximale		Qmax =	292.7						
- sécurité par rapport à Qc(Z)		=	417.0	F=	1.42				
- sécurité par rapport à Ql(Z)		=	595.6	F=	2.03				

In particular, Taspie+ provides, on an indicative basis, the settlement that would be obtained without reinforcements (value obtained by an elastic and unidimensional approach): it is about 11 cm. The use of a reinforcement by rigid inclusions allowed here a reduction of the settlements by a ratio of 4 approximately, with a maximum settlement value of the reinforced soil volume of 2.7 cm.

It is also interesting to reveal the stress “concentration” ratio right above the inclusion: “Slab” effect lead to concentrate on top of the inclusions 72% of the total load.

The maximum stress in the inclusion is 2.3 MPa and it is reached at elevation -4.30 m.

F.4.3.7 Additional checks – Bearing capacity of the inclusions

Taspie+ assesses, at the end of each calculation, the safety factor F against the maximal force in the inclusion and the critical creep load calculated below the neutral plane. Here we have F = 1.42.

		y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)
Sans renforcement		0.1094				
Avec renforcement		Pieu	0.0274	231.375	0.723	1841.224
		Sol (moyenne)	0.0274	88.625	0.277	22.875
		Maille		320.000	1.000	80.000
sollicitations dans l'inclusion						
- contrainte maximale		S_max =	2329.4			
- atteinte à cote		Z =	-4.300			
- charge maximale		Qmax =	292.7			
- sécurité par rapport à Qc(Z)		=	417.0	F=	1.42	
- sécurité par rapport à Ql(Z)		=	595.6	F=	2.03	

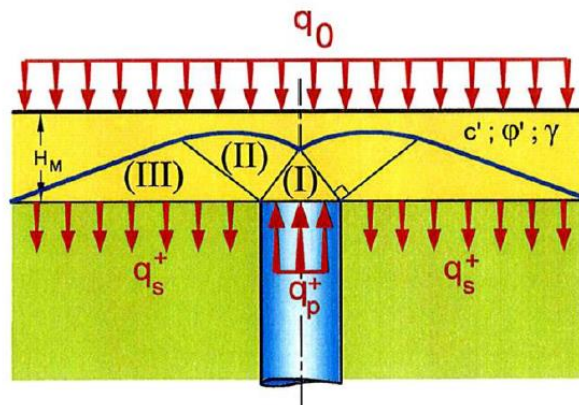
Actually, this check is necessary only if the inclusions are intended to ensure the stability of the structure. In our case, the required safety should be at least 1.1 for “SLS characteristic” combination and at least 1.4 for “SLS quasi-permanent” combination (see French standard

NF P 94 262). However, in the case where the inclusions are used only for reducing the settlements, this check is not necessary.

F.4.3.8 Additional checks – Punching of the mattress

F.4.3.8.1 Calculation of the limit stress at top of the inclusions

For the applied external load, this check consists in the assessment of a limit value of the stress on top of the inclusion that is compatible with the characteristics of the mattress material. This limit value can be calculated by using the Prandtl diagram:



This diagram allows the expression of the limit value of the stress on top of the inclusion as follows:

$$q_p^+ = \frac{N_q}{1 + \alpha(N_q - 1)} q_0^*$$

Where:

- α : "substitution" ratio (ratio between the inclusion section and the section of the mesh);
- N_q : factor depending on the internal friction angle of the mattress;
- q_0^* : mean stress at the bottom of the mattress: $q_0^* = q_0 + \gamma_{\text{fill}} \cdot h_{\text{fill}}$.

Numerical application:

$q_0^* = 90$ kPa, $\alpha = 0.0314$ and $N_q = 48.9$ for an internal friction angle supposed to be 38° .

We obtain: $q_p^+ = 1760$ kPa.

This value is to be compared to the stress actually applied on top of the inclusions resulting from the Taspie+ calculation (for example, by displaying the formatted results file of the last calculation that we run).

Elément	cote	tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	dsigma pieu	dsigma sol
001	0.500	0.274E-01	0.274E-01	0.231E+03	0.886E+02	-0.105E+02	0.184E+04	0.229E+02
001	0.450	0.256E-01	0.274E-01	0.233E+03	0.915E+02	-0.214E+02	0.185E+04	0.236E+02
002	0.450	0.256E-01	0.274E-01	0.233E+03	0.915E+02	-0.260E+02	0.185E+04	0.236E+02
002	0.400	0.237E-01	0.274E-01	0.234E+03	0.937E+02	-0.260E+02	0.186E+04	0.242E+02
003	0.400	0.237E-01	0.274E-01	0.234E+03	0.937E+02	-0.260E+02	0.186E+04	0.242E+02
003	0.350	0.219E-01	0.274E-01	0.236E+03	0.960E+02	-0.260E+02	0.186E+04	0.248E+02
004	0.350	0.219E-01	0.274E-01	0.236E+03	0.960E+02	-0.260E+02	0.186E+04	0.248E+02
004	0.300	0.200E-01	0.273E-01	0.238E+03	0.982E+02	-0.260E+02	0.189E+04	0.254E+02
005	0.300	0.200E-01	0.273E-01	0.238E+03	0.982E+02	-0.260E+02	0.189E+04	0.254E+02
005	0.250	0.181E-01	0.273E-01	0.240E+03	0.100E+03	-0.260E+02	0.191E+04	0.259E+02
006	0.250	0.181E-01	0.273E-01	0.240E+03	0.100E+03	-0.260E+02	0.191E+04	0.259E+02
006	0.200	0.162E-01	0.273E-01	0.241E+03	0.103E+03	-0.260E+02	0.192E+04	0.265E+02
007	0.200	0.162E-01	0.273E-01	0.241E+03	0.103E+03	-0.260E+02	0.192E+04	0.265E+02
007	0.150	0.142E-01	0.273E-01	0.243E+03	0.105E+03	-0.260E+02	0.193E+04	0.271E+02
008	0.150	0.142E-01	0.273E-01	0.243E+03	0.105E+03	-0.260E+02	0.193E+04	0.271E+02
008	0.100	0.123E-01	0.272E-01	0.245E+03	0.107E+03	-0.260E+02	0.195E+04	0.277E+02
009	0.100	0.123E-01	0.272E-01	0.245E+03	0.107E+03	-0.260E+02	0.195E+04	0.277E+02
009	0.050	0.103E-01	0.272E-01	0.247E+03	0.109E+03	-0.260E+02	0.196E+04	0.282E+02
010	0.050	0.103E-01	0.272E-01	0.247E+03	0.109E+03	-0.260E+02	0.196E+04	0.282E+02
010	0.000	0.836E-02	0.272E-01	0.248E+03	0.112E+03	-0.260E+02	0.198E+04	0.288E+02
011	0.000	0.836E-02	0.272E-01	0.248E+03	0.112E+03	-0.750E+01	0.198E+04	0.288E+02
011	-0.100	0.834E-02	0.266E-01	0.249E+03	0.111E+03	-0.750E+01	0.198E+04	0.286E+02
012	-0.100	0.834E-02	0.266E-01	0.249E+03	0.111E+03	-0.750E+01	0.198E+04	0.286E+02
012	-0.200	0.832E-02	0.260E-01	0.250E+03	0.110E+03	-0.750E+01	0.199E+04	0.283E+02
013	-0.200	0.832E-02	0.260E-01	0.250E+03	0.110E+03	-0.750E+01	0.199E+04	0.283E+02
013	-0.300	0.830E-02	0.255E-01	0.251E+03	0.109E+03	-0.750E+01	0.200E+04	0.281E+02
014	-0.300	0.830E-02	0.255E-01	0.251E+03	0.109E+03	-0.750E+01	0.200E+04	0.281E+02
014	-0.400	0.828E-02	0.249E-01	0.252E+03	0.108E+03	-0.750E+01	0.201E+04	0.278E+02
015	-0.400	0.828E-02	0.249E-01	0.252E+03	0.108E+03	-0.750E+01	0.201E+04	0.278E+02
015	-0.500	0.826E-02	0.244E-01	0.253E+03	0.107E+03	-0.750E+01	0.201E+04	0.276E+02
016	-0.500	0.826E-02	0.244E-01	0.253E+03	0.107E+03	-0.750E+01	0.201E+04	0.276E+02
016	-0.600	0.824E-02	0.238E-01	0.254E+03	0.106E+03	-0.750E+01	0.202E+04	0.274E+02
017	-0.600	0.824E-02	0.238E-01	0.254E+03	0.106E+03	-0.750E+01	0.202E+04	0.274E+02
017	-0.700	0.822E-02	0.233E-01	0.255E+03	0.105E+03	-0.750E+01	0.203E+04	0.271E+02
018	-0.700	0.822E-02	0.233E-01	0.255E+03	0.105E+03	-0.750E+01	0.203E+04	0.271E+02
018	-0.800	0.820E-02	0.227E-01	0.256E+03	0.104E+03	-0.750E+01	0.204E+04	0.269E+02
019	-0.800	0.820E-02	0.227E-01	0.256E+03	0.104E+03	-0.750E+01	0.204E+04	0.269E+02
019	-0.900	0.818E-02	0.222E-01	0.257E+03	0.103E+03	-0.750E+01	0.204E+04	0.266E+02
020	-0.900	0.818E-02	0.222E-01	0.257E+03	0.103E+03	-0.750E+01	0.204E+04	0.266E+02
020	-1.000	0.816E-02	0.217E-01	0.258E+03	0.102E+03	-0.750E+01	0.205E+04	0.264E+02
021	-1.000	0.816E-02	0.217E-01	0.258E+03	0.102E+03	-0.750E+01	0.205E+04	0.264E+02
021	-1.100	0.814E-02	0.211E-01	0.259E+03	0.101E+03	-0.750E+01	0.206E+04	0.261E+02

