

LATERAL PILE ANALYSIS · P-Y METHOD

Solpile

User Manual

Building, running and reporting lateral pile analyses
with Solpile.

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SPL-SP-004	Solpile — Release Notes	Scope, requirements and known limitations of release 1.0.0.
SPL-SP-005	Solpile — Third-Party Software Notices	Open-source components distributed with Solpile and their licences.

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1 Introduction

1.1 Purpose and scope of this manual

This manual explains how to use Solpile to analyse a single pile under lateral load: how to describe the pile, the ground and the actions, how to run the analysis, how to judge whether the results are credible, and how to report them. It is written for civil and geotechnical engineers who are familiar with the design of deep foundations. It does not teach foundation design, and it does not replace the codes and guidelines that apply to a project.

The theory behind each calculation — the governing equation, the numerical method, the p - y models and the section mechanics — is given in the Technical Reference (SPL-SP-003). This manual refers to it where a modelling decision depends on that theory.

1.2 What Solpile computes

Solpile treats the pile as a beam-column supported along its length by nonlinear springs that represent the lateral resistance of the soil or rock (the p - y method). For each load case it computes, at every point along the pile:

- lateral deflection y and slope S ;
- bending moment M , shear force V and curvature;
- soil reaction p (force per unit length of pile) and the secant soil modulus E_s ;
- bending stiffness EI when the section has nonlinear bending properties.

In addition it computes the moment–curvature relation and interaction diagram of nonlinear sections, the pile-head stiffness, the pushover and buckling response of the pile, the head deflection as a function of pile length, and LRFD checks of moment and shear.

1.3 Conventions used in this manual

Table 1.1 — Typographic conventions

Example	Meaning
Analysis ▸ Run Analysis	A menu command: menu, then command
Pile Sections	A label, button, tab or step as shown on the screen
F9 , Ctrl + Z	A key or a key combination
edit loads 1 v1=150	Text that is typed: a command, a file name, a parameter key
y , c_u , ϵ_{50}	Symbols, defined in Appendix E

Notes are set off as follows.

NOTE Information that helps to use a function correctly.

WARNING A condition that can produce wrong results or lose data if it is ignored.

1.4 Documentation set

Solpile is delivered with five documents: the End-User Licence Agreement (SPL-SP-001), this User Manual (SPL-SP-002), the Technical Reference (SPL-SP-003), the Release Notes (SPL-SP-004) and the Third-Party Software Notices (SPL-SP-005). An abridged version of this manual is available inside the program under **Help ▸ Solpile Manuals** (**F1**).

2 Installation, licence and start-up

2.1 Requirements

Solpile runs on 64-bit Windows 10 or Windows 11. The minimum and recommended configurations are listed in the Release Notes (SPL-SP-004). A display of at least 1280 × 720 pixels is needed so that every data window fits on the screen without scrolling.

2.2 Installing

Install Solpile with the Setup program supplied by Solplan (Solpile-1.0.0-Setup.exe). No separate Python installation is needed. Setup adds the folder bin of the installation to the system path, so the command `solpile` is available in every new command window. Without arguments it opens the program; with arguments it runs the command-line tool described in Section 14.4, which also contains the MCP server for AI assistants (Section 14.5).

2.3 Licence and sign-in

Use of Solpile is governed by the End-User Licence Agreement. The rules that affect daily work are these:

1. Each user signs in inside Solpile with a personal `solplan.id` account: the e-mail address and password registered at `solplan.id`, or **Sign in with Google**, which opens the browser to confirm a short code. No other program is needed for the licence. The command-line tool signs in with `solpile login`.
2. An account can be signed in on one computer at a time. Signing in on a second computer ends the session on the first one; the first computer offers to save open work before it closes.
3. A multi-seat (Team) licence lets as many members work at the same time as it has seats; each seat admits up to five members. When all seats are in use, Solpile shows who is using them.
4. Solpile checks the licence every few minutes while it runs. If the licence server cannot be reached, it warns and tries again after three minutes; after a second failure it offers to save open work and closes.
5. To work without a connection, borrow the licence beforehand in **Help ▸ Licence...** for 1 to 30 days (never beyond the end of the licence). Return it there when you are back on-line.
6. Changing the computer date or time, or using tools that misrepresent it, is not permitted. When Solpile detects an inconsistency it asks for an on-line validation; it never deletes or changes project files.

Table 2.1 — Licence types

Type	Who uses it	What differs
Personal	one user	full use
Team	members of an organisation, five per seat	full use; as many users at a time as seats
Academic	a university, per campus: any number of users who sign in with an e-mail address of the university	teaching and non-commercial research; reports and exported images are marked “Student version”
Trial	anyone, seven days, once per program for each account and computer	results can be viewed and projects saved, but nothing can be exported, printed or copied

NOTE Project files are always stored on your own computer. The licence service receives account and session data only, never project data (EULA, clause 10).

2.4 Starting the program

Start Solpile from the launcher supplied with the release, or type `solpile` at a command prompt. To open a project directly, give its file name: `solpile pile.lpx`. A new session starts with an empty SI project.

2.5 Files and folders

Table 2.2 — Files and folders used by Solpile

File or folder	Content
*.lpx	Project. A JSON text file in UTF-8 encoding. It contains the complete input, but no results: results are recomputed when the project is analysed.
*.lrfdc	A set of LRFD load combinations, saved with File ▶ Save LRFD Combos and read with File ▶ Load LRFD Combos .
%APPDATA%\Geostruktur\GeoPile	User settings, the custom reinforcing-bar catalogue (Tools ▶ Edit Custom Rebar Data) and the folder logs with the diagnostic log geopile.log.

Saving is atomic: Solpile writes a temporary file and replaces the previous file only when the write has succeeded. An interrupted save therefore never damages the existing project.

3 Modelling concepts

3.1 The analysis model

The pile is a vertical (or battered) beam-column. Its bending stiffness may be constant, may vary from section to section, or may depend on the bending moment. Along the embedded length the pile is supported by soil springs. The force-displacement law of each spring is a p - y curve: the soil reaction p , a force per unit length of pile, as a function of the lateral deflection y of the pile at that depth (Figure 3.1).

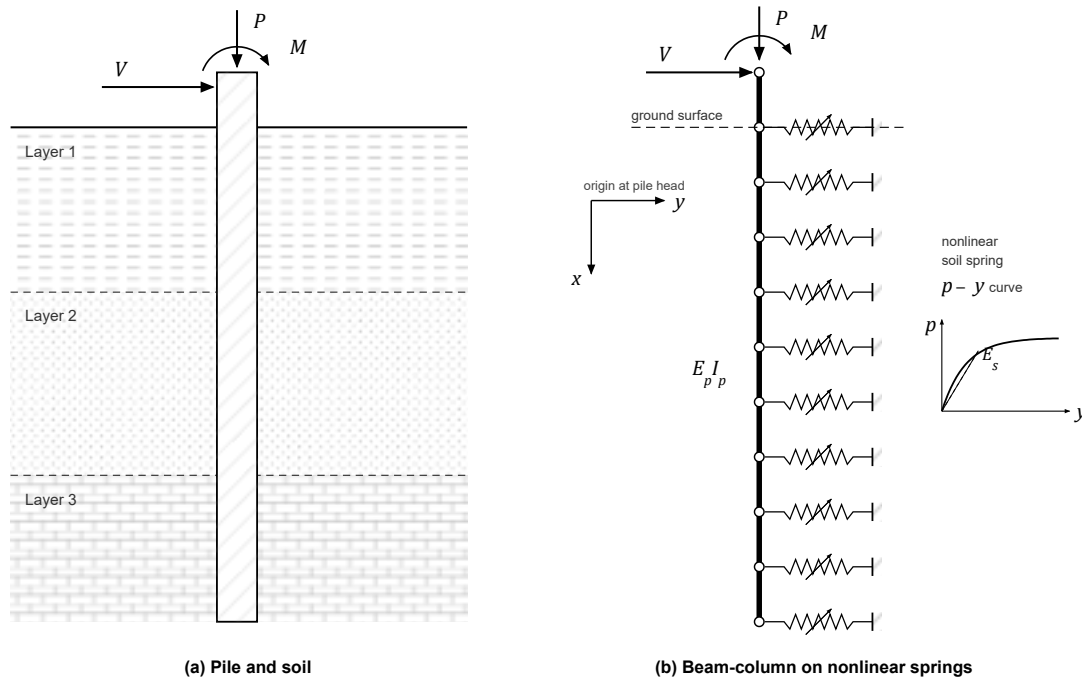


Figure 3.1 — Idealisation of a laterally loaded pile

The p - y curves are generated by Solpile from the soil parameters and the p - y model chosen for each soil material, at every node of the pile. Because the curves are nonlinear, the solution is iterative: Solpile repeats the solution of the beam-column equation with updated soil stiffnesses until the deflections no longer change by more than the convergence tolerance.

The model has the following basic limits, which apply to every analysis:

- one pile, loaded in one plane; a pile group is represented only through p - and y -multipliers;
- the soil springs act independently of each other (no shear coupling between springs);
- loads are applied statically; cyclic loading is represented by cyclic p - y curves, not by a dynamic analysis;
- the axial load is used for its second-order (P - Δ) effect and for the bending properties of nonlinear sections. Axial settlement and axial capacity are outside the scope of Solpile.

3.2 Coordinates and sign convention

Depth x is measured downwards from the pile head. Lateral deflection y is positive in the direction of a positive pile-head shear. The convention is shown in Figure 3.2.

