



PART H: GROUPIE+ MODULE

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H.1. GENERAL PRESENTATION

H.1.1. Introduction

The Groupie+ module is used to calculate a foundation on a group of piles, rectangular piles or micro-piles. This is a hybrid programme which takes advantage of the power of the matrix formulations derived from finite elements for the study of soil-structure interaction problems. The calculation process is fully automated to facilitate modelling and minimise calculation time. However, the "classic" version based on manual calculation has been retained.

In any case, the three-dimensional problem is split into two parts: the piles and the surrounding soil. The piles, which can be spatially oriented, are modelled as elastic beams characterised by their axial and bending rigidity, discretised in finite elements. The piles/soil interaction is modelled by non-linear "p-y" and "t-z" type transfer laws. Finally, the loading of the footing is defined by a six-component global forces and moments vector.



Figure H 1: Foundation on group of piles

H.1.2. Calculation methods

Two calculation methods are available:

- Manual management of the calculation process (Manual Groupie mode): Each pile is
 to be characterised by an equivalent pile head stiffness matrix previously defined
 using the Taspie+ and Piecoef+ modules. The problem can thus be reduced to the
 equilibrium of the footing subjected to the external global forces and moments and to
 the reactions at the top of the piles. The iterations to be carried out, in particular in the
 event of soil plastification, have to be managed manually by the user for each load
 case and each pile.
- Automatic calculation management (Automatic Groupie+ and Advanced Automatic Groupie+ modes): the piles are discretised into beam elements characterised by axial rigidity and a product of inertia in each direction. The user-defined multilayer soil, with elastoplastic behaviour, offers the possibility of introduce dips in both directions. The problem is to resolve the overall equilibrium of the group of piles. The calculation process is both independent and automatic.



H.2. THEORETICAL ASPECTS

H.2.1. Notations and conventions

H.2.1.1. Definition of the connecting footing – global system of coordinates

The global system of coordinates $(O, \vec{X}, \vec{Y}, \vec{Z})$ is a direct orthonormal system of coordinates whose axis (O, \vec{Z}) is vertical descending. The external global forces and moments applied to the footing and that of the resultant displacements are expressed at point O according to the conventions of mechanics. The forces and displacements are positive if oriented in the same direction as the axes of the global system of coordinates. The moments and rotations are positive if their associated vectors are positive as defined by the corkscrew rule (see Figure H 2:).



Figure H 2: Conventions and systems of coordinates

H.2.1.2. Definition of piles – local systems of coordinates

"n_p" is the total number of piles. Each pile "i" is defined by the coordinates of its head (X_P, Y_P, Z_P) and by two angles α and β specifying its orientation in the global system of coordinates (see Figure H 2:). The local system of coordinates, noted $(P, \vec{x}, \vec{y}, \vec{z})$, is such that the axis (P, \vec{y}) always remains orthogonal to axis (O, \vec{Z}) . The global forces and moments at the top of each pile (calculation result) is expressed in its local system of coordinates, while adopting the particular sign conventions presented in Figure H 3:.



Figure H 3: Forces at pile head



A pile is characterised by different geometrical and mechanical parameters. Its layout and spatial orientation are defined by the following elements:

- X_{P} : X-axis of pile head in the global system of coordinates;
- Y_{p} : Y-axis of pile head in the global system of coordinates;
- $Z_{\rm P}$: elevation of the pile head;
- L : length of the pile;
- α : angle between the direction of the pile and the vertical $\alpha \in [0^{\circ}, 90^{\circ}]$;
- β : angle defined by rotation of the pile around the vertical axis $\beta \in [0^{\circ}, 360^{\circ}]$.

The mechanical characteristics of a pile are:

- EI_x : product of inertia of the pile in direction x;
- EI_{y} : product of inertia of the pile in direction y;
- ES : pile axial rigidity;
- Γ : equivalent torsional stiffness at pile head.

Link with the footing:

Binding : type of binding between pile and footing (articulated or clamped).

If the piles are not free at the base, additional lateral translation and rotational stiffnesses may be defined to simulate the base binding of each pile.

H.2.1.3. Definition of soil layers

The foundation soil consists of one or more layers of different geometrical and mechanical characteristics. The geometrical parameters introduce stresses on the piles mesh. These then force the creation of imposed nodes at the points of intersection between the piles and the layer interfaces. Each soil layer is characterised by the following parameters:

*Elev*_{base}: elevation of the base at axis (O, \vec{Z}) ;

- $\alpha_{\rm Y}$: angle between the base and axis $(O, \vec{\rm Y})$ with $\alpha_{\rm Y} \in -90^{\circ}, 90^{\circ}$ [;
- α_x : angle between the base and axis (O, \vec{X}) with $\alpha_x \in -90^\circ, 90^\circ$.

The other characteristics are used to define pile-soil reaction laws taking account of the dimensions of the piles (reaction width, perimeter, cross-section).

H.2.2. Representation by equation

H.2.2.1. Modelling the behaviour of a pile "i"

Each pile is compared to a beam with linear elastic behaviour. The beams are considered to have homogeneous cross-section, which enables bending behaviour to be dissociated from that in traction/compression.



The combined bending behaviour of the beam representative of a pile "i" can be described using the following system of equations:

$$ES^{i} \frac{d^{2}u_{z}^{i}(z)}{dz^{2}} = q_{z}^{i}(z) - r_{z}^{i}(z)$$

$$EI_{x}^{i} \frac{d^{4}u_{x}^{i}(z)}{dz^{4}} = q_{x}^{i}(z) - r_{x}^{i}(z)$$

$$EI_{y}^{i} \frac{d^{4}u_{y}^{i}(z)}{dz^{4}} = q_{y}^{i}(z) - r_{y}^{i}(z)$$
(1)

With:

- $u_k^i(z)$: displacement of pile "i" in direction "k" (k = x, y or z);
- EI_k^i : product of inertia of pile "i" in direction "k" (k = x, y);
- *ESⁱ*: axial rigidity of pile "i";
- qⁱ_k(z): component "k" of the external linear load density on pile "i" other than the soil reaction (k = x, y or z);
- $r_k^i(z)$: component "k" of soil reaction on pile "i" (k = x, y or z).

This system of equations can be modelled numerically by discretising the pile into finite beam elements. To do this, we use "classic" elements with 2 nodes and 5 degrees of freedom per node: one axial displacement, two transverse displacements and two rotations. At any point, the rotation of the beam coincides with the derivative of the transverse displacement field (Bernoulli approximation). In the context of this discretisation, the equilibrium of the pile is represented by an equivalent matrix system of size $5(p_i+1) \times 5(p_i+1)$ where p_i designates the total number of elements of pile "i":

$$\mathbf{K}_{p}^{i} \cdot \mathbf{u}^{i} = \mathbf{F}_{ext}^{i} - \mathbf{R}_{s}^{i}$$
⁽²⁾

With:

- **K**^{*i*}_{*p*}: rigidity matrix of pile "i" constituted by an assembly of elementary rigidity matrices:
- \mathbf{F}_{ext}^{i} : load vector relative to the transverse loads on pile "i" other than soil reaction;
- **R**^{*i*}_{*s*}: load vector related to the soil reaction on pile "i";
- \mathbf{u}^i : equivalent displacement vector of pile "i" constituted by displacements (u_x, u_y, u_z) and rotations (θ_x , θ_y) at each node.

H.2.2.2. Modelling of piles/soil interaction

The interaction between the piles and the surrounding soil can be described by:

- A frontal reaction with two components (decoupled), along x and y;
- An axial reaction (friction) along z;
- A base reaction, usually limited to its axial component along z.

The modelling of each of these components is based on the principles of the "p-y" (frontal components) and "t-z" (axial components) models. These models consist in comparing the frontal and axial responses of the surrounding soil to those of a distribution of juxtaposed elastoplastic springs (see following figure).



terrasol

Figure H 4: Soil/pile interaction modelling principle

Each of these spring distributions is characterised by a mobilisation law with three plateaux linking soil reaction (for a given component) to relative pile displacement (along a given axis), as shown in the following figure. The relative nature of the displacement shown on the X-axis in particular makes it possible to deal with cases of interference (transverse effects of type "g(z)" or negative friction) developing in one or more soil layers.



Figure H 5: General form of the soil reaction mobilisation law



According to the notations in the above figure, the soil transverse reaction r(z) is expressed thus:

 $r = \alpha [u - g] + \beta$

With:

• For the 1st plateau: $\alpha = K_1$ & $\beta = 0$; • For the 2nd plateau: $\alpha = K_2$ & $\beta = P_1 \cdot \left(1 - \frac{K_2}{K_1}\right)$; • For the 3rd plateau: $\alpha = 0$ & $\beta = P_2$;

In the context of the finite elements discretisation chosen for pile "i", this relation can be written in the form of the following matrix:

$$\mathbf{R}_{s}^{i} = \mathbf{K}_{s}^{i} \cdot \left(\mathbf{u}^{i} - \mathbf{g}^{i} \right) + \mathbf{c}_{s}^{i}$$
(3)

Where:

- **K**^{*i*}_{*s*}: matrix of soil rigidity in contact with pile "i", corresponding to the elastic part of the mobilisation curve in each element;
- \mathbf{c}_{s}^{i} : equivalent load vector corresponding to the "plastic" part of the soil reaction in contact with pile "i";
- **g**^{*i*}: equivalent displacement vector corresponding to free displacement of the soil in contact with pile "i".

Combining the previous equations leads to the global formulation of the system representing the response of pile "i" interacting with the surrounding soil:

$$\left(\mathbf{K}_{p}^{i}+\mathbf{K}_{s}^{i}\right)\mathbf{u}^{i}=\mathbf{F}_{ext}^{i}+\mathbf{K}_{s}^{i}\cdot\mathbf{g}^{i}-\mathbf{c}_{s}^{i}$$
(4)

Soil plastification is managed using an iterative process during which \mathbf{K}_{s}^{i} and \mathbf{c}_{s}^{i} change until a compatible solution is obtained, at all points on the pile and in each direction, with the soil reaction mobilisation law.

H.2.2.3. Modelling footing/piles interaction

Interaction between the footing and the piles is described using a "clamped" or "articulated" type contact condition. In the first case, we consider equality between the displacements and rotations of the footing and those of the pile head. In the second, only equality of displacements is considered.

In both cases, the static equilibrium of the footing can be written in the form:

$$\mathbf{K}_{foot} \cdot \mathbf{u}_{pile}^{top} = \mathbf{T}_{ext} - \mathbf{T}_{pile}^{top}$$
(5)

With:

- **K**_{foot}: footing rigidity matrix;
- **T**_{*ext*}: vector representing the external loading global forces and moments applied to the footing (problem data);
- u^{top}_{pile}: vector representing displacements and rotations at the piles heads. This vector is directly linked to the displacement vectors uⁱ for each pile;
- \mathbf{T}_{pile}^{top} : vector representing the forces and moments at the piles heads. It is directly linked to the external loading vectors \mathbf{F}_{ext}^{i} for each pile.



H.2.3. Implementation

Model implementation is based on the creation and resolution of the global system of equations governing the equilibrium of the "footing + piles" system interacting with the soil. Thus, in the same matrix system, the Groupie+ calculation engine assembles the footing equilibrium equation (5) with those representing the local equilibriums of each pile (4). The elements of this system can be supplemented by additional support conditions introduced at any point on the pile in the form of a elastic point support. As the calculation is non-linear, resolution is iterative.

Resolution of the final system gives the displacements, rotations and reactions at all points on each pile, in particular at the head. Once the reactions are known, the internal forces (T_x T_y T_z M_x M_y) are then calculated by integration using the following general formula:

$$T_{k}(z) = \int_{0}^{z} [q_{k}(t) - r_{k}(t)] dt + T_{k}(0) \qquad k = x, y \text{ or } z$$
$$M_{k}(z) = \int_{0}^{z} T_{k}(t) dt + M_{k}(0) \qquad k = x \text{ or } y$$

The model can also be used to define an equivalent <u>tangent</u> stiffness system at the centre of the footing, which can then be used as an input parameter for the "structure" model. The system of head stiffnesses comprises a 6x6 symmetric stiffness "matrix" and a "constant" term according to the following general formula:

$\begin{bmatrix} T_X \end{bmatrix}$		k _{ux,ux}	k_{u_X,θ_Y}	k_{u_X,u_Y}	k_{u_X,θ_X}	k_{u_X,u_Z}	k_{u_X,θ_Z}		u _x		T _{0X}
M _Y		•	k_{θ_Y,θ_Y}	k_{θ_Y,u_Y}	k_{θ_Y,θ_X}	k_{θ_Y,u_Z}	k_{θ_Y,θ_Z}		θ_{Y}		M _{0Y}
T _Y	_	•		k_{u_Y,u_Y}	k_{u_Y,θ_X}	k_{u_Y,u_Z}	k_{u_Y,θ_Z}		u _y		T _{0Y}
M _X	_	•			k_{θ_X,θ_X}	k_{θ_X,u_Z}	k_{θ_X,θ_Z}	•	$\boldsymbol{\theta}_X$	T	M _{0X}
T _Z		•				k_{u_Z,u_Z}	k_{u_Z,θ_Z}		u_{Z}		T _{0Z}
$\left\lfloor M_{Z} \right\rfloor$		•	•		•	•	k_{θ_Z, θ_Z}		$\theta_{\rm Z}$		M_{0Z}

H.2.4. Validity limits

The previous formulation is valid in the case of piles with a homogeneous cross-section authorising decoupling between the axial and bending behaviour. The validity of the system considered also assumes that the piles are slender enough to ignore the influence of deformation caused by shear forces.

The validity of the general model also assumes prior adaptation of the pile/soil interaction laws to take account of certain special cases, such as that of a foundation situated close to a bank or pile zones close to the surface. The group effect between piles (pile/soil/pile interaction) is also such as to require a prior degradation of the slope parameters and/or plastic plateaux characterising the soil reaction mobilisation law.

As an example, the following figure recalls the principle of the adaptations recommended in standard NF P94-262 in the case of a group effect affecting the transverse behaviour of the piles. Values ρ_1 and ρ_2 are a function of the diameter to spacing ratio.





Figure H 6: Processing of group effects with respect to transverse behaviour of piles

H.2.5. Implementation in "manual" mode

The manual mode consists in characterising the response of each pile by an equivalent head stiffness matrix resulting from a prior calculation made using the Taspie+ and Piecoef+ modules (see figure below).

The mathematical formulation of the system is then adapted, replacing equation (4) by that represented by the head stiffness matrices taken from Taspie+ and Piecoef+.



Figure H 7: Equivalent stiffness matrices at pile head (Piecoef+, Taspie+)



H.2.6. Definition of "p-y" and "t-z" laws from pressuremeter tests

H.2.6.1. "p-y" frontal reaction mobilisation law

As defined in standard NF P94-262, the frontal reaction mobilisation law can be defined according to the general shape of the following figure.



Figure H 8: General shape of the soil frontal reaction mobilisation law

Where k_{sref} is a reference reaction coefficient (stress per unit length), expressed as a function of the pressuremeter modulus E_M , the rheological coefficient α , the (equivalent) diameter of pile B and a reference diameter B_0 considered to be equal to 0.6 m:

$$\begin{split} & ks_{ref} = \frac{1}{B}.\frac{18.E_{M}}{\left(4.\left(2,65.\frac{B}{B_{0}}\right)^{\alpha}.\frac{B_{0}}{B}+3.\alpha\right)} \quad si \quad B \geq B_{0} \\ & ks_{ref} = \frac{1}{B}.\frac{18.E_{M}}{\left(4.\left(2,65\right)^{\alpha}+3.\alpha\right)} \quad si \quad B \leq B_{0} \end{split}$$

The values of β_i and $p_i,$ which vary according to the type of loads, are summarised in the following table:

Type of load	βı	β₂	р1	p2
Case in which permanent loads predominate at the head	1	0		pf*
Case in which loads caused by lateral earth pressure predominate		1/2	p.*	pı*
Case in which short-duration loadings at the head predominate	2	0	pf	p _f *
Case in which very short accidental loadings at the head predominate	2	1		рі*

 Table H 1: Parameters of the frontal reaction mobilisation law

Where p_1^* and p_1^* respectively designate the soil <u>net</u> creep pressure and the <u>net</u> limit pressure resulting from the pressuremeter test. It should be noted that for the case in which $p_1 = p_2$, we have $\beta_2 = 0$ and therefore have a two-plateau mobilisation curve (elastoplastic law).



H.2.6.2. Shaft friction and base resistance

As defined in standard NF P94-262, the shaft friction and base resistance mobilisation laws can be defined according to the general shape of the following figure.



Figure H 9: General shape of the soil axial reaction mobilisation law

Where q_{sl} and q_{pl} are the limit shaft friction and the limit base resistance respectively, E_M the pressuremeter modulus and B the equivalent pile diameter. The values of β_t and β_p are given in the following table for the case of a bored pile. In the absence of specific experimental data, we can use the same values for driven piles.

Type of soil	βt	β _p
Fine soils	2.0	11
Granular soils	0.8	4.8

Table H 2: Parameters of axial reaction mobilisation laws



H.3. USER'S MANUAL

This chapter is devoted to presenting the interface of the Groupie+ module. It describes the following elements in detail:

- The input parameters necessary for the calculation;
- The results generated by the calculation.

To build a model, the Groupie+ module offers three possibilities, referred to by modes: Manual Groupie, Automatic Groupie+ or Automatic Advanced Groupie+. The choice of any given mode determines the content of the active tabs and also influences their number:

- Manual Groupie : 4 tabs;
- Automatic Groupie+: 5 tabs;
- Automatic Advanced Groupie+: 3 tabs

+ an additional tab per created family.

The presentation of the results also varies according to the selected mode.

To select a mode, simply click the corresponding button. This choice is to be defined in the first tab activated by default.



ManualGroupie: this mode is used in conjunction with Taspie+ and Piecoef+. Each pile is modelled by its equivalent stiffnesses matrix at pile head. Groupie resolves the equilibrium of the footing, assumed to be infinitely rigid, subjected to external global forces and moments and to pile reactions. If the plastic soil deformation occurs, the iterative calculation is managed manually by the three modules alternately.



Automatic Groupie+ (default mode selected): this is an autonomous mode that does not interact with the other modules. It is dedicated to the case of a group of piles with a uniform circular cross-section. The piles may have different geometrical/mechanical characteristics and any spatial distribution. The soil medium is defined overall as multiple layers independently of the foundation and can accept the input of layer dips in both directions.



Automatic Advanced Groupie+: this mode works primarily in families. It was originally designed to allow the calculation of rectangular piles. Unlike the previous mode, a cross-section with variable sections can be assigned and soil/pile transverse interaction laws specific to each direction can be defined.

In this manual, the Groupie+ module inputs and outputs are presented per mode and then per tab.

This chapter does not detail the actual user interface and its operations (buttons, menus, etc.). These aspects are covered in part C of the FoXta v3 user's manual.



H.3.1. Manual Groupie Mode

H.3.1.1. "Settings/Piles" tab

settings/piles	U Sumnesses	o initial state	V Footing load			<u></u>		
						Genera	al settings	s and pi
seneral paramete	15							
			Calculation t	Example 01				
				G	+ G+			
Piles definition			X	Y		2	0	
Piles definition		Family	X _p [m]	Y _P [m]	D [m]	α [*]	β [*]	Connection
Piles definition		Family A	X _p [m] -3,00	Y _P [m] -3,00	D [m] 0,60	α [[*]] 0,0	β [*] 0,0	Connection
Piles definition		Family A B	X _p [m] -3,00 3,00	Y _P [m] -3,00 -3,00	D [m] 0,60 0,60	α [*] 0,0 0,0	β [*] 0,0 0,0	Connection Clamped Clamped
Piles definition		Family A B A	X _p [m] -3,00 3,00 -3,00	Y _p [m] -3,00 -3,00 3,00	D [m] 0,60 0,60 0,60	α [*] 0,0 0,0 0,0	β [*] 0,0 0,0 0,0	Connection Clamped Clamped Clamped
Piles definition	В	Family A B A	X _p [m] -3,00 3,00 -3,00 3,00 3,00	Y _P [m] -3,00 -3,00 3,00 3,00	D [m] 0,60 0,60 0,60 0,60	α [*] 0,0 0,0 0,0 0,0	β [*] 0,0 0,0 0,0 0,0	Connection Clamped Clamped Clamped Clamped
Piles definition N ⁰ 1 2 3 4	B Pas de l	Family A B A V	X _p [m] -3,00 -3,00 -3,00 -3,00	Y _P [m] -3,00 -3,00 3,00 3,00	D [m] 0,60 0,60 0,60 0,60	a [*] 0,0 0,0 0,0 0,0	β [*] 0,0 0,0 0,0	Connection Clamped Clamped Clamped Clamped
Piles definition	B Pas de 1 A	Family A A famile	Xp [m] -3,00 3,00 -3,00 3,00	Yp [m] -3,00 3,00 3,00	D [m] 0,60 0,60 0,60 0,60	a [*] 0,0 0,0 0,0 0,0	β [*] 0,0 0,0 0,0 0,0	Connection Clamped Clamped Clamped Clamped Articulated
Piles definition	B Pas de 1 A B	Family A A famile	X _p [m] -3.00 3.00 -3.00 3.00	Yp [m] -3.00 -3.00 3.00 3.00	D [m] 0.60 0.60 0.60 0.60	0 [1] 0,0 0,0 0,0 0,0	β [*] 0,0 0,0 0,0 0,0	Connection Clamped Clamped Clamped Clamped Articulated

Select the Manual Groupie mode by clicking the 💦 button.

Figure H 10: "Settings/Piles" tab in Manual Groupie

This table comprises two frames:

- General parameters;
- Piles definition.

H.3.1.1.1. "General parameters" frame

It contains the following data:

- Calculation title;
- Manual Groupie mode: selected.

H.3.1.1.2. "Piles definition" frame

This frame is used to define the distribution and orientation of the piles, as well as their connection to the footing.

It is possible to allocate a family to a set of piles, enabling the forces obtained on all the piles of a given family to be grouped. To allocate a family to a pile, simply select a letter from the "Family" drop-down list. If you do not wish to manage families, simply leave the default " no family " () value.

To add a pile, click the "Add line" 🚽 button then define its characteristics. The following data are then to be input:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Pile family	-	No family	Always	Yes	-
X_P : X-axis of pile head – global system of coordinates	m	0	Always	Yes	-
Y _P : Y-axis of pile head – global system of coordinates	m	0	Always	Yes	-
D : diameter of pile cross- section (*)	m	0	Always	Yes	> 0
α : angle of inclination of pile to axis (OZ)	o	0	Always	Yes	-
β: orientation of pile around axis (OZ)	o	0	Always	Yes	-
Connection : connection at pile head: clamped or articulated (ball and socket joint)	-	Clamped	Always	Yes	-

Table H 3: "Settings/Piles" tab – "Piles definition" frame

(*) Unlike the other parameters, the diameter input in Manual Groupie is not a calculation parameter. Its value simply allows configuration of the graphic representation of the foundation.

Two help diagrams are available which give a schematic representation of the global coordinates system of the foundation (OXYZ).

• Perspective view:



Figure H 11: Help diagram: Global coordinates system of foundation – perspective view

Top view:



Figure H 12: Help diagram: Global coordinates system of foundation - top view

H.3.1.2. "Stiffnesses" tab

In this tab, the equivalent stiffnesses at the pile head are input. These stiffnesses can be easily evaluated by the Taspie+ and Piecoef+ modules.

The "Stiffnesses" tab comprises a single frame with an import wizard.