The stress applied on top of the inclusions is 1980 kPa, and it is higher than the limit value as calculated above by using the Prandtl diagram. This means that there is a punching effect of the inclusions within the mattress creating plastic deformations.

It is possible to simulate this “plastification” of the mattress material right above the inclusion by decreasing its strain modulus (in the “inclusion domain”) in order to reduce the stress on top of the inclusion down to 1760 kPa.

F.4.3.8.2 Simulation of the plastification of the mattress material

Go back to the input window.

“Pile” tab:

- Modify the modulus of the pile in the first layer (mattress): replace the existing value (50 MPa) with 30 MPa.

Pile definition in each layer				
Name	Z _{base} [m]	E _{pile} [kPa]	D [m]	
Layer 1		0,00	3,00E04	0,40
Layer 2	-2,00		1,00E07	0,40
Layer 3	-4,00		1,00E07	0,40
Layer 4	-6,00		1,00E07	0,40
Layer 5	-6,50		1,00E07	0,40

F.4.3.8.3 Calculations and results

Run the calculations again and check that the stress applied on top of the inclusion is 1740 kPa, hence compatible with the limit of Prandtl. We note here that this “plastification” triggered an additional settlement of about 1 cm on top (3.6 cm of total settlement).

Elément	cote	tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	dsigma pieu	dsigma sol
001	0.500	0.356E-01	0.356E-01	0.201E+03	0.119E+03	-0.105E+02	0.160E+04	0.307E+02
001	0.450	0.329E-01	0.356E-01	0.202E+03	0.122E+03	-0.264E+02	0.161E+04	0.314E+02
002	0.450	0.329E-01	0.356E-01	0.202E+03	0.122E+03	-0.260E+02	0.161E+04	0.314E+02
002	0.400	0.302E-01	0.355E-01	0.204E+03	0.124E+03	-0.260E+02	0.162E+04	0.320E+02
003	0.400	0.302E-01	0.355E-01	0.204E+03	0.124E+03	-0.260E+02	0.162E+04	0.320E+02
003	0.350	0.275E-01	0.355E-01	0.206E+03	0.126E+03	-0.260E+02	0.164E+04	0.326E+02
004	0.350	0.275E-01	0.355E-01	0.206E+03	0.126E+03	-0.260E+02	0.164E+04	0.326E+02
004	0.300	0.247E-01	0.355E-01	0.208E+03	0.128E+03	-0.260E+02	0.165E+04	0.332E+02
005	0.300	0.247E-01	0.355E-01	0.208E+03	0.128E+03	-0.260E+02	0.165E+04	0.332E+02
005	0.250	0.220E-01	0.354E-01	0.209E+03	0.131E+03	-0.260E+02	0.167E+04	0.337E+02
006	0.250	0.220E-01	0.354E-01	0.209E+03	0.131E+03	-0.260E+02	0.167E+04	0.337E+02
006	0.200	0.192E-01	0.354E-01	0.211E+03	0.133E+03	-0.260E+02	0.168E+04	0.343E+02
007	0.200	0.192E-01	0.354E-01	0.211E+03	0.133E+03	-0.260E+02	0.168E+04	0.343E+02
007	0.150	0.164E-01	0.354E-01	0.213E+03	0.135E+03	-0.260E+02	0.169E+04	0.349E+02
008	0.150	0.164E-01	0.354E-01	0.213E+03	0.135E+03	-0.260E+02	0.169E+04	0.349E+02
008	0.100	0.135E-01	0.353E-01	0.215E+03	0.137E+03	-0.260E+02	0.171E+04	0.355E+02
009	0.100	0.135E-01	0.353E-01	0.215E+03	0.137E+03	-0.260E+02	0.171E+04	0.355E+02
009	0.050	0.107E-01	0.353E-01	0.216E+03	0.140E+03	-0.260E+02	0.172E+04	0.360E+02
010	0.050	0.107E-01	0.353E-01	0.216E+03	0.140E+03	-0.260E+02	0.172E+04	0.360E+02
010	0.000	0.780E-02	0.352E-01	0.218E+03	0.142E+03	-0.260E+02	0.174E+04	0.366E+02
011	0.000	0.780E-02	0.352E-01	0.218E+03	0.142E+03	-0.750E+01	0.174E+04	0.366E+02
011	-0.100	0.778E-02	0.345E-01	0.219E+03	0.141E+03	-0.750E+01	0.174E+04	0.364E+02
012	-0.100	0.778E-02	0.345E-01	0.219E+03	0.141E+03	-0.750E+01	0.174E+04	0.364E+02
012	-0.200	0.776E-02	0.338E-01	0.220E+03	0.140E+03	-0.750E+01	0.175E+04	0.361E+02
013	-0.200	0.776E-02	0.338E-01	0.220E+03	0.140E+03	-0.750E+01	0.175E+04	0.361E+02
013	-0.300	0.775E-02	0.331E-01	0.221E+03	0.139E+03	-0.750E+01	0.176E+04	0.359E+02
014	-0.300	0.775E-02	0.331E-01	0.221E+03	0.139E+03	-0.750E+01	0.176E+04	0.359E+02
014	-0.400	0.773E-02	0.324E-01	0.222E+03	0.138E+03	-0.750E+01	0.177E+04	0.356E+02
015	-0.400	0.773E-02	0.324E-01	0.222E+03	0.138E+03	-0.750E+01	0.177E+04	0.356E+02
015	-0.500	0.771E-02	0.316E-01	0.223E+03	0.137E+03	-0.750E+01	0.177E+04	0.354E+02
016	-0.500	0.771E-02	0.316E-01	0.223E+03	0.137E+03	-0.750E+01	0.177E+04	0.354E+02
016	-0.600	0.769E-02	0.309E-01	0.224E+03	0.136E+03	-0.750E+01	0.178E+04	0.352E+02
017	-0.600	0.769E-02	0.309E-01	0.224E+03	0.136E+03	-0.750E+01	0.178E+04	0.352E+02
017	-0.700	0.767E-02	0.302E-01	0.225E+03	0.135E+03	-0.750E+01	0.179E+04	0.349E+02
018	-0.700	0.767E-02	0.302E-01	0.225E+03	0.135E+03	-0.750E+01	0.179E+04	0.349E+02
018	-0.800	0.766E-02	0.295E-01	0.226E+03	0.134E+03	-0.750E+01	0.180E+04	0.347E+02
019	-0.800	0.766E-02	0.295E-01	0.226E+03	0.134E+03	-0.750E+01	0.180E+04	0.347E+02