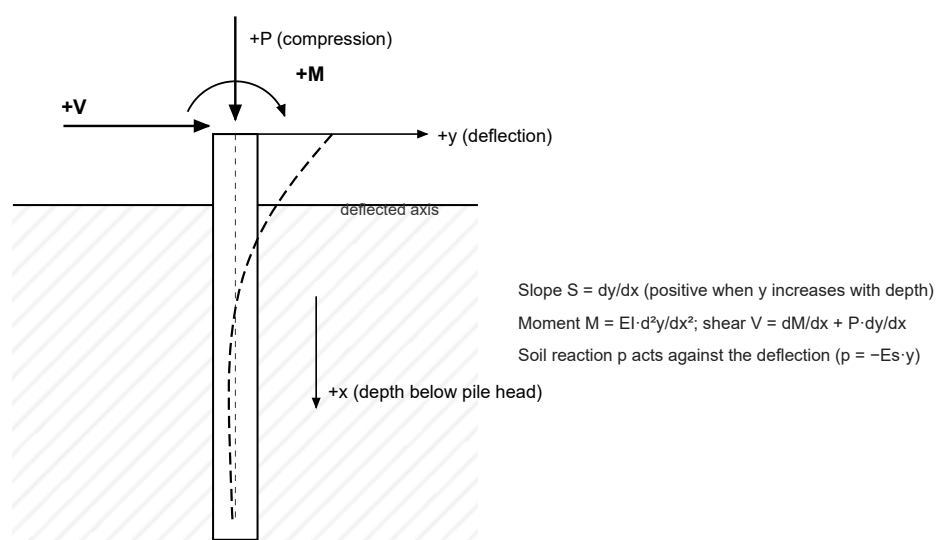


Figure 3.2 — Sign convention

Table 3.1 — Quantities and their positive sense

Quantity	Symbol	Positive when
Depth	x	below the pile head
Deflection	y	in the direction of a positive head shear
Slope	$S = dy/dx$	the deflection increases with depth
Bending moment	$M = EI \cdot d^2y/dx^2$	a moment applied at the head rotates the head in the direction that produces positive deflection
Shear force	V	a head shear acts in the positive y direction
Axial thrust	P	compression
Soil reaction	p	the soil pushes the pile in the positive y direction; for positive deflection the reaction is therefore negative

Soil layer depths, the water table and the depth of the ground surface are measured from the ground surface. Results are reported against depth below the pile head. When the pile head is above the ground surface, the two differ by the free length of the pile.

3.3 Units and number entry

A project uses one of two unit systems, selected in **Program Options**:

Table 3.2 — Unit systems

Quantity	SI	US customary
Depth and length along the pile (section lengths, layer depths, water table, output depths, pile lengths of a variable-length analysis, depth columns of the results)	m	ft
Deflection (pile deflection, pushover and stiffness deflections), convergence tolerance and deflection limit	m	in
Section dimensions, soil movement	mm	in
Force	kN	lbs
Moment	kN·m	in-lbs

Quantity	SI	US customary
Undrained shear strength of clay and silt, residual strength of liquefied sand	kPa	psf
Other stresses and strengths (concrete, steel, rock, moduli)	kPa	psi
Soil unit weight	kN/m ³	pcf
Subgrade modulus k , E_s	kN/m ³	lb/in ³
Moment-curvature, capacity and interaction-diagram output (moment, bending stiffness, axial thrust, stress)	kN·m, kN·m ² , kN, kPa	in·kips, kip·in ² , kips, ksi
Soil reaction p	kN/m	lb/in

When the unit system is changed, Solpile asks whether to **Convert values** — every number of the project is recomputed in the new units — or to **Relabel only**, which keeps the numbers as they are displayed and changes only the unit labels (a depth shown as 10 ft becomes 10 m). Use relabelling only to correct a project that was entered in the wrong system. A new project that has no input yet is converted without asking, so its default values (for example the deflection limit of the analysis options) are expressed in the new units. In both cases every window and table shows the labels of the new system at once.

Numbers may be typed with a decimal point or a decimal comma. Do not type thousands separators. On computers set to a locale that uses the full stop as the thousands separator, an entry such as 200.000 is ambiguous and is rejected with the message *Ambiguous number; type 200000 or 200,5 instead.*

3.4 Unit weight and water table

Each soil material carries two **total** unit weights: γ for soil above the water table and γ_{sat} for soil below it. The water table is defined once for the project. Solpile derives the effective unit weight below the water table as $\gamma' = \gamma_{\text{sat}} - \gamma_w$ (with $\gamma_w = 9.81 \text{ kN/m}^3$) and integrates the vertical effective stress from the ground surface. Do not enter effective unit weights.

3.5 Analysis modes and loading type

Table 3.3 — Analysis modes

Mode	Purpose
Conventional analysis	Pile-head load cases are analysed as entered (working loads or factored loads, as the user decides). Special analyses can be run with them.
LRFD	Unfactored loads are entered by category, combined with load factors, analysed, and the developed moment and shear are checked against factored section capacities.
Nonlinear EI only	No pile–soil analysis. Solpile computes the moment–curvature relation, the bending stiffness and the interaction diagram of the nonlinear sections only.

The **loading type** selects static or cyclic p-y curves for all soil materials. For cyclic loading the number of load cycles is entered as well (2 to 5000); it is used by the models whose cyclic curves depend on it.

3.6 How changes are applied

Each data step opens its own window. **OK** applies the changes made in the window. **Cancel**, **[Esc]** or the close button restores the project exactly as it was when the window was opened, including results. Every applied change can be undone with **[Ctrl]+[Z]** and redone with **[Ctrl]+[Y]**.

Any change to the input discards the previous results. What is shown in the result windows therefore always belongs to the model as it is now.

4 The workspace

4.1 Main window

The main window (Figure 4.1) consists of the menu bar and tool bar, the **data sidebar** on the left, the **canvas** in the centre, and the **status bar**. The **Command Line** window can be shown from the status bar or from **Window ▸ Command Line**.

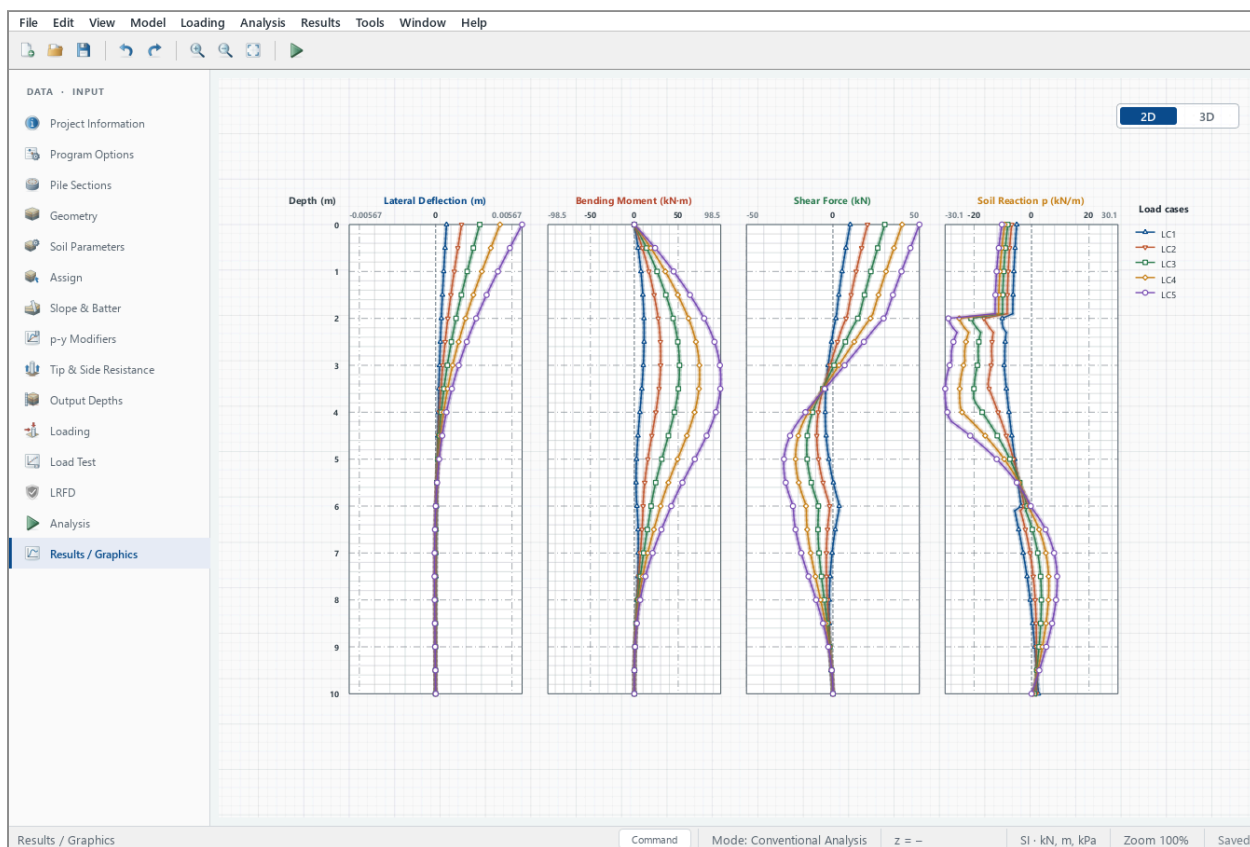


Figure 4.1 — Main window after an analysis, with the Results / Graphics step selected

Table 4.1 — Areas of the main window

Area	Function
Data sidebar	The steps of the input in their working order, from Project Information to Results / Graphics . Selecting a step opens its window. Steps that do not apply to the current analysis mode or options are disabled.
Canvas	The pile, soil layers, water table and loads, in two or three dimensions (2D / 3D switch). After an analysis, the Results / Graphics step shows the response profiles of all load cases. The canvas follows every change of the input. Zoom with the mouse wheel; View ▸ Fit to View (Ctrl + 0) re-frames the drawing.
Command Line	A text console for the command language of Chapter 14.
Status bar	Messages, analysis mode, depth under the cursor, unit system, zoom and the saved / modified state of the project.