H.3.1.2.1. "Equivalent stiffnesses at pile head" frame

This frame is used to define the equivalent stiffnesses at the piles heads. They are expressed in the local coordinates system (Pxyz) of each pile. The parameters required are shown in the following table.



Designation	Unit	Default value	Display condition	Mandatory value	Local checks
μ: equivalent axial stiffness	kN/m	0	Always	Yes	> 0
ρ ₁ : translation stiffness along (Px)	kN/m	0	Always	Yes	≥ 0
p ₂ : "combined" translation/rotation stiffness in plane (Pxz)	kN	0	Always	Yes	≥ 0
p ₃: rotation stiffness in plane (Pxz)	kN.m/rad	0	Always	Yes	≥ 0
ρ ₄: translation stiffness along (Py)	kN/m	0	Always	Yes	≥ 0
ρ ₅: "combined" translation/rotation stiffness in plane (Pyz)	kN	0	Always	Yes	≥ 0
p ₆ : rotation stiffness in plane (Pyz)	kN.m/rad	0	Always	Yes	≥ 0
Γ : equivalent torsional stiffness	kN.m/rad	1.0	Always	Yes	≥ 0

Table H 4: "Stiffnesses" tab – "Equivalent stiffnesses at pile head" frame



Figure H 13: "Stiffnesses" tab

H.3.1.2.2. Wizard for importing piles into Groupie

This wizard is used to import the calculated stiffnesses from the Taspie+ and Piecoef+ modules. To use it, simply select a line in the "Stiffnesses" table and click the vitable button. Once started, the import wizard comprises two sub-tabs.

"Import from Taspie+" sub-tab

This wizard is used to import the axial stiffness μ along direction z.





Figure H 14: Import from Taspie+ wizard

Procedure:

- Select a pile;
- To import the values for all piles, click the <u>Import into several piles at once</u> button. With the mouse, select the various piles which appear, as in the following window. Click the <u>ok</u> button.

Otherwise, the value will only be imported for the line selected.

Select the destination piles	×
Pile 1 (No family)	
Pile 2 (No family)	
Pile 3 (No family)	
Pile 4 (No family)	

Figure H 15: Import from Taspie+ wizard – Selection of piles

Nota:

- The value of $\boldsymbol{\mu}$ imported corresponds to the secant stiffness at SLS in quasi-permanent combination.
- The imported value of T_{z0} is always equal to 0. This is because stiffness μ is defined as being the secant stiffness and not the tangent stiffness (see diagram below).







"Import from Piecoef+" wizard

Proceed in the same way as for import from Taspie+.

Groupie pile importation wizard		×
Import directory		
E:\Users\margareth.touraine\Documents\Logiciels T	ferraso/\Foxtav3\picoe	MMTO/EXEMPLE 02A
Import from Taspie+ Import from Piecoef+		
Exemple 02a (Pile 1)		
Exemple 02a (Pile 2)		
	Calculation date	Lundi 30 novembre 2015 16:50:00
	ρ ₁	133807.0
	ρ2	127387.0
	ρ ₃	286427.0
	т _о	-330.494
	Mo	1409.21
	Import along O:	xz axis
	Import along O	yz axis
	Import along bo	oth axes
Ok Cancel	Import in	nto several piles at once

Figure H 17: Piecoef+ import wizard

NB: Importing from Piecoef+ allows $\rho 1$, $\rho 2$, $\rho 3$, T_0 and M_0 to be imported in direction x, y or in both directions at the same time.

H.3.1.3. "Initial state" tab

For the values introduced in the previous tab to make sense, each stiffness value must be assigned a reference (origin value). Apart from the axial and torsional stiffnesses, which are defined as secant, the other stiffnesses tend more to be tangent and their initial state must be characterised.



Figure H 18: "Initial state" tab

The initial state can be expressed by forces (default option) or by displacements at the origin. If the "Stiffnesses" tab was defined via the import wizard, the forces at the origin associated with the lateral stiffness matrices are filled out automatically.



H.3.1.3.1. "Forces of pile head at the origin" frame

The elements to be defined are presented in the following table. They are expressed in the pile local coordinates system (Pxyz)

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
T1 ₀ : side force at origin defined along (Px)	kN	0	Always	Yes	-
M1 ₀ : bending moment at origin defined around (-Py)	kN.m	0	Always	Yes	-
T2 ₀ : side force at origin defined along (Py)	kN	0	Always	Yes	-
M2 ₀ : bending moment at origin defined around (Px)	kN.m	0	Always	Yes	-
Tz ₀ : axial force at origin defined along (Pz)	kN	0	Always	Yes	-
Mz ₀ : torsional moment at origin defined around (Pz)	kN.m	0	Always	Yes	-

Table H 5: "Initial state" tab – "Forces of pile head at origin" frame

H.3.1.3.2. "Displacements of pile head at the origin" frame

The table of values is only visible if the "Activate displacement at the origin" box is ticked. The parameters to be defined are listed in the following table:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
u1 ₀ : horizontal displacement at origin defined along (Px)	m	0	Always	Yes	-
θ1₀: rotation at origin defined around (-Py)	rad 0 Always Yes		o: rotation at origin defined rad		-
u2 ₀ : horizontal displacement at origin defined along (Py)	nt at m 0 Always Ye		Yes	-	
θ_{2_0} : rotation at origin defined around (Px)	rad	0	0 Always Yes		-
uz ₀ : vertical displacement at origin defined along (Pz)	splacement at m 0 Always Yes		Yes	-	
$\theta \mathbf{z}_0$: rotation at origin defined around (Pz)	rad	0	Always	Yes	-

Table H 6: "Initial state" tab – "Displacement of pile head at the origin" frame

H.3.1.4. "Footing load" tab

This tab is used to define one or more load cases expressed at point O at the centre of the global coordinates system, characterised by the project's reference elevation. A load case is defined by six components of global forces and moments (3 forces and 3 torques). The resultant displacement global forces and moments give the 3 translations and 3 rotations of the footing at the centre of the coordinates system.



			1.0			Load cas
1 00000			- defin	ed at the	centre of	the footil
Cases	Τ _χ	Mv	Ty	Mx	T ₇	M ₇
N°	[KN]	[kN.m]	[kN]	[kN.m]	[KN]	[kN.m]
1	5000,00	0,00	0,00	0,00	5000,00	10000,00 *
2	5000,00	16000,00	0,00	0,00	5000,00	10000,00
3	2000,00	0,00	-2000,00	0,00	5000,00	10000,00
	· · · ·					

Figure H 19: "Footing load" tab

The only frame available, "Load case", is used to fill out the reduction elements of the global forces and moments expressed at point O. Details of the input are given in the following table.

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
T _x : horizontal force along (OX)	kN				
M _Y : moment around (OY)	kN.m		Always	Yes	
T _Y : horizontal force along (OY)	kN	0			
M _x : moment around (OX)	kN.m	0			-
Tz: vertical force along (OZ)	kN				
M _z : moment around (OZ)	kN.m				

Table H 7: "Footing load" tab – "Load cases" frame

H.3.1.5. Calculation

The calculation can be started from any tab, provided that the project has been correctly filled out, that is when all the tabs are marked with a green tick (for example: Settings/piles).

A tab is marked with a red cross (for example: Settings/piles) if incorrectly filled out (data missing or not conforming to the expected values).

To start the calculation, click the vstart calculation button.

In this mode (Manual Groupie), the calculation is virtually instantaneous, because the iterations are managed manually. The calculation time is slightly influenced by the number of piles or load cases.

H.3.1.6. Results

Manual Groupie only proposes numerical results presented as "Formatted results" and "Result tables".



Figure H 20: Groupie results window

H.3.1.6.1. Numerical results: Formatted results

This type of result is only accessible for calculations in Manual Groupie mode.



Copy all Copy only the selection Back to the index Programme Groupie v3.0.8 (c) TERRASOL 2015 File : R:\Logiciels\Foxta\Foxt Calcul réalisé le : 15/07/2015 à 14h40 by : Terrasol Pieux en chevalet ____CARACTERISTIQUES DES PIEUX__ Zp D хр Yp Alfa Beta Tete 0.000 -30.000 -30.000 -30.000 0.000 -30.000 0.000 0.000 0.000 0.000 0.000 0.000 0.600 0.600 0.600 0.600 0.600 0.000 -4.000 -4.000 0.000 0.000 4.000 4.000 0.000 0.000 0.000 0.000 0.000 0.000 ncastre encastree encastree encastree encastree et spirale suivant direction locale Pz mu n0 dz 0 gamma mz 0 wz 0 277000.00 270000.00 277000.00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.100E+01 0.100E+01 0.100E+01 0.100E+01 0.100E+01 0.100E+01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 1 1 2 2 3 1 4 2 5 1 6 2 0.000E+00 0.000E+00 0.000E+00 277 000.00 0.000E+00 Raideur dans le plan Pxz du re ère local r2 rз tO n code r1 130444.00 128601.00 130444.00 128601.00 130444.00 128601.00 ___ RESULTATS DES DIFFERENTS CAS DE CHARGE __ 100238.00 96816.80 100238.00 96816.80 100238.00 96816.80 118.80 136.77 118.80 136.77 118.80 136.77 295800.00 293256.00 295800.00 293256.00 295800.00 295800.00 293256.00 4 5 6 EFFORTS SUR LA SEMELLE / REPERE GENERAL TX = 5000.000 MY = 0.000 TY = 0.000 MX = 0.000 TZ = 5000.000 MZ = 10000.000 dX = 0.3269E-01 rot./Y = -0.3017E-03 dY = 0.0000E+00 rot./X = 0.0000E+00 dZ = 0.1106E-01 rot./Z = 0.3624E-02 ere local r2 r3 tO r1 n code 121926.00 121707.00 121926.00 121707.00 121926.00 121926.00 121707.00 134294.00 133618.00 134294.00 133618.00 134294.00 134294.00 133618.00 296692.00 294573.00 296692.00 294573.00 296692.00 0.00 0.00 0.00 0.00 0.00 EFFORTS DANS LES PIEUX / REPERE LOCAL PROPRE A CHACUN n code t1 m1 t2 tz |t| |m| 1666.666 1666.666 833.334 833.334 -409.363 -409.363 -204.336 -204.336 -416.666 416.666 -416.666 416.666 102.514 -102.514 102.514 -102.514 1147.717 1352.283 1147.717 1352.283 0.004 0.004 0.004 1717.960 1717.960 931.695 931.695 422.004 422.004 228.609 0000 EFFORTS SUR LA SEMELLE / REPERE GENERAL 5000.000 16000.000 0.000 5000.000 10000.000 dX = rot./Y = dY = rot./X = dZ = rot./Z = TX MY TY MX TZ EFFORTS DANS LES PIEUX / REPERE LOCAL PROPRE A CHACUN n code t1 m1 t2 m2 |t| [m] tz -418.367 -418.367 -213.340 -213.340 1666.666 1666.666 833.334 833.334 -416.666 416.666 -416.666 416.666 0.004 0.004 0.004 1717.960 1717.960 931.695 931.695 430.744 430.744 236.691 236.691 EFFORTS SUR LA SEMELLE / REPERE GENERAL = 2000.000 = 0.000 = -2000.000 = 0.000 = 5000.000 = 10000.000 $\begin{array}{rcl} dx &=& 0.1308E{-}01\\ rot./Y &=& -0.1207E{-}03\\ dY &=& -0.1308E{-}01\\ rot./X &=& -0.1207E{-}03\\ dZ &=& 0.1106E{-}01\\ rot./Z &=& 0.3624E{-}02 \end{array}$ TX MY TY MX TZ MZ EFFORTS DANS LES PIEUX / REPERE LOCAL PROPRE A CHACUN n code t1 m1 t2 tz |t| [m] 916.666 916.666 83.334 83.334 -225.254 -225.254 -20.226 -20.226 -916.666 -83.334 -916.666 -83.334 1296.362 920.446 920.446 117.852 225.254 20.226 225.254 20.226 0.004 0.004 0.004 318.557 226.160 226.160 28.604 1 0 2 0 3 0 4 0 1250.000 1331.827 1168.173 1250.000

Figure H 21: Manual Groupie Formatted results

The formatted results contain:

- A recapitulation of the pile characteristics
 - o Definition of piles (distribution, orientation and type of anchor);
 - Vertical and spiral stiffnesses along the local direction (Pz);
 - o Stiffnesses in the (Pxz) plane of local coordinates system;
 - o Stiffnesses in the (Pyz) plane of local coordinates system.
- The results of the different load cases:



- Forces on footing and displacements at centre of footing / general coordinates system;
- Forces at pile heads / coordinates system specific to each one.

H.3.1.6.2. Numerical results: Results tables

This table contains the forces at the pile heads obtained following the Manual Groupie calculation. These values already appear in the Formatted results, although they cannot be exported in table format. This table is created for this purpose.

							Exporter 🙀 Retour
Numéro du cas de ch.	Numéro du pieu	T1	M1	T2	M2	Tz	Mz
1	1	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	2	371,23	17,52	0,00	0,00	-548,73	-0,00
1	3	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	4	371,23	17,52	0,00	0,00	-548,73	-0,00
1	5	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	6	371,23	17,52	0,00	0,00	-548,73	-0,00

Figure H 22: Groupie Results table

Details of the results table are given below:

Designation	Unit	Display condition
T1: side force at pile head – direction x	kN	
M1: bending moment at pile head – direction x	kN.m	
T2: side force at pile head – direction y	kN	Alwove
M2: bending moment at pile head – direction y	kN.m	Aiways
Tz: axial force at pile head – direction z	kN	
Mz: torsional moment at pile head – around z	kN.m	

Table H 8: Details of Groupie numerical results

These forces at pile head are expressed in the local coordinates system of each pile. The additional results (displacements and internal loadings in the piles) can be evaluated during post-processing, after convergence of the Manual Groupie calculation, by inputting the forces at pile heads in the Taspie+ and Piecoef+ modules.



Pile local coordinates system

Figure H 23: Pile local coordinates system help diagram along Pxz, Pyz and Pz



H.3.2. Automatic Groupie+ Mode

H.3.2.1. "Parameters" tab

Select Automatic Groupie+ mode by clicking the G+ button.

🕈 Parameters 🖉 Piles 🖉 Soils 🖉 F	ree g(z) soil displacement 🛛 🛛 Footing los	d	
			General setting
General parameters			
	Calculation title Exemple 01		
	K G	+ G+	
	Maximum step	0,25 🗘	
	Footing thickness	1.00 ^	
		~	
A. d			
Advanced parameters			
Modify advanced parameters			
	Calculation	🗵 See results	

Figure H 24: Automatic Groupie+ "Parameters" tab

This tab comprises two frames:

- General parameters;
- Advanced parameters (masked by default).

H.3.2.1.1. "General parameters" frame

In this frame, Automatic Groupie+ requests the following information:

- Calculation title;
- Automatic Groupie+ Mode: selected;
- Maximum step (pitch) (m): maximum length of pile subdivisions (value of 0.5 m by default);
- Footing thickness (m): perfectly rigid footing.

H.3.2.1.2. "Advanced parameters" frame

If the "Modify advanced parameters" box is activated, the following fields appear:

- Number of increments of the global forces and moments;
- Relative tolerance used for the convergence check;
- Maximum number of iterations;
- Use the azimuth: if this option is activated, the soil layer dips are defined using an azimuth angle and a dip angle instead of the angles projected along the (OY) and (OX) axes. This option is exclusive to this mode;
- Use an optimised algorithm: ultra-fast resolution by comparison with the default situation.



Advanced parameters		
Modify advanced parameters		
	Number of increments	10
	Relative tolerance	1,0E-04
	Maximum iteration number	100 🗢
	Use the azimuth	
	Use an optimised algorithm	
Figure 110E, "A dur	a a a al la a va va ata va	"frame of Automotic Croumic.

Figure H 25: "Advanced parameters" frame of Automatic Groupie+

H.3.2.2. "Piles" tab

This tab is used to input parameters defining the piles.

Parameters	O Piles	O Soils	Tree g(z) s	soll displacemen	t ♥ F0	oting load						
Pies definition										Piles	s defi	nitic
N ^o	X _p [m]	Y _P [m]	Elev _{head} [m]	α [*]	β [°]	L [m]	D [m]	Connection	El _x [kN.m ²]	Ely [kN.m ²]	ES [kN]	F [kN.m/ra
1	-3,00	-3,00	44,00	0,0	0,0	14,00	0,6	0 Clamped	6,36E04	6,36E04	2,83E06	1
2	3,00	-3,00	44,00	0,0	0,0	14,00	0,6	0 Clamped	6,36E04	6,36E04	2,83E06	
3	-3,00	3,00	44,00	0,0	0,0	14,00	0,6	0 Clamped	6,36E04	6,36E04	2,83E06	
4	3,00	3,00	44,00	0,0	0,0	14,00	0,6	0 Clam 🗸	6,36E04	6,36E04	2,83E06	
								Clamped				
								Articulated				
EL []	Piles	number :	4							•	1	*
iditional base	stiffnesse	s of the pile:	8									
			K _x			ĸ			C _x		C _y	
	N		[kN/m	1		[kN/m]		[kN	.m/rad]		[kN.m/rad]
	1			0,00E00			0,00E00		0,0	0E00		0,0
	2			0,00E00			0,00E00		0,0	DE00		0.00
	3			0,00E00			0,00E00		0,0	0E00		0,00
	4			0,00E00			0,00E00		0,0	0E00		0,00
												0,00
												0,00

Figure H 26: "Piles" tab of Automatic Groupie+

The geometrical parameters must be input (as for Manual Groupie), but also the mechanical characteristics of the piles.

It should be remembered that in this mode, each pile is characterised by a uniform crosssection along its entire length, which is also why the piles and soils domains are defined independently.

This tab contains two frames:

- Piles definition;
- Base stiffnesses (masked by default).

H.3.2.2.1. "Piles definition" frame

The pile orientation conventions are comparable to those used in the Manual Groupie mode.

It should be recalled that the "Piles" tab remains marked by a red cross until the following "Soils" tab is completely filled out. FoXta checks that the pile bases are not out of the soil.

It should be noted that if a pile head has an elevation strictly lower than the reference elevation, it is connected perfectly rigidly to the footing. The opposite case is not possible.

The pile characteristics detailed in the following table must be defined.



Designation	Unit	Default value	Display condition	Mandatory value	Local checks
X_P : X-axis of pile head – global coordinates system					
Y _P : Y-axis of pile head – global coordinates system	М	0.00	Always	Yes	-
Elev _{head} : elevation of pile head read on the ascending vertical axis					
 α: angle of inclination of pile in relation to axis (OZ) 	o	0.00	Alwavs	Yes	-
β : orientation around axis (OZ)					
L: pile length	М	0.00	Always	Yes	> 0 and ≤ soil depth
D : diameter of pile section (*)	М	0.00	Always	Yes	> 0
Connection: articulated or clamped	-	Clamped	Groupie+	Yes	-
EI_x : product of inertia of pile in direction x – local coordinates system	kN.m²				
El _y : product of inertia of pile in direction y – local coordinates system	kN.m²	0.00	Alwovo	Voo	> 0
ES: axial rigidity of pile – local coordinates system	kN	0.00	Always	165	2 0
Γ : equivalent torsional stiffness at pile head - local coordinates system	kN.m/ rad				

Table H 9: "Piles" tab – "Piles definition" frame

(*) Contrary to the Manual Groupie mode, the pile diameter is a decisive parameter for calculating the foundation.

H.3.2.2.2. "Base stiffnesses" frame

This frame is used to add the lateral stiffnesses at the pile bases. These stiffnesses are defined in the local coordinates system associated with each pile. If the "Additional base stiffnesses of the piles" box is ticked, Groupie+ asks for the following data to be input:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
K _x : Point restoring stiffness for lateral translation in direction x	kN/m	0	Always	Yes	≥ 0
K _y : Point restoring stiffness for lateral translation in direction y	kN/m	0	Always	Yes	≥ 0
C _x : Point restoring stiffness for rotation in direction x	kN.m/rad	0	Always	Yes	≥ 0
C _y : Point restoring stiffness for rotation in direction direction y	kN.m/rad	0	Always	Yes	≥ 0

Table H 10: "Piles" tab – "Base stiffnesses" frame



H.3.2.3. "Soils" tab

This tab is used to define the soil model for a calculation in Automatic Groupie+ mode. It consists of a permanent "Soil definition" frame and a "Laws" frame displayed in certain conditions.

	Soil definition
Type of reaction curve	- Sol definition
Reference elevation 44,00 🗘	N ⁰ Name Cobur Eliviyasa 0 ₁₇ 0 ₂ Lateraliaw Friction law Base law
IN Internet Cabul (Pai) (Pai) <th< th=""><th>1 Band 42,00 4.0 6.0 Color (PR) PR task tor 2 Joint (Color (PR)) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 4 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) Joint (Pr) PR task tor PR task tor 1 Join</th></th<>	1 Band 42,00 4.0 6.0 Color (PR) PR task tor 2 Joint (Color (PR)) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 3 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 4 Joint (Pr) 20,00 0.0 0.0 0.0 PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) PR task tor PR task tor PR task tor 1 Joint (Pr) Joint (Pr) Joint (Pr) PR task tor PR task tor 1 Join

H.3.2.3.1. "Soil definition" frame

The first option is to choose the type of "p-y" and "t-z" transfer curves. The transfer laws can be defined in two ways:

- "From pressuremeter data"
- "Point-by-point input"

The theoretical framework of these laws (general shape, definition of parameters) is presented in the technical guide available at the beginning of this manual.

If the choice was made to define the reaction curves "From pressuremeter data", the predominant "Lateral loading type" must be specified. There are four possible choices:

- Mainly permanent loading at pile head;
- Mainly lateral earth pressure loadings;
- Mainly short loading at pile head;
- Mainly very short accidental loading.

The second important parameter is the project reference elevation (in metres).

The following table describes the soil parameters to be input. Some columns use laws described in the "Laws" frame presented later.

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Elev base: elevation of base read on ascending vertical axis	E	0	Always	Yes	The elevations do not overlap and are strictly descending
α_{Y} : dip of layer base around (OY) – global coordinates system	o	0	Always	Yes	-
α_X : dip of layer base around (OX) – global coordinates system	o	0	Always	Yes	-



Designation	Unit	Default value	Display condition	Mandatory value	Local checks
E _M : pressuremeter modulus	kPa	0	From pressuremeter data	Yes	≥ 0
α: Ménard's rheological coefficient	-	0		Yes	0 < α ≤ 1
p f*: net creep pressure	kPa	0		Yes	≥ 0
p I*: net limit pressure	kPa	0		Yes	≥ p _f
q _{si} : limit shaft friction	kPa	0		Yes	≥ 0
Soil type: fine or granular	-	Fine soil		Yes	-
q_{pl}: base resistance pressure	kPa	0		Yes	≥ 0
Lateral law : lateral reaction law – local coordinates system	-	-		Yes	-
Friction law: shaft friction law - local coordinates system	-	-	Manual input point by point	Yes	-
Base law: base force law – local coordinates system	-	-		Yes	-

Table H 11: "Soils" tab – "Soil definition" frame

H.3.2.3.2. "Laws" frame

This frame only appears if "Point by point input" is selected as the type of reaction curve.

To add a law:

• click the 🗣 button;

To edit a law:

- double-click the corresponding line
- Or
- select it and click the "Edit" button *[*.

To copy a law:

- select the required law;
- click the we button: the law is copied, with only the names of the laws being numbered so that they can be differentiated from each other.

There are two options for defining a law.