072	-6.100	0.660E-02	0.184E-03	0.237E+03	0.123E+03	0.800E+02	0.189E+04	0.317E+02
072	-6.200	0.658E-02	0.143E-03	0.227E+03	0.133E+03	0.800E+02	0.181E+04	0.343E+02
073	-6.200	0.658E-02	0.143E-03	0.227E+03	0.133E+03	0.800E+02	0.181E+04	0.343E+02
073	-6.300	0.656E-02	0.987E-04	0.217E+03	0.143E+03	0.800E+02	0.173E+04	0.369E+02
074	-6.300	0.656E-02	0.987E-04	0.217E+03	0.143E+03	0.800E+02	0.173E+04	0.369E+02
074	-6.400	0.655E-02	0.510E-04	0.207E+03	0.153E+03	0.800E+02	0.165E+04	0.395E+02
075	-6.400	0.655E-02	0.510E-04	0.207E+03	0.153E+03	0.800E+02	0.165E+04	0.395E+02
075	-6.500	0.653E-02	0.163E-07	0.197E+03	0.163E+03	0.800E+02	0.157E+04	0.421E+02

	tassement pieu	tassement sol	effort pieu	effort sol	frottement latéral	dsigma pieu	dsigma sol
max+	0.356E-01	0.356E-01	0.271E+03	0.163E+03	0.800E+02	0.216E+04	0.421E+02
max-	0.653E-02	0.163E-07	0.197E+03	0.886E+02	-0.264E+02	0.157E+04	0.229E+02

	y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)
Sans renforcement	0.1094				
Avec renforcement					
Pieu	0.0356	201.000	0.628	1599.507	44977.8
Sol (moyenne)	0.0356	119.000	0.372	30.715	863.2
Maille		320.000	1.000	80.000	

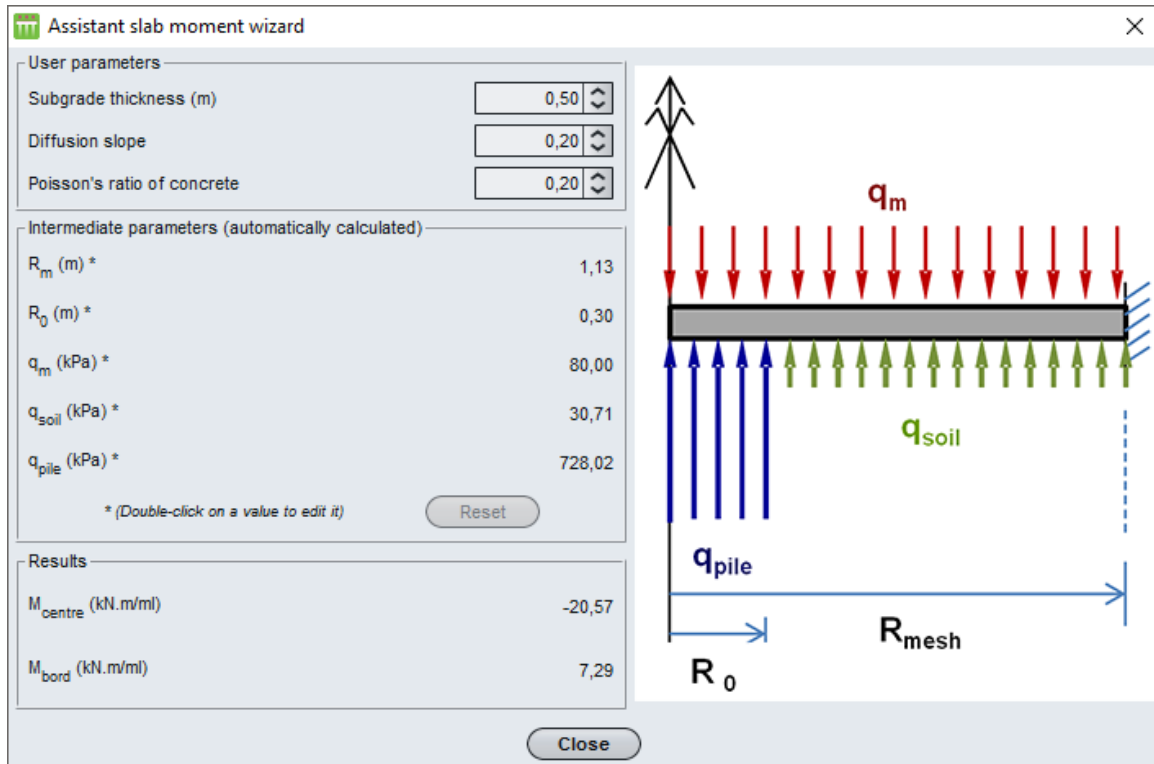
Sollicitations dans l'inclusion

- contrainte maximale	S_max =	2159.7	
- atteinte à cote	Z =	-4.700	
- charge maximale	Qmax =	271.4	
- sécurité par rapport à Qc(Z)		409.9	F= 1.51
- sécurité par rapport à Q1(Z)		585.6	F= 2.16

F.4.3.9 Additional checks - Determination of the "additional forces" in the slab

The results of Taspie+ can be used to assess the additional forces triggered in the slab due to the presence of the inclusions. These forces are to be combined with the ones calculated for a slab laying on an equivalent homogenised soil volume.

These additional forces can be calculated by using the "Moment slab wizard" accessible from the results window (external wizard):

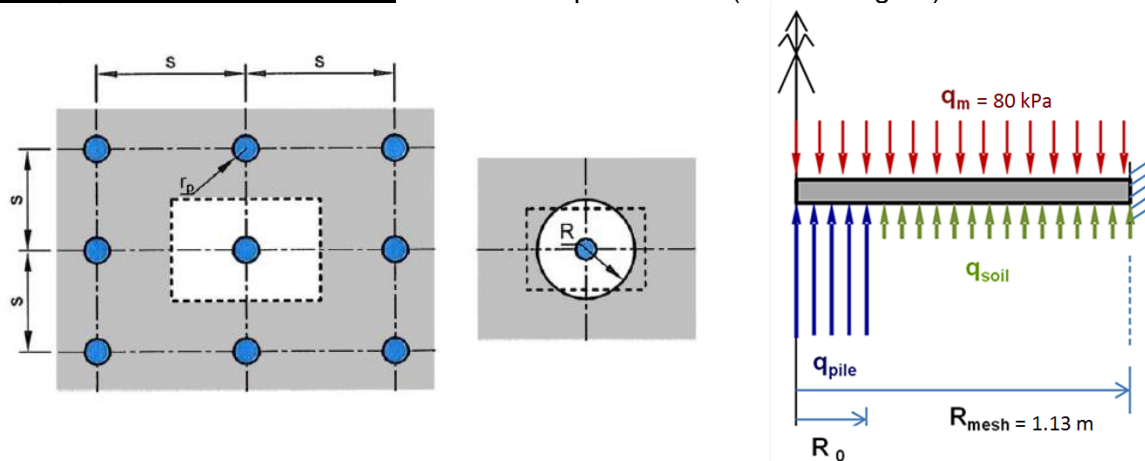


Upper part of the wizard window: additional input

It should be input the following complementary data:

- Subgrade thickness (i.e. load transfer mattress, in the present case): 0.50 m;
- Diffusion slope (of the stresses within the mattress): 0.20 (we keep the default value which corresponds to 1H/5V);
- Poisson's ratio of concrete: 0.20 (0.0 for reinforced concrete, 0.20 for the concrete without steel reinforcement nor fibres).