4.2 Data steps

Table 4.2 — Data steps of the sidebar

No.	Step	Content	Section
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No.	Step	Content	Section
1	Project Information	Title, project name, job number, client, engineer, date and notes. Printed on reports.	Section 5.2
2	Program Options	Analysis mode, units, loading type, numerical controls, optional features	Section 5.3
3	Pile Sections	Sections from the pile head down; free length above ground	Chapter 6
4	Geometry	Soil layers and water table	Section 7.1
5	Soil Parameters	Soil materials: p-y model, unit weights, parameters	Section 7.2
6	Assign	Soil material of each layer	Section 7.4
7	Slope & Batter	Ground slope and pile batter	Section 7.5
8	p-y Modifiers	p- and y-multipliers against depth	Section 7.6
9	Tip & Side Resistance	Shear and moment resistance at the tip; side-resistance moment	Section 7.7
10	Output Depths	Depths at which p-y curves are reported; elevation shift of the pile	Section 7.8
11	Loading	Pile-head load cases, loads along the pile, special analyses	Chapter 8
12	Load Test	Measured load–deflection data for comparison	Section 8.3
13	LRFD	Unfactored loads, combinations and resistance factors	Section 8.4
14	Analysis	Model summary and run	Chapter 9
15	Results / Graphics	Charts and tables of the results	Chapter 11

4.3 Menus

Table 4.3 — Menu bar

Menu	Commands
File	New, Open, Open Recent, Save, Save As; Save / Load LRFD Combos; Export PNG of the canvas; Exit
Edit	Undo, Redo
View	Zoom In, Zoom Out, Fit to View, Redraw
Model	Project Information, Pile Sections, Axial Thrust Loads for Interaction Diagram, Soil Layer Geometry, Soil Parameters, Assign Materials to Layers, Slope & Batter, p-y Modification Factors, Tip & Side Resistance, Output Depths for p-y
Loading	Loading, Load Test Data, Load & Resistance Cases (LRFD)
Analysis	Program Options, Model Summary, Run Analysis, View Input Text File, View Processor Run Notes
Results	Results / Graphics, Export Report / Tables (Word, PDF, Excel), Text Viewer
Tools	Simple Calculator, Battered Pile Load Calculator, Edit Custom Rebar Data, Multi-File Analysis (Batch Run)
Window	Data Sidebar, Command Line, Reset Layout
Help	Solpile Manuals, Licence (account, borrowing for off-line use, sign-out), About

4.4 Tools

Table 4.4 — Tools menu

Tool	Use
Simple Calculator	Arithmetic without leaving the program
Battered Pile Load Calculator	Resolves vertical and horizontal loads into components normal and parallel to the axis of a battered pile; can read the forces of a load case, paste the result into a load case, or rotate all load cases with a shear head condition

Tool	Use
Edit Custom Rebar Data	A user catalogue of reinforcing bars (name, area, diameter). Custom bars appear in the Bar Size lists of concrete sections. The catalogue is stored per user, not in the project. A bar that exists in the catalogue is always taken from it, so editing the catalogue changes every section that uses the bar (the results are cleared and the analysis must be repeated); the area and diameter stored in the project are used only where the catalogue does not contain the bar.
Multi-File Analysis (Batch Run)	Analysis of several saved projects in one run (Chapter 13)

5 Building a model

5.1 Workflow

An analysis is prepared and run in eight stages (Figure 5.1). The data steps of the sidebar follow the same order. A model can be built in any order; but a model check (Chapter 9) is made before every analysis, and it reports what is missing or inconsistent.

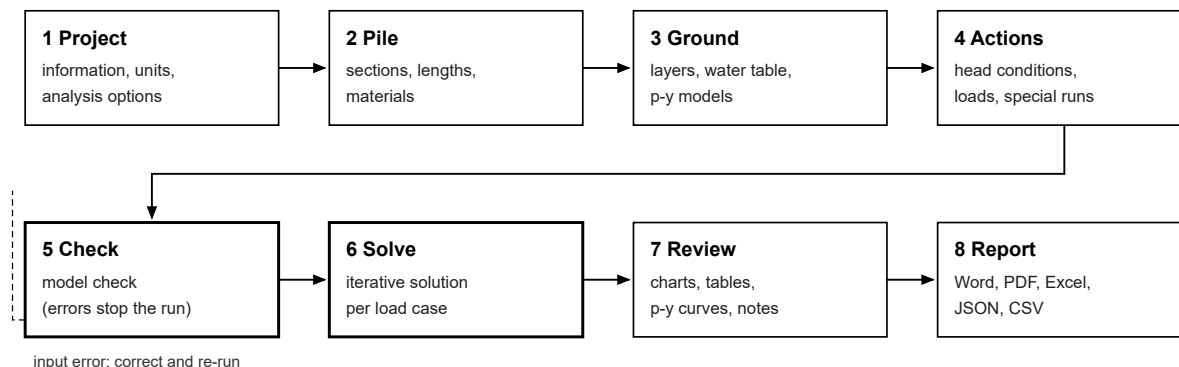


Figure 5.1 — Stages of an analysis

Before entering data, collect at least the following:

- the pile type, its dimensions and material properties, the length of each section, and the free length above the ground surface;
- the soil profile: layer boundaries, total unit weights above and below the water table, the depth of the water table, and the strength and stiffness parameters required by the p-y model chosen for each layer (Appendix B);
- the pile-head conditions (free, fixed, elastically restrained, or prescribed deflection) and the loads, including axial thrust, for every load case;
- whether the loading is static or cyclic, and, for cyclic loading, the number of cycles.

5.2 Project information

The **Project Information** step identifies the project: title, project name, job number, client, engineer, date and free notes. The entries are printed on the first page of every report. None of them affects the analysis.

5.3 Program options

Program Options controls the analysis as a whole. The options are grouped as in Table 5.1. Options that switch on optional data also enable the corresponding data steps in the sidebar.

Table 5.1 — Program options

Option	Effect	Default
Computation mode and units		
Computation mode	Conventional analysis, LRFD, or Nonlinear EI only (Table 3.3)	Conventional
Unit system	SI or US customary; see Section 3.3	SI
Loading		
Static / Cyclic Loading	Selects static or cyclic p-y curves	Static
Number of Cycles	Load cycles for cyclic p-y curves (2 to 5000)	100
Analysis control		

Option	Effect	Default
Number of Pile Increments	Number of equal increments into which the pile is divided (40 to 500). The results are reported at the nodes between increments.	100
Maximum Number of Iterations	Iteration limit per load case (30 to 1000)	500
Convergence Tolerance on Deflections	The iteration has converged when no nodal deflection changes by more than this value between two iterations	2.54×10^{-7} m (SI) / 1×10^{-5} in (US)
Deflection Iteration Limit at Pile Head	A load case is stopped and reported without results when the head deflection exceeds this value, which indicates that the lateral capacity of the soil is exceeded	2.54 m (SI) / 100 in (US)
Include P-Delta (axial-load) effects	Includes the second-order moment of the axial thrust	on
Include in the analysis		
Include Pile Batter and/or Ground Slope	Enables the Slope & Batter step	off
Include p-y Modification Factors	Enables the p-y Modifiers step	off
Include Shearing Resistance at Pile Tip	Enables the tip shear table	off
Include Moment Resistance at Pile Tip	Enables the tip moment table	off
Include Moment due to Side Resistance along Pile	Enables the side-resistance table	off
Include Shear Deformation Effects (Only Elastic Sections)	Adds the shear deflection of sections of the type Elastic Section with rectangular, circular, pipe or embedded-pole shape (Technical Reference, Section 4.6)	off
Data and output		
Input Load Test Data for Comparison	Enables the Load Test step	off
Extend p-y Curves to Maximum Pile Deflection	Extends the reported p-y curves to the largest computed deflection	off
Soil layering		
Use Layering Correction (Method of Georgiadis)	Corrects the p-y curves of a layer for the different layers above it by an equivalent depth (Technical Reference, Section 5.12)	on
Do not Compute Layering Correction if Layer Above is Same Type	Skips the correction where the layer above uses the same p-y model	on

NOTE The defaults of the analysis-control group are appropriate for most problems. Increase the number of increments for short piles, for piles with many sections, or where a load or a layer boundary must be resolved more finely (see Section 9.3).

6 Describing the pile

6.1 Pile sections

The pile is described by up to 20 **sections** listed from the pile head downwards. Each section has a type, a length and the data of its type. The total pile length is the sum of the section lengths and is shown below the table. **Pile Length Above Ground (free)** sets the distance from the pile head down to the ground surface; enter zero when the head is at the ground surface.

Use **Add Section**, **Insert Section** (adds a section above the selected one), **Copy Section**, **Edit Section** and **Delete Section** to manage the list. New sections start from the data of the selected section. A section is edited in the section window (Figure 6.1), whose tabs depend on the section type. The preview on the right shows the cross-section as it will be analysed, including reinforcement and strands.

Figure 6.1 — Section window for a round concrete shaft

6.2 Choosing the section type

Table 6.1 — Section types

Type	Bending	Use and main data
Elastic Section (Non-yielding)	linear	Any shape whose bending stiffness can be taken as constant: dimensions, area, moment of inertia and modulus. Area and inertia can be computed from the dimensions of standard shapes. Width, diameter and inertia may vary linearly over the section (taper). For an embedded pole the Section Diameter is the diameter of the drilled hole, which sets the width for the p-y curves, and the Pole Diameter is the diameter of the pole itself, which sets the extreme fibre for the bending stresses.
Elastic Section with Specified Moment Capacity	elastic–plastic	As above, with a plastic moment capacity at which the stiffness drops. Along a section the capacity follows the top value and the dimensions (Technical Reference, moment–curvature relations)
Rectangular Concrete Section	nonlinear	Width, depth, concrete, longitudinal bars (pattern or manual layout), transverse reinforcement, optional confinement
Round Concrete Shaft (Bored Pile)	nonlinear	Diameter, concrete, bars on a circle or manual layout, spiral or hoops, optional confinement

Type	Bending	Use and main data
Round Concrete Shaft with Permanent Casing	nonlinear	As above, with a steel casing that contributes to bending
Round Shaft with Casing and Core/Insert	nonlinear	Casing plus a steel core (pipe, H or AISC shape), optionally filled
Steel Pipe Section	nonlinear	Outer diameter, wall thickness, yield stress, modulus
Steel H Section, strong / weak axis	nonlinear	Depth, flange width and thickness, web thickness
Steel C Section (strong axis)	nonlinear	Depth, flange width and thickness, web thickness, corner radius, optional stiffening lip (length and thickness)
Steel T Section (weak axis)	nonlinear	Depth, flange width and thickness, web thickness
Steel Box Section	nonlinear	Depth, width, flange and web thickness, corner radius
Steel AISC Section, strong / weak axis	nonlinear	Shape chosen from the AISC library (W, M, S and HP shapes, channels, tees, single and double angles, hollow structural sections); dimensions and properties are filled in
Round, Square, Octagonal Prestressed Concrete (with or without void)	nonlinear	Outer size, void, concrete, strand type and size, number of strands, prestress force and losses, strand positions
User Defined Non-linear Bending Section	user curve	Moment–curvature or EI–moment data for each axial thrust, and the width used for the p-y curves

The parameters of each type, their units, defaults and limits are listed in Appendix A.