Manual data

The law parameters (slopes and plateaux) are defined explicitly. This concerns the three types of law: lateral reaction, shaft friction and base resistance.



"Lateral" type law:

👖 Add a new law			×
Manual data Pressuremeter data			
Law type	Lateral		
Name of the law	mari	Soil reaction	
k _{s1} (kPa/m)	1,87E05	r (kra)	
p ₁ (KPa)	2000,0	P2 k _{s2}	
$k_{s2}^{}$ (kPa/m)	9,36E04	0	Relative displacement (u-g) _{x,y}
p ₂ (kPa)	3000,0		
		Ok Cancel	

Figure H 28: Manual data – "Lateral" type law

"Friction" type law:

🛅 Add a new law			×
Manual data Pressuremeter data			
Law type	Friction V		
Name of the law	mari	Soil skin friction τ (kPa)	
k _{t1} (kPa/m)	8,33E04	1	
$q_{g1}^{}\left(k^{p}a\right)$	60,0 3	q ₅₂ q ₅₁ k ₁₂	-
k ₁₂ (kPa/m)	1,67E04		Relative displacement (u-g) _z
q _{s2} (kPa)	120,0		
		Cancel	

Figure H 29: Manual data – "Friction" type law

"Base" type law:

Add a new law			×
Law type	Base		
Name of the law	Mari	Base stress	
k _{p1} (kPa/m)	4,50E05	q _p (kPa)	
q _{p1} (kPa)	2000,0	q _{p2} k _{p2}	_
k _{p2} (kPa/m)	9,71E04 🗘	0 k _{p1}	Relative displacement (u-g) _z
q _{p2} (kPa)	4000.0		
		Cancel	

Figure H 30: Manual data – "Base" type law



The following table describes the various parameters of the laws defined by "Manual data":

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Name of law	-	-	Always	Yes	Specific name never blank
k _{s1} : reaction coefficient at 1 st plateau	kPa/m				
p ₁: plastification pressure at 1 st plateau	kPa				
k _{s2} : reaction coefficient at 2 nd plateau	kPa/m	0	"Lateral" type law	Yes	-
p₂ : plastification pressure at 2 nd plateau	kPa				
k _{t1} : 1 st slope of friction mobilisation curve	kPa/m		"Friction" type law	Yes	
q ₅1: 1 st plateau of friction mobilisation curve	kPa	0 "I			
k _{t2} : 2 nd slope of friction mobilisation curve	kPa/m				-
q s2: 2 nd plateau of friction mobilisation curve	kPa				
k _{p1} : 1 st slope of base resistance mobilisation curve	kPa/m				
q _{p1} : 1 st plateau of base resistance mobilisation curve	kPa		"Pose" type low	Yee	
k_{P2}: 2 nd slope of base resistance mobilisation curve	kPa/m		разе туре јам	res	-
q _{p2} : 2 nd plateau of base resistance mobilisation curve	kPa				

Table H 12: "Soils" tab – Laws definition: Manual da	ata
--	-----



Pressuremeter data

The parameters of laws (slopes and plateaux) are defined indirectly on the basis of pressuremeter data. The three types of laws are possible. "Lateral" type law (4 different types of loading):



Figure H 31: Pressuremeter data – "Lateral" type law



"Friction" type law (two different soil types):



Figure H 32: Pressuremeter data – "Friction" type law

"Base" type law (two different soil types):



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The following table describes the various law parameters based on "Pressuremeter" data:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Name of law	-	-	Always	Yes	Specific name never blank
Pressuremeter modulus	kPa	0	Always	Yes	-
Pile diameter	m	0	Always	Yes	> 0
Ménard's rheological coefficient	-	0	"Lateral" type law"	Yes	0 < α ≤1
Net creep pressure	kPa	0	"Lateral" type law	Yes	> 0
Net limit pressure	kPa	0	"Lateral" type law	Yes	> 0
Loading types ⁽¹⁾	-	Mainly permanent at pile head	"Lateral" type law	Yes	-
Limit shaft friction	kPa	0	"Friction" type law	Yes	-
Base resistance pressure	kPa	0	"Base" type law	Yes	-
Soil type ⁽²⁾	-	Fine soil	"Friction" or "Base" type law	Yes	-

Table H 13: "Soils" tab – Laws definition: Pressuremeter data

Observations:

1. For "Lateral" type laws

The "Loading type" field offers a choice between four values:

- o mainly permanent loading at pile head;
- mainly lateral earth pressure loading;
- mainly short loading at pile head;
- mainly very short accidental loading.

Depending on the type of loading chosen, the programme calculates and displays the values of k_{s1} , p_1 , k_{s2} and p_2 at the bottom of the tab. The meaning of these parameters is mentioned on the diagram displayed in the right-hand part of the wizard.

2. For the "Friction" and "Base" type laws

The "Soil type" field offers a choice of two values:

- o fine soil;
- o granular soil.

Depending on the soil type chosen, the programme calculates and displays the following at the bottom of each tab:

- the values of k_{t1} , q_{s1} , k_{t2} and q_{s2} at the bottom of the "Friction" law tab;
- the values of k_{p1} , q_{p1} , k_{p2} and q_{p2} at the bottom of the "Base" law tab.

The meaning of these parameters is given in the diagram presented in the right-hand part of the wizard.



Four help diagrams 🛃 are available.

- Diagrams accessible whatever the type of reaction curve: •
 - Layer dip: conventions to be adopted for definition of a soil layer with a non-0 horizontal base.



Figure H 34: Help diagram for soil layer dip

Diagrams only accessible if the "From pressuremeter data" option was chosen. They . show the shape of the transfer law as a function of mainly lateral loadings (lateral reaction law) or of the soil type (friction law and base resistance).



Figure H 35: Help diagram for the lateral law



o Friction law



Figure H 36: Help diagram for the friction law

o Base law



Figure H 37: Help diagram for the base law

H.3.2.4. "Free g(z) soil displacement" tab

This (optional) function can be used to define a global soil displacement in the three spatial directions. It can be used to simulate:

• A free lateral displacement g(z) of the soil: this is a horizontal displacement field defined in the global coordinates system by components along X or Y, the amplitude of which depends only on the elevation (thus implicitly on Z).

This displacement is generally developed within a layer that is compressible under the effect of a bank created following installation of piles as schematically shown in the following figure (cross-section orthogonal to X).





Figure H 38: Lateral g(z) soil displacement

• Imposed y_s(z) soil settlement: this is a vertical displacement field defined in the global coordinates system by a component along Z. Its amplitude depends only on the elevation.

The applied displacement represents an imposed soil settlement around the piles, which leads to the creation of negative friction on a part of their shafts.

In practice, the global displacement is defined by the following table. The values must be listed in descending order of elevation. At least two rows with different elevations must be filled out.

efinition - global coordinate system		5(-7	F
Elev _{g(z)}	9 _X	9 _Y	У _S
[m]	[m]	[m]	[m]
0,50	-1,000	0,0000	0,0000
7.50	0,0250	0,0300	0,0029
7,00	0.0300	0,0000	0.0040
6.50	0.0324	0.0590	0,0090
6.00	0.0348	0.0718	0.0095
5.50	0.0370	0.0846	0.0114
5.00	0.0392	0.0974	0.0133
4,50	0.0412	0,1102	0,0152
4,00	0,0431	0,1230	0,0171
3,50	0,0448	0,1358	0,0191
3,00	0,0463	0,1486	0,0210
2,50	0,0476	0,1614	0,0229
2,00	0,0486	0,1742	0,0248
1,50	0,0494	0,1870	0,0267
1,00	0,0498	0,1998	0,0286
0,50	0,0500	0,2126	0,0305
0,00	0,0498	0,2254	0,0324
-0,50	0,0493	0,2382	0,0343
-1,00	0,0484	0,2510	0,0362
-1,50	0,0471	0,2638	0,0382
-2,00	0,0454	0,2766	0,0401
-2,50	0,0432	0,2894	0,0420
-3,00	0,0406	0,3022	0,0439
-3,50	0,0374	0,3150	0,0458
-4,00	0,0338	0,3278	0,0477
-4,50	0,0296	0,3406	0,0496
-5,00	0,0249	0,3534	0,0515
-5,50	0,0196	0,3662	0,0534
-6,00	0,0137	0,3790	0,0554
-6,50	0,0072	0,3918	0,0573
-7,00	0,0000	0,4046	0,0592

Figure H 39: "Free g(z) soil displacement" tab

This tab comprises a single "g(z) definition" frame, which can be filled out with the import wizard described later.

H.3.2.4.1. "g(z) definition" frame

The following table describes the properties to be input in this tab:

Designation Unit	Default value	Display condition	Mandatory value	Local checks
------------------	------------------	-------------------	--------------------	--------------


Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Elev _{g(z)} : elevation m		0	Always	Yes	-
g _X : lateral soil displacement – direction X	m	0	Always	Yes	-
g _Y : lateral soil displacement – direction Y	teral soil acement – m 0 Always ion Y		Always	Yes	-
y s: imposed soil displacement – direction Z	m	0	Always	Yes	-

Table H 14: "Free g(z) soil displacement" tab – "g(z) definition" frame

H.3.2.4.2. Import wizard

It is also possible to import data from an outside file (Excel for example) using the import wizard. This is accessible in several FoXta modules.

Select the data to be imported and copy them to clipboard.

• Click the 🌉 "Table modification wizard".



Figure H 40: Table modification wizard

If the "g(z) definition" frame already contained rows, they will be automatically displayed in the wizard.

Click the Import... button.



Clipboard import wizard			;			
Column 1	Columo 2	Column 3	Column 4			
8.5		1 0	0			
	0,02	5 0,03	0,0029			
7,	0,027	5 0,038	0,003			
	0,0	3 0,04	0,004			
6,5	0,032	4 0,059	0,009			
	0,034	8 0,0718	0,0095			
5,5	0,03	7 0,0846	0,0114			
	0,039	2 0,0974	0,0133			
4,5	0,041	2 0,1102	0,0152			
	0,043	1 0,123	0,0172			
3,5	0,044	8 0,1358	0,0191			
:	0,046	3 0,1486	0,021			
2,5	0,047	6 0,1614	0,0229			
1	0,048	6 0,1742	0,0248			
1,5	0,049	4 0,187	0,0267			
	0,049	8 0,1998	0,0286			
0,5	0,0	5 0,2126	0,0305			
(0,049	8 0,2254	0,0324			
-0,5	0,049	3 0,2382	0,0343			
-	0,048	4 0,251	0,0363			
-1,5	0,047	1 0,2638	0,0382			
-4	0,045	4 0,2766	0,0401			
-2,5	0,043	2 0,2894	0,042			
	0,040	6 0,3022	0,0439			
-3,5	0,037	4 0,315	0,0458			
	0,033	8 0,3278	0,0477			
-4,	0,029	6 0,3406	0,0496			
4	0,024	9 0,3534	0,0515			
-5,1	0,019	6 0,3662	0,0534			
lev_(-)	a,	av.	Y ₂			
(m)	5X [m]	▼ [m]	[m]			
		1	No import			
puons			Flev			
	Only the black-font cells will be imported					
	First row to import Dow 1 we lest row to import Dow 29 we					
	Hirst row to import Row 1 V Last row to import Row 38 V					
Number of rows to in	Number of rows to import into the table : 38 Number of columns to import into the table : 4 Number of rows to create					
			Im]			
	Import	Cancel	v			
			78			

Figure H 41: Clipboard import wizard

"Clipboard contents" frame

The import wizard automatically displays in black the data to be imported into the four columns available, corresponding to the four columns of the "Free g(z) soil displacement" tab. The shaded data will be ignored.

At the bottom of each column, a drop-down list is used to establish the correspondence between the displayed data from the file to be imported and the columns of the "Free g(z) soil displacement" tab.

"Options" frame

Using drop-down lists, the rows to be imported are specified: the first and the last.

Groupie+ then indicates the following information (cannot be modified):

- the number of rows to be imported into the table;
- the number of columns to be imported into the table;
- the number of rows to be created in the table.

Click the **Import** button. The imported values are now available in the project.

H.3.2.5. "Footing load" tab

This tab is used to define the load cases applied to the footing. This tab is comparable to that of the Manual Groupie mode described in paragraph H.3.1.4.



H.3.2.6. Calculation

The calculation can be started from any tab provided that the project has been correctly filled out, in other words, when all the tabs are marked with a green tick (for example: Settings/piles

A tab is marked with a red cross (for example: Settings/piles)) as long as it is not correctly filled out (data missing or not in conformity with expected values).

To start the calculation, click the v Start calculation button.

The Automatic Groupie+ mode can be used to manage models for which the piles mesh has a size of several thousand elements. However, the maximum memory that can be allocated to the programme under Microsoft Windows[®] may be a limiting factor. It is therefore recommended that the maximum mesh size does not exceed 2500 elements.

The general calculation process involves the following steps:

- 1. Read data:
- 2. Construct mesh:
- 3. Run equation;
- 4. Study each load case:
 - Initialisation
 - Iterations
 - Calculation of displacements, reactions and loadings
- 5. Generate output files;
- 6. End of programme.

The user is informed of the progress of the various calculation steps in the following window.

T Calculation	n runnir	ng		×		
		Maillage Mise en équation	Nombre d'éléments 2 Nombre d'équations 11	.94		
CHARGE	1	Initialisation Résolution Itération	Taux de convergence			
		1 2 3 4 5	76.0 % 93.6 % 95.8 % 99.6 % 100.0 %			
		Fin de calcul Déplacements Réactions & sollicitat Impression des résulta	ions ts			
CHARGE	2	Initialisation Résolution Itération	Taux de convergence			
		1 2 3 4 5	83.5 % 88.7 % 94.6 % 99.6 % 100.0 %	~		
Stop calculation Close						
		Eigure H 42: "Calculati	ion running" window			

To display the calculation results, click the Close button as necessary and then the See results button.



H.3.2.7. Results

The Automatic Groupie+ mode gives numerical and graphical results. The available results are presented in the following paragraphs.

	Calculated : 19 seconds ago (Calculation date : Aug 2, 2016 5:03:17 PM)	Back to the data
	Interference Interference Access Access Access Access <td></td>	
∼ Graphical resutts	Lateral behaviour	

Figure H 43: Window of Automatic Groupie+ results

H.3.2.7.1. Numerical results

Numerical results: Results tables

This window contains the footing displacements produced by each load case. It also gives access to the overall stiffnesses of the footing.

Footing loads and displacements

This is an exportable table which, for each load case, gives the resultant displacement global forces and moments.

\$ (Global stiffnesses) Loads and displacements at the footing centre												
Load case #	T _X [kN]	M _Y [kN.m]	T _Y [kN]	M _X [kN.m]	T _Z [kN]	M _Z [kN.m]	U _X [m]	rot/Y [rad]	U _Y [m]	rot/X [rad]	U _Z	rot/Z [rad]
1	5000,00	0,00	0,00	0,00	5000,00	10000,00	1,798E-02	-4,834E-04	-1,083E-04	3,067E-06	4,444E-03	2,015E-03
2	5000,00	16000,00	0,00	0,00	5000,00	10000,00	1,585E-02	1,592E-03	-9,959E-05	2,649E-06	5,481E-03	1,954E-03
3	2000,00	0,00	-2000,00	0,00	5000,00	10000,00	5,219E-03	-1,631E-04	-5,321E-03	-1,642E-04	4,361E-03	1,465E-03

Figure H 44: : Numerical results - "Loads and displacements at the footing centre"

Details of the various elements of the previous table are given below (the whole is expressed at centre O of the footing).

Designation (*)	Unit	Display condition
T _x : horizontal force along (OX)	kN	
M _Y : moment around (OY)	kN.m	
T _Y : horizontal force along (OY)	kN	
M_x : moment around (OX)	kN.m	Always
Tz: vertical force along (OZ)	kN	
Mz: moment around (OZ)	kN.m	
$\mathbf{U}_{\mathbf{X}}$: translation in direction X	m	
rot/Y: rotation around axis (OY)	rad	Always



Table H 15: Numerical results – "Footing load/displacement"

Global stiffnesses of footing

Clicking the **Global stiffnesses** button gives the global stiffness matrices for the foundation expressed at the centre of the footing. Choose the relevant load case from the drop-down list.

-											
	ilobal stiffne	sses									×
	Load case 1 : TX=5000,00 kN, MY=0,00 kN.m, TY=0,00 kN, MX=0,00 kN, m, TZ=5000,00 kN, MZ=10000,00 kN, m										
	Load case 1 : TX=5000,00 kN, MY=0,00 kN.m, TY=0,00 kN, MX=0,00 kN.m, TZ=5000,00 kN, MZ=10000,00 kN.m										
	Load case 2 : TX=5000,00 kN, MY=16000,00 kN.m, TY=0,00 kN, MX=0,00 kN.m, TZ=5000,00 kN, MZ=10000,00 kN.m Load case 3 : TX=2000.00 kN, MY=0.00 kN m, TY=-2000.00 kN, MX=0.00 kN, m, TZ=5000.00 kN, MZ=10000.00 kN, m										
	Tangent stiffnesses at the footing centre $F = K \cdot U + F_0$										
	uX	rY	uY	rX	uZ	rZ					
uX	+1,537E05	+1,649E05	-1,364E-12	+6,821E-13	-3,647E-11	-2,278E05	T.X	+2,776E03			
rY	+1,649E05	+7,920E06	+1,432E-11	-1,891E-09	+3,876E05	-1,300E05	M.Y	-5,962E02			
uΥ	-8,185E-12	+9,727E-10	+3,756E05	-2,718E05	+3,288E-10	+6,779E04	T.Y	-9,504E01			
rX	-7,503E-12	-1,262E-10	-2,718E05	+7,986E06	-1,439E-10	-4,019E04	M.X	+2,702E01			
uZ	+4,270E-12	+3,876E05	+5,189E-12	-6,306E-10	+8,467E05	-1,334E-11	T.Z	+1,424E03			
٢Z	-2,278E05	-1,300E05	+6,779E04	-4,019E04	+8,813E-10	+4,763E06	M.Z	+4,444E03			
	Rotational stiffness term (kN/m) Force at the origin (kN)										
	Rotational stiffness term (kN.m) Moment at the origin (kN.m)										
	Cross stiffness term (kN)										
	Export these stiffnesses to Excel for : Current load case All load cases Close										

Figure H 45: Global stiffnesses of foundation

It is possible to export the following stiffnesses to an EXCEL spreadsheet:

- a single load case by clicking the Current load case button
- Or
- all load cases by clicking the All load cases button

A help diagram explains the various symbols:





Figure H 46: Help diagram for foundation global stiffnesses

Numerical results: Forces at pile heads

This table is comparable to that available in the Manual Groupie mode (see chapter H.3.1.6.2).

s at pile heads						2 B	port 🛛 🔇 💘 Back to the index 🕽
Load case #	orse # Die #	T1	M	Т2	M2	Tz	Mz
		[kN]	[kN.m]	[kN]	[kN.m]	[kN]	[kN.m]
1	1	1369,960	-1128,090	-648,097	417,442	925,903	0,002
1	2	1500,510	-1271,070	648,097	-429,129	1570,200	0,002
1	3	1039,650	-702,127	-648,097	417,442	930,393	0,002
1	4	1089,880	-760,940	648,097	-429,129	1573,500	0,002
2	1	1388,390	-1198,520	-629,966	404,645	2237,460	0,002
2	2	1518,340	-1341,150	629,966	-416,624	258,546	0,002
2	3	1020,250	-767,995	-629,966	404,645	2239,560	0,002
2	4	1073,010	-830,185	629,966	-416,624	264,428	0,002
3	1	903,537	-606,943	-910,613	612,436	1253,690	0,001
3	2	941,903	-652,763	-89,387	51,415	1467,600	0,001
3	3	76,196	-41,438	-910,613	612,436	1022,090	0,001
3	4	78,364	-44,175	-89,387	51,415	1256,620	0,001

Figure H 47: Numerical results - "Forces at pile heads"



Figure H 48: Help diagram for forces at pile heads

H.3.2.7.2. Graphical results

For each load case, these curves present the deformations and loads in each pile. The results of several load cases and/or piles can be superposed. Navigating through these results is described below:

- From the menu at top-left, select the load case to be displayed;
- At the bottom-left, select the pile to be displayed;
- At the bottom of each graphic, the minimum and maximum bounds of each physical quantity are given for the selected elements.

Several load cases or several piles can be selected by holding the Ctrl or Shift key on the keyboard.

The results obtained are expressed in the pile local coordinates system. There are various choices for exporting graphical results.

Graphical results: Lateral behaviour

This window gives the deformation and loading curves for the piles in the local (oxz) and (oyz) planes.

• Pile deflection and lateral soil displacement (m):- u1, gz1: in direction x

- u2, gz2: in direction y

- Bending moment (kN.m): M1: in direction x
 - M2: in direction y



- T1: in direction x



• Shear force (kN):



Figure H 49: Graphical results – "Lateral behaviour" curves

Graphical results: Axial behaviour

This window gives the piles deformation and loading curves in the axial direction (oz).

- uz, ys : pile and soil settlement (m);
- fmob, qs : mobilised and limit shaft friction (kPa);
- Nz : axial force (kN).



Figure H 50: Graphical results – "Axial behaviour" curves



Graphical results: Additional results

This window gives access to the following results:

- Tcomb: combined axial force (kN);
- Mcomb: combined bending moment (kN.m);
- Ratios: ratios in directions x, y and z (%) which, at a given level, represent the mobilisation ratio:
 - $\circ~$ of lateral soil reaction with respect to the plastification pressure (ratio x and ratio y);
 - \circ of mobilised shaft friction with respect to limit friction (ratio z).



Figure H 51: Graphical results – "Additional results" curves



H.3.3. Advanced Automatic Groupie+ Mode

H.3.3.1. "Parameters" tab

Select the Advanced Automatic Groupie+ mode by clicking the Gt button. The buttons for the other modules are then shaded.

			General setting						
General parameters									
	Calculation title Example	: 01							
		G+ G+							
Reference elevation	44,00 🗘	Families							
		Family vertical micropiles (1) [1 pile] Family micropiles 45° (2) [1 pile]							
Maximum step	0,25 🗘	Family micropiles 25* (3) [1 pile]							
Footing thickness	1.00	Family micropiles 25" 2 (4) [1 pile]							
		J							
Laws									
[Lateral] Footing 1, K _{s1} =1,00E-03, P ₁ =0,0, K	G ₈₂ =1,00E-03, P ₂ =0,0		â						
[] steral MMC 4 K =4 50504 P = 105,0, K _{S2} =	-0.00E00, P_2=103,0								
II aterali SM K .=1.00E04 P.=50.0 K .=0.0	12-0,00200, P_2-200,0								
Laterall CSO D 1. K .= 2.25E05. P.=625.0. K	=0.00E00. P==625.0								
[Lateral] CSO 1. K .= 2.20E04. P.= 150.0. K .	=0.00E00, P_=150.0								
[Friction] footing 2, K, =1,00E-03, Q, =0.0,	K.a=1.00E-03, Q_a=0.0								
[Friction] RB 2, K+1=4,00E04, Q_1=0,0, K+2=8,	,00E03, Q=0,0								
[Friction] MMG 2, K, =1,26E05, Q, =118,0, H	K,_=2,50E04, Q=236,0								
[Friction] SB, K+=9,00E03, Q==35,0, K+==2,3	25E03, Q_2=71,0								
[Friction] C SO D 2, K1=6,28E05, Q1=145,0	, K ₁₂ =1,26E05, Q _{s2} =291,0								
[Friction] CSO 2, Kt1=6,30E04, Q51=106,0, K	12=1,30E04, Q ₉₂ =212,0								
			• 🖉 🗣 🕤						
Modify advanced parameters									
	0 1 L L L L L		Calculation						

Figure H 52: "Parameters" tab of Advanced Automatic Groupie+

This tab comprises three frames:

- General parameters;
- Laws;
- Advanced parameters (masked by default).