Central part of the wizard window: intermediate parameters (see next figure)



These parameters are automatically pre-calculated by the software, but it is possible to modify them by a double-click:

- R_m : equivalent radius of the unit cell, directly linked to the mesh step in both direction "a":

$$R_m = a / \pi^{1/2} = 1.13 \text{ m}$$

- R_0 : "Impact" radius under slab directly above inclusions, calculated by considering a diffusion of the stress by $1H/5V$ within the mattress, from the top of the inclusion up to underside of the slab. For inclusions 40 cm in diameter and a 50 cm thick mattress:

$$R_0 = 20 + 50 \times 1/5 = 30 \text{ cm}$$

- q_m : average stress applied on the unit cell (at the slab upper side surface), taken from the input data:

$$q_m = 80 \text{ kPa}$$

- q_{soil} : average stress transmitted to the soil (at the underside of the slab):

$$q_{\text{soil}} = 30.71 \text{ kPa}$$

- q_{pile} : average stress (complementary) applied directly above the inclusions at the underside of the slab (distributed along the impact radius R_0):

$$q_{\text{pile}} = 728.02 \text{ kPa}$$

The latter is calculated thanks to the following formula:

$$q_{\text{pile}} = q_m \times (R_m / R_0)^2 + q_{\text{soil}} \times [1 - (R_m / R_0)^2]$$

Lower part of the wizard window: results

These values are calculated in function of the previously entered values (they are not modifiable):

- $M_{\text{centre}} = -20.6 \text{ kN.m/ml}$: Moment at unit mesh centre;
- $M_{\text{edge}} = +7,3 \text{ kN.m/ml}$: Moment at unit mesh edge.

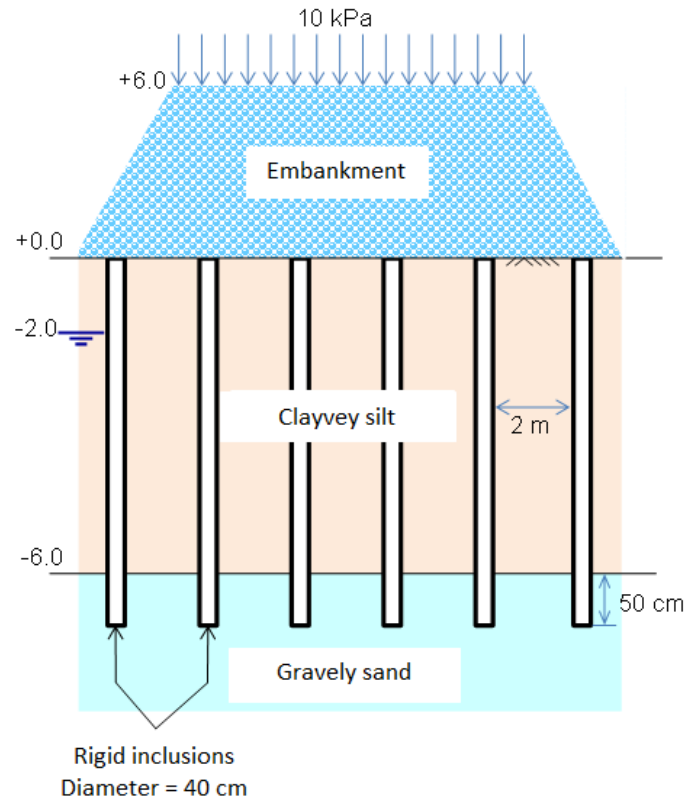
These two values (centre and edge) constitute an envelope [M_{inf} , M_{sup}] with $M_{\text{inf}} = -20.6 \text{ kN.m/ml}$ obtained directly above the inclusions and $M_{\text{sup}} = +7,3 \text{ kN.m/ml}$ obtained at the edge. This corresponds to "mb" term as pair with the calculation rules presented in the ASIRI recommendations. These additional moments are to be combined with the forces calculated for a slab laying on a homogenised soil volume.

Note: Negative symbol of the moments obtained directly above the inclusion mean that the upper fibre is in traction ("hard point" effect).

F.4.4. Example 4: Embankment on soil reinforced by rigid inclusions

The figure below illustrates the current study case.

The study case is a road embankment of 6 m thick bearing a live load of 20 kPa at its surface. In-place soil conditions required the reinforcement by rigid inclusions in order to reduce the settlements and ensure the stability against the punching effect.



The characteristics of the in-place soils and the inclusions are the same as the previous project (example 3: slab on soils reinforced by rigid inclusions). They are given in the table below:

Layer	Z _{top} (m)	γ (kN/m ³)	E _M (MPa)	P _i * (MPa)	q _{sl} (kPa) ^(**)	E (MPa) ^(*)
Embankment	+6.00	20	15	--	--	50
Clayey silt	+0.00	19	2,5	0.3	20	5
Gravely sand	-6.00	20	20	2.0	80	80

(*) E is the vertical elastic strain modulus.

(**) q_{sl} is the unit limit skin friction (soil/inclusion).

Note: as the soil layers of this example are similar to those of the previous example, it would be useful to use the soil database. This would allow the share of the soil layers and their characteristics between two projects and prevent to input them again.

It is still possible to use the soil database: if you wish, open example 3 before starting the example 4, and export the soil layers of the example 3 to the general soil database. Then activate the use of the database in the example 4 (in the module selection window), and import the soil layers from the general database to the current project. See chapter C for further explanations about the use of soil databases.

F.4.4.1 Data input

Double-click on the Foxta icon to run the software, chose the type of connection and the language. Then click on button.

At the beginning, Foxta proposes:

- To create a new project;
- To open an existing project;
- To open recent project.

In the case of this example:

- To create a new project, click on the New project radio-button;
- Click on the button.

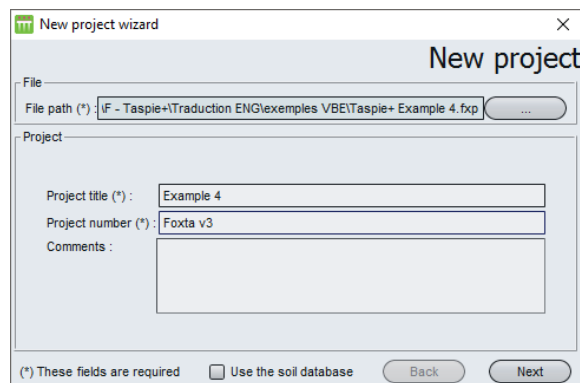
F.4.4.1.1 New project wizard

"File" frame:

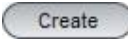
- Click on the button to choose the work directory;
- Name and save the file.

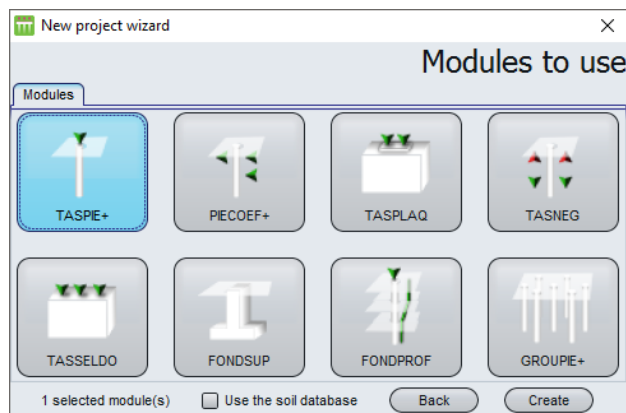
"Project" frame:

- Define a title for the project;
- Define a project number;
- Complete comments if necessary;
- Leave the "Use the soil database" box unchecked (for this example we will not use the soil database), and click on the button.



F.4.4.1.2 New project wizard: Module selection

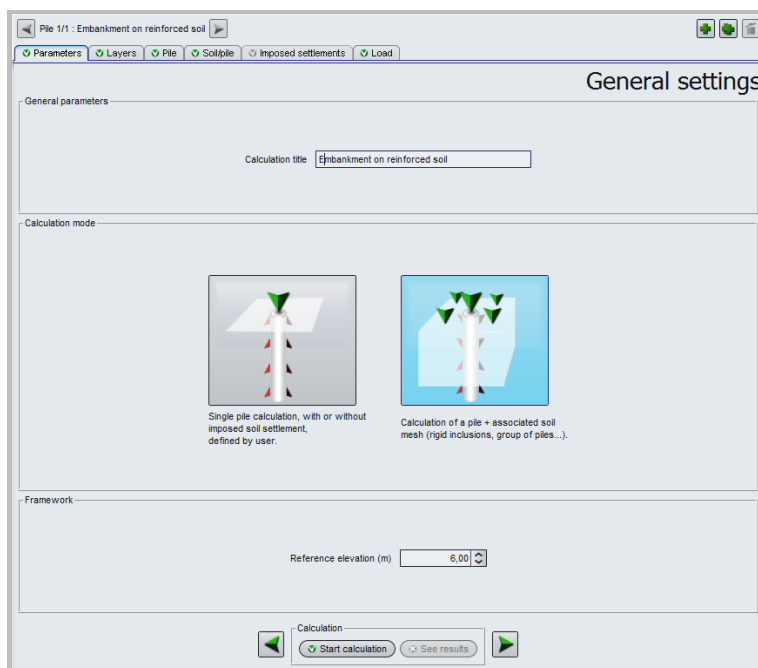
In the "Modules to use" window, select Taspie+ and Tasplaq modules and click on the  button



The input data window of Taspie+ is now displayed. All data tabs should now be completed in the right zone of the screen.