WARNING The width used for the p-y curves is the width of the section at that depth: the diameter of round sections, the face width of rectangular, square and octagonal sections, the flange width or depth of H sections according to the axis of bending, unless an equivalent diameter is entered in the **Options** tab (below). Check that the axis selected for an H or AISC shape matches the direction of loading.

6.3 Section options

The **Options** tab of the section window holds four settings of the section. They are printed with the section in the report.

- **Use Equivalent Diameter for p-y Calculations** replaces the width of the section by the entered **Equivalent Diameter** when the p-y curves are generated. The bending stiffness, the moment–curvature relation and the capacities still use the actual cross-section. When the option is selected the field is filled with the diameter of a circle of equal area: the area of the bounding rectangle for rectangular and square sections and for H, AISC, C, T and box shapes, the octagon for octagonal sections, and the outer diameter of round sections and pipes (Technical Reference, Section 6.8). For tapered Elastic sections a second value, **Equivalent Diameter at Bottom**, is interpolated along the section. The option is not available for user-defined nonlinear sections, nor for the General and Embedded Pole shapes of Elastic sections, whose entered diameter is already the width for the p-y curves.
- **Compute Equivalent Elastoplastic Moment Curvature (CALTRANS)** replaces the computed moment–curvature curve by a bilinear one: an elastic line through the first yield of the reinforcement (cracking for prestressed sections) and a plastic plateau at the moment that makes the areas under both curves equal beyond first yield (Technical Reference, Section 6.8).
- **Adjust Softening of Moment Curvature** (on by default) keeps the moment from decreasing once the curve has reached its peak, so that the bending stiffness used in the analysis does not drop on a falling branch. It is switched off while the CALTRANS option is selected, because the bilinear curve has no falling branch.
- **Estimate Resistance Factors and Shear Capacity** lets Solpile compute the resistance factors and the nominal shear capacity of round and rectangular reinforced-concrete sections for the LRFD checks (Section 8.4; Technical Reference, Section 7.6).

6.4 Nonlinear sections and axial thrust

For a nonlinear section Solpile computes the moment–curvature relation by integrating the stresses over the cross-section (Technical Reference, *Chapter 6*). The relation depends on the axial thrust. During a load-case analysis Solpile uses the thrust of that load case. For the interaction diagram and for reporting, the thrusts are entered in **Model ▶ Axial Thrust Loads for Interaction Diagram**; they must lie between the tensile and compressive capacity of the section. The values are either axial loads or factors of the nominal axial capacity (negative = tension), entered one by one or generated from a number of values, a minimum, a maximum and the option to include zero. All User-Defined Nonlinear sections use the axial thrust values of the first such section.

Concrete properties default to the values derived from the compressive strength (modulus, rupture strength, strain at peak stress) unless they are entered. Transverse reinforcement is used for confinement (when **Consider Confined Concrete** is selected) and for the shear capacity in LRFD checks.

NOTE **Bar Size** offers the standard bar catalogue: US #3–#18, Canadian 10M–55M, European 6–40 mm, Japanese JD 6–41, Australian AS12–AS36, New Zealand NZ6–NZ40 and metric 3–90 mm, with the catalogue diameter and area. Three-bar bundles are not available for the largest sizes (the bundle option returns to two bars). Other bars are defined once in **Tools ▶ Edit Custom Rebar Data**, or per section by choosing **Custom** and entering the bar diameter; the area is then $\pi d^2/4$ unless **Edit bar area manually** is checked. Custom bars are single bars.

Reinforcement tools in the section window:

- **Bar/Bundle Options** (round sections) opens a rebar calculator: a grid of bar size against number of bars or bundles, filtered by the steel ratio and the clear-spacing rules (bar diameter, aggregate size and an absolute spacing). Selecting a cell applies the size, number and bundling.
- **Continue Rebar Pattern and Size from Section Above** copies the longitudinal bars of the section above and locks them; later changes to that section are copied again.
- Choosing the **Manual** pattern (or switching off automatic bar positions) fills an empty position table with the current automatic layout, each row with its bar size, diameter and area.
- In SI projects **Show in m** displays area and moment of inertia in m^2 and m^4 ; the stored values do not change.
- For Elastic sections **Copy Top Properties to Bottom** makes a tapered section prismatic.

7 Describing the ground

7.1 Soil layers and water table

In the **Geometry** step the profile is described by up to 40 layers from the ground surface downwards. Each layer is defined by its thickness, or equivalently by the depth of its bottom. The lowest layer must reach at least the pile tip; Solpile reports an error otherwise.

The water table is entered as an elevation relative to the ground surface (zero or negative; for example -2.5 m for a water table 2.5 m below the ground surface), or switched off with **No water table**.

7.2 Soil materials

A **soil material** combines a p-y model, two total unit weights and the parameters of that model. Materials are defined in **Soil Parameters** (Figure 7.1) and assigned to layers in the next step, so that one material can be used for several layers. The parameter fields shown depend on the selected model.

Figure 7.1 — Soil material window

7.3 Choosing a p-y model

Choose the model that represents the soil and the loading. Table 7.1 gives a first orientation; the basis and the limits of each model are described in the Technical Reference, *Chapter 5*.

Table 7.1 — Guide to the p-y models

Model	Typical use	Required data
Cohesive soils		
Soft Clay (Matlock)	soft to medium clay, especially below water	c_u , ε_{50}
API Soft Clay (user-defined J)	as above, with a chosen J factor	c_u , ε_{50} , J
Stiff Clay with Free Water (Reese)	stiff clay below free water at the ground surface	c_u , ε_{50} , k
Stiff Clay without Free Water (Reese)	stiff clay above the water table or without free water	c_u , ε_{50}

Model	Typical use	Required data
Modified Stiff Clay without Free Water	stiff clay where an initial modulus is known	c_u , ε_{50} , k
ISO Clay (ISO 19901-4)	soft to stiff clay, offshore and large-diameter piles, static or cyclic	s_u and the test it comes from, gapping, PI, OCR, TE/DSS strength ratio; for cyclic loading the depth of rotation and the design condition
Cohesionless soils		
Sand (Reese)	sand, static or cyclic	φ' , k ; enhanced option: K_0 , α , m , n
API Sand (O'Neill)	sand, offshore and onshore practice	φ' , k ; enhanced option: K_0 , α , m , n
Small Strain Sand	sand where the small-strain shear modulus is known	φ' , k , and either G_0 , a , b or the void ratio e and the uniformity coefficient C_u
Liquefied Sand (Rollins)	liquefied sand, depth up to 6 m	none (depth and pile width)
Liquefied Sand Hybrid Model	liquefied sand with residual strength	residual strength or $(N_1)_{60-CS}$, ε_{50}
Rock		
Weak Rock (Reese)	weak rock, uniaxial strength up to a few MPa	q_u , E_{ir} , RQD, k_{rm}
Strong Rock (Vuggy Limestone)	strong, brittle rock	q_u
Massive Rock	rock mass described by the Hoek–Brown criterion	σ_{ci} , m_i , v , GSI, E_i or E_{rm}
Calcareous Rock (weak carbonate rock)	brittle carbonate rock, q_u about 0.5 to 5 MPa	q_u , residual friction angle φ_r , displacement factor after peak
Calcareous Sand (CPT)	cemented calcareous sand and weak calcareous sandstone	CPT tip resistance q_c , stiffness factor SF
Other		
Piedmont Residual	residual soils of weathered rock	initial modulus or a field test (SPT, CPT, DMT, PMT)
Loess	loess, 1 to 10 load cycles	CPT tip resistance q_c
Silt (Cemented Soils)	soils with cohesion and friction	c , φ' , ε_{50} , k
Elastic Subgrade	linear springs, checks and special cases	subgrade modulus k_h
User-input p-y curves	curves measured or derived elsewhere	table of (y, p) points

The **Enhanced sand option** of Sand (Reese) and API Sand scales the initial stiffness of the curves with depth and pile diameter; for piles whose diameter differs from the test piles behind the original models, and lets you enter K_0 and the wedge angle. An entry of zero keeps the default of each parameter.

7.3.1 Default values

For several models, a value of zero for ε_{50} or for the subgrade modulus k means “use the default”. Solpile then assigns a value from the soil strength (and, for sand, from the friction angle and the position relative to the water table). The default rules are given in the Technical Reference, *Section 5.13*. Strength parameters (c_u , φ' , q_u , σ_{ci} , q_c , subgrade modulus) have no default: a value of zero means that the layer gives no lateral resistance, and the model check reports it.

7.3.2 Parameters that vary with depth

Where a parameter of a layer varies with depth, divide the layer into thinner layers, each with its own material. Within a layer Solpile uses the material parameters of that layer at every node.

7.3.3 User-input p-y curves

A user-input p-y material is a table of at least two (y, p) points that starts at $y = 0$ and has strictly increasing y . Between points the curve is linear; beyond the last point p is constant. The same curve is used at every node of the layers to which the material is assigned.

7.4 Assigning materials

In **Assign** select the material of each layer. Labels L1, L2, ... on the canvas correspond to the layer numbers of the table. A layer without a material stops the analysis.

7.5 Ground slope and pile batter

When **Include Pile Batter and/or Ground Slope** is selected, the ground slope angle and the pile batter angle are entered in **Slope & Batter**. The angles reduce or increase the ultimate resistance of the shallow soil wedge according to the direction of loading. Clearing **Slope is in the direction of loading** mirrors the ground slope only (the slope rises in the direction of loading); the pile batter angle is kept as entered. Separate slope angles can be given for the two sides of the pile. For a battered pile, soil properties are taken at the vertical depth of each node, and the pile-head height above the ground is measured vertically.