H.3.3.1.1. "General parameters" frame

In this frame, Advanced Automatic Groupie+ asks for the following information:

- Calculation title;
- Advanced Automatic Groupie+ mode: selected;
- Maximum step (m): maximum thickness of the layers subdivisions (value of 0.5 m by default);
- Footing thickness (m): perfectly rigid footing.

This same frame contains a "Families" zone. This is used to indicate the pile family or families, which will enable the piles of the same category to be grouped together. Each time a family is created, Advanced Automatic Groupie+ adds an extra tab. This latter will contain the characteristics common to the piles of the family in question.

At least one family must be defined, which will then be assigned to one or more piles.

Click the **b** button to create a family. When creating an extra family, the programme proposes using an existing family as the basis. In this case, the new family is created as a copy of the existing family.



lrea	te a family	>
	Create a new empty family	
Create a new empty family		
Create a carbon copy of vertical micropiles family		

Figure H 53: Creating a family

When the family is created and piles assigned to it, the programme states the number of piles assigned between parentheses, just after its name.

When the user double-clicks a family, Advanced Automatic Groupie+ automatically switches to the corresponding tab.

H.3.3.1.2. "Laws" frame

This frame comprises the pile-soil interaction laws to which the user can refer when defining the "Soils/Piles" frame in the "Family X" tab.

To add a law:

• Click the 🗣 button.

To edit a law:

• Double-click the corresponding row;

Or

Select the law and click the "Edit" button *Select*.

To copy a law:

- Select the relevant law;
- Click the solution: the law is copied identically but the names are numbered so that they can be differentiated from each other. It should be noted that the list of laws is ordered in three blocks that are identifiable by a prefix [type of law] before the name of the law. The laws in each block retain the order in which they were created.

Whatever its type, a law is defined by two slope parameters and two characteristic points. All the laws are explicitly defined by manual data. Particular attention must be paid to the law parameters, especially their units.

"Lateral" type law:

🔟 Add a new law		×
Manual data		
Law type	Lateral 🗸	Lineal soil reaction
Name of the law	RB 1	R (kN/m)
K _{s1} (kN/m/m)	3,60E04	P2
P ₁ (kN/m)	163,0	P
K_{s2} (kN/m/m)	0,00E00	K _{s1} Relative
P ₂ (kN/m)	163,0 🗘	0 (u-g) _{x,y}
		Ok Cancel
	Fiaure	H 54: "Lateral" type law



"Friction" type law:

📅 Add a new law			×
Manual data			
Law type	Friction	Soil lineal	
Name of the law	RB 1	skin friction T (kN/m)	
K _{t1} (kN/m/m)	3,60E04	Q ₅₂	
Q _{s1} (kN/m)	163,0 🗘	K _{t2}	
K _{t2} (kN/m/m)	0,00E00		Relative
Q _{s2} (kN/m)	163,0	0	(u-g) _z
		Ok Cancel	



"Base" type law:



Clicking the OK button validates the law and adds it to the block corresponding to its type.

The following data must be input:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Type of law	-	Lateral	Alweye	Vee	
Name of law	-	-	Always	Tes	-
\mathbf{K}_{s1} : soil reaction modulus at 1 st plateau	kN/m/m				
P ₁ : soil reaction at 1 st plateau	kN/m	0	"Lateral" type law	Yes	
\mathbf{K}_{s2} : soil reaction modulus at 2 nd plateau	kN/m/m	0			-
P ₂ : soil reaction at 2 nd plateau	kN/m				
K _{t1} : 1 st slope of friction mobilisation curve	kN/m/m				
Q _{s1} : 1 st plateau of friction mobilisation curve	kN/m	0	"Friction" type law	Yes	-
K _{t2} : 2 nd slope of friction mobilisation curve	kN/m/m				

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					Selec
Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Q _{s2} : 2 nd plateau of friction mobilisation curve	kN/m				
K _{p1} : 1 st slope of base resistance mobilisation curve	kN/m				
Q _{p1} : 1 st plateau of base resistance mobilisation curve	kN		"Base" type	Yes	
K _{p2} : 2 nd slope of base resistance mobilisation curve	kN/m		law		-
Q _{p2} : 2 nd plateau of base resistance mobilisation curve	kN				

Table H 16: "Parameters" tab - Laws: Manual data



H.3.3.1.3. "Advanced parameters" frame

Except for the use of azimuth, which does not apply in this mode, the content of this frame is comparable to that presented for the Automatic Groupie+ mode.

Advanced parameters		
Modify advanced parameters		
N	Number of increments	1 🗘
	Relative tolerance	1,0E-04
h	Maximum iteration number	100 🗘
u u	Use an optimised algorithm	
[Calculation	ee results

Figure H 57: "Advanced parameters" frame of Advanced Automatic Groupie+

H.3.3.2. "Piles" tab

This tab is used to create piles. The X and Y coordinates of their heads can be input and they can be assigned to the families previously defined in the project. The initially shaded pile then takes on the colour corresponding to the family of which it is a member.



Figure H 58: "Piles" tab of Advanced Automatic Groupie+

This tab only contains a single frame, the parameters of which are described below.

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Pile family	-	No family	Always	Yes	-
X _P : X-axis of pile head – global coordinates system	~	0.00	Alwaya	Vac	
Y _P : Y-axis of pile head – global coordinates system	τn	0.00	Aiways	res	-

Table H 17: "Piles" tab – "Piles definition" frame



H.3.3.3. "Family" tabs

There are as many "Family" tabs as there are families created in the "Parameters" tab (see paragraph H.3.3.1). When a family is created, the programme automatically allocates it a number and asks for a name to be filled in. The family number is used to name the tab. Its full name appears at the top of an active tab.

The piles belonging to a given family have the following parameters in common:

- Orientation;
- Section and length;
- Mechanical characteristics;
- Footing binding type;
- Geotechnical model: elevations and transfer curves, point stiffnesses, g(z).



Figure H 59: "Family" tab

The "Family" tab comprises three frames, the last one of which is optional.

- Parameters;
- Soil/pile definition;
- Options.

H.3.3.3.1. "Parameters" frame

This frame completes the definition of the pile distribution. The parameters to be filled out are described in the following table.

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
α: inclination of piles of this family with respect to axis (OZ) – global coordinates system	O	0	Always	Yes	-
 β: orientation of piles of this family around axis (OZ) – global coordinates system 	o				



Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Elev _{head} : elevation of head of piles of this family on ascending vertical axis	m				
Γ : equivalent torsional stiffness at pile head – local coordinates system	kN.m/rad	1	Always	Yes	≥ 0
Binding type : clamped or articulated (ball-joint)	-	Clamped	Always	Yes	-

Table H 18: "Family" tab – "Parameters" frame

The "Colour" field is used to display all the piles of a given family with a single colour, with the aim of making it easier to differentiate between the various families in the graphical part.

H.3.3.3.2. "Soil/Pile definition" frame

The layer interfaces should not exceed the reference elevation recalled in each "Family" tab. Furthermore, they are considered to be horizontal at each family. This hypothesis was adopted to remain consistent with the notion of family which consists in retaining a single geotechnical model for all the piles in a given family.

Remir	Reminder of the reference elevation : 44,00 m										
			[III]		-		[kN.m [*]]	[kN.m ⁺]			
1	Footing		41,93	Footing 1	Footing 1	Footing 2	1,00E07	1,00E07	1,00E08		
2	Bank		40,00	RB 1	<< Please choose a law a	RB 2	3,50E03	3,50E03	1,00E06		
3	Mari		35,50	MMG 1	Footing 1	MMG 2	3,50E03	3,50E03	1,00E06		
4	Sand		34,00	SM	RB 1	SB	3,50E03	3,50E03	1,00E06		
5	CSO D		32,00	CSO D 1	MMG 1	C SO D 2	3,50E03	3,50E03	1,00E06		
					CSO D 1 CSO 1 << Create a law >>						
Base law pointe nulle 🗸											

Figure H 60: "Soil/Pile" definition frame

The soil characteristics table then needs to be filled out: three columns use the laws defined in the "Parameters" tab. However, it is also possible to create them directly from the dropdown list by clicking the "Create a law" option. In this case, the laws created will be added to the "Laws" frame in the "Parameters" tab in accordance with the classification previously presented.

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Elev _{base} : elevation of bottom of layer read on ascending vertical axis	m	0	Always	Yes	-
Lateral law x: lateral reaction law in direction x – local coordinates system	-	-	Always	Yes	Not blank
Lateral law y: lateral reaction law in direction y – local coordinates system	-	-	Always	Yes	Not blank



Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Friction law: shaft friction mobilisation law – local coordinates system	-	-	Always	Yes	Not blank
El _x : product of inertia of pile section in direction x - local coordinates system	kN.m²	0	Always	Yes	≥ 0
El _y : product of inertia of pile section in direction y – local coordinates system	kN.m²	0	Always	Yes	≥ 0
ES: axial rigidity of pile section – local coordinates system	kN	0	Always	Yes	≥ 0

Table H 19: "Family" tab – "Soil/Pile definition" frame

The last element to be defined in this frame is the **Base law** which must be chosen from the drop-down list.

H.3.3.3.3. "Options" frame

This frame comprises two optional tables.

Point restoring stiffnesses

If the "Activate point restoring stiffnesses" box is ticked, the point stiffnesses (translation and rotation) at the layer interfaces can be defined. It should be noted that these stiffnesses are expressed in the local coordinates system of each pile.

The data to be filled out are detailed in the following table.

Designation	Unit Default value		Display condition	Mandatory value	Local checks
Z: elevation	m	Function of "Soil/Pile definition" frame	Always	Yes	Not modifiable
k _x : point restoring stiffness in lateral translation in direction x	kN/m				
k _y : point restoring stiffness in lateral translation in direction y	kN/m	0	Always	Yes	≥ 0
C _x : point restoring stiffness in rotation direction x	kN.m/rad	0			
C _y : point restoring stiffness in rotation direction y	kN.m/rad				

Table H 20: "Family" tab – "Options" frame – Point restoring stiffnesses

Free g(z) displacement

If the "Define g(z) soil displacement" box is ticked, a g(z) displacement applied to the piles of the family in question can be defined. The components of g(z) are expressed in the global coordinates system. The definition method is comparable to that used for the Automatic Groupie+ mode (see chapter H.3.2.4).



The data to be input are detailed in the following table:

Designation	Unit	Default value	Display condition	Mandatory value	Local checks
Elev _{g(z)}					
g _x : lateral soil displacement – direction X					
g _Y : lateral soil displacement – direction Y	m	0	Always	Yes	-
y _s : imposed soil settlement – direction Z					

Table H 21: "Family" tab – "Options" frame – "Define g(z)"

H.3.3.4. "Footing loading" tab

This tab is used to define the load cases to which the anchor footing is subjected. This tab is comparable to that of the Manual Groupie mode described in paragraph H.3.1.4.

H.3.3.5. Calculation

The calculation approach is exactly the same as in Automatic Groupie+ mode (chapter H.3.2.6).

H.3.3.6. Results

The results of Advanced Automatic Groupie+ are comparable to those presented in Automatic Groupie+ mode (chapter H.3.2.7).



H.3.3.6.1. Numerical results

Same as for Automatic Groupie+ mode (see chapter H.3.2.7.1).



H.3.3.6.2. Graphical results

Same as for Automatic Groupie+ mode (see chapter H.3.2.7.2).

Advanced Automatic Groupie+ also enables the list of piles to be filtered by family. It is possible to select a pile family from the drop-down list initialised by default at "All families".

NB: It should be noted that the friction along the piles, given in the "Axial behaviour" window, is expressed in kN/m instead of kPa. This is the only difference between the results of the Automatic modes.



H.4. EXAMPLES



H.4.1. Example 1: Footing on circular piles

H.4.1.1. Data input

When the application opens, FoXta proposes:

- Creating a new project;
- Opening an existing project;
- Automatically opening the last project used.

In the case of this example:

- Choose to create a new project by selecting the
 New project radio-button;
- Click the OK button.

H.4.1.1.1. New project wizard

"File" frame

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

"Project" frame

- Give the project a title;
- Enter a project number;
- Add a commentary if required;
- Leave the "Use database" box unticked (we will not use the database for this example) and click the Next button.

H.4.1.1.2. New project wizard: choice of modules

In the "Choose modules" window, select the Groupie+ module then click the Create button.



9 Parameters 🛛 🕈 Piles 🛛 😳 Soils	Stree g(z) soil displacement Street Footing load	
		General setting
General parameters		
	Calculation title Example 01	
	🚮 <mark>G+</mark> 🚰	
	Maximum step	0,25 🗘
	Footing thickness	1,00 🗘

The Groupie+ window appears. Fill out the various data tabs.

H.4.1.1.3. "Parameters" tab

This tab contains two separate frames:

"General parameters" frame

- Title of Groupie+ calculation: for this example, we will simply use "Example 01";
- Automatic Groupie+ Mode: selected;
- Maximum step (m): 0.25;
- Footing thickness (m): perfectly rigid footing.

"Advanced parameters" frame

• Modify the advanced parameters: unticked.

H.4.1.1.4. "Piles" tab

This tab is used to define the pile characteristics. We first of all consider them to be clamped in the connection footing.

s definition -										Pi	les de	finitio
N°	X _P [m]	Y _P [m]	Elev _{head} [m]	α [*]	β [*]	L [m]	D [m]	Connection	El _x [kN.m ²]	Ely [kN.m ²]	ES [kN]	F [kN.m/rad
1	-3,00	-3,00	8,50	0,0	0,0	14,00	0,60	Clamped	6,36E04	6,36E04	2,83E06	1
2	3,00	-3,00	8,50	0,0	0,0	14,00	0,60	Clamped	6,36E04	6,36E04	2,83E06	1
3	-3,00	3,00	8,50	0,0	0,0	14,00	0,60	Clamped	6,36E04	6,36E04	2,83E06	1
4	3,00	3,00	8,50	0,0	0,0	14,00	0,60	Clamped	6,36E04	6,36E04	2,83E06	1

"Piles definition" frame

• Create 4 piles by clicking the 🗣 button.

The data to be input are as follows:

Pile N°	Х_Р (m)	Υ _Ρ (m)	Elev _{head} (m)	α (°)	β (°)	L (m)	D (m)	Connection	El _x (kN.m²)	El y (kN.m²)	ES (kN)	Г (kN.m/rad)
1	-3.00	-3.00	8.50	0	0	14.0	0.6	Clamped	6.36E04	6.36E04	2.83E06	1.00
2	3.00	-3.00	8.50	0	0	14.0	0.6	Clamped	6.36E04	6.36E04	2.83E06	1.00
3	-3.00	3.00	8.50	0	0	14.0	0.6	Clamped	6.36E04	6.36E04	2.83E06	1.00
4	3.00	3.00	8.50	0	0	14.0	0.6	Clamped	6.36E04	6.36E04	2.83E06	1.00

"Base stiffnesses" frame

• Specific stiffnesses at pile bases: unticked

Note: the "Piles" tab remains marked by a red cross until the following "Soils" tab has been completely filled out. FoXta checks that the piles are not out of the ground.



H.4.1.1.5. "Soils" tab

The third tab is used to define the soil characteristics.

In this example, the reaction laws are defined on the basis of pressuremeter data. The lateral loadings at pile head are accidental.

- Type of reaction curve: "From pressuremeter data";
- Lateral loading type: "Mainly very short accidental loading";
- Reference elevation: 8.50 m.

The data characterising the soil layers are listed below:

Name	Elevation ^{base} (m)	θγ (°)	θ x (°)	E м (kPa)	α (-)	p f* (kPa)	p ı* (kPa)	q ₅ı (kPa)	Soil type	q _{рі} (kPa)
Bank	5.5	0	0	1.5E04	0.33	8.0E02	1.2E03	60	granular	1650
Sandy marl	-4.0	0	0	8.0E03	0.67	6.0E02	9.0E02	40	fine	1200
Marl	-10.0	0	0	2.5E04	0.50	2.0E03	3.0E03	160	fine	4000



The "Piles" and "Soils" tabs are now marked by a green tick indicating that the data input in them are coherent.

H.4.1.1.6. "Free g(z) soil displacement" tab

This tab is not used in this example.

H.4.1.1.7. "Footing loading" tab

The load cases are expressed at the centre of the footing, at point O.

Three different load cases are studied.



Load case N°	T _x (kN)	M Y (kN.m)	Τ _Υ (kN)	M x (kN.m)	Tz (kN)	M z (kN.m)
1	5000	0	0	0	5000	10000
2	5000	16000	0	0	5000	10000
3	2000	0	-2000	0	5000	10000

Parameters 🛛 🦁 Piles	🕈 Soils 🍸 🖏 Free g(z) soil displa	cement 🛛 🗸 Footing load				
						Load case
ad cases			_	defined at	the centre	of the footing
	Тх	MY	Т _Ү	M _X	Τ _Z	Mz
N	[kN]	[kN.m]	[kN]	[kN.m]	[kN]	[kN.m]
1	5000,00	0,00	0,00	0,00	5000,00	10000,00
2	5000,00	16000,00	0,00	0,00	5000,00	10000,00
3	2000,00	0,00	-2000,00	0,00	5000,00	10000,00
	2000,00	0,00	2000,00	0,00	0000,00	

H.4.1.2. Calculation and results

H.4.1.2.1. Calculation

Until all mandatory tabs have been filled out, the button used to start the calculation is marked by a red cross: Start calculation.

Once all the data have been correctly input, the **Start calculation** button (accessible from all the tabs) becomes active.

Clicking this button will start the calculation and display the calculation progress window.



At the end of calculation, click the Close button.

To access the results, click the versults button.



Results	Calculated : 1 minute ago (Calculation date : Aug 25, 2016 12:23:27 PM)	Back to the data
r rumenca resultă	Indiana Indiana Image: Control Image: Control Image: Control Image: Control	
~ Graphical results	Lateral behaviour	

H.4.1.2.2. Results

Numerical results

Results tables:

Loads and displacements at the footing centre: for each load case, this table gives the displacement global forces and moments at point O.

Global stiffnesses	Loads and disp	lacements at th	e footing centre	•						?	Export 候	Back to the index
Load case #	T _X [kN]	M _Y [kN.m]	T _Y [kN]	M _X [kN.m]	T _Z [kN]	M _Z [kN.m]	U _X [m]	rot/Y [rad]	U _Y [m]	rot/X [rad]	U _Z	rot/Z [rad]
1	5000,00	0,00	0,00	0,00	5000,00	10000,00	1,682E-02	-6,680E-04	-1,334E-17	2,834E-19	5,408E-03	1,869E-03
2	5000,00	16000,00	0,00	0,00	5000,00	10000,00	1,325E-02	2,848E-03	-1,137E-17	9,278E-19	9,341E-03	1,774E-03
3	2000,00	0,00	-2000,00	0,00	5000,00	10000,00	5,120E-03	-2,355E-04	-5,120E-03	-2,355E-04	5,322E-03	1,401E-03

The global stiffnesses are accessible by clicking the Global stiffnesses button; simply choose the relevant load case from the drop-down list.

	Global stiffne	sses									
	Load cas	se 1 : TX=500	0,00 kN, MY=	0,00 kN.m, TY	=0,00 kN, MX:	=0,00 kN.m, T2	2=5000,00	kN, MZ=1000	00,00 kN.m	~	
	Load ca	se 1 : TX=500	0,00 kN, MY=	0,00 kN.m, TY	=0,00 kN, MX	=0,00 kN.m, T2	Z=5000,00	kN, MZ=1000	00,00 kN.m		
	Load ca	se 2 : TX=500	0,00 kN, MY=	16000,00 kN.r	n, TY=0,00 kN	I, MX=0,00 kN.	m, TZ=50	00,00 kN, MZ=	=10000,00 kN.m		
	Load ca	se 3 : 1X=200	0,00 KN, MY=	0,00 KN.M, TY	=-2000,00 KN	, MX=0,00 KN.	m, 12=500	10,00 KN, MZ=	10000,00 KN.M		
	- .										
	langent	stiffnesse	es at the f	ooting ce	ntre	F=K	· U + F	0		2	
	uX	rY	uΥ	rX	uZ	rZ					
Х	+1,929E05	+1,894E05	+6,462E-27	+6,049E-10	-2,030E-10	-2,978E05	T.X	+2,439E03]		
Y	+1,894E05	+6,265E06	-7,829E-11	+9,180E-10	+2,948E05	-1,444E05	M.Y	-3,256E02]		
IΥ	+1,879E-11	+4,376E-11	+4,379E05	-2,906E05	-6,449E-12	+8,178E-10	T.Y	+4,144E-12]		
х	-3,081E-11	+1,280E-10	-2,906E05	+6,321E06	+4,014E-10	-4,735E-10	M.X	-6,350E-12			
ιZ	-1,006E-11	+2,948E05	-2,610E-11	+2,514E-10	+6,597E05	+1,859E-11	T.Z	+1,629E03			
z	-2,978E05	-1,444E05	+8,119E-10	+4,419E-09	-5,817E-10	+5,677E06	M.Z	+4,303E03]		
	_						_				
	Rotati	onal stiffness	term (kN/m)				F	orce at the or	rigin (kN)		
	Rotati	onal stiffness	term (kN.m)				- N	foment at the	origin (kN.m)		
	Cross	stiffness terr	n (kN)								
			. ,								
										_	
		Export the	ese stiffnesse	es to Excel for	: Current k	oad case	All load ca	ases	Close	\supset	





Forces at piles heads:

This table presents the forces transmitted at the piles heads. The conventions used are recalled in the following figure.

ces at pile heads						2 🕒	(port) 🙀 Back to the index
Load case #	Pile #	T ₁	M1	T ₂	M2	Tz	Mz
		[KN]	[KN.m]	[KN]	[KN.m]	[KN]	[KN.m]
1	1	1469,580	-1220,810	-613,757	407,263	928,896	0,0
1	2	1469,580	-1220,810	613,757	-407,263	1571,100	0,0
1	3	1030,420	-705,815	-613,757	407,263	928,896	0,0
1	4	1030,420	-705,815	613,757	-407,263	1571,100	0,0
2	1	1500,610	-1342,580	-582,724	386,671	2221,980	0,0
2	2	1500,610	-1342,580	582,724	-386,671	278,020	0,0
2	3	999,391	-825,542	-582,724	386,671	2221,980	0,0
2	4	999,391	-825,542	582,724	-386,671	278,020	0,0
3	1	916,666	-631,222	-916,666	631,222	1251,820	0,0
3	2	916,666	-631,222	-83,334	44,070	1473,280	0,0
3	3	83,334	-44,070	-916,666	631,222	1023,080	0,0
3	4	83,334	-44,070	-83,334	44,070	1251,820	0,0



Graphical results

Lateral behaviour:

Load case N°1 – Pile N°1



The shape of the lateral displacement of the pile is compatible with the fact that it is clamped in the anchor footing. As the piles are vertical, the rotations at their heads are equal to the rotations of the footing.



All load cases - Pile N°1



Pile N°1 is the most heavily loaded laterally. Moreover, given the clamping of the piles in the footing, the moment and shear force are maximum at the head. They are then attenuated over the first 6 metres of the pile, finally reaching very low values.