F.4.4.1.3 “Parameters” tab

This tab allows the definition of the general parameters:



"General parameters" frame:

- Calculation title: "Embankment on reinforced soil".

"Calculation mode" frame:

- Choose "Calculation of a pile + associated soil mesh".

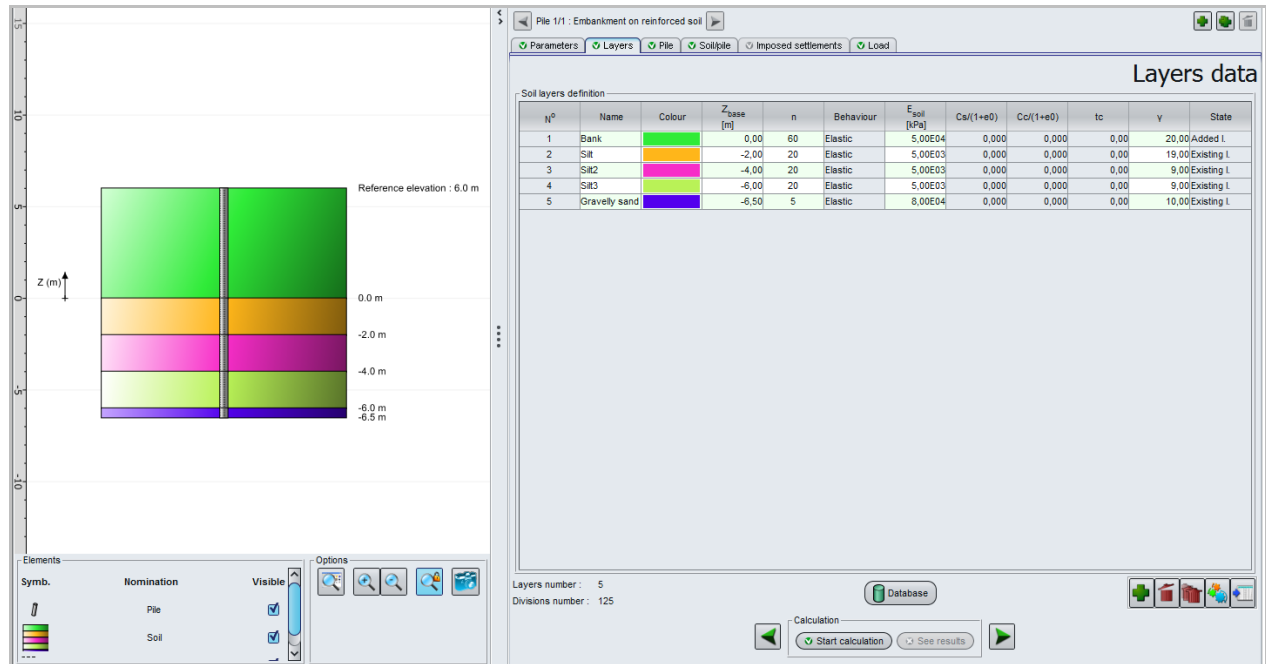
"Framework" frame


- Change the reference elevation: +6.0 m, corresponding to the top of the embankment.

To shift to the next tab, click either on the name of the tab “Layers”, or on the  button.

F.4.4.1.4 "Layers" tab

This tab is for the definition of the soil layers. Like in the exercise 3, the silt layer has been divided into sublayers of 2 m thick each, in order to assign some parameters refined by depth. The bottom of the model corresponds to the toe of the inclusions.



Use the  button under the table to create soil layers one by one.

The input parameters are summarised in the table below:

Name	Z _{base} (m)	n	Behaviour	E _{soil} (kPa)	γ' (kN/m ³)	State
Embankment	0.00	60	Elastic	5.00E+04	20	Added I.
Silt 1	-2.00	20	Elastic	5.00E+03	19	Existing I.
Silt 2	-4.00	20	Elastic	5.00E+03	9	Existing I.
Silt 3	-6.00	20	Elastic	5.00E+03	9	Existing I.
Sand	-6.50	5	Elastic	8.00E+04	10	Existing I.

F.4.4.1.5 "Pile" tab

This tab allows the definition of the "pile domain". This domain includes the inclusion itself and the soil volume directly above the pile (extended from the pile cap up to the top of the model).

"Pile type" frame

- Implementation mode of pile: "With displacement";
- Type of pile section: "Circular section".

"Pile parameters" frame

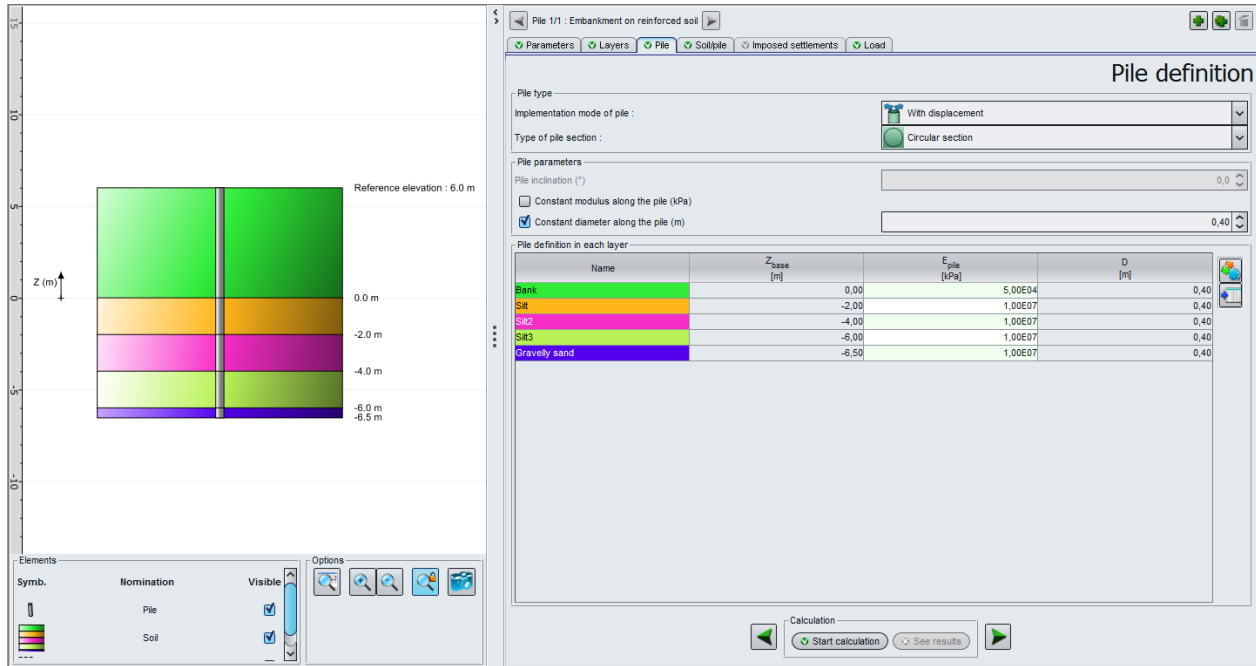
- Pile inclination: 0°;
- "Constant modulus along the pile": unchecked;

- “Constant diameter along the pile”: checked, D = 0.40 m.