7.6 p-y modification factors

The p-multiplier P_m and y-multiplier Y_m scale the p-y curves:

$$p'(y) = P_m p\left(\frac{y}{Y_m}\right) \quad (7.1)$$

They are entered as a table against depth below the ground surface and interpolated linearly between rows. Above the first row and below the last row both multipliers are 1.0. Multipliers are used mainly to represent the reduction of resistance of piles in a group (shadowing), or other effects not covered by the p-y model. P_m must be zero or positive, Y_m positive.

7.7 Tip and side resistance

For short, large-diameter shafts the resistance at the base and the moment of the vertical side shear can matter. Three optional tables are available:

- **Shear-resistance curve at pile tip** — shear force against lateral tip deflection;
- **Moment-resistance curve at pile tip** — moment against tip rotation (radians);
- **Side resistance along pile** — ultimate unit side friction against depth. The moment that it produces is mobilised with the local rotation of the pile (Technical Reference, Section 5.14).

Each table must start at zero movement and increase from row to row.

7.8 Output depths and elevation shift

Output Depths lists the depths below the pile head at which p-y curves are reported in the results and the report. Depths must lie between the ground surface and the pile tip. In the same step, **Shift Pile Elevation in Soil Profile** moves the pile downwards (positive) or upwards (negative) in the soil profile without changing the layer thicknesses; this allows the same soil profile to be used with different pile-head levels. **View Elevations Report** lists the layer boundaries as depths below the pile head, or as elevations relative to a datum when the ground-surface elevation is entered.

8 Describing the actions

8.1 Pile-head load cases

A load case defines the two boundary conditions at the pile head and the axial thrust. Five types of head condition are available (Figure 8.1, Table 8.1). Up to 100 load cases can be entered; each is analysed independently.

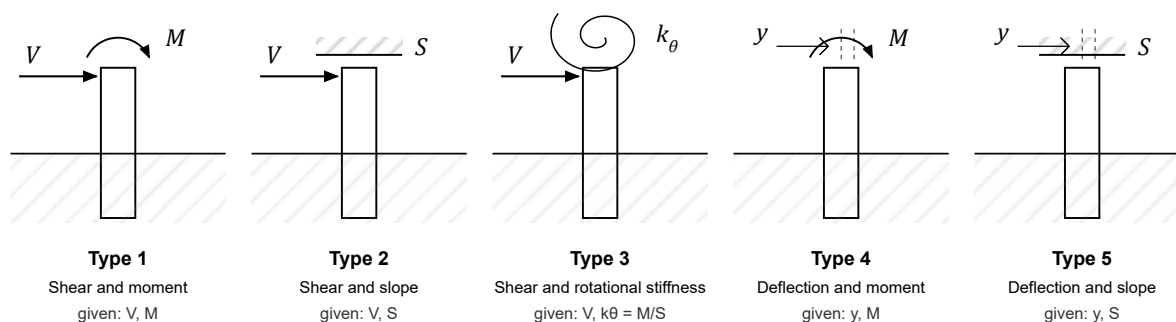


Figure 8.1 — Types of pile-head condition

Table 8.1 — Pile-head conditions

Type	Condition 1	Condition 2	Typical use
1	shear V	moment M	free head ($M = 0$) or known head moment
2	shear V	slope S (rad)	fixed head ($S = 0$) or known rotation
3	shear V	rotational stiffness $k_\theta = M/S$	head restrained by a cap or a structure of known stiffness
4	deflection y	moment M	imposed head displacement
5	deflection y	slope S	imposed displacement and rotation

The axial thrust P (compression positive) is entered with each load case. It produces the P - Δ moment when that option is on, and it governs the bending properties of nonlinear sections.

NOTE A fully fixed head is modelled with type 2 and a slope of zero. A head that is partially restrained by a pile cap is better modelled with type 3, with a rotational stiffness taken from the structure.

8.2 Loads along the pile

Three kinds of load act along the pile. Each can be defined once for all load cases or separately for each load case; entering data switches the corresponding load on.

Table 8.2 — Loads along the pile

Load	Definition
Distributed lateral load	Load intensity (force per length) against depth below the pile head, linear between points. For example wave, current or earth pressure on the free length.
Lateral soil movement	Free-field soil displacement against depth. The p - y curves act on the difference between pile deflection and soil movement. In layers of massive rock, Piedmont residual soil and loess the movement changes the soil stiffness but applies no load, and in strong rock it is ignored (Technical Reference, Section 5.15).
Concentrated loads	Lateral force and moment at a depth below the pile head. A load between nodes is shared by the two adjacent nodes.

8.3 Load-test data

Measured load-test data can be entered in **Load Test** for comparison with the computed response. Each row is one load level with its pile-head shear and deflection; for each level a bending-moment profile and a deflection profile against depth can be added. **Read/Save Load Test Data** exchanges the data as .LTData load-test files (converted to the project units). The data are plotted with the results when display is selected, and do not affect the analysis.

8.4 LRFD loads and combinations

In LRFD mode the load cases of the Loading step are replaced by unfactored loads and load combinations:

1. **Unfactored loads.** Each load has a category (DL, LL, EQ, IM, W, HW, Ice, Hs, Lr, Rn, Sn, Tm or Sp), a shear, a moment and an axial force at the pile head, and optionally a distributed lateral load.
2. **Load combinations.** Each combination has a load factor for every category and two resistance factors: ϕ for flexure and ϕ for shear. Combinations can be saved to and loaded from .lrfdc files.
3. **Capacity check.** **F9** (or **Run Capacity Check (M & V)**) analyses each factored combination and compares the developed moment and shear of every section with ϕM_n and ϕV_n .

The factored loads of combination i are

$$(V, M, P)_i = \sum_c \gamma_{i,c} \sum_{j \in c} (V_j, M_j, P_j) \quad (8.1)$$

where $\gamma_{i,c}$ is the factor of category c in combination i . LRFD checks need a moment capacity: use nonlinear sections, or elastic sections with a specified moment capacity. The shear capacity V_n is the value entered for the section; with **Estimate Resistance Factors and Shear Capacity** (reinforced-concrete sections) Solpile computes V_n and the resistance factors following ACI 318 (Technical Reference, LRFD check).

9 Checking and running the model

9.1 Model check

Before every analysis Solpile checks the model. The check can also be called on its own from the **Analysis** step (**Model Summary**) or with the command `check`. Each finding has a level and a code:

Table 9.1 — Levels of model-check findings

Level	Meaning
Error	The model cannot be analysed as it is: for example a section without bending stiffness, a layer without a material, a soil profile that ends above the pile tip. The analysis is not started.
Warning	The model can be analysed, but an input is outside the documented range of a model or a combination of options has a consequence the user should know. The analysis runs; the warning is listed again in the run notes and in the report.
Note	Information about how Solpile interprets the input.

The codes, their meaning and the action to take are listed in Appendix C.

9.2 Running the analysis

Press **[F9]** or select **Analysis ▶ Run Analysis**. The analysis runs in the background. If it lasts longer than half a second a progress window appears with a **Cancel** button; cancelling discards the partial results and leaves the project unchanged. While an analysis runs, the main window does not accept input, so that the results always belong to the project that was analysed.

In conventional mode the run analyses all load cases and the special analyses that are switched on in the Loading step. In LRFD mode, run the capacity check from the LRFD step. In *Nonlinear EI only* mode, the run computes the section properties only.

9.3 Convergence and numerical control

For each load case Solpile repeats the solution of the beam-column equation with updated secant soil moduli (and updated bending stiffness for nonlinear sections) until the largest change of nodal deflection between two iterations is smaller than the convergence tolerance. Three outcomes are possible:

Table 9.2 — Outcome of a load case

Outcome	Meaning and action
Converged	Results are available.
Deflection limit exceeded	The head deflection exceeded the deflection limit. The lateral capacity of the soil is exceeded, or the pile is unstable under the axial thrust. Reduce the load or review the soil strengths. Raising the deflection limit does not create capacity.
Did not converge	The iteration limit was reached. Increase the iteration limit or the number of increments; check for very soft layers, discontinuous p-y curves (strong rock, user curves) or loads near the capacity.

Load cases without a solution are reported after the run; the other load cases keep their results. The convergence history of every load case is listed in **Analysis ▶ View Processor Run Notes**.

The finite-difference solution converges with the square of the increment length (Technical Reference, *Section 8.3*). With the default of 100 increments the error from discretisation is typically a few tenths of a per cent in head deflection. Use more increments when the pile is short in relation to its relative stiffness, when thin layers or many sections must be resolved, or when a result is needed at a precise depth.

10 Special analyses

Special analyses are set up and switched on in the **Loading** step. Each one has its own controls; switched-on analyses are computed with **F9** together with the load cases, or individually with their **Run** button.

10.1 Pile-head stiffness

Computes the lateral stiffness terms of the pile head for use in a structural model of the superstructure. Because the soil is nonlinear, the stiffness depends on the load level, and Solpile computes it at a series of load levels up to the shear and moment of load case 1 (or up to a stated head deflection and rotation):

- $K_{22} = V/y$ and $K_{32} = M/y$, from analyses with an applied shear and zero head rotation;
- $K_{23} = V/\theta$ and $K_{33} = M/\theta$, from analyses with an applied moment and zero head deflection.

The load levels are spaced arithmetically or logarithmically. Load case 1 must be of type 1 with non-zero shear and moment.

10.2 Pushover analysis

Imposes increasing head deflections and records the head shear, the maximum moment and its depth, for a free (pinned) head, a fixed head, or both. For nonlinear sections the moment–curvature relation at the pushover axial thrust is used, and the formation of plastic hinges is reported. The deflections are spaced arithmetically, logarithmically, or entered by the user. **Show values** lists the deflections that will be computed; 2 to 101 steps are accepted, and the loading direction applies to the generated deflections only.

With the method **Based on loading of Load Case 1**, the loads of load case 1 are multiplied by a series of factors from a minimum to a maximum value, and each factor is analysed with the head condition of load case 1; a factor of 1 gives load case 1.