Axial behaviour:

Load case N°3 – Pile N°2



Pile N°2 is subjected to an axial load at the head of 1473 kN. The mobilised friction, which is positive over the length of the shaft, has a resultant value of 1190 kN. The rest of the load (283 kN) is taken up at the base.



Load case N°3 – All piles



For this load case, all the piles work in compression (pile N°2 is the most heavily loaded).

H.4.1.3. Articulated piles variant

In this part we will study the differences obtained by using articulated piles instead of clamped piles.

H.4.1.3.1. Modification of data

The only modification to make is setting the piles as "articulated at the top" using the dropdown list in the "Connection" column of the "Piles" tab.

🛛 Parame	ters 🔍 Piles	🛛 Soils 🐧	Free g(z) s	oil displaceme	ent 🛛 🛛 Footi	ng load						
										Pile	s def	initior
Piles defi	nition											
No	Х _Р [m]	Y _P [m]	Elev _{head} [m]	α [*]	β [*]	L [m]	D [m]	Connection	El _x [kN.m ²]	Ely [kN.m ²]	ES [kN]	F [kN.m/rad]
1	-3,00	-3,00	8,50	0,0	0,0	14,00	0,60	Articulated	6,36E04	6,36E04	2,83E06	1,00
2	3,00	-3,00	8,50	0,0	0,0	14,00	0,60	Articulated	6,36E04	6,36E04	2,83E06	1,00
3	-3,00	3,00	8,50	0,0	0,0	14,00	0,60	Articulated	6,36E04	6,36E04	2,83E06	1,00
4	3,00	3,00	8,50	0,0	0,0	14,00	0,60	Artic 🗸	6,36E04	6,36E04	2,83E06	1,00
								Clamped				
								Articulated				

Tip: to give the same value to all the boxes in a column:

• Right-click the header of the "Connection" column, then click the "Fill the whole column with a value..." option

"Connection" column
Fill the whole column with a value

Here choose "Articulated" and click the OK button.

Fill the whole column with a value									
Input of the column :	Articulated	~							
Clamped									
Articulated									
	0k Cancel								



H.4.1.3.2. Calculation and results

Restart the calculation by again clicking the **Start calculation** button and then **See results** to access the results.

Results tables:

Loads and displacements at the footing centre:

Global stiffnesses	Read suffresses Loads and displacements at the footing centre											
Load case #	T _X [kN]	M _Y [kN.m]	T _Y [kN]	M _X [kN.m]	T _Z [kN]	Mz [kN.m]	U _X [m]	rot/Y [rad]	U _Y [m]	rot/X [rad]	U _Z [m]	rot/Z [rad]
1	5000,00	0,00	0,00	0,00	5000,00	10000,00	8,587E-02	-1,909E-19	3,469E-18	-1,909E-19	5,310E-03	6,360E-03
2	5000,00	16000,00	0,00	0,00	5000,00	10000,00	8,587E-02	5,643E-03	3,469E-18	-1,084E-18	1,669E-02	6,360E-03
3	2000,00	0,00	-2000,00	0,00	5000,00	10000,00	1,657E-02	-1,909E-19	-1,657E-02	-1,909E-19	5,310E-03	5,012E-03

Forces at pile heads:

Forces at pile heads) 🛛 👔 🔳	xport 🛛 🙀 Back to the index	
Load case #	Pile #	T ₁	M1	Т2	M2	Tz	Mz	
		[kN]	[kN.m]	[kN]	[kN.m]	[kN]	[kN.m]	
1	1	1332,470	0,000	-750,864	0,000	1250,000	0,000	
1	2	1332,470	0,000	750,864	0,000	1250,000	0,000	
1	3	1167,530	0,000	-750,864	0,000	1250,000	0,000	
1	4	1167,530	0,000	750,864	0,000	1250,000	0,000	
2	1	1332,470	0,000	-750,864	0,000	2583,330	0,000	
2	2	1332,470	0,000	750,864	0,000	-83,333	0,000	
2	3	1167,530	0,000	-750,864	0,000	2583,330	0,000	
2	4	1167,530	0,000	750,864	0,000	-83,333	0,000	
3	1	916,667	0,000	-916,667	0,000	1250,000	0,000	
3	2	916,667	0,000	-83,333	0,000	1250,000	0,000	
3	3	83,333	0,000	-916,667	0,000	1250,000	0,000	
3	4	83,333	0,000	-83,333	0,000	1250,000	0,000	
				J		J		

As the piles are articulated at the anchor footing, no moment is transmitted to their heads (M1 = 0 kN and M2 = 0 kN).

<u>Lateral behaviour</u>: Load case N°1 – Pile N°1





All load cases - Pile N°1



The pile heads are free to rotate, which explains the shape of their lateral displacements. The moments, which are nil at the head, reach their maximum at a depth of 1.5 to 2m with respect to the base of the footing. The shear forces tend to be the highest at the heads.

Axial behaviour:

Load case N°3 – All piles



For this load case, the four piles are evenly loaded (1250 kN = 5000 kN / piles). The same remark applies to the 1^{st} load case.



Load case N°2 – All piles



For this load case, the two piles N°2 and 4 work in traction and thus develop negative friction on their shafts. The base resistance related to these piles is nil.



Comparison of results: Clamped piles / Articulated piles.

Lateral behaviour:

All load cases – All piles

		Deflec		Ве	nding mor	nent (kN.m)	Shear force (kN)				
	Clamped Articulated			Clamped Articulated			Clan	nped	Articulated			
	u1	u2	u1	u2	M1	M2	M1	M2	T1	T2	T1	T2
Min. bound	-1.661E-03	-9.322E-03	-6.596E-03	-3.160E-02	-1342.58	-407.26	-59.53	-583.58	-130.99	-916.67	-523.11	-916.67
Max. bound	2.242E-02	5.606E-03	1.049E-01	1.908E-02	303.82	631.22	1232.76	401.25	1500.61	613.76	1332.47	750.86

Axial behaviour :

All load cases – All piles

	uz: Settle	ement (m)	fmob: Shaft f	riction (kPa)	Nz: Axial force (kN)		
	Clamped	Articulated	Clamped	Articulated	Clamped	Articulated	
Min. bound	1.427E-04	-2.422E-04	4.31	-4.84	18.50	-83.33	
Max. bound	1.789E-02	3.362E-02	160.00	160.00	2221.98	2583.33	

Under the same load cases, the pile (and footing) displacement are amplified when the piles are articulated. The overall behaviour of the foundation then becomes more flexible. By comparison with the solution with piles clamped in the connection footing, the case of articulated piles shows larger axial forces combined with lower shear forces and bending moments.



H.4.2. Example 2: Foundation of a noise-abatement structure

This example deals with the design of a group of piles representing the foundation of a noiseabatement structure. The foundation comprises 6 piles, 3 of which are vertical and 3 inclined.



The first step is to produce the project in Automatic Groupie+ mode. As a comparison, the second step presents the approach to be followed to carry out the same calculation in Manual Groupie using the Taspie+ and Piecoef+ modules.

H.4.2.1. Step 1: Automatic Groupie+ mode

H.4.2.1.1. Data input

The approach to create a new project is comparable to that presented in example 01 (see chapter H.4.1.1).

"Parameters" tab

"General parameters" frame

- Calculation title: simply enter "Easel piles";
- Automatic Groupie+: selected;
- Maximum step: 0.50 m.

"Advanced parameters" frame

• Modify advanced parameters: unticked.

▼ Parameters ♥ Piles ♥ Soils ♥ Free g(z) soil displacement ♥ Footing load	
	General settings
⊂ General parameters —	5
Calculation title Example 02	
G + G +	
Maximum step 0,50 🗘	
Footing thickness 1,00 🗘	



<u>"Piles" tab</u>

This tab is used to define the characteristics of the piles.



"Piles definition" frame

• Create 6 piles with the 🗣 button.

The data to be input are as follows:

N° of piles	X _P (m)	Y _P (m)	Elev. head	α (°)	B (°)	L (m)	D (m)	Connecti on	El _x (kN.m²)	El _y (kN.m²)	ES (kN)	Г (kN.m/rad)
1	0.0	-4.0	0.0	0	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00
2	0.0	-4.0	0.0	-30	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00
3	0.0	0.0	0.0	0	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00
4	0.0	0.0	0.0	-30	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00
5	0.0	4.0	0.0	0	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00
6	0.0	4.0	0.0	-30	0	12.0	0.6	Clamped	3.22E05	3.22E05	7.60E06	1.00

"Base stiffnesses" frame

• Additional base stiffnesses of the piles: unticked



"<u>Soils" tab</u>

The third tab is used to define the characteristics of the soils.

				\$ 💽	Parame	ters 🛛 🛛 Piles 🖉 🖉 Sa	oils 🛛 🛛 Free	g(z) soil disp	lacement)	💐 Footing k	bad				
	I													Soil def	inition
	V	L_X		- 5	ioil defini	tion — Type o	of reaction cu	● From ○ Point	n pressurem I-by-point inp	eter data out					
						Later	ral loading typ	e Mainly sh	ort loading a	t pile head				~	
						Reference	ce elevation							0,00 🗘	
					N ^o	Name	Colour	Elev _{base} [m]	a _Y a _X ['] [']	E _M [kPa]	α	p _f * [kPa] [i	p _l * [kPa]	q _{si} Type of soil [kPa]	q _{pl} [kPa]
					1	Blank Deepe eende		-4,00	0,0 0	0,0 1,00E0	4 0,33	5,00E02 1,	,00E03	0,00 Granular soil	0,10
					3	Loose Sands		-20,00	0,0 0	0,0 2,00E0	3 0,33	5,00E02 8,	,00E02	60,00 Granular soil	1000,00
- Elements			Coptions												
Symb.	Nomination	Visible	🟹 🔍 🔍 🦓 📸	ĺ	2	000									
	Soil	1						Calc	ulation						
	Piles	V							Start calcu	lation	See resi	uits	·		

The interaction of the piles with the soil will be modelled by reaction laws based on pressuremeter parameters. They are appropriate for short duration lateral loads.

- Type of reaction curve: "From pressuremeter data";
- Lateral loading type: "Mainly short loading at pile head";
- Reference elevation (m): 0.00.

Name	Elev _{base} (m)	α _Υ (°)	αx (°)	Е м (kPa)	α (-)	p f* (kPa)	p ı* (kPa)	q ₅ı (kPa)	Soil type	q _{pl} (kPa)
Backfill	-4	0	0	1.0E04	0.33	5.0E02	1.0E03	0.001	granular	0.1
Dense sands	-10	0	0	2.0E04	0.33	1.0E03	2.0E03	120	granular	0.1
Loose sands	-20	0	0	8.0E03	0.33	5.0E02	8.0E02	60	granular	1000

"Free g(z) soil displacement"

This tab is not used in this example.

"Footing load" tab

A single load case is to be defined. It is expressed at the centre of the footing (point O) and corresponds to a horizontal force T_X of 3000 kN. Only the T_X box is to be filled out, with the values in the other boxes kept at 0.



H.4.2.1.2. Calculation and results

Carry out the calculation according to the procedure presented in example 1 (chapter H.4.1.2.1).

Numerical results

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Loads and displacements at the footing centre:

This table gives the components of the footing displacement field expressed at point O. Given the data of the problem (geometrical symmetries and loading), this field is entirely defined in the OXZ plan. The components which are not part of this plane are null.

Global stiffne	Global stiffnesses Loads and displacements at the footing centre											
Load case #	Load case # T _X M _Y T _Y M _X T _Z M _Z U _X rot/Y U _Y rot/X U _Z rot/Z [kN] [kN.m] [kN] [kN.m] [kN] [kN.m] [kN] [kN.m] [m] [rad] [m] [rad] [m] [rad]											
1	3000,00	0,00	0,00	0,00	0,00	0,00	6,389E-03	-2,835E-03	-6,450E-20	-2,566E-19	1,176E-03	4,337E-19

The global stiffness of the foundation is accessible by clicking the (Global stiffnesses) button.

Forces at pile heads:

The piles are loaded in their local planes Pxz ($T_2 = M_2 = M_z = 0$). The vertical piles are subjected to compression in ($T_z > 0$) while the inclined piles are subjected to tensile work ($T_z < 0$). The piles which are part of each family of piles (vertical or inclined) are loaded in exactly the same way.

Forces at pile he	eads		Export	Back to the index			
Load case #	Pile #	T ₁ [kN]	M ₁ [kN.m]	T ₂ [kN]	M ₂ [kN.m]	T _z [kN]	M _z [kN.m]
1	1	390,934	-16,547	-0,000	-0,000	325,444	0,000
1	2	364,744	16,547	0,000	-0,000	-586,375	0,000
1	3	390,934	-16,547	-0,000	-0,000	325,444	0,000
1	4	364,744	16,547	-0,000	0,000	-586,375	0,000
1	5	390,934	-16,547	0,000	-0,000	325,444	0,000
1	6	364,744	16,547	-0,000	0,000	-586,375	0,000

Graphical results

In this part of the results, it is possible to access the deformation and internal loading diagrams along the shafts.



Lateral behaviour:

The shear force is maximal at pile head. However, the bending moment reaches its maximum at the sections with a curvilinear X-axis close to 2 m. These loadings are attenuated at depth to reach very low values in the sections situated at more than 7 m from the pile heads.


Pile N°1 vertical



Pile N°2 inclined





Axial behaviour:

Pile N°1 vertical

The vertical piles work in compression. They are subjected to a pile head force of 325 kN, the contribution of the base is 15 kN. As friction is ignored in the backfill, the axial force remains constant in this first layer.



Pile N°2 inclined

The inclined piles are tensile loaded. The pile head force is -586 kN and is fully balanced by friction at the pile/soil interface (base force is nil).





Additional results:

These diagrams give the combined lateral loads, as well as the mobilisation ratios of the lateral reactions and shaft friction. These curves show that:

- The soil is plastified laterally in direction x-x over a length of 0.5 m;
- Beyond the layer of backfill in which friction was ignored, shaft friction mobilisation remains elastic because the corresponding ratios remain below 50%.

Pile N°1 vertical









H.4.2.2. Step 2: Manual Groupie mode

Using the Manual Groupie mode means that the equivalent axial and lateral stiffnesses at the pile heads have to be determined with Taspie+ and Piecoef+. These stiffnesses will be used as the basis for calculating the distribution of forces at the pile heads using Manual Groupie.

By alternating between the three modules, the values of displacements of the footing and consequently the values of the forces at the pile heads, will stabilise. When they virtually cease to vary, we can consider that the calculation has converged.

Below is the procedure for this calculation:

- Save the project under a different name, "Easel piles Manual mode" for example.
- Add the Taspie+ and Piecoef+ modules to the project:
 - Project menu, "Modify project data and modules";
 - o "Modules" tab: select Taspie+ and Piecoef+, in addition to Groupie+.



- Click the OK button.
- From the Groupie+ module window, select Manual Groupie mode.



TASPIE+

Switch to the Taspie+ module by clicking

In this module, we will build a vertical pile model and an inclined pile model.



H.4.2.2.1. Calculation of axial stiffness of a vertical pile (Taspie+)

"Parameters" tab

This tab concerns the general calculation parameters.

	- T T TT .
Pile 1/1 : Vertical pile L = 12 m	
Parameters O Layers O Pile O Soliple O Imposed settlements O Load	
	General settings
Calculation title Vertical pile L = 12 m	
Single pie catculation, with or without imposed soil settement, defined by user.	
Reference elevation (m) 0,00 C	
Calculation	

"General parameters" frame

• Give the calculation title: "Vertical pile L = 12 m" for example.

"Calculation mode" frame

• Select "Single pile calculation".

"Framework" frame

• Reference elevation (m): 0.00.

"Layers" tab

This tab concerns the definition of soil layers.

	iie P	inoject	? •								17 🎹 🔨
-						\$	Pile 1/1 : Vertical pile L = 12 m	A			
10							🕈 Parameters 🔊 Layers 🔍 F	Pile 🚺 Soil/pile 🛛 💐 Imposed :	settlements 🔍 Load		
							┌ Soil layers definition				Layers data
<u>-</u>							N°	Name	Colour	Zbase	n
							1	Bank		-4,00	10
11							2	Dense sand		-10,00	20
	2 (m)				Reference elevation : 0.0 m		3	Loos sand		-12,00	10
					-4.0 m -10.0 m -12.0 m	:					
5 20 · · · · · · · · · · · · · · · · · ·	lements ymb.	Nominat Pile Soil	ion	Visible C	1005		Layers number : 3 Divisions number : 40		Calculation		• í 🕅 🌯 🖅

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Click the 🗣 button to create each layer.



Elements to be input for the various soil layers:

Name	Z _{base} (m)	n
Bank	-4.00	10
Dense sand	-10.00	20
Loose sand	-12.00	10

<u>"Pile" tab</u>

This tab concerns the piles parameters.

File File	Project	? •							1	
. 10					\$	Pile 1/1 : Vertical pile L = 12 m	Colletta (S. Inconsel and Inconstant (S. I. and)		• • 1
						- Pile type	Solupile O imposed setuements O Load	1	Pile de	finition
						Implementation mode of pile :		Without displacement		~
						Type of pile section :		Circular section		~
-	Z (m)			Reference elevation : 0.0 m		Pile inclination (*)				0,0 🗘
						Constant modulus along the pile (kPa)				2,70E07 🗘
				-4.0 m		Pile definition in each layer				
						Name	Z _{base} [m]	E _{pile} [kPa]	D [m]	
						Bank Dense sand	-4,00	2,70E07 2,70E07		0,60
10				-10.0 m	:	Loos sand	-12,00	2,70E07		0,60
	L			-12.0 m	:					
-15										
-20										
-25										
Elements	Nomi	ination	Visible Options							
1	Non	Pile								
	:	Soil					Calculation Start calculation	See results		

"Pile type" frame

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

"Pile parameters" frame

- Pile inclination (°) : 0.0;
- Constant modulus along the pile (kPa):
- Constant diameter along the pile (m):

Ticked: 2.70E07; Ticked: 0.60.

"Pile definition in each layer" frame

As the characteristics are constant along the pile, the data were taken automatically.

"Soil/Pile" tab

This tab concerns the friction mobilisation laws and the base resistance.



File	🕬 • 🔐 • 🔲 💌 🖾 🐱							1	1111 ×
+		\$	Pile 1/1 : Vertical pile L = 12 m	*					
	qp=f(yp) curve		🛛 Parameters 🖉 Layers 🖉	Pile 🗸 Soil/pile 🔇	imposed set	lements 🛛 😎 Load			
			Mobilisation law for the shaft fric	ion of the soil and the	base resistar	ice. ressuremeter data (Frank & Zh:	ao law) 🔽	Soil/pile int	terface
Ę			Definition of a shaft friction mobil	sation law from press	suremeter data	E.,	α.		
) e	800		Name	[m]		[kPa]	[kPa]	Type of soil	
ano	700		Bank Dense send		-4,00	1,00E04	120	00 Granular soil	
sist	700		Loos sand		-10,00	2,00E04 8,00E03	120	1,00 Granular soll 1,00 Granular soll	
ě	600								
d bas	500								
lisec	400								
mobi	300	:							
ģ	200		Definition of the mobilisation law	of the base resistance	,				
	100								
	0,00 0,01 0,02 0,03 0,04 0,05				Base resi	stance pressure(kPa)	1000,0 0		
	yp - Pile/soil relative settlement at the pile toe (m)				Law type	Granu	lar soil 🗸		
	dp=f(yp) curve								
Element	Options		Wizards						
Symb.	Nomination Visible 🔍 🔍 쏜 🚰					The second secon			
	qs=f(y) curve				0-1-	ulatia a			
	dp=f(yp) curve €					Start calculation	esuits		

"Mobilisation law for the shaft friction of the soil and the base resistance" frame

• Choose from the drop-down list: "From pressuremeter data (Frank & Zhao law)".

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

The parameters to be input are given below:

Nom	Z _{base} (m)	E _M (kPa)	q _{si} (kPa)	Type of soil
Bank	-4.00	1.00E04	0.001	Granular soil
Dense sand	-10.00	2.00E04	120.00	Granular soil
Loose sand	-12.00	8.00E03	60.00	Granular soil

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

- Base resistance pressure (kPa): 1000.0;
- Law type: Granular soil.

"Imposed settlements" tab

This tab does not need to be filled out for this example.

"Load" tab

Input a pile head load of 100 kN. For this initial calculation, this value is not of any great importance.

	T 🖬 🕇
Pile 1/1 : Vertical pile L = 12 m	• •
V Parameters V Layers V Pile V Soil/pile V Imposed settlements V Load]
	Load
Top load (kN)	100,0
	Modify advanced parameters



Once the mandatory data have been input, the calculation can be started.

The equivalent axial stiffness, used for the Manual Groupie calculation, is given at the end of the "Formatted results" file. For this initial calculation, we take 2.44E05 kN/m which corresponds to the equivalent stiffness under a load equal to 70% of the creep load of a vertical pile.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
come une charactérile à pour de la charactérie de fluces			
Sous une charge egale a 70% de la charge de Fluage	8/4.81	0.00359	0.244E+06
Sous la charge définie par l'utilisateur	100.00	0.00036	0.277E+06

In order to create the inclined pile model, go back to the data by clicking the *seck to the index* button.

H.4.2.2.2. Calculation of axial stiffness of an inclined pile (Taspie+)

We will duplicate the existing pile and make a few modifications specific to the inclination of the pile.

To do this, click the "Duplicate the current pile" lotton.

The tabs to be modified are listed below.

"Parameters" tab

• Change the calculation title. For example: "Inclined pile 30° L = 12 m".

	🕇 🕂 🕅 🗸
Pile 2/2 : Inclined pile 30° L = 12 m	• • 1
🛇 Parameters 🗋 🛛 Layers 📋 🖉 Pile 📋 🖉 Soil/pile 📋 🖉 Imposed settlements 📋 🖉 Load	
	General settings
Octice at parameters	
Calculation tile Inclined pile 30° L = 12 m	

"Layers" tab

Given that we are modelling an inclined pile, the elevation of the base of the last layer is to be modified.

• Elevation of "loose sand" layer: -10.40 m (to obtain a pile length of 12 m).

			1	7 市 前
Pile 2/2 : Inclined pile	30° L = 12 m 🕨			
Parameters 🛛 🕺 Lave	rs 🗸 Pile 🖉 Soil/pile 🖉 Imposed	d settlements 🛛 💐 Load		
o Luy				
Soil layers definition				Layers dat
Soil layers definition	Name	Colour	Z _{base} [m]	Layers dat
Soil layers definition	Name	Colour	Z _{base} [m] -4,00	Layers dat
Soil layers definition	Name Bank Dense sand	Colour	Z _{base} [m] -4,00 -10.00	n 10 20

"Pile" tab

The only data to be modified is the pile inclination:

"Pile parameters" frame

• Pile inclination: 30°



⊡ . File	Project	? ■ ■ ■ ■					1	गाग -
				\$ Pile 2/2 : Inclined pile 30° L = 12 r	m	✓ Load		• • 1
10				O'r hur			Pile de	efinition
				Implementation mode of pile :		Without displacement		~
				Pile parameters		Circular section		
(m)			Reference elevation : 0.0 m	Pile inclination (*)	(kPa)			2,70E07 C
			-4.0 m	Pile definition in each layer	Z	E .	D	0,00
-5 -10			-10.2 m	 Name Bank Dense sand Loose sand	(m) -4,00 -10,00 -10,40	[kPa] 2,70E07 2,70E07 2,70E07	[m]	0,60 0,60 0,60
-15								
Elements								
Symb.		Nomination Plie Soli			Calculation	n 🕡 See results		

The axial stiffness μ necessary for the Manual Groupie calculation is given at the end of the "Formatted results" file. For this initial calculation, we take 2.48E05 kN/m which corresponds to the equivalent stiffness under a load equal to 70% of the creep load of an inclined pile.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
Sous une charge égale à 70% de la charge de fluage Sous la charge définie par l'utilisateur	892.45 100.00	0.00360 0.00036	0.248E+06 0.279E+06

H.4.2.2.3. Calculation of lateral stiffnesses of a vertical pile (Piecoef+)

Switch to the Piecoef+ module by clicking the corresponding icon at the top-right of the window.