“Pile definition in each layer” frame

The strain moduli for each layer of the “pile domain” have to be defined here. These moduli correspond to:

- The modulus of the embankment (50 MPa) in the first layer;
- The modulus of the inclusion’s constitutive concrete down to the base of the model (10 000 MPa).



Trick: to save time, it is possible to check “Constant modulus along the pile” option at first, define the modulus value as 10 000 MPa, then uncheck the option and finally modify the modulus value for the first layer only (50 MPa).

The input data are the following:

Name	Z _{base} (m)	E _{pile} (kPa)	D (m)
Embankment	0.00	5.00E04	0.40
Silt 1	-2.00	1.00E07	0.40
Silt 2	-4.00	1.00E07	0.40
Silt 3	-6.00	1.00E07	0.40
Sand	-6.50	1.00E07	0.40

F.4.4.1.6 “Soil/Pile” tab

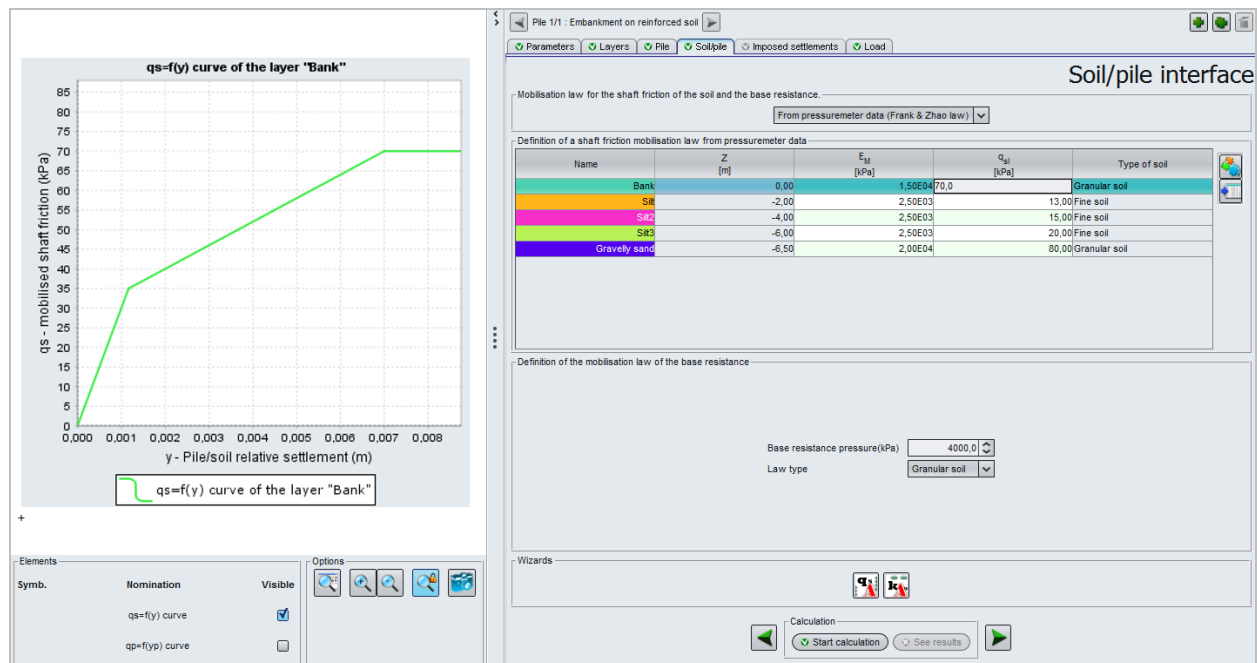
This tab allows the definition of the skin friction and base resistance mobilisation laws.

As for the exercise 3, the skin friction mobilisation law to be use is Frank and Zhao law built up from the pressuremeter data. The limit skin friction is 20 kPa in silt sublayers (for the first iteration). The skin friction mobilisation law in the embankment corresponds to a “soil/soil” interface where the shear resistance is limited by the vertical effective stress in between the inclusions ($k\sigma_v = 1$).

In a preliminary approach, we make the choice of taking into account a limit friction value in the embankment of 70 kPa corresponding to the weight of the soils at mid-depth of the layer (60 kPa) + the load applied on top of the model (10 kPa).

The mobilisation law of the base resistance is Frank and Zhao for granular soil with a limit resistance pressure of $q_{pl} = k_p \times p_l^* = 2.0 \times 2000 = 4000$ kPa.

Note again that these suggested laws are strictly valid for a bored pile. Their use for an inclusion installed with displacement of the surrounding soil within sand and/or gravel constitutes a pessimistic approach.



"Mobilisation law for the shaft friction of the soil and the toe force" frame:

- Select in the drop-down list: “From pressuremeter data (Frank & Zhao law)”.

“Definition of a shaft friction law” frame:

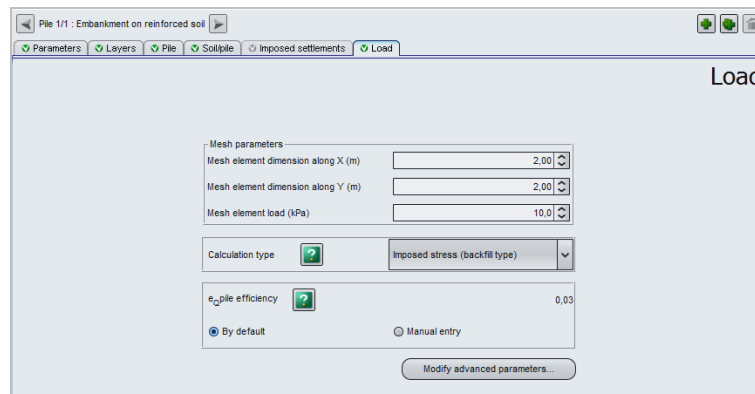
Name	E _M (kPa)	q _{sl} (kPa)	Soil type
Embankment	1,50E+04	70.0	Granular soil
Silt 1	2,50E+03	20.0	Fine soil
Silt 2	2,50E+03	20.0	Fine soil
Silt 3	2,50E+03	20.0	Fine soil
Sand	2.00E+04	80.0	Granular soil

“Definition of the mobilisation law of the base resistance” frame:

- Base resistance pressure: “4000” kPa;
- Law type: “Granular soil”.

F.4.4.1.7 “Load” tab

This tab allows defining the mesh of the inclusions and the loading conditions on top of the model.



“Mesh parameters” frame:

- Mesh element dimension along X: 2.0 m;
- Mesh element dimension along Y: 2.0 m;
- Mesh element load: 10 kPa. This corresponds to the mean stress applied at top of the model (road load).

“Calculation type” frame:

- Calculation type: imposed stress (backfill type).

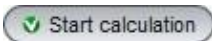
“e_Qpile efficiency” frame:

- e_Qpile efficiency: 0.03 (default value).

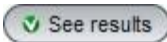
The "e_Qpile" is the ratio of the force transmitted to the pile domain and the total load applied on the mesh. The proposed default value is in proportion of the inclusion/mesh sections, which is equivalent to a uniform distribution of the stress on top of the model.