10.3 Buckling analysis

Keeps a lateral head load constant and increases the axial thrust from a minimum to a maximum value. The head deflection grows without bound as the thrust approaches the buckling load. Solpile fits a hyperbola to the computed thrust–deflection points and reports its asymptote as the estimated buckling load (Technical Reference, *Section 7.3*). The lateral head load must not be zero.

10.4 Head deflection versus pile length

Repeats the analysis for a series of pile lengths, from a maximum length down to a minimum length, and reports the head deflection, maximum moment and maximum shear for each length. The plot shows the length below which the head deflection starts to increase: the *critical length*. A longer pile does not reduce the head deflection significantly. The sweep can also be requested for an individual load case of type 1, 2 or 3.

The sweep has its own head loading: shear with moment, slope or rotational stiffness, or a specified head displacement with moment or slope (the input boxes follow the selected condition); if both values are zero, load case 1 is used. With **enter number of pile lengths** the first $N-1$ lengths step down from the maximum by the increment and the last length is the minimum; when you press OK the increment is set to $(\text{maximum} - \text{minimum})/(N-1)$, so the lengths are evenly spaced. One length analyses the minimum length only. With **enter pile length increment** the number of lengths is set to $(\text{maximum} - \text{minimum})/\text{increment} + 1$ and the lengths step down from the maximum; the minimum itself is not added. With **Manual — enter pile lengths** the lengths are typed in a list and analysed from the longest to the shortest. **Use total pile length** takes the maximum length from the pile sections. The automatic settings accept 2 to 20 lengths. Lengths of zero or less are skipped. A pile length larger than the defined pile extends the lowest section, and the lengths are measured from the pile head. The soil profile must reach the tip of the longest pile, and at least one length must be analysed; a maximum below the minimum or a zero increment is analysed as entered, with a warning.

10.5 Shear demand along the pile

Estimates the moment and shear that a pile used to stabilise a slope has to carry when the soil above a sliding surface moves. Solpile repeats the analysis for a series of sliding-surface depths below the pile head. For each depth the soil above it moves by the entered profile, either linear from the ground surface to the pile tip or a table of depths and movements, and the soil below does not move; the pile head carries the load entered for this analysis. The results give, for each depth, the head deflection, rotation, shear and moment, the moment and shear at the sliding surface and the maximum moment. Use them together with a slope stability analysis, which gives the resistance the piles must provide.

10.6 Interaction diagram

For nonlinear sections, Solpile computes the nominal moment capacity at each axial thrust listed in **Model ▶ Axial Thrust Loads for Interaction Diagram** and plots the axial force–moment interaction diagram, nominal and, if requested, factored. The **Load Case Demand Interaction Diagram** of a conventional analysis adds one point per load case to the diagram of each section: the axial thrust and the largest moment within the section.

11 Results

11.1 Results on the canvas

After a run the **Results / Graphics** step shows the deflection, bending moment, shear force and soil reaction of all load cases against depth (Figure 4.1). The scale of each panel is labelled with its maximum and minimum values.

11.2 Result charts

Results ► **Results / Graphics** opens the list of available charts. Double-click a chart to display it. Table 11.1 lists the charts; charts of special analyses appear when those analyses were run.

Table 11.1 — Charts

Chart	Content
Input data	
Pile-Soil Geometry	Pile sections, layers and water table
p-y Curves	The generated p-y curves at the output depths
Distributed Lateral Loads, p and y Modifiers, Lateral Soil Movement vs. Depth	Input profiles, when defined
Moment–curvature, EI–moment, interaction diagram	For nonlinear sections
Computed results	
Deflection, Moment, Shear, Soil Reaction, Slope, Curvature, Total Stress vs. Depth	Response profiles of all load cases
Mobilized EI vs. Depth	Bending stiffness used in the final iteration
Soil Modulus Es vs. Depth	Secant modulus of the p-y curves at the computed deflection
4-panel and 3-panel charts	Combined profiles for reports
Summary charts	Head deflection and maximum moment against head shear, one point per load case
Soil Movement & Pile Deflection	Imposed soil movement and pile deflection on one axis
Special analyses	Stiffness terms, pushover curves, buckling curve, head deflection vs. length, LRFD demand vs. capacity

11.3 p-y curves at output depths

The p-y curves generated at the output depths can be displayed as charts and printed in the report as tables. They are generated at the requested depths by the same rules as the curves used in the analysis, including the effects of layering, slope and multipliers.

An example of p-y curves at three output depths is shown in Figure 15.2.

11.4 Checking the results

Solpile solves the model that it is given. Whether that model represents the pile and the ground is a matter of engineering judgement. The following checks are recommended for every analysis that will be relied upon.

Table 11.2 — Checks of the results

No.	Check	What to look for
1	Input echo	View Input Text File and the report reproduce the model as entered: sections and their computed properties, unit weights, layers, water table and soil parameters. Where a default is requested (an entry of zero), check its effect in the generated p-y curves at the output depths.

No.	Check	What to look for
2	Warnings	Every warning in the run notes is understood and accepted.
3	Equilibrium	The integral of the soil reaction over the pile equals the head shear, and its moment equals the head moment plus the P-Δ moment (see the worked example, Section 15.1.5).
4	Deflected shape	For a long pile, the deflection decays to practically zero above the tip. If the tip deflects significantly the pile behaves as a short (rigid) pile; check that the tip conditions and the deep soil are modelled correctly.
5	Mobilisation of the soil	Compare the deflections near the ground surface with the characteristic deflection of the p-y curves (for example y_{50} of clay models). Deflections far beyond the range of the model indicate that the soil near the surface is fully mobilised.
6	Structural capacity	For elastic sections, compare the maximum moment with the moment capacity of the real section. For nonlinear sections, check whether the curvature exceeded the computed moment–curvature curve (warning CURVATURE - LIMIT).
7	Sensitivity	Vary the governing soil parameters within their credible range and check the effect on the design values.
8	Independent check	Compare with a simple independent method, such as the closed-form solution for a pile in elastic soil, or with measured behaviour of comparable piles.

12 Reports and data exchange

12.1 Report export

Results ▸ Export Report / Tables opens the report builder (Figure 12.1). Select the report sections, model views, result charts, special-analysis charts and p-y depths; the preview follows the selection. The report can be exported as:

- **Word** (.docx) — text, tables and figures, for editing and incorporation into a design report;
- **PDF** — for issue;
- **Excel** (.xlsx) — tables only, each on its own sheet, with numbers stored as numbers.

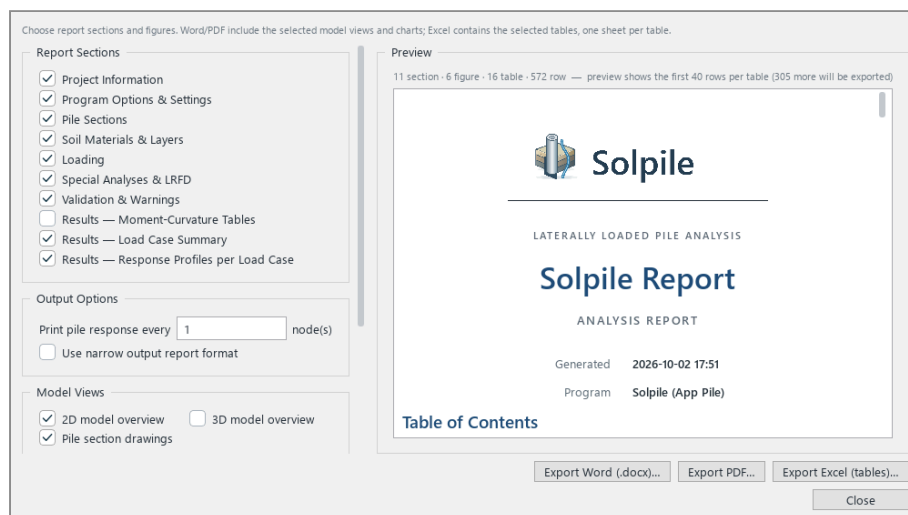


Figure 12.1 — Report builder

Table 12.1 — Report sections

Section	Content
Project Information	Identification of the project
Program Options & Settings	Mode, units, loading, numerical control, options
Pile Sections	Sections, dimensions, materials, computed properties
Soil Materials & Layers	Materials, layers, water table, effective stresses
Loading	Load cases and loads along the pile
Special Analyses & LRFD	Controls and results of the special analyses
Validation & Warnings	Findings of the model check and of the run
Moment-Curvature Tables	Moment–curvature data of nonlinear sections (off by default)
Load Case Summary	Head deflection, maximum moment and shear of every load case
Response Profiles	Deflection, slope, moment, shear, soil reaction and stiffness against depth; the printing interval and a narrow format can be chosen
Generated p-y Curves	p-y tables at the output depths (off by default)

12.2 Other exports

- **File ▸ Export PNG** saves the canvas as an image.
- The command export (Chapter 14) writes all results as JSON, a load-case summary as CSV, or any of the report formats.
- Tables in the data windows can be copied to and pasted from spreadsheets (tab-separated).

13 Multi-file analysis

Tools ▸ Multi-File Analysis (Batch Run) analyses several saved projects one after the other, without opening them and without changing the open project. Each file is checked as with **F9**; files with input errors are reported and skipped. LRFD projects are analysed for their load combinations. The result table lists for each file the number of load cases, the maximum head deflection and moment of the load cases with a solution (with their units), and the status, and can be saved as CSV. **Cancel** stops after the current file. The files are not modified. The file list can be saved and opened again as a text file (**Save List / Open List**); one run holds at most 100 files.

14 Automation

14.1 One command language, four entry points

Every operation on a model can also be expressed as a text command. The same command language is used in four places:

Table 14.1 — Entry points of the command language

Entry point	Use
Command Line window	Inside the program; acts on the open project and appears in its undo history
Scripts	Python or any other language calls the command-line tool and reads its JSON export; parameter studies, integration with other tools
Command-line tool	<code>solpile run check exec script shell</code> ; batch files and scheduled jobs
MCP server	<code>solpile mcp</code> ; AI assistants that support the Model Context Protocol

Scripts, the command-line tool and the MCP server do not need the graphical interface. They work on their own copy of a project in memory and never change an open Solpile window. The use of these interfaces is subject to the licence (EULA, clause 5).