"Parameters" tab



		1 🖬 🎹 🔹
Pile 1/2 : Vertical pile L = 12 m 🕨		
♥ Parameters ♥ Soil/pile ♥ External loads	on pile 🛛 🕏 Free g(z) soil displacement	
		General settings
Calculation type		
Die calculation under transverse	hade	
based on pressuremeter	er data input (elasto-plastic)	~
S if short term	oads applied at pile head are dominant	~
		i
- Calculation parameters		
Calculation title	Vertical pile L = 12 m	
Reference elevation (m)		0,00 🗘
Inclination angle of the pile (*)		0,00 🗘
Pile family	A	(Internet internet
		Load incrementation
	Calculation	



"Calculation type" frame

Select:

- "Pile calculation under transverse loads";
- "Based on pressuremeter data input" (elasto-plastic)";
- "If short-term loads applied at pile head are dominant".

"Calculation parameters" frame

- Give the calculation title: for example "Vertical pile L = 12 m";
- Reference elevation (m): 0.00;
- Inclination angle of the pile (°): 0.00;
- Pile family: A.

Note: In order to differentiate between inclined piles and vertical piles, we assign them to a family, which enables them to be differentiated when building the project in Manual Groupie. Vertical piles are part of family A, inclined piles are part of family B.

"Soil/Pile" tab

This tab concerns soil layers definition and pile discretisation.



"Soil layers definition" frame

The parameters to be input are given below:

Note: in the same way as for Taspie+, the model stops at the base of the pile.

Name	Z _{base} (m)	E _M (kPa)	α	B (m)	p _f * (kPa)	pı* (kPa)
Bank	-4.00	1.00E04	0.33	0.60	500	1000
Dense sand	-10.00	2.00E04	0.33	0.60	1000	2000
Loose sand	-12.00	8.00E03	0.33	0.60	500	800

"Pile discretisation" frame

Consideration of shear force: Unticked.



Enter the pile properties for each layer:

- Product of inertia of pile EI;
- Number of subdivisions of layer n.

The layer thickness h is automatically deduced from the data previously input.

Name	h (m)	E.I (kN.m²)	n
Bank	4,00	3,22E05	10
Dense sand	6,00	3,22E05	20
Loose sand	2,00	3,22E05	10

"External loads on pile" tab

This tab does not need to be filled out for this calculation phase.

Note: The lateral stiffnesses are calculated first of all for an unloaded pile.

"Free g(z) soil displacement" tab

This tab does not need to be filled out for this example.

Calculation and results

Once the mandatory data have been filled out, the calculation can be started.

The lateral stiffnesses ρ used for the Manual Groupie calculation are accessible from the "Main Curves" using the Groupie parameters button. This table displays the results of the calculation for a vertical pile (family A).



These stiffnesses will be imported into Manual Groupie with the help of the import wizard.

In order to model inclined piles, go back to the data input part by clicking the *ack to the index* button and then the *ack to the data* button.

H.4.2.2.4. Calculation of lateral stiffnesses of an inclined pile (Piecoef+)

Click the white button to copy the model of pile N°1 (vertical pile) to pile N°2 (inclined pile).



"Parameters" tab

	T 👎 🕅 💌
Pie 22 : inclined pile L = 12 m Pie 22 : inclined pile L = 12 m Pie 20 Solitylie 0 Schernel loads on pile 0 Free g(z) soil displacement	
Calculation type	General settings
Pie calculation under transverse loads	~
based on pressuremeter data input (elastic-plastic)	~
If short term loads appled at pile head are dominant	~
Calculation parameters	
Calculation title Inclined pile L = 12 m	
Reference elevation (m)	0,00
Pile family B	30,00 V
<u> </u>	Load incrementation
Calculation See results	

Modify the following parameters:

"Calculation parameters" frame

- Modify the calculation title: "Inclined pile L = 12 m" for example;
- Pile inclination angle (°): 30.00;
- Pile family: B.

"Soil/Pile" tab

The elevation of the base of the last soil layer (loose sand) is to be modified to obtain a pile 12 m long. We take $Z_{\text{base}} = -10.40$ m.





The lateral stiffnesses ρ used for the Manual Groupie calculation are as follows (family B).



These stiffnesses will be imported into Manual Groupie with the help of the import wizard.

H.4.2.2.5. Distribution of forces at pile heads (Manual Groupie)

Switch to the Groupie+ module by clicking the button.

"Settings/Piles" tab

This tab is used to define piles.

"General parameters" frame

- Give the calculation title: "Easel piles" for example;
- Select Manual Groupie.



"Piles definition" frame

Input the following characteristics:

N°	Family	X _P (m)	Y _P (m)	D (m)	α (°)	β (°)	Connection
1	А	0.00	-4.00	0.60	0.00	0.00	Clamped
2	В	0.00	-4.00	0.60	-30.00	0.00	Clamped
3	A	0.00	0.00	0.60	0.00	0.00	Clamped
4	В	0.00	0.00	0.60	-30.00	0.00	Clamped
5	А	0.00	4.00	0.60	0.00	0.00	Clamped
6	В	0.00	4.00	0.60	-30.00	0.00	Clamped



"Stiffnesses" tab

🦰 Council a flations a station or insult		~		
Grouple pile importation wizard		×		
- Import directory				
E:\Users\margareth.touraine\Documents\Logiciels T	errasoNFoxtav3\Manu	International In		
Import from Taspie+ Import from Piecoef+				
Exemple 02 (Pile 1)				
Exemple 02 (Pile 2)				
			Calect the destination piles	~
	Calculation title	Pieu	Jelect the destination piles	^
	Calculation data	Mercredi 8 octobre 2014 15:18:42	Pile 1 (Family A)	
	Culculation date	moreredro octobre 2014 10.10.42	Pile 2 (Family B)	
	μ	244000.0	Pile 3 (Family A)	
	Tz	0.0	Pile 4 (Family B)	
	.~0	0.0	Pile 5 (Family A)	
			Pile 6 (Family B)	
Ok Cancel	Import in	nto several piles at once	Ok Cancel	

"Import from Taspie+" tab:

- Select "Example 02 (pile 1)" and import these values for the piles of family A (vertical piles) by clicking on the Import into several piles at once button. With the mouse, select the 3 piles of family A. Click the OK button in the two windows of the wizard.
- Repeat the operation with pile n°2 using the Import into several piles at once button and select the 3 piles of family B (inclined piles).

"Import from Piecoef+" tab:

- Select "Example 02 (pile 1)", choose "Import along both axes" and import these values for All piles of family A (vertical piles) by clicking the Import into several piles at once button. Click the OK button.
- Repeat the operation with pile n°2 using the Import into several piles at once button and select All piles of family B (inclined piles).

Groupie pile importation wizard			×		
E:\Users\margareth.touraine\Documents\Logici	els Terraso/Foxtav3\Manu	JeNGroupie+WITO\EXEMPLE 02	\supset		
Import from Tasnies Import from Discosfs					
Exemple 02 (Pile 1)			_		
Exemple 02 (Pile 2)					
	Calculation date	Mercredi 8 octobre 2014 15:06:00			
	Ρ1	121703.0			
	ρ2	133615.0		🥮 Calantatian disationation ailan	
	0-	294571.0		Select the destination plies	
		20101110	_	Pile 1 (Family A)	
	'o	0.0		Pile 2 (Family D) Dile 3 (Family A)	_
	Mo	0.0		Pile 4 (Family R)	
	Import along O	xz axis		Pile 5 (Family A)	
				Pile 6 (Family B)	
	Import along Og	yz axis			
	Import along bo	oth axes			
Ok Cance	I) (Import in	nto several piles at once		Ok Cancel	



• The equivalent torsional stiffness Y, which by default is set at 1, is not modified.

N°	μ (kN/m)	ρ ₁ (kN/m)	ρ₂ (kN)	ρ₃ (kN.m/rad)	ρ₄ (kN/m)	ρ₅ (kN)	ρ₅ (kN.m/rad)	Г (kN.m/rad)
1	2.440E05	1.219E05	1.343E05	2.967E05	1.219E05	1.343E05	2.967E05	1.000E00
2	2.480E05	1.217E05	1.336E05	2.946E05	1.217E05	1.336E05	2.946E05	1.000E00
3	2.440E05	1.219E05	1.343E05	2.967E05	1.219E05	1.343E05	2.967E05	1.000E00
4	2.480E05	1.217E05	1.336E05	2.946E05	1.217E05	1.336E05	2.946E05	1.000E00
5	2.440E05	1.219E05	1.343E05	2.967E05	1.219E05	1.343E05	2.967E05	1.000E00
6	2.480E05	1.217E05	1.336E05	2.946E05	1.217E05	1.336E05	2.946E05	1.000E00

Following these operations, the following table is obtained:



"Initial state" tab

This tab is automatically filled out when the stiffnesses are imported (operation carried out in previous tab). All the values remain nil for this initial phase.

"Footing load" tab

This is the same load case as for step 1 of the example.



Define a load case with the following values:

I	N°	T _X (kN)	M _Y (kN.m)	T _Y (kN)	M _x (kN.m)	T _z (kN)	M _z (kN.m)
	1	3000	0	0	0	0	0



Numerical results

Results table:

File Project ?							ቸ ፑ 🔟
\$ 2 Export data be ind							
Number of load case	Number of pile	T ₁ [kN]	M ₁ [kN.m]	T ₂ [kN]	M2 [kN.m]	T [kN]	M _z [kN.m]
1	1	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	2	371,23	17,52	0,00	0,00	-548,73	-0,00
1	3	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	4	371,23	17,52	0,00	0,00	-548,73	-0,00
1	5	404,14	-17,52	-0,00	0,00	289,60	-0,00
1	6	371,23	17,52	0,00	0,00	-548,73	-0,00

Note the values obtained for each type of pile:

Vertical pile (family A):

- ✓ Side force at pile head in plane (Pxz): T1 = 404.14 kN
- ✓ Bending moment at pile head in plane (Pxz): M1= -17.52 kN.m
- ✓ Axial force at pile head: Tz= 289.6 kN

Inclined pile (family B):

- \checkmark Side force at pile head in plane (Pxz): T1 = 371.23 kN
- ✓ Bending moment at pile head in plane (Pxz): M1= 17.52 kN.m
- ✓ Axial force at pile head: Tz= -548.73 kN

The various stiffnesses used in the Manual Groupie calculation must now be updated. To do this, we reuse the Taspie+ and Piecoef+ models, introducing the forces at the pile heads presented above. This operation, which consists in updating the stiffnesses followed by the Manual Groupie calculation, is to be repeated until there is virtually no further change in the distribution of forces. The iterative process is then said to have converged.

Save your project under a different name: "Ex2 iteration1", for example.

Go back to the Taspie+ module by clicking the corresponding icon TASPIE+ and go to pile

N°1.

H.4.2.2.6. Updating axial stiffness of a vertical pile (Taspie+)

"Parameters" tab

• Modify the calculation title: "Vertical pile L= 12 m – Iteration 1" for example.

"Load" tab

Input the force previously obtained for a vertical pile following the Manual Groupie calculation.

- Implementation (0,0 m)
 Figure elevation (0,0 m)

 Reference elevation (0,0 m)
 Top load (01)
- Load at pile head: 290.0 kN



Note that the stiffness obtained under the load defined by the user is 2.77E05 kN/m for the vertical pile. The stiffness has changed. The axial stiffness is greater than initially anticipated.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
Sous une charge égale à 70% de la charge de fluage Sous la charge définie par l'utilisateur	874.81 290.00	0.00359 0.00105	0.244E+06 0.277E+06

We will proceed in the same way for the inclined pile.

Switch to the inclined pile (Pile N°2) by clicking the button.

H.4.2.2.7. Updating axial stiffness of an inclined pile (Taspie+)

"Parameters" tab

• Modify the calculation title: "Inclined pile 30° L = 12 m - Iteration 1" for example.

<u>"Load" tab</u>

• Input the load resulting from the Manual Groupie calculation: -549.0 kN



Calculation and results

Note that the stiffness obtained under the load defined by the user is 2.70E05 kN/m for the inclined pile.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
Sous une charge égale à 70% de la charge de fluage	-793.49	-0.00298	0.266E+06
Sous la charge définie par l'utilisateur	-549.00	-0.00203	0.270E+06

H.4.2.2.8. Update of lateral stiffnesses of a vertical pile (Piecoef+)

For the side force – bending moment pair obtained, the new equivalent pile head stiffnesses must be determined. To do this, we reuse the Piecoef+ models and define the loads at the pile heads.

Switch to the Piecoef+ module by clicking the corresponding icon





"Parameters" tab

• Modify the calculation title: "Vertical pile L = 12 m - Iteration 1" for example.

"External loads on pile" tab

Input side force T1 and bending moment M1 at the vertical pile head.

- Point side force T: 404.14 kN
- Point bending moment M: -17.52 kN.m



Calculation and results



The stiffnesses obtained will be imported into Manual Groupie, through the import wizard. We will proceed in the same way for the inclined pile.

H.4.2.2.9. Update of lateral stiffnesses of an inclined pile (Piecoef+)

"Parameters" tab

• Modify the calculation title: "Inclined pile L = 12 m - Iteration 1" for example.

"External loads on pile" tab

Input the following forces on the head of the inclined pile:

- Point side force T: 371.23 kN
- Point bending moment M: 17.52 kN.m







We will now recalculate the new distribution of forces at the pile heads following updating of the equivalent stiffnesses.

To do this, click the use button and directly access the "Stiffnesses" tab.



H.4.2.2.10. Distribution of forces – 1st iteration (Manual Groupie)

"Stiffnesses" tab

The stiffness resulting from the new Taspie+ and Piecoef+ calculations must be updated.

- Input the equivalent axial stiffness defined by the user for each type of pile, resulting from the Taspie+ calculations:
 - \circ vertical pile μ : 2.77E05 kN/m
 - \circ ~ inclined pile μ : 2.70E05 kN/m ~

Note: you may not use the import wizard to retrieve the stiffness values. This is because the wizard always points to the stiffnesses corresponding to 70% of the creep load.

- Import the different stiffnesses P_1 to P_6 obtained with Piecoef+:
 - select a row from the table then click on the "Import wizard" button
 - \circ from the "Import from Piecoef+" tab, select pile N°1;
 - o tick the "Import along oxz axis" radio button;
 - click the Import into several piles at once button and select All piles of family A (vertical piles).
 - \circ click the **OK** button in the two windows of the wizard.

Repeat the operation for pile N°2, using the <u>Import into several piles at once</u> button and only select the piles of family B (inclined piles).

Once these operations are completed, the stiffnesses table contains the following values:

N°	μ (kN/m)	ρ ₁ (kN/m)	ρ₂ (kN)	ρ₃ (kN.m/rad)	ρ₄ (kN/m)	ρ₅ (kN)	ρ₀ (kN.m/rad)	Ƴ (kN.m/rad)
1	2.770E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
2	2.700E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00
3	2.770E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
4	2.700E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00
5	2.770E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
6	2.700E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00

							17 17	îi îi îi
ettings/piles	🛛 Stiffnesses 💽	Initial state 🛛 🗸 F	Footing load					
uvalent stiffne	sses at pile head - loo	cal coordinate sys	tems of piles	Equiv	alent s	tiffness	es at pi	le hea
N°	μ	ρ ₁	ρ2	ρ ₃	ρ ₄	ρ ₅	ρ ₆	г
	[KN/m]	[kN/m]	[kN]	[kN.m/rad]	[kN/m]	[kN]	[kN.m/rad]	[kN.m/rad]
1	2,770E05	[kN/m] 1,002E05	[kN] 1,304E05	[kN.m/rad] 2,958E05	[kN/m] 1,219E05	[kN] 1,343E05	[kN.m/rad] 2,967E05	[kN.m/rad] 1,000
1 2	2,770E05 2,700E05	[kN/m] 1,002E05 9,681E04	[kN] 1,304E05 1,286E05	[kN.m/rad] 2,958E05 2,933E05	[kN/m] 1,219E05 1,217E05	[kN] 1,343E05 1,336E05	[kN.m/rad] 2,967E05 2,946E05	[kN.m/rad] 1,000 1,000
1 2 3	2,770E05 2,700E05 2,770E05	[kN/m] 1,002E05 9,681E04 1,002E05	[kN] 1,304E05 1,286E05 1,304E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05	[kN/m] 1,219E05 1,217E05 1,219E05	[kN] 1,343E05 1,336E05 1,343E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05	[kN.m/rad] 1,000 1,000 1,000
1 2 3 4	2,770E05 2,700E05 2,770E05 2,770E05 2,660E05	[kN/m] 1,002E05 9,681E04 1,002E05 9,681E04	[kN] 1,304E05 1,286E05 1,304E05 1,286E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05 2,933E05	[kN/m] 1,219E05 1,217E05 1,219E05 1,217E05	[kN] 1,343E05 1,336E05 1,343E05 1,336E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05 2,946E05	[kN.m/rad] 1,000 1,000 1,000 1,000
1 2 3 4 5	2,770E05 2,700E05 2,770E05 2,660E05 2,770E05	[kN/m] 1,002E05 9,681E04 1,002E05 9,681E04 1,002E05	[kN] 1,304E05 1,286E05 1,304E05 1,286E05 1,286E05 1,304E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05 2,933E05 2,958E05	[kN/m] 1,219E05 1,217E05 1,219E05 1,219E05 1,219E05	[kN] 1,343E05 1,336E05 1,343E05 1,336E05 1,343E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05 2,946E05 2,946E05 2,967E05	[kN.m/rad] 1,000 1,000 1,000 1,000 1,000

"Initial state" tab

When importing stiffnesses into the oxz planes, Manual Groupie automatically fills out the loads and displacements at the origin for each pile. It should be noted that these values are no longer null, which indicates soil plastification in the lateral direction x-x. This finding can be visualised by accessing the graphical results of the Piecoef+ models.



					1	ाः 🏢
Settings/piles 🕇 🛡 Si	iffnesses 🛛 💐 Initial stat	e 🔮 Footing load				
			Loads and	d displace	ements a	at the orio
Forces of pile head at	the origin					
Forces of pile head at	T1 ₀	M1 ₀	T2 ₀	M2 ₀	Tz _o	Mz ₀
Forces of pile head at N ⁰	T1 ₀ [kN]	M1 ₀ [kN.m]	T2 ₀ [kN]	M2 ₀ [kN.m]	Tz ₀ [kN]	Mz ₀ [kN.m]
Forces of pile head at N ^o	the origin T1 ₀ [kN] 118,80	M1 ₀ [kN.m] -21,19	T2 ₀ [kN] 0,00	M2 ₀ [kN.m] 0,00	Tz ₀ [kN] 0,00	Mz ₀ [kN.m] 0,00
Forces of pile head at N ⁰ 1 2	the origin T1 ₀ [kN] 118,80 136,77	M1 ₀ [kN.m] -21,19 -27,74	T2 ₀ [kN] 0,00	M2 ₀ [kN.m] 0,00 0,00	Tz ₀ [kN] 0,00 0,00	Mz ₀ [kN.m] 0,00
Forces of pile head at N ⁰ 1 2 3	the origin T1 ₀ [kN] 118,80 136,77 118,80	M1 ₀ [kN.m] -21,19 -27,74 -21,19	T2 ₀ [kN] 0,00 0,00 0,00	M2 ₀ [kN.m] 0,00 0,00 0,00	Tz ₀ [kN] 0,00 0,00 0,00	Mz ₀ [kN.m] 0,00 0,00
Forces of pile head at N ⁰ 1 2 3 4	the origin T1 ₀ [kN] 118,80 136,77 118,80 136,77	M1 ₀ [kN.m] -21,19 -27,74 -21,19 -27,74	T2 ₀ [kN] 0,00 0,00 0,00 0,00	M2 ₀ [kN.m] 0,00 0,00 0,00 0,00	Tz ₀ [kN] 0,00 0,00 0,00 0,00	Mz ₀ [kN.m] 0,00 0,00 0,00
Forces of pile head at N ⁰ 1 2 3 4 5	the origin T1 ₀ [IN] 118,80 136,77 118,80 136,77 118,80	M1 ₀ [kN.m] -21,19 -27,74 -21,19 -27,74 -21,19	T2 ₀ [kN] 0,00 0,00 0,00 0,00 0,00	M2 ₀ [kN.m] 0,00 0,00 0,00 0,00 0,00	Tz ₀ [kN] 0,00 0,00 0,00 0,00 0,00	Mz ₀ [kN.m] 0,00 0,00 0,00 0,00 0,00

Now restart the calculation by clicking the **Start calculation** button then access the results tables.

rile Project ?							ተ ፑ 📶 🔪
						2 Ex	port 🛛 💓 Back to the index
Number of load case	Number of pile	T ₁ [kN]	M ₁ [kN.m]	T2 [kN]	M2 [kN.m]	T _z [kN]	M _z [kN.m]
1	1	389,79	-16,22	0,00	0,00	326,50	0,00
1	2	365,21	16,22	0,00	0,00	-587,86	0,00
1	3	389,79	-16,22	0,00	0,00	326,50	0,00
1	4	365,21	16,22	0,00	0,00	-587,86	0,00
1	5	389,79	-16,22	0,00	0,00	326,50	0,00
1	6	365,21	16,22	0,00	0,00	-587,86	0,00

Note the values obtained for each type of pile:

Vertical pile:

Inclined pile:

✓ T1: 389.79 kN
 ✓ M1: -16.22 kN.m
 ✓ Tz: 326.50 kN
 ✓ Tz: -587.86 kN

The loads and displacements at the pile heads have changed, so a second iteration will be carried out.

Save your project under a different name: "Ex2 iteration 2" for example

Go back to the Taspie+ module by clicking the corresponding icon And display pile N°1.

H.4.2.2.11. Updating the axial stiffness of a vertical pile (Taspie+)

"Parameters" tab

Change the calculation title: "Vertical pile L = 12 m - Iteration 2" for example.

"Load" tab

Input the Tz value from the Manual Groupie calculation, for a vertical pile:

• Top load: 326.5 kN

	17 111 -
Pile 1/2 : Vertical pile L = 12 m - Iteration # 2	
Parameters V Layers V Pile V Solikpile V Imposed settlements V Load	
	Load
Top load (kH) 326,5 🗘	
Modify advanced parameters	



We can see that the equivalent stiffness under the new load defined by the user is exactly the same as that of the first iteration: 2.77E05 kN/m.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
Sous une charge égale à 70% de la charge de fluage	874.81	0.00359	0.244E+06
Sous la charge définie par l'utilisateur	326.50	0.00118	0.277E+06

Repeat the operation for an inclined pile.

H.4.2.2.12. Updating the axial stiffness of an inclined pile (Taspie+)

"Parameters" tab

Change the calculation title: "Inclined pile 30° L = 12 m - Iteration 2" for example.