F.4.4.2 Calculations and results

F.4.4.2.1 Calculation

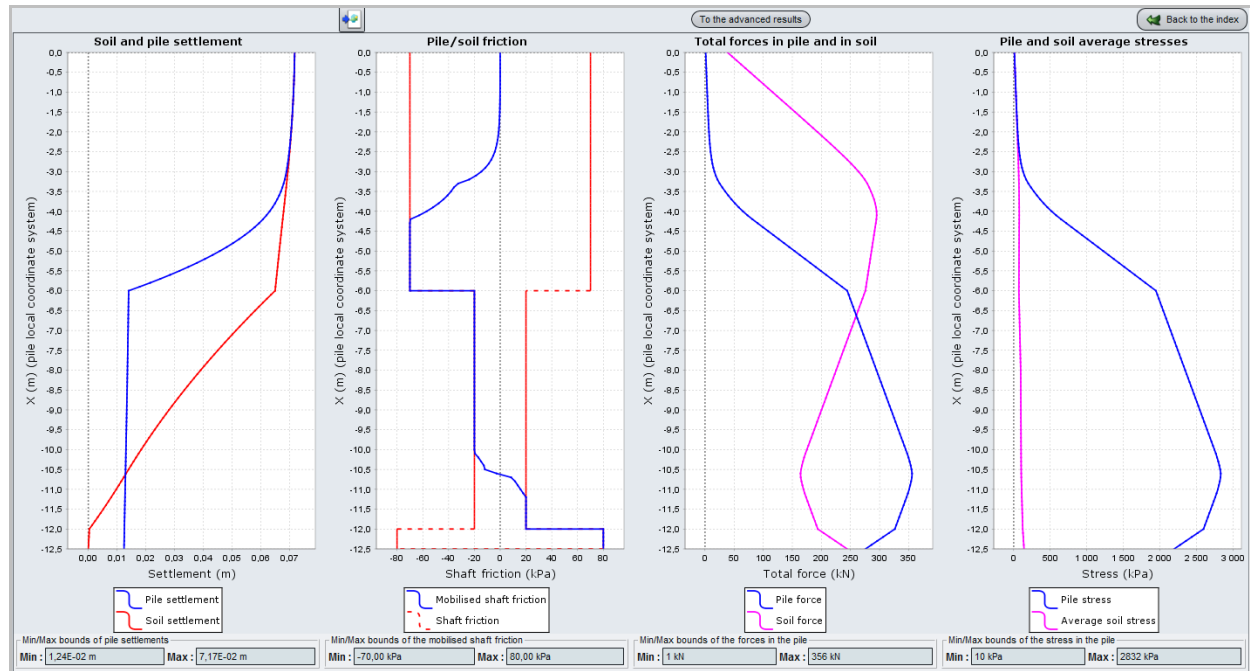
When the input data are correctly entered, click on the  button to run the calculations.

F.4.4.2.2 Results

To display the results, click on the  button.

"Graphical results"

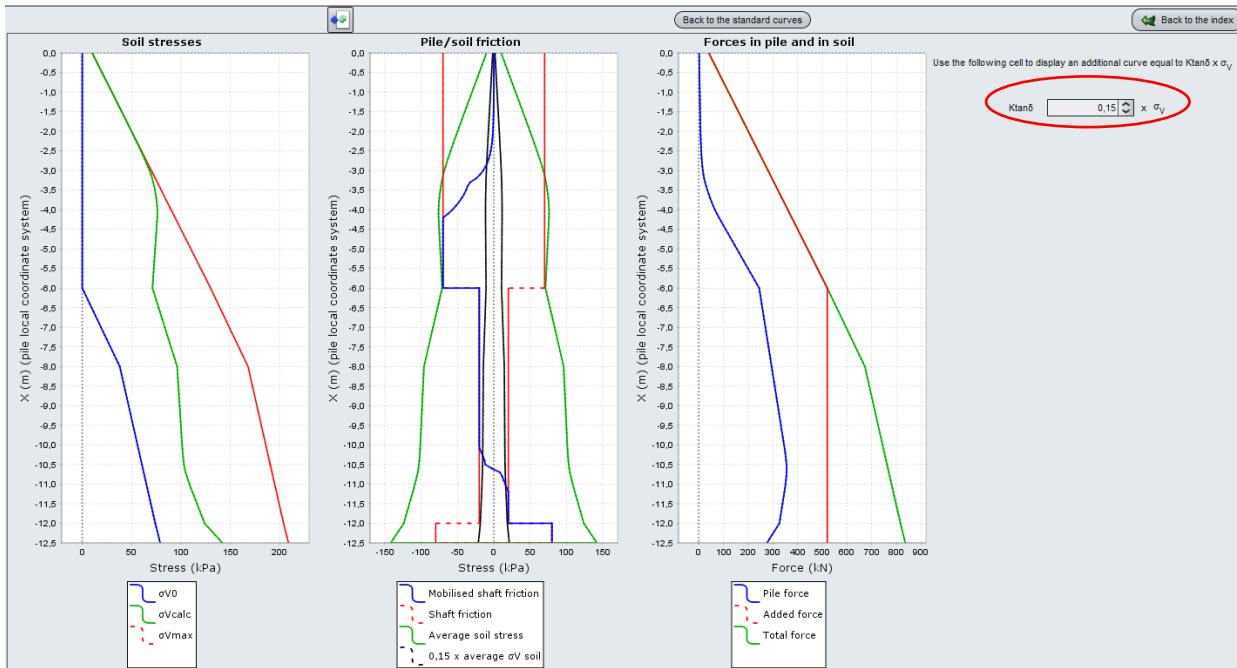
Click on the "Main results" button. This will allow you to access to the settlement curves, skin friction values, forces and stresses with depth.



The maximum settlement is about 7 cm of which 5.5 cm occurred in the embankment (directly above the inclusion). We observe, here also, the development of two equal settlement planes:

- The first one is obtained in the embankment material and it relates to the formation of an arch effect: above this neutral plane, the embankment material settles uniformly and no vertical shear is created;
- The second is obtained in depth, at elevation -4.5 m approximately (this corresponds to -10.5 m in the local coordinates of the pile) and indicates the bottom of the negative friction zone.

Shift to additional results by clicking on the [To the advanced results](#) button.



These results show that the mobilised vertical shear within the embankment material is compatible with the vertical stress level in the embankment. However, the display of the curve $0.15 \times \sigma_v$ indicates the need of an adjustment of the limit friction in the first four meters of the silts where the friction is negative.

Restarting the calculation by limiting the friction in the silt layers 1 and 2 respectively to 13 and 15 kPa allows reaching a negative friction profile compatible with the vertical stress, at all depths, without influencing the global behaviour of the reinforcement system.

F.4.4.3 Additional checks

F.4.4.3.1 Bearing capacity of the inclusions

Taspie+ assesses, at the end of each calculation, the safety factor F against the maximal force in the inclusion and the critical creep load calculated below the neutral plane. Here we have $F = 1.19$.

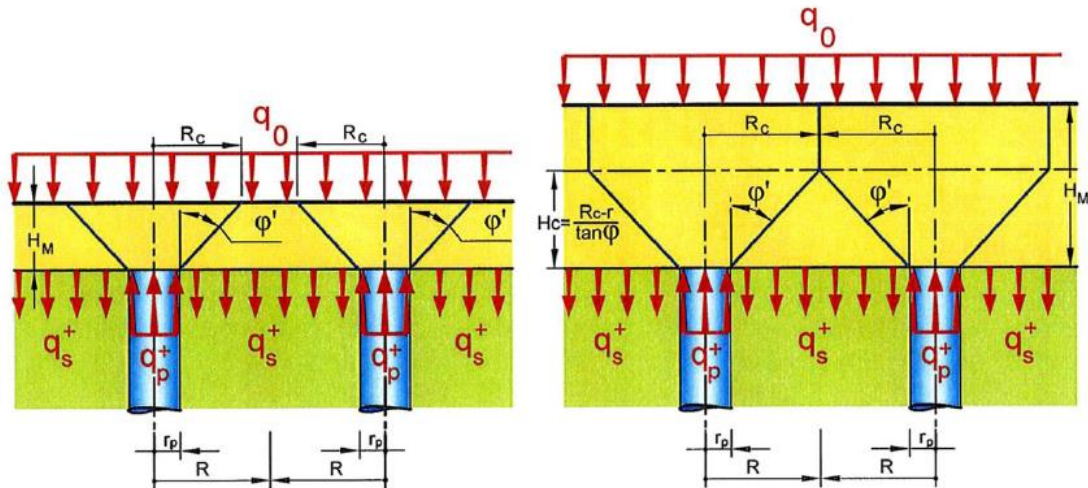
		y tete (L)	Q tete (F)	%	Sigma tete (FL-2)	raideur surf. (FL-3)
Sans renforcement		0.1652				
Avec renforcement	Pieu	0.0743	1.257	0.031	10.000	134.6
	Soil (moyenne)	0.0743	38.743	0.969	10.000	134.6
	Maille		40.000	1.000	10.000	
Solicitations dans l'inclusion						
- contrainte maximale	S_max =		2719.0			
- atteinte à cote	Z =		-4.900			
- charge maximale	Qmax =		341.7			
- sécurité par rapport à Qc(Z)	=		406.4	F= 1.19		
- sécurité par rapport à Ql(Z)	=		580.6	F= 1.70		

For this particular study case, the inclusions serve to reduce the settlements and to ensure the stability of the structure. Therefore, the check of the bearing capacity of the inclusions is necessary. The calculated safety factor ($1.19 > 1.10$) is assumed to be acceptable to justify the stability of the structure against the bearing capacity for SLS characteristic load combination.