Three rules apply everywhere:

1. Items of a collection are numbered **from 1**: `sections[1]` is the first section.
2. Values are in the project's **base units** (SI: kN, m, kPa; US: lbs, in, psi); `units` lists the labels. The display units of the GUI (ft, psf, pcf, kips) do not apply to commands.
3. Every change is one undo step and discards earlier results.

14.2 Commands

Table 14.2 — Commands

Command	Purpose
<code>help [command]</code>	List the commands, or explain one
<code>new [SI US] · open <file> · save [file]</code>	Project files; saving is atomic
<code>info · status</code>	Project summary; session state as JSON
<code>units [SI US]</code>	Show unit labels, or convert the project
<code>get <path></code>	Read a value: <code>get options.loading_type</code> , <code>get sections[1].params</code>
<code>set <path> <value> ...</code>	Change values: <code>set water_table_depth 1.5</code>
<code>list [collection]</code>	List a collection, or the collection names
<code>add <collection> key=value ...</code>	Append an item
<code>insert <collection> <n> key=value ...</code>	Insert before item <i>n</i>
<code>edit <collection> <n> key=value ...</code>	Change item <i>n</i>
<code>delete <collection> <n></code>	Remove item <i>n</i>
<code>types sections soils loads collections</code>	Available section types, p-y models, head conditions
<code>fields section <type> · fields soil <model></code>	Parameter keys, units, defaults and limits
<code>check</code>	Model check
<code>run</code>	Analyse (load cases and switched-on special analyses, or the LRFD combinations)
<code>special pushover buckling stiffness varlen lrfd sheardemand</code>	Run one special analysis
<code>results · profile [lc] [every=n]</code>	Load-case summary; response against depth

Command	Purpose
py <depth> [points=n]	p-y curve at a depth below the pile head
mphi [section] [axial] · interaction [section]	Moment–curvature; interaction diagram
export <file>	.xlsx .docx .pdf report, .json all results, .csv summary, .lpx copy of the project
undo · redo	Undo or redo the last change

The Command Line window adds three commands that act on the window: fit, clear and data <n> (open data step n). Values that contain spaces are quoted: set info.title "Pier 3, abutment A". File names with spaces must be quoted as well.

14.2.1 Collections

Table 14.3 — Collections

Name	Items	Name	Items
sections	pile sections, head to tip	modifiers	p-y multipliers against depth
soils	soil materials	outdepths	p-y output depths
layers	soil layers, top down	tipshear	tip shear curve
loads	pile-head load cases	tipmoment	tip moment curve
dist	distributed load segments	sideres	side resistance table
movements	soil movement profile	lrfdloads	LRFD unfactored loads
conc	concentrated loads	lrfdcases	LRFD combinations
thrusts	axial thrusts for the interaction diagram	loadtest	load-test points

Shortcuts in add and edit: sections take type= and their parameters directly; soils take model= and gamma= (sets both unit weights); layers take soil= (number or name); load cases take type=1..5, v1=, v2= and axial=.

14.2.2 Example session

```
new SI
edit sections 1 type=steel_pipe length=20 diameter=610 wall_thickness=12.7 fy=355000
edit soils 1 model=soft_clay cu=20 eps50=0.02 gamma=17
edit layers 1 thickness=22 soil=1
set water_table_depth 1.5
edit loads 1 type=1 v1=100 v2=0 axial=500
add loads type=2 v1=200 v2=0 axial=500
check
run
results
profile 1 every=10
py 4
export "pile_study.xlsx"
```

14.3 Scripts (Python and other languages)

A script drives Solpile by calling the command-line tool (Section 14.4) with a sequence of commands and reading the results from an exported .json file: status, units, summary (one row per load case: lc, y_top, M_max, z_M_max, ...), profiles (depth, y, slope, moment, shear, soil reaction, Es, EI per load case), special and findings. A command that fails ends the tool with exit code 1, so the script can stop on it. A parameter study in Python:

```
import json, subprocess

for cu in (15, 20, 25, 30):
    subprocess.run(["solpile", "exec", "open pile.lpx", f"edit soils 1 cu={cu}", "run", "export r.json"],
                   check=True)
    r = json.load(open("r.json", encoding="utf-8"))["summary"][0]
    print(f"cu = {cu:4.0f} kPa    y_top = {r['y_top']*1000:6.1f} mm    M_max = {r['M_max']:7.1f} kN·m")
```

For longer sequences, write the commands to a text file and run `solpile script commands.txt`.

14.4 Command-line tool

```
solpile                open the program
solpile pile.lpx       open the program with a project
solpile run pile.lpx --out report.xlsx check, analyse, print the summary, export
solpile check pile.lpx model check only
solpile exec "open pile.lpx" "edit loads 1 v1=150" "run" "export r.json"
solpile script commands.txt one command per line, # starts a comment
solpile shell pile.lpx  interactive prompt
```

Add `--json` for machine-readable output. The exit code is 0 on success, 1 when a command fails or the model has input errors, and 3 when `solpile run` finished but one or more load cases have no solution, so that batch files can test it.

14.5 MCP server for AI assistants

The MCP server lets an AI assistant that supports the Model Context Protocol build, run and read Solpile models. It is headless: it works on its own copy of the project and never touches the Solpile window. It is part of the installation; register it with the assistant, for example with Claude Code:

```
claude mcp add solpile -- solpile mcp
```

Table 14.4 — MCP tools

Tool	Function
<code>solpile_status</code>	Session state
<code>solpile_project</code>	new, open, save, info, units
<code>solpile_model</code>	get, set, list, add, insert, edit, delete, types, fields
<code>solpile_check</code>	Model check
<code>solpile_run</code>	Analysis or a special analysis
<code>solpile_results</code>	summary, profile, p-y curve, moment–curvature, interaction, special results, findings
<code>solpile_export</code>	Report or data export
<code>solpile_command</code>	Any text command

WARNING An AI assistant can make mistakes in building a model or in reading results. Treat a model built by an assistant like a model built by a colleague: review the input echo and the warnings, and check the results (Section 11.4) before relying on them. Project data passed to an external assistant is subject to the terms of that service.

15 Worked examples

The two examples below show a complete analysis from input to checked result. All numbers in this chapter were computed with Solpile 1.0.0; the project files Example1.lpx and Example2.lpx are supplied with the documentation so that the results can be reproduced. The soil data are illustrative and are not taken from a real site.

15.1 Example 1 — Steel pipe pile in layered soil

15.1.1 Problem

A steel pipe pile, 610 mm in outside diameter with a 12.7 mm wall, 20 m long, supports a lateral load at its head, which is at the ground surface. The soil consists of 3 m of soft clay over 9 m of medium dense sand over stiff clay. The water table is 1.5 m below the ground surface. The axial load is 500 kN. Three load cases are analysed: a free head with 100 kN and 200 kN of lateral load, and a fixed head (zero rotation) with 200 kN. The loading is static.

Table 15.1 — Example 1 — pile

Item	Value
Section type	Steel Pipe Section
Outer diameter / wall thickness	610 mm / 12.7 mm
Length / free length above ground	20 m / 0 m
Yield stress f_y / modulus E	355 MPa / 200 GPa

Table 15.2 — Example 1 — soil profile (water table 1.5 m below the ground surface)

Layer	Depth (m)	p-y model	$\gamma / \gamma_{\text{sat}}$ (kN/m ³)	Parameters
1	0 – 3	Soft Clay (Matlock)	16.5 / 17.0	$c_u = 20$ kPa, $\epsilon_{50} = 0.02$
2	3 – 12	Sand (Reese)	18.0 / 19.5	$\phi' = 33^\circ$, $k = 0$ (default)
3	12 – 22	Stiff Clay with Free Water	19.0 / 19.5	$c_u = 100$ kPa, $\epsilon_{50} = 0$ and $k = 0$ (defaults)

15.1.2 Input

- Program Options:** Conventional analysis, SI, static loading; the analysis-control values are left at their defaults (100 increments).
- Pile Sections:** one section of type **Steel Pipe Section** with the data of Table 15.1; **Pile Length Above Ground** = 0.
- Geometry:** three layers of 3, 9 and 10 m; water table elevation –1.5 m.
- Soil Parameters:** three materials as in Table 15.2. **Assign:** material 1 to layer 1, and so on.
- Output Depths:** 1, 4 and 8 m.
- Loading:** load cases of type 1 ($V = 100$ kN, $M = 0$), type 1 ($V = 200$ kN, $M = 0$) and type 2 ($V = 200$ kN, $S = 0$), each with an axial thrust of 500 kN.
- Run with **F9**. The model check reports no findings.

15.1.3 Results

Table 15.3 — Example 1 — summary of results

Load case	Head deflection (mm)	Head slope (rad)	Max. moment (kN·m)	Depth of max. moment (m)	Iterations
LC1 — free head, $V = 100$ kN	15.64	–0.00457	227.0	3.6	15
LC2 — free head, $V = 200$ kN	42.44	–0.01142	536.7	3.8	16

Load case	Head deflection (mm)	Head slope (rad)	Max. moment (kN·m)	Depth of max. moment (m)	Iterations
LC3 — fixed head, $V = 200$ kN	10.75	0	-458.2	0.0	13