"Load" tab

Input value Tz for an inclined pile, resulting from the Manual Groupie calculation:

• Top load: -587.9 kN

	🚹 🕂 🎹 🖌
Pile 2/2 : Pieu incliné 30° L = 12 m - Rération 2	
Parameters O Layers O Pile O Sculpile O imposed settlements O Load	Load
Top load (kN)	-587,9 🗘
	Modify advanced parameters

Calculation and results

We can see that the equivalent stiffness under the new load defined by the user is exactly the same as that of the first iteration: 2.70E05 kN/m.

RAIDEUR EQUIVALENTE			
	Charge	Déplacement	Raideur
Sous une charge égale à 70% de la charge de fluage Sous la charge définie par l'utilisateur	-793.49 -587.86	-0.00298 -0.00218	0.266E+06 0.270E+06

Switch to the Piecoef+ module and go to the vertical pile (Pile N°1).

H.4.2.2.13. Updating the lateral stiffnesses of a vertical pile (Piecoef+)

"Parameters" tab

"Calculation parameters" frame

• Change the calculation title: "Vertical pile L = 12 m - Iteration 2" for example.

"External loads on pile" tab

The load is defined by:

- Point side force T: 389.79 kN
- Point bending moment M: -16.22 kN.m



					1	- 📭 m
Pile 1/2 : Ve	rtical pile L=1	2m - Iteration #2 庨				
Parameters	Soil/pile	🕈 External loads on pil	e 🛛 🎖 Free g(z) soil disp	placement		
oint loads non	mal to the pile				External	loads on p
'oint loads non N ⁰	mal to the pile	Z (m)	T [KN]	M [kN.m]		loads on pi
loint loads non N ⁰ 0	mal to the pile	Z [m] 0,00	T [kN] 389,79	M [kN.m] -16,22	K [kN/m] 0,00E00	loads on pi
loint loads non N ^o 0 1	mal to the pile	Z [m] -4,00	T [kN] 389,79 0,00	M [kN.m] -16,22 0,00	External	C [kN.m/rad] 0,00E00
loint loads non N ⁰ 0 1 2	mal to the pile	Z [m] -4,00 -10,00	T [kN] 389,79 0,00 0,00	M [kN.m] -16,22 0,00 0,00	K [kW/m] 0,00E00 0,00E00 0,00E00	C [kl.m/rad] 0,00E00 0,00E00

Now restart the calculation. The new stiffnesses will be imported into Manual Groupie with the help of the import wizard.

Repeat the operation for the inclined pile.

H.4.2.2.14. Updating the lateral stiffnesses of an inclined pile (Piecoef+)

"Parameters" tab

Change the calculation title: "Inclined pile L = 12 m - Iteration 2" for example.

"External loads on pile" tab

The load is defined by:

- Side force T: 365.21 kN
- Point bending moment M: 16.22 kN.m

				1	r 📭 🕅
Pile 2/2 : Inclined Pile	e 30° L=12m - Iteration #2	>			
arameters 🛛 👽 Soil	pile 🔿 External loads or	n pile 🛛 🔊 Free g(z) soil o	displacement		
	·				
	<u> </u>			Evtornal	loads on n
it loads normal to the	e pile			External	loads on p
nt loads normal to the	e pileZ	T	М	External	loads on p
nt loads normal to the	e pileZ [m]	T [kN]	M [kN.m]	External	loads on p
It loads normal to the N ^O 0	e pile Z [m] 0,00	T [kN] 365,21	M [kN.m] 16,22	K [kN/m] 0,00E00	C [KN.m/rad] 0,00E00
nt loads normal to the N ⁰ 0 1	e pile Z [m] -4,00	T [kN] 365,21 0,00	M [kN.m] 16,22 0,00	External	loads on p
nt loads normal to the N ⁰ 0 1 2	z [m] [m] 	T [kN] 365,21 0,00 0,00	M [kN.m] 16,22 0,00 0,00	K [kV/m] 0,00E00 0,00E00 0,00E00	loads on p

Calculation and results

Now restart the calculation. The new stiffnesses obtained will be imported into Manual Groupie with the help of the import wizard.

Switch to the Groupie+ module and go directly to the "Stiffnesses" tab.

H.4.2.2.15. Distribution of forces – 2nd iteration (Manual Groupie)

"Stiffnesses" tab

Earlier on, we observed that the stiffnesses produced by the two Taspie+ calculations are identical with respect to the previous iteration. No modification needs to be considered in the first column.

The stiffnesses from the last Piecoef+ calculations must now be imported, in the same way as for the first iteration. The following values are then obtained.

Pile N°	μ (kN/m)	ρ1 (kN/m)	ρ2 (kN)	ρ3 (kN.m/rad)	ρ4 (kN/m)	ρ5 (kN)	ρ6 (kN.m/rad)	Г (kN.m/rad)
1	2.77E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
2	2.70E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00
3	2.77E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
4	2.70E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00
5	2.77E05	1.002E05	1.304E05	2.958E05	1.219E05	1.343E05	2.967E05	1.000E00
6	2.70E05	9.681E04	1.286E05	2.933E05	1.217E05	1.336E05	2.946E05	1.000E00



							T T	íjiji ▼
Settings/piles	Stiffnesses	🔮 Initial state	Footing load)				
quivalent stiffn	esses at pile head	- local coordinate	e systems of piles	Equival	lent sti	ffnesse	es at pil	e hea
~	μ	ρ ₁	ρ2	ρ3	ρ ₄	ρ ₅	ρ _e	Г
N°	[kN/m]	[kN/m]	[kN]	[kN.m/rad]	[kN/m]	[kN]	[kN.m/rad]	[kN.m/rad]
N ^v 1	[kN/m] 2,770E05	[kN/m] 1,002E05	[kN] 1,304E05	[kN.m/rad] 2,958E05	[kN/m] 1,219E05	[kN] 1,343E05	[kN.m/rad] 2,967E05	[kN.m/rad] 1,000E0
N° 1 2	[kN/m] 2,770E05 2,700E05	[kN/m] 1,002E05 9,681E04	[kN] 1,304E05 1,286E05	[kN.m/rad] 2,958E05 2,933E05	[kN/m] 1,219E05 1,217E05	[kN] 1,343E05 1,336E05	[kN.m/rad] 2,967E05 2,946E05	[kN.m/rad] 1,000E0 1,000E0
N° 1 2 3	[kN/m] 2,770E05 2,700E05 2,770E05	[kN/m] 1,002E05 9,681E04 1,002E05	[kN] 1,304E05 1,286E05 1,304E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05	[kN/m] 1,219E05 1,217E05 1,219E05	[kN] 1,343E05 1,336E05 1,343E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05	[kN.m/rad] 1,000E0 1,000E0 1,000E0
N° 1 2 3 4	[kN/m] 2,770E05 2,700E05 2,770E05 2,700E05	[kN/m] 1,002E05 9,681E04 1,002E05 9,681E04	[kN] 1,304E05 1,286E05 1,304E05 1,286E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05 2,933E05	[kN/m] 1,219E05 1,217E05 1,219E05 1,217E05	[kN] 1,343E05 1,336E05 1,343E05 1,336E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05 2,946E05	[kN.m/rad] 1,000E0 1,000E0 1,000E0 1,000E0
N° 1 2 3 4 5	[kN/m] 2,770E05 2,700E05 2,770E05 2,700E05 2,770E05	[kN/m] 1,002E05 9,681E04 1,002E05 9,681E04 1,002E05	[kN] 1,304E05 1,286E05 1,304E05 1,286E05 1,304E05	[kN.m/rad] 2,958E05 2,933E05 2,958E05 2,933E05 2,938E05	[kN/m] 1,219E05 1,217E05 1,219E05 1,217E05 1,217E05 1,219E05	[kN] 1,343E05 1,336E05 1,343E05 1,336E05 1,343E05	[kN.m/rad] 2,967E05 2,946E05 2,967E05 2,946E05 2,946E05 2,967E05	[kN.m/rad] 1,000E0 1,000E0 1,000E0 1,000E0 1,000E0

Now restart the calculation and access the results tables.

File Project ?	i i i i i i i i i i i i i i i i i i i						ተ ፑ 🛄
						Ex Ex	port 🛛 💓 Back to the index
Number of load case	Number of pile	T ₁ [KN]	M ₁ [kN.m]	T ₂ [kN]	M ₂ [kN.m]	T _z [kN]	M _z [kN.m]
1	1	389,79	-16,22	0,00	0,00	326,50	0,00
1	2	365,21	16,22	0,00	0,00	-587,86	0,00
1	3	389,79	-16,22	0,00	0,00	326,50	0,00
1	4	365,21	16,22	0,00	0,00	-587,86	0,00
1	5	389,79	-16,22	0,00	0,00	326,50	0,00
1	6	365,21	16,22	0,00	0,00	-587,86	0,00

It can be seen that the forces at the pile heads are identical to those obtained with the first iteration. The Manual Groupie calculation has therefore converged.

It can also be seen that these results are very similar to those obtained with the Automatic Groupie+ calculation, considered to be the reference. The calculation results in Manual Groupie mode (step 2) deviated from the reference by an average of 3 ‰.



H.4.3. Example 3: Rectangular piles

This involves studying the behaviour of an infinitely rigid footing built on an assembly of three $1.80 \text{ m} \times 0.62 \text{ m}$ rectangular piles. Given the transverse dimensions of the rectangular piles and their orientation, it is essential to switch to Advanced Automatic Groupie+ mode. Two rectangular pile families are to be considered.



For easier understanding, below is the list of soil layers defined in this example:

- RB: Bank (backfill);
- MMG: Gypsum media and Marls (Marl);
- SM: Monceau sands (Sand);
- CSO: Saint-Ouen marly limestone (Marly Limestone).

H.4.3.1. Data input

A new project is created and the modules chosen in exactly the same way as presented in example 01 (see first two sub-parts § H.4.1.1).

H.4.3.1.1. "Parameters" tab

			General setting
General parameters			5
	Calculation title	ample 03	
	3	G+ G+	
Reference elevation	42,00 🗘	Families	
		Family strip foundation // OY (1) [1 pile] Family strip foundation // OX (2) [2 piles]	•
Maximum step	0,20 🗘	[
Footing thickness	1,00 🗘		
Laws			
[Lateral] RB - B, K_s=1,14E04, P_=186,0, I	K -4.005.04 D -480.0		
	s2=1,00E-01, P2=100,0		
[Lateral] MMG - B, K _{s1} =7,49E04, P ₁ =661,	0, K _{s2} =3,75E04, P ₂ =1260,0		ŕ
[Lateral] MMG - B, K _{s1} =7,49E04, P ₁ =661, [Lateral] SM - B, K _{s1} =1,41E05, P ₁ =378,0,	0, K _{s2} =3,75E04, P ₂ =1260,0 K _{s2} =7,05E04, P ₂ =1267,0		
[Lateral] MMG - B, K _{s1} =7,49E04, P ₁ =661, [Lateral] SM - B, K _{s1} =1,41E05, P ₁ =378,0, [Lateral] CSO - B, K _{s1} =6,83E04, P ₁ =661,0	N ₈₂ =1,00=01, P ₂ =106,0 0, K ₈₂ =3,75E04, P ₂ =1260,0 K ₈₂ =7,05E04, P ₂ =1367,0 0, K ₈₂ =3,42E04, P ₂ =826,0		
$\label{eq:lateral} \begin{array}{l} \text{ILMERG} I \\ \text{[Lateral]} & \text{ILMEG} I \\ \text{[Lateral]} & \text{SM} - \text{B}, \text{K}_{s1} \text{=} 1,41\text{EOS}, \text{P}_{1} \text{=} 378,0, \\ \text{[Lateral]} & \text{CSO} - \text{B}, \text{K}_{s1} \text{=} 6,83\text{EO4}, \text{P}_{1} \text{=} 681,0 \\ \text{[Lateral]} & \text{RB} - \text{L}, \text{K}_{s1} \text{=} 1,71\text{EO4}, \text{P}_{1} \text{=} 540,0,1 \end{array}$	A ₂₂ =1,00=01, + ₂ =106,0 0, K ₃₂ =3,75E04, P ₂ =1260,0 K ₅₂ =7,05E04, P ₂ =1367,0 1, K ₅₂ =3,42E04, P ₂ =826,0 K ₅₂ =1,00E-01, P ₂ =540,0		
$\label{eq:lateral} \begin{array}{l} \textbf{Lateral} \mbox{ MMG - B, K_{g1} = 7,49E04, P_1 = 681, \\ \textbf{Lateral} \mbox{ SM - B, K_{g1} = 1,41E05, P_1 = 378, 0, \\ \textbf{Lateral} \mbox{ CSO - B, K_{g1} = 6,83E04, P_1 = 661, 0 \\ \textbf{Lateral} \mbox{ RB - L, K_{g1} = 1,71E04, P_1 = 540, 0, \\ \textbf{Lateral} \mbox{ MMG - L, K_{g1} = 4,89E04, P_1 = 2700 \\ \end{array}$	$\begin{split} & \sum_{s_2=0}^{s_2=0} \pi(u_0e^{-u_1}, P_2^{=160,0}) \\ & 0, K_{s_2}^{-1}, 375604, P_2^{-1260,0} \\ & K_{s_2}^{-1}, 0.5604, P_2^{-1367,0}) \\ & K_{s_2}^{-1}, 842604, P_2^{-826,0} \\ & K_{s_2}^{-1}, 100E^{-01}, P_2^{-8540,0} \\ & 0, 0, K_{s_2}^{-1}, 00E^{-01}, P_2^{-2700,0} \end{split}$		r
$eq:lateral_la$	w ₂₂ *1,000-01, p ₂ *168,0 0, K ₂₂ =3,75604, P ₂ =1280,0 K ₂₀ *7,05604, P ₂ =1367,0 K ₂₀ =3,42504, P ₂ =826,0 K ₂₀ =4,2044, P ₂ =826,0 K ₂₀ =4,100E-01, P ₂ =540,0 0,0, K ₂₂ =1,00E-01, P ₂ =2700,0 ,1, K ₂₂ =1,00E-01, P ₂ =3420,0		r
$\label{eq:constraints} \begin{split} & [Latera] \ MMG - B, \ K_{3} = 7,4504, \ P_{1} = 681, \\ & [Latera] \ SM - B, \ K_{3} = 4,41605, \ P_{1} = 578, 0, \\ & [Latera] \ SM - B, \ K_{3} = 6,8504, \ P_{1} = 661, 0 \\ & [Latera] \ MMG - L, \ K_{3} = 4,9504, \ P_{1} = 7270, \\ & [Latera] \ MMG - L, \ K_{3} = 4,9504, \ P_{1} = 7270, \\ & [Latera] \ MMG - L, \ K_{3} = 4,9504, \ P_{1} = 7270, \\ & [Latera] \ SM - L, \ K_{3} = 4,9504, \ P_{1} = 720, \\ & [Latera] \ SM - L, \ K_{3} = 4,9504, \ P_{1} = 720, \\ & [Latera] \ SM - L, \ K_{3} = 4,9504, \ P_{1} = 720, \\ & [Latera] \ SM - L, \ K_{3} = 4,9504, \ P_{1} = 720, \\ & [Latera] \ SM - L, \ K_{3} = 4,9504, \ P_{1} = 720, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{1} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 140, \\ & [Latera] \ SM - L, \ K_{3} = 5,13204, \ P_{3} = 10, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\ & [Latera] \ SM - L, \ K_{3} = 1,140, \\$	$\begin{split} & \kappa_{22}^{-1},000-01, p_2^{-1}68,0 \\ & \kappa_{22}^{-1},75E04, p_2^{-1}280,0 \\ & \kappa_{22}^{-1},75E04, p_2^{-1}367,0 \\ & \kappa_{22}^{-1},42E04, p_2^{-8}28,0 \\ & \kappa_{22}^{-1},00E-01, p_2^{-5}40,0 \\ & 0,0, \kappa_{22}^{-1},00E-01, P_2^{-2}700,0 \\ & 0,\kappa_{32}^{-1},00E-01, P_2^{-2}420,0 \\ & 0,\kappa_{32}^{-1},00E-01, P_2^{-2}440,0 \\ \end{split}$		
$ \begin{split} & [Latera] \; MMG - B, \; K_{3} = 7,4904, \; P_{1} = 861, \\ & [Latera] \; SM - B, \; K_{3} = 1,41005, \; P_{1} = 730, \\ & [Latera] \; CSO - B, \; K_{3} = 6,35204, \; P_{1} = 681, \\ & [Latera] \; R = L, \; K_{3} = 1,71054, \; P_{1} = 540, \\ & [Latera] \; R = L, \; K_{3} = 1,71054, \; P_{1} = 540, \\ & [Latera] \; R = L, \; K_{3} = 1,71054, \; P_{1} = 540, \\ & [Latera] \; SM - L, \; K_{3} = 1,24005, \; P_{1} = 340, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; R = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; SM - L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; P_{1} = 100, \\ & [Latera] \; CM = L, \; K_{3} = 1,71054, \; CM = 100, \\ & [Latera] \; CM = 10,71054, \; CM = 100, \\ & [Latera]$	$\begin{split} & \sum_{k=2}^{m} (\log_{k} - 1), \sum_{p=1}^{m} (\log_{k} 0) \\ & (k_{22} - 3, 7 \leq 0, P_{2} - 1) \leq 0, \\ & (k_{22} - 3, 7 \leq 0, P_{2} - 1) \leq 3, 7, 0 \\ & (k_{22} - 3, 42 \leq 0, 4, P_{2} - 82 \leq 0, 0) \\ & (k_{22} - 1, 0 \leq 0, 1), P_{2} - 54 \geq 0, 0 \\ & (0, K_{22} - 1, 0 \leq 0, -1), P_{2} - 34 \geq 0, 0) \\ & (0, K_{22} - 1, 0 \leq 0, -1), P_{2} - 34 \geq 0, 0) \\ & (0, K_{21} - 1, 0 \leq 0, -1), P_{2} - 34 \geq 0, 0) \\ & (0, K_{21} - 1, 0 \leq 0, -1), P_{2} - 34 \geq 0, 0) \\ & (0, K_{21} - 1, 0 \leq 0, -1), P_{2} - 34 \geq 0, 0) \\ & (2, 50 \geq 0), Q_{22} - 0, 1) \end{split}$		Ĩ
$\label{eq:constraints} \begin{array}{l} [Latera] MMG - B, K_{g} = 7,45E04, P_{g} = 851, \\ [Latera] SM - B, K_{g} = 6,31E04, P_{g} = 651, \\ [Latera] CSO - B, K_{g} = 6,35E04, P_{g} = 651, \\ [Latera] BB - L, K_{g} = 6,35E04, P_{g} = 670, \\ [Latera] MMG - L, K_{g} = 6,35E04, P_{g} = 740, \\ [Latera] MMG - L, K_{g} = 7,35E04, P_{g} = 1440, \\ [Latera] SM - L, K_{g} = 7,35E04, P_{g} = 1440, \\ [Latera] SM - L, K_{g} = 7,35E04, P_{g} = 1440, \\ [Latera] SM - L, K_{g} = 7,35E04, P_{g} = 140, \\ [Latera] SM - L, K_{g} = 7,35E04, P_{g} = 140, \\ [Latera] SM - L, K_{g} = 7,35E04, P_{g} = 140, \\ [Latera] SM - L, K_{g} = 7,35E04, \\ [Latera] SM - L, K_{g} = 7,55E04, \\ [Latera] SM - L, K_{g} = 7,55E$	$\begin{split} & \sum_{k_{2}=1}^{2} 1.000(1, p_{2}^{-1}160) \\ & K_{2}=3760(4, p_{2}-1280, 0) \\ & K_{2}=3760(4, p_{2}-1287, 0) \\ & K_{2}=3.2264, p_{2}-628, 0) \\ & K_{2}=1.000(-1), p_{2}-540, 0) \\ & K_{2}=1.000(-1), p_{2}-2700, 0) \\ & K_{2}=2.5500(3, q_{2}-0) \\ & K_{2}=2.5500(3, q_{2}-0) \\ & K_{2}=0.000(-1), p_{2}-2700, 0) \\ & K_{2}=0.000(-1), p_{2}-2700(-1), p_{2}-2700, 0) \\ & K_{2}=0.000(-1), p_{2}-2700(-1), p_{2}-270(-1), p_{2}-270(-1), p_{2}-270(-1), p_{2}-270(-1), p_{2}-270(-1), p_{2}-270(-1)$		Ĭ
$\label{eq:result} \begin{array}{l} [Lateral] MMG - B, K_{3} = 7,4904, P_{1} = 661, \\ [Lateral] SM - B, K_{3} = 1,4105, P_{1} = 730, \\ [Lateral] SM - B, K_{3} = 6,3204, P_{1} = 6610, \\ [Lateral] RB - L, K_{3} = 6,38044, P_{2} = 700, \\ [Lateral] MMG - L, K_{3} = 6,38044, P_{2} = 700, \\ [Lateral] MMG - L, K_{3} = 6,38044, P_{2} = 700, \\ [Lateral] SM - L, K_{3} = 1,24054, P_{1} = 1420, \\ [Lateral] SM - L, K_{3} = 1,25044, Q_{3} = 0, \\ [Lateral] SM - L, K_{4} = 1,25044, Q_{3} = 0, \\ [Lateral] SM - K_{4} = 1,25044, Q_{3} = 0, \\ [Lateral] SM - K_{4} = 1,25044, Q_{3} = 0, \\ [Friction] MMK, K_{4} = 1,25044, Q_{3} = 330, \\ [Friction] SM, K_{4} = 6,26044, Q_{3} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{3} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, K_{4} = 6,26044, Q_{4} = 1940, \\ [Friction] SM, $	$\begin{split} & \sum_{k_2=1,0\in (k_1,k_2)=166,0} \\ & (k_{k_2}=3,564,0,k_{k_2}=1560,0, \\ & (k_{k_2}=3,4260,0,k_{k_2}=1660,0, \\ & (k_{k_2}=1,06-0,1, p_{k_2}=460,0, \\ & (k_{k_2}=1,00-0,1, p_{k_2}=480,0, \\ & (k_{k_2}=1,00-0,1, p_{k_2}=180,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=180,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=180,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=180,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=1,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=1,0, \\ & (k_{k_2}=1,00,1, p_{k_2}=1,0, \\ & (k_{k_2}=1,0,0,1, p_{k_2}=1,0, \\ & (k_{k_2}=1,0,0,1, p_{k_2}=1,0, \\ & (k_{k_2}=1,0,1, p_{k_2}=1,0,1, \\ & (k_{k_2}=1,0,1, p_{k_2}=1,0,1, \\ & (k_{k_2}=1,0,1, p_{k_2}=1,0,1, \\ & (k_{k_2}=1,0,1,1, \\ & (k_{k_2}=1,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1$		
$ \begin{array}{l} \label{eq:constraints} \\ eq:con$	V ₂₂ -1.00-01, P ₂ =186,0 V ₂₂ -3.7564, P ₂ =1280,0 K ₂₄ -3.7564, P ₂ =1280,0 K ₂₄ -3.7564, P ₂ =1287,0 V ₂₂ -3.42264, P ₂ =286,0 K ₂₄ -1.00-01, P ₂ =540,0 V ₂₄ -1.00-01, P ₂ =2420,0 V ₂₄ -1.00-01, P ₂ =2420,0 V ₂₄ -1.00-01, P ₂ =2420,0 V ₂₄ -1.00-01, P ₂ =240,0 Z50E03, O ₄₂ =0.1 K ₄₂ =1.00-01, O ₄₂ =387,0 C ₄₂ =1.08E04, O ₄₂ =678,0		
$ \begin{split} & [Latera] \; MMG - B, \; K_{3} = 7,49204, \; P_{1} = 861, \\ & [Latera] \; SM - B, \; K_{3} = 1,41005, \; P_{1} = 73.0, \\ & [Latera] \; CS = 0, \; K_{3} = 6,32044, \; P_{1} = 65404, \\ & [Latera] \; RB - L, \; K_{3} = 6,32044, \; P_{1} = 5400, \\ & [Latera] \; MIG - L, \; K_{3} = 6,32044, \; P_{1} = 54004, \\ & [Latera] \; MIG - L, \; K_{3} = 6,32044, \; P_{1} = 54004, \\ & [Latera] \; SD - L, \; K_{3} = 6,32044, \; P_{1} = 14004, \\ & [Fricton] \; MS, \; K_{1} = 1,26054, \; Q_{2} = 330, \\ & [Friction] \; MS, \; K_{1} = 6,28044, \; Q_{3} = 3390, \\ & [Fricton] \; CSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; CSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{1} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{2} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 3390, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,432044, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,43204, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,5304, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,504, \; Q_{3} = 330, \\ & [Fricton] \; SSO, \; K_{3} = 9,504, \; Q_{3} = 30, \\ & [Fricton] \; SSO, \; K_{3} = 9,504, \; Q_{3} = 1, \\ & [Fricton] \; SSO$	$\begin{split} & \sum_{k=2}^{2} 1.000-01, P_2^{-1100,0}\\ & K_{k}^{-1}, 7560, P_{k}^{-1100,0}\\ & K_{k}^{-1}, 7560, P_{k}^{-1100,0}\\ & K_{k}^{-1}, 2, 4260, P_{k}^{-100,0}\\ & K_{k}^{-1}, 0, 0, 0, P_{k}^{-100,0}\\ & 0, K_{k}^{-1}, 0, 0, 0, R_{k}^{-100,0}\\ & 0, K_{k}^{-1}, 0, 0, 0, R_{k}^{-10,0}\\ & 0, K_{k}^{-1}, 0, 0, 0, R_{k}^{-10,0}\\ & 0, K_{k}^{-1}, 0, 0, 0, R_{k}^{-10,0}\\ & 0, K_{k}^{-10,0}\\ & 0, K_{k}^{-10,0}\\ & 0, K_{k}^{-10,0}\\ & 0, K_{k}^{-10,0}\\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, $		
$ \begin{array}{l} [Latera] MMG - B, K_{3} = 7,4504, P_{1} = 681, \\ [Latera] SM - B, K_{3} = 1,41605, P_{1} = 73.0, \\ [Latera] CS - B, K_{3} = 6,8364, P_{1} = 661, \\ [Latera] RB - L, K_{3} = 6,8364, P_{1} = 620, \\ [Latera] RB - L, K_{3} = 6,8964, P_{2} = 70, \\ [Latera] RMG - L, K_{3} = 6,8964, P_{2} = 70, \\ [Latera] RG - L, K_{3} = 6,8964, P_{1} = 70, \\ [Latera] RG - L, K_{3} = 1,2604, Q_{3} = 0, \\ [Latera] RS, K_{1} = 1,2604, Q_{3} = 0, \\ [Latera] RS, K_{1} = 1,2604, Q_{3} = 0, \\ [Fricton] MR, K_{1} = 1,2604, Q_{3} = 0, \\ [Fricton] MS, K_{1} = 1,2604, Q_{3} = 0, \\ [Fricton] SM, K_{1} = 6,2804, Q_{3} = 194, 0, \\ [Fricton] SG, K_{1} = 6,2804, Q_{3} = 194, 0, \\ [Fricton] CSO, K_{1} = 6,3804, Q_{3} = 339, 0, \\ \\ [Fricton] CSO, K_{1} = 6,3804, Q_{3} = 339, 0, \\ \\ \end{tabular}$	$\begin{split} & \left(\begin{array}{c} & \left(\sum_{q=1}^{q}, 2560, 0, q \right) \\ & \left(\sum_{q=2}^{q}, 2564, P_{q}^{-1}367, 0 \right) \\ & \left(\sum_{q=2}^{q}, 34260, P_{q}^{-1}367, 0 \right) \\ & \left(\sum_{q=2}^{q}, 34260, P_{q}^{-1}367, 0 \right) \\ & \left(\sum_{q=2}^{q}, 1000, 0, 1, P_{q}^{-2}420, 0 \right) \\ & \left(\sum_{q=2}^{q}, 1000, 0, 1, P_{q}^{-2}420, 0 \right) \\ & \left(\sum_{q=2}^{q}, 1000, 0, 1, P_{q}^{-2}420, 0 \right) \\ & \left(\sum_{q=2}^{q}, 1000, 0, 1, P_{q}^{-1}440, 0 \right) \\ & \left(\sum_{q=2}^{q}, 2560, 0, Q_{q}^{-1}68, 0 \right) \\ & \left(\sum_{q=2}^{q}, 12660, 0, Q_{q}^{-2}670, 0 \right) \\ & \left(\sum_{q=1}^{q}, 12660, 0, Q_{q}^{-2}677, 0 \right) \end{split}$		
[Latera] MMG - B, K ₁ =7,4904, P ₁ =661, [Latera] SM - B, K ₂ =7,41005, P ₁ =7740, [Latera] SM - B, K ₂ =6,8304, P ₁ =6610, [Latera] SM - L, K ₂ =6,8304, P ₁ =640, 0, [Latera] SM - L, K ₂ =6,38044, P ₁ =740, [Latera] SM - L, K ₂ =6,13604, P ₁ =1440, [Fricton] MB, K ₁ =1,2604, O ₂₁ =0,1, K ₂ =2 [Fricton] MB, K ₁ =1,2604, O ₂₁ =0,1, K ₂ =2 [Fricton] SM, K ₁ =6,28044, O ₂₁ =0,1, K ₂ =2 [Fricton] SM, K ₁ =6,28044, O ₂₁ =0,0,0 [Fricton] SS, K ₁ =9,43044, O ₂₁ =0,0 [Fricton] SS, K ₁ =9,43044, O ₂₁ =0,0 [Fricton] SS, K ₁ =9,43044, O ₂₁ =0,0 [Fricton] SS, K ₁ =0,0 [Fricton] SS, K_{1}=0,0 [Fricton] SS, K_{1}=0,0 [Fricton] SS, K_{1}=0,0 [Fricton] SS, K_{1}	N ₂₂ -1.00±01, P ₂ -1500,0 K ₂₂ -3.75±04, P ₂ -1500,0 K ₂₂ -3.75±04, P ₂ -1500,0 K ₂₂ -3.42±04, P ₂ -2500,0 N ₂₂ -3.42±04, P ₂ -2500,0 N ₂₂ -1.00±01, P ₂ -2700,0 N ₂₂ -1.00±01, P ₂ -2420,0 O ₁ -K ₂₁ -1.00±01, P ₂ -2700,0 N ₂₂ -1.00±04, P ₂₂ -450,0 O ₁ -K ₂₁ -0.10±04, P ₂₂ -450,0 O ₂ -41.00±04, P ₂₂ -450,0 Z ₂₁ -1.00±04, Q ₂₂ -678,0 =1.26±04, Q ₂₂ -457,0 C ₂₁ -1.08±04, Q ₂₂ -678,0		