To check the bearing capacity for SLS quasi-permanent load combinations, a calculation without road load can be carried out by targeting this time a minimum safety factor of 1.40.

F.4.4.4 Punching of the mattress

The approach of the embankment case is similar to the one of the mattress (example 3). However, in addition to the examination of the diagram of Prandtl described previously, a diffusion cone type rupture diagram (see figure below) shall be examined also. Then the rupture mechanism providing the lowest limit stress at top of the inclusion should be taken into account.



The application of these two diagrams (not detailed here), lead to a limit stress at top of the inclusion of 2540 kPa by considering an internal friction angle of the embankment material of 38° (in this case, it is the Prandtl diagram which provides the envelop value of 2540 kPa. The “diffusion cone” diagram provides, in this case, a limit stress of 3690 kPa). This value is to be compared to the one of the stress actually applied on top of the inclusion calculated by Taspie+ model: 2020 kPa. Thus, there is no punching effect of the inclusions into the embankment material.

043	1.700	0.605E-01	0.700E-01	0.100E+03	0.284E+03	-0.700E+02	0.797E+03	0.733E+02
044	1.700	0.605E-01	0.700E-01	0.100E+03	0.284E+03	-0.700E+02	0.797E+03	0.733E+02
044	1.600	0.588E-01	0.699E-01	0.109E+03	0.283E+03	-0.700E+02	0.869E+03	0.730E+02
045	1.600	0.588E-01	0.699E-01	0.109E+03	0.283E+03	-0.700E+02	0.869E+03	0.730E+02
045	1.500	0.570E-01	0.698E-01	0.118E+03	0.282E+03	-0.700E+02	0.941E+03	0.727E+02
046	1.500	0.570E-01	0.698E-01	0.118E+03	0.282E+03	-0.700E+02	0.941E+03	0.727E+02
046	1.400	0.550E-01	0.696E-01	0.127E+03	0.281E+03	-0.700E+02	0.101E+04	0.724E+02
047	1.400	0.550E-01	0.696E-01	0.127E+03	0.281E+03	-0.700E+02	0.101E+04	0.724E+02
047	1.300	0.529E-01	0.695E-01	0.136E+03	0.280E+03	-0.700E+02	0.109E+04	0.722E+02
048	1.300	0.529E-01	0.695E-01	0.136E+03	0.280E+03	-0.700E+02	0.109E+04	0.722E+02
048	1.200	0.507E-01	0.693E-01	0.145E+03	0.279E+03	-0.700E+02	0.116E+04	0.719E+02
049	1.200	0.507E-01	0.693E-01	0.145E+03	0.279E+03	-0.700E+02	0.116E+04	0.719E+02
049	1.100	0.483E-01	0.692E-01	0.154E+03	0.278E+03	-0.700E+02	0.123E+04	0.716E+02
050	1.100	0.483E-01	0.692E-01	0.154E+03	0.278E+03	-0.700E+02	0.123E+04	0.716E+02
050	1.000	0.458E-01	0.690E-01	0.164E+03	0.276E+03	-0.700E+02	0.130E+04	0.714E+02
051	1.000	0.458E-01	0.690E-01	0.164E+03	0.276E+03	-0.700E+02	0.130E+04	0.714E+02
051	0.900	0.431E-01	0.689E-01	0.173E+03	0.275E+03	-0.700E+02	0.137E+04	0.711E+02
052	0.900	0.431E-01	0.689E-01	0.173E+03	0.275E+03	-0.700E+02	0.137E+04	0.711E+02
052	0.800	0.403E-01	0.687E-01	0.182E+03	0.274E+03	-0.700E+02	0.145E+04	0.708E+02
053	0.800	0.403E-01	0.687E-01	0.182E+03	0.274E+03	-0.700E+02	0.145E+04	0.708E+02
053	0.700	0.373E-01	0.686E-01	0.191E+03	0.273E+03	-0.700E+02	0.152E+04	0.706E+02
054	0.700	0.373E-01	0.686E-01	0.191E+03	0.273E+03	-0.700E+02	0.152E+04	0.706E+02
054	0.600	0.342E-01	0.685E-01	0.200E+03	0.272E+03	-0.700E+02	0.159E+04	0.703E+02
055	0.600	0.342E-01	0.685E-01	0.200E+03	0.272E+03	-0.700E+02	0.159E+04	0.703E+02
055	0.500	0.310E-01	0.683E-01	0.209E+03	0.271E+03	-0.700E+02	0.166E+04	0.700E+02
056	0.500	0.310E-01	0.683E-01	0.209E+03	0.271E+03	-0.700E+02	0.166E+04	0.700E+02
056	0.400	0.276E-01	0.682E-01	0.218E+03	0.270E+03	-0.700E+02	0.173E+04	0.697E+02
057	0.400	0.276E-01	0.682E-01	0.218E+03	0.270E+03	-0.700E+02	0.173E+04	0.697E+02
057	0.300	0.240E-01	0.680E-01	0.227E+03	0.269E+03	-0.700E+02	0.181E+04	0.695E+02
058	0.300	0.240E-01	0.680E-01	0.227E+03	0.269E+03	-0.700E+02	0.181E+04	0.695E+02
058	0.200	0.204E-01	0.679E-01	0.236E+03	0.268E+03	-0.700E+02	0.188E+04	0.692E+02
059	0.200	0.204E-01	0.679E-01	0.236E+03	0.268E+03	-0.700E+02	0.188E+04	0.692E+02
059	0.100	0.165E-01	0.678E-01	0.245E+03	0.267E+03	-0.700E+02	0.195E+04	0.689E+02
060	0.100	0.165E-01	0.678E-01	0.245E+03	0.267E+03	-0.700E+02	0.195E+04	0.689E+02
060	0.000	0.126E-01	0.676E-01	0.254E+03	0.266E+03	-0.700E+02	0.202E+04	0.687E+02
061	0.000	0.126E-01	0.676E-01	0.254E+03	0.266E+03	-0.130E+02	0.202E+04	0.687E+02
061	-0.100	0.125E-01	0.663E-01	0.256E+03	0.264E+03	-0.130E+02	0.203E+04	0.682E+02
062	-0.100	0.125E-01	0.663E-01	0.256E+03	0.264E+03	-0.130E+02	0.203E+04	0.682E+02
062	-0.200	0.125E-01	0.649E-01	0.257E+03	0.263E+03	-0.130E+02	0.205E+04	0.678E+02
063	-0.200	0.125E-01	0.649E-01	0.257E+03	0.263E+03	-0.130E+02	0.205E+04	0.678E+02
063	-0.300	0.125E-01	0.636E-01	0.259E+03	0.261E+03	-0.130E+02	0.206E+04	0.674E+02
064	-0.300	0.125E-01	0.636E-01	0.259E+03	0.261E+03	-0.130E+02	0.206E+04	0.674E+02
064	-0.400	0.125E-01	0.622E-01	0.261E+03	0.259E+03	-0.130E+02	0.207E+04	0.670E+02
065	-0.400	0.125E-01	0.622E-01	0.261E+03	0.259E+03	-0.130E+02	0.207E+04	0.670E+02
065	-0.500	0.125E-01	0.609E-01	0.262E+03	0.258E+03	-0.130E+02	0.209E+04	0.666E+02
066	-0.500	0.125E-01	0.609E-01	0.262E+03	0.258E+03	-0.130E+02	0.209E+04	0.666E+02
066	-0.600	0.124E-01	0.595E-01	0.264E+03	0.256E+03	-0.130E+02	0.210E+04	0.661E+02
067	-0.600	0.124E-01	0.595E-01	0.264E+03	0.256E+03	-0.130E+02	0.210E+04	0.661E+02