"General parameters" frame

- Groupie+ calculation title: simply enter "Example 03";
- Advanced Automatic Groupie+: selected;
- Reference elevation (m): 42.00;
- Maximum step (m): 0.20;
- Footing thickness (m): perfectly rigid footing.

The advanced mode calls up the secondary "Families" frame:

Two rectangular pile families are to be created by clicking the 🗣 button:

• Create a new empty family:

Name of the family: Rectangular pile // OY and click the OK button;

Treate a family	×
Create a new empty family	
Name of the family : strip founddation // OY	
Ok Cancel	

 Create a new empty family: Name of the family: Rectangular pile // OX and click the OK button.

🎹 Create a family	\times
Create a new empty family	
Name of the family : strip foundation // OX	
Ok Cancel	

After creating these two families, two tabs appear, marked with a red cross Family 1 Family 2 because they have not been filled out yet.

"Laws" frame

The laws created here are used to allocate parameters to the soil layers. These will be defined in the "Family 1" and "Family 2" tabs.

• Click the 🗣 button to add a law:

Lateral laws:

The following data are to be input:

Name of law	K _{s1} (kN/m/m)	P 1 (kN/m)	K _{s2} (kN/m/m)	P ₂ (kN/m)
RB – B	1.14E04	186.0	1.00E-01	186.0
MMG – B	7.49E04	661.0	3.75E04	1260.0
SM – B	1.41E05	378.0	7.05E04	1367.0
CSO – B	6.83E04	661.0	3.42E04	826.0
RB – L	1.71E04	540.0	1.00E-01	540.0
MMG – L	4.89E04	2700.0	1.00E-01	2700.0
SM – L	1.24E05	3420.0	1.00E-01	3420.0
CSO – L	5.13E04	1440.0	1.00E-01	1440.0

Friction laws:

The following data are to be input:

Name of law	K _{t1} (kN/m/m)	Q _{s1} (kN/m)	K _{t2} (kN/m/m)	Q _{s2} (kN/m)
RB	1.26E04	0.1	2.50E03	0.1
MMG	1.26E05	339.0	2.51E04	678.0
SM	6.28E04	194.0	1.26E04	387.0
CSO	9.42E04	339.0	1.88E04	678.0

Base law:

The following data are to be input:

Name of law	K _{p1} (kN/m)	Q _{p1} (kN)	K _{p2} (kN/m)	Q _{p2} (kN)
CSO - Base	1.64E05	1200.0	3.28E04	2400.0

"Advanced parameters" frame

• Modify advanced parameters: unticked.

H.4.3.1.2. "Piles" tab

Three elements (rectangular piles) are created with the **+** button.



The following data are to be input:

Pile N°	Family	X _P	Υ _Ρ
1	Family rectangular piles // OY (1)	-2.70	0.00
2	Family rectangular piles // OX (2)	2.20	2.20
3	Family rectangular piles // OX (2)	2.20	-2.20

Note: the colours are automatically assigned to each family.



H.4.3.1.3. "Family 1" tab

This first "Family 1" tab is used to define the characteristics of the first family of rectangular piles. The name of the "Rectangular piles // OY" family input in the "Parameters" tab is given at the top of the tab.

Parameters	🔍 Piles 🔍 F	amily 1 📀 Far	mily 2 🛛 💐 F	footing load					
			[1] Definition	of the far	nily str	ip four	ndation	// OY
Parameters -			-	-					
		Inclina	tion α	0,0 😂	Stiffness F	1,0	00 0		
		Orienti	ation β	0,0 🗘	Binding type	Clamped	~		
		Elev _{he}	ad	42,00 🗘	Colour				
Soil/pile definit	tion								
Reminder of t	he reference elev	ation : 42,00 m						_	
N°	Name	Colour	Elev _{base} [m]	Lateral law along X axis	Lateral law along Y axis	Friction law	El _x [kN m ²]	Ely [kN m ²]	ES [kN]
1	Laver 1		40	.00 RB - L	RB - B	RB	3.57E05	3.01E06	1.12E07
2	Laver 2		35	50 MMG - L	MMG - B	MMG	3.57E05	3.01E06	1.12E07
3	Laver 3		34	.00 SM - L	SM - B	SM	3.57E05	3.01E06	1,12E07
4	Layer 4		30	.00 CSO - L	CSO - B	CSO	3,57E05	3,01E06	1,12E07
Base law	50 - Tin								
Ontinen	· · · ·								
Enable po	int restoring stiffn	ess			Define soil deflection	n g(z)			
				Calculation	See results				

"Parameters" frame

Data to be input:

- α: Inclination (°): 0.0
- β: Orientation (°): 0.0
- **Elev**_{head} (m): 42.00
- γ: Stiffness (kN.m/rad): 1.00

- Binding type: clamped
- **Colour**: automatically initialised at creation of family.

"Soil/Pile definition" frame

Advanced Automatic Groupie+ recalls the reference elevation: 42.0 m.

Data	to	be	input:
Duiu	ω	00	input.

Layer name	Elev _{base} (m)	Lateral law x	Lateral law y	Friction law	El _x (kN.m²)	El _y (kN.m²)	ES (kN)
Bank	40.0	RB - L	RB - B	RB	3.57E05	3.01E06	1.12E07
Marl	35.5	MMG - L	MMG - B	MMG	3.57E05	3.01E06	1.12E07
Sand	34.0	SM - L	SM - B	SM	3.57E05	3.01E06	1.12E07
Marly limestone	30.0	CSO - L	SM - B	CSO	3.57E05	3.01E06	1.12E07

• Base law: CSO – Base

"Options" frame

- Enable point restoring stiffness: unticked
- Define soil deflection g(z): unticked

H.4.3.1.4. "Family 2" tab

This second "Family 2" tab is used to define the characteristics of the second family of rectangular piles. The name of the "Rectangular piles // OX" family input in the "Parameters" tab is given at the top of the tab.



			[2]	Definition	of the far	nily str	ip foun	dation	// (
arameters -		Inclina	tion a	0.0 ^	Stiffness [10			
		incline		0,0 🗸	Samoaar		~~		
		Orient	ation β	90,0 😂	Binding type	Clamped	~		
		Elev _{he}	ad	42,00 🗘	Colour				
oil/pile defir	nition								
teminder of	the reference elev	vation : 42,00 m	Elevhase	Lateral Ison altera Mania	Laboration along Marcia	Estation Inc.	El _x	El	ES
No	Name	Colour	[m]	Lateral law along X axis	Lateral law along Y axis	Friction law	[kN.m ²]	[kN.m ²]	[kN]
1	Layer 1		40,00	0 RB - L	RB - B	RB	3,57E05	3,01E06	1,1
2	Layer 2		35,50	0 MMG - L	MMG - B	MMG	3,57E05	3,01E06	1,1
3	Layer 3		34,00	0 SM - L	SM - B	SM	3,57E05	3,01E06	1,1
4	Laver 4		30.00	0 CSO - L	CSO - B	CSO	3,57E05	3,01E06	1,1
				1					
lase law (
lase law C	- Tip		×.						<u></u>
lase law C ptions] Enable p	SO - Tp	less	×.		Define soil deflector	1 g(z)			

"Parameters" frame

Data to be input:

- α: Inclination (°): 0.0
- β: Orientation (°): 90.0
- **Elev**_{head} (m): 42.00
- **y**: Stiffness (kN.m/rad): 1.00
- Binding type: clamped
- **Colour**: automatically initialised at creation of the family.



"Soil/pile definition" frame

Advanced Automatic Groupie+ recalls the reference elevation: 42.00 m.

Data to be input:

Name of layer	Elev _{base} (m)	Lateral law x	Lateral law y	Friction law	El x (kN.m²)	El _y (kN.m²)	ES (kN)
Bank	40.0	RB - L	RB - B	RB	3.57E05	3.01E06	1.12E07
Marl	35.5	MMG - L	MMG - B	MMG	3.57E05	3.01E06	1.12E07
Sand	34.0	SM - L	SM - B	SM	3.57E05	3.01E06	1.12E07
Marly limestone	30.0	CSO - L	SM - B	CSO	3.57E05	3.01E06	1.12E07

• Base law: CSO – Base

"Options" frame

- Enable point restoring stiffness: unticked
- Define soil deflection g(z): unticked

Note: the only difference between the two families is the orientation of the rectangular piles around the OZ axis, so it is possible to create family 2 as an exact copy of family 1 and then make the minor modification ($\beta = 90^{\circ}$).

H.4.3.1.5. "Footing load" tab

The load cases input in this tab are expressed at the centre of the footing O.





"Load case" frame

Data to be input:

Load case N°	T _X (kN)	M _Y (kN.m)	T _Y (kN)	M _X (kN.m)	T _z (kN)	M z (kN.m)
1	-2000	-4000	0	0	6000	0
2	-3000	-6000	-2000	-4000	6800	0
3	-5000	-10000	-1000	-2000	7000	0
4	-7000	-14000	0	0	8000	5000
5	8000	16000	-3000	-4000	10000	0

H.4.3.2. Calculation and results

H.4.3.2.1. Calculation

The calculation procedure presented in example 01 applies (see chapter H.4.1.2.1).

H.4.3.2.2. Results

Numerical results:

Loads and displacements at the footing centre

This table presents the displacements of the foundation, expressed at the centre of the footing, with a reminder of the associated load global forces and moments.

Global stiffnesses	Global stiffnesses Loads and displacements at the footing centre								Export 4	🕻 Back to the index		
Load agon #	Тх	MY	TY	M _X	Tz	Mz	U _X	rot/Y	UY	rot/X	U _z	rot/Z
Luau case #	[kN]	[kN.m]	[kN]	[kN.m]	[kN]	[kN.m]	[m]	[rad]	[m]	[rad]	[m]	[rad]
1	-2000,00	-4000,00	0,00	0,00	6000,00	0,00	-6,001E-03	3,065E-04	3,085E-18	-4,202E-20	2,779E-03	6,329E-18
2	-3000,00	-6000,00	-2000,00	-4000,00	6800,00	0,00	-8,774E-03	3,634E-04	-9,171E-03	-1,055E-03	3,379E-03	-1,599E-04
3	-5000,00	-10000,00	-1000,00	-2000,00	7000,00	0,00	-1,452E-02	4,948E-04	-4,501E-03	-4,847E-04	3,445E-03	-8,959E-05
4	-7000,00	-14000,00	0,00	0,00	8000,00	5000,00	-2,189E-02	7,398E-04	6,531E-04	-7,539E-05	4,212E-03	1,836E-03
5	8000,00	16000,00	-3000,00	-4000,00	10000,00	0,00	2,349E-02	-7,233E-06	-1,428E-02	-1,832E-03	5,588E-03	-2,573E-04

To obtain the overall stiffnesses of the foundation, click the **Global stiffnesses** button. Use the drop-down list to change load cases.

m (Global stiffnesses										
	Load case 3 : TX=-5000,00 kN, MY=-10000,00 kN, m, TY=-1000,00 kN, MX=-2000,00 kN m, TZ=7000,00 kN, MZ=0,00 kN m										
	Tangent stiffnesses at the footing centre $F = K \cdot U + F_0$										
	uX	rY	uY	rX	uZ	٢Z					
uΧ	+3,432E05	+8,378E05	-2,612E-11	+1,114E-11	-1,160E-10	-7,158E03	T.X	-4,313E02			
r۲	+8,378E05	+1,407E07	+4,462E-11	-3,961E05	-1,899E06	-1,275E04	M _e Y	+1,554E03			
uΥ	+6,975E-11	-2,489E-10	+2,896E05	-6,022E05	-1,143E-12	-1,278E05	T.Y	-1,203E-12			
rX	-3,781E-10	-3,961E05	-6,022E05	+9,264E06	+1,801E05	+6,110E05	M _• X	-5,891E02			
uZ	-1,435E-11	-1,899E06	-4,653E-11	+1,801E05	+1,949E06	-9,060E-11	T.Z	+1,314E03			
٢Z	-7,158E03	-1,275E04	-1,278E05	+6,110E05	+3,171E-10	+3,122E06	M _e Z	-9,676E01			
	Rotational stiffness term (kNim) Force at the origin (kN)										
	Rotational stiffness term (kN.m) Moment at the origin (kN.m)										
	Cross stiffness term (kN)										
	Export these stiffnesses to Excel for : Current load case) All load cases Close										

Forces at pile heads

For each load case, this table gives the forces transmitted at the head of each rectangular pile.



Forces at pile heads						2 E	xport (💘 Back to the index)
Load case #	Pile #	T ₁ [kN]	M ₁ [kN.m]	T ₂ [kN]	M ₂ [kN.m]	T _z [kN]	M _z [kN.m]
1	1	-368,797	534,183	-0,000	0,000	2751,310	0,000
1	2	0,000	-0,000	815,601	-1873,630	1624,340	0,000
1	3	0,000	-0,000	815,601	-1873,630	1624,340	0,000
2	1	-548,010	805,157	-947,282	1741,560	3167,120	-0,000
2	2	-526,359	685,894	1171,070	-2737,840	199,773	-0,000
2	3	-526,359	685,894	1280,920	-3015,870	3433,110	-0,000
3	1	-917,971	1362,840	-473,270	896,453	3375,530	-0,000
3	2	-263,365	348,539	2013,960	-4816,630	995,521	-0,000
3	3	-263,365	348,539	2068,060	-4960,650	2628,940	-0,000
4	1	-1384,420	2056,130	-641,898	1577,660	4010,420	0,002
4	2	320,949	-507,254	3229,310	-8302,170	1866,800	0,002
4	3	320,949	-507,254	2386,270	-5692,760	2122,780	0,002
5	1	1567,080	-2430,250	-1397,220	2397,400	3739,580	-0,000
5	2	-801,389	1016,350	-3272,450	8799,350	1214,280	-0,000
5	3	-801,389	1016,350	-3160,460	8446,450	5046,140	-0,000

Graphical results:

Lateral behaviour

Load case N°5: Family N°1 "Rectangular piles // OY" – Rectangular pile N°1



Minimum and maximum bounds of the various physical quantities:

	Deflection (m)		Bending (kN	moment .m)	Shear force (kN)		
	u1	u2	M1	M2	T1	T2	
Min. bound	-6.948E-04	-1.359E-02	-2430.25	-1356.26	-187.82	-1397.22	
Max. bound	2.349E-02	1.453E-03	631.48	2397.40	1567.08	290.72	



Load case N°4: Family N°2 "Rectangular piles // OX" - Rectangular piles N° 2 and 3



Minimum and maximum bounds of the various physical quantities:

	Deflection (m)		Bending (kN	moment .m)	Shear force (kN)		
	u1	u2	M1	M2	T1	Т2	
Min. bound	-1.398E-04	-3.827E-03	-507.25	-8302.17	-37.69	-567.35	
Max. bound	4.692E-03	2.593E-02	126.49	2289.51	320.95	3229.31	

Axial behaviour

Load case N°1: Family N°1 "Rectangular piles // OY" - Rectangular pile N°1





Minimum and maximum bounds of the various physical quantities:

	Settlement (m)	Shaft friction (kN/m)	Axial force (kN)
Min. bound	1.912E-03	0.10	313.59
Max. bound	3.606E-03	349.49	2751.31

Note: the mobilised friction is expressed in linear form (kN/m) which corresponds to the entire friction within the perimeter of each rectangular pile.

Load case N°4: Family N°2 "Rectangular piles // OX" – Rectangular piles N°2 and 3



Minimum and maximum bounds of the various physical quantities:

	Settlement (m)	Shaft friction (kN/m)	Axial force (kN)
Min. bound	1.279E-03	0.10	209.80
Max. bound	2.751E-03	298.03	2122.78


Additional results





Minimum and maximum bounds of the various physical quantities:

	Combined shear force (m)	Combined bending moment (kN/m)	Ratios (%)
Min. bound	0.00	0.00	-53.48
Max. bound	1094.38	1918.67	100.00

Note: as friction is ignored in the banks, the mobilisation ratio easily reaches 100% in this layer. This explains the vertical parts at 100% on the blue curves.



Load case N°5: Family N°2 "Rectangular piles //OX" – Rectangular piles N°2 and 3



Minimum and maximum bounds of the various physical quantities:

	Combined shear force (m)	Combined bending moment (kN/m)	Ratios (%)
Min. bound	0.00	0.00	-100.00
Max. bound	3369.15	8857.85	100.00

Note: soil plastification occurs in the local direction y-y for rectangular piles of family 2 under load case N°5. This shows that the lateral reaction produced over the width of the rectangular piles (noted B) reaches its limit over the entire height of the bank layer.