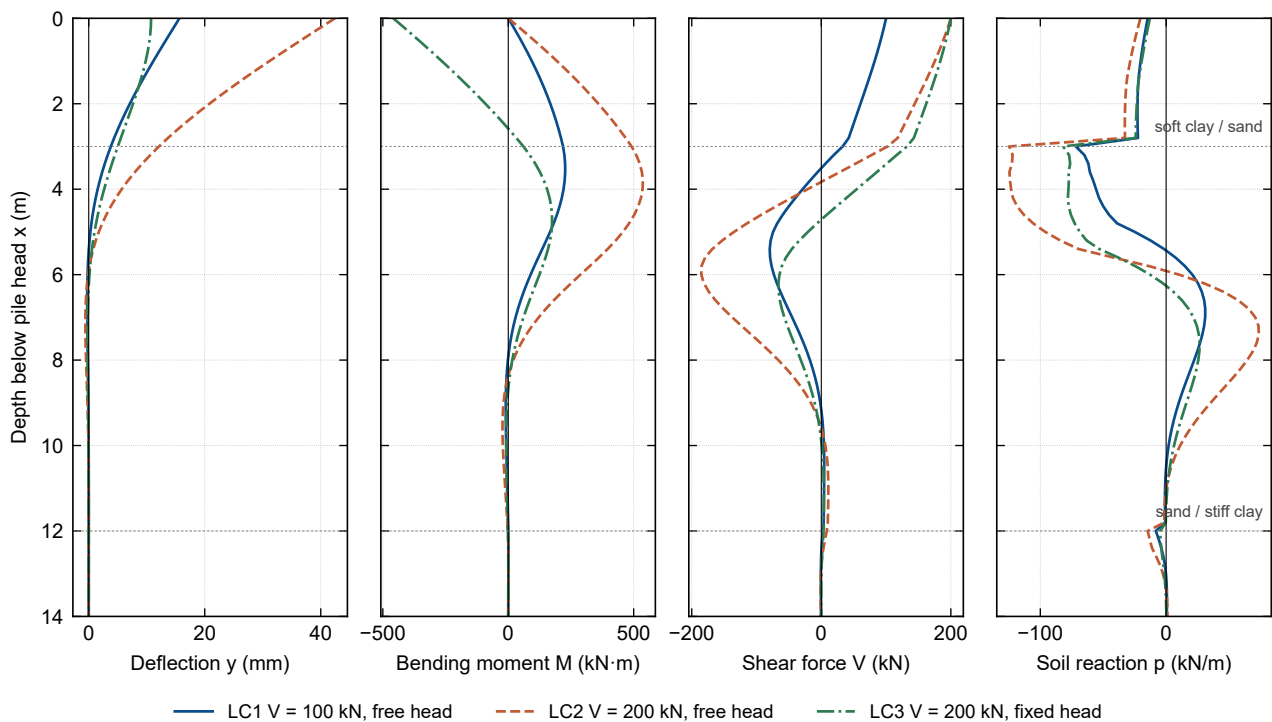


Figure 15.1 — Example 1 — response profiles (upper 14 m of the pile)

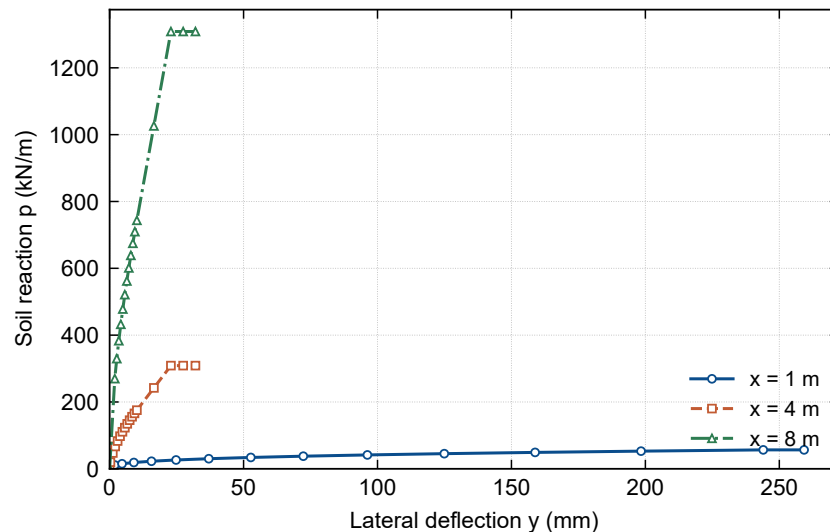


Figure 15.2 — Example 1 — p-y curves at the output depths

15.1.4 Interpretation

- **Nonlinearity.** Doubling the free-head load from 100 to 200 kN increases the head deflection by a factor of about $0.04244/0.01564 \approx 2.7$ and the maximum moment by a factor of about 2.4. The soft clay near the surface is close to its ultimate resistance, so the load is carried increasingly by the sand below, and the point of maximum moment moves down.
- **Head fixity.** Fixing the head against rotation reduces the head deflection under 200 kN to about a quarter, but moves the largest moment to the head, where it has the opposite sign. The connection to the cap must be

designed for this moment.

- **Layer boundaries.** The soil reaction changes abruptly at 3 m, where the soft clay meets the much stiffer sand, and the deflection below about 8 m is practically zero: the pile is long in relation to its stiffness and behaves as a flexible pile.
- **Structural capacity.** The largest moment, 537 kN·m, is well below the first-yield moment of the section, $f_y \cdot I / (D/2) = 1238 \text{ kN}\cdot\text{m}$. The section therefore remains elastic.

15.1.5 Equilibrium check

The soil reactions must balance the loads at the head. With the depth x measured from the head, the conditions of horizontal force and moment equilibrium for the whole pile are

$$V_0 + \int_0^L p \, dx = 0 \quad (15.1)$$

$$\int_0^L p \, x \, dx - M_0 - P(y_0 - y_L) = 0 \quad (15.2)$$

where the last term is the moment of the axial thrust P acting through the relative displacement of head and tip (P-Δ effect). Table 15.4 shows the two conditions evaluated from the computed profiles by numerical integration.

Table 15.4 — Example 1 — global equilibrium of the computed solution

Load case	V_0 (kN)	$\int p \, dx$ (kN)	M_0 (kN·m)	$\int p \, x \, dx$ (kN·m)	$P(y_0 - y_L)$ (kN·m)	Residual, moment (kN·m)
LC1	100.00	−100.00	0.00	7.82	7.82	−4.7e−10
LC2	200.00	−200.00	0.00	21.22	21.22	−3.4e−10
LC3	200.00	−200.00	−458.19	−452.81	5.38	1.5e−10

The residuals are at the level of rounding, which confirms that the solution is in equilibrium. A check of this kind takes a few minutes with the exported profiles and is recommended for any result that will be relied upon.

15.2 Example 2 — Bored pile with nonlinear bending stiffness

15.2.1 Problem

A bored pile of 1.0 m diameter and 24 m length is reinforced with 20 bars of 25 mm diameter (cover 75 mm) and a spiral. The concrete strength is 30 MPa and the yield stress of the bars 420 MPa. The upper 6 m of soil is a stiff clay above the water table, below which a dense sand extends to depth. Two load cases are analysed at a service level and at twice that level, each with an axial thrust of 2500 kN.

Table 15.5 — Example 2 — input

Item	Value
Section	Round Concrete Shaft (Bored Pile), $D = 1000 \text{ mm}$, $L = 24 \text{ m}$
Concrete	$f_c = 30 \text{ MPa}$ (other properties derived)
Reinforcement	20 bars, custom size: area 490.87 mm^2 , diameter 25 mm; cover 75 mm; $f_y = 420 \text{ MPa}$
Layer 1, 0 – 6 m	Stiff Clay without Free Water: $c_u = 75 \text{ kPa}$, $\varepsilon_{50} = 0.007$; $\gamma = 18.5 \text{ kN/m}^3$
Layer 2, 6 – 28 m	API Sand: $\phi' = 36^\circ$, k default; $\gamma_{\text{sat}} = 20.0 \text{ kN/m}^3$
Water table	6 m below the ground surface
Load cases (type 1)	LC1: $V = 300 \text{ kN}$, $M = 150 \text{ kN}\cdot\text{m}$; LC2: $V = 600 \text{ kN}$, $M = 300 \text{ kN}\cdot\text{m}$; $P = 2500 \text{ kN}$
Thrusts for the interaction diagram	0, 2500 and 5000 kN

15.2.2 Section response

Solpile computes the moment–curvature relation of the section at the axial thrust of the load cases (Figure 15.3). The uncracked bending stiffness is $1556 \text{ MN}\cdot\text{m}^2$. At a moment of about $647 \text{ kN}\cdot\text{m}$ the concrete cracks and the stiffness falls; the curve then rises to the nominal moment capacity.

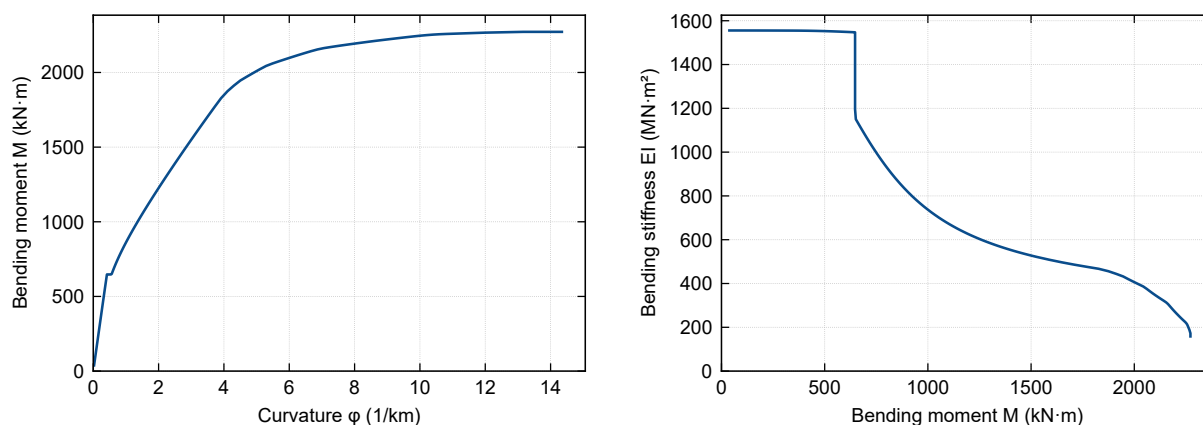


Figure 15.3 — Example 2 — moment–curvature relation and bending stiffness at $P = 2500$ kN

Table 15.6 — Example 2 — nominal moment capacity (interaction diagram)

Axial thrust (kN)	M_n (kN·m)
0	1560
2500	2248
5000	2732

15.2.3 Results

Table 15.7 — Example 2 — summary of results

Load case	Head deflection (mm)	Max. moment (kN·m)	Depth (m)	Lowest EI along the pile (MN·m²)	Iterations
LC1	6.17	623	3.12	1548	27
LC2	46.46	1479	3.60	533	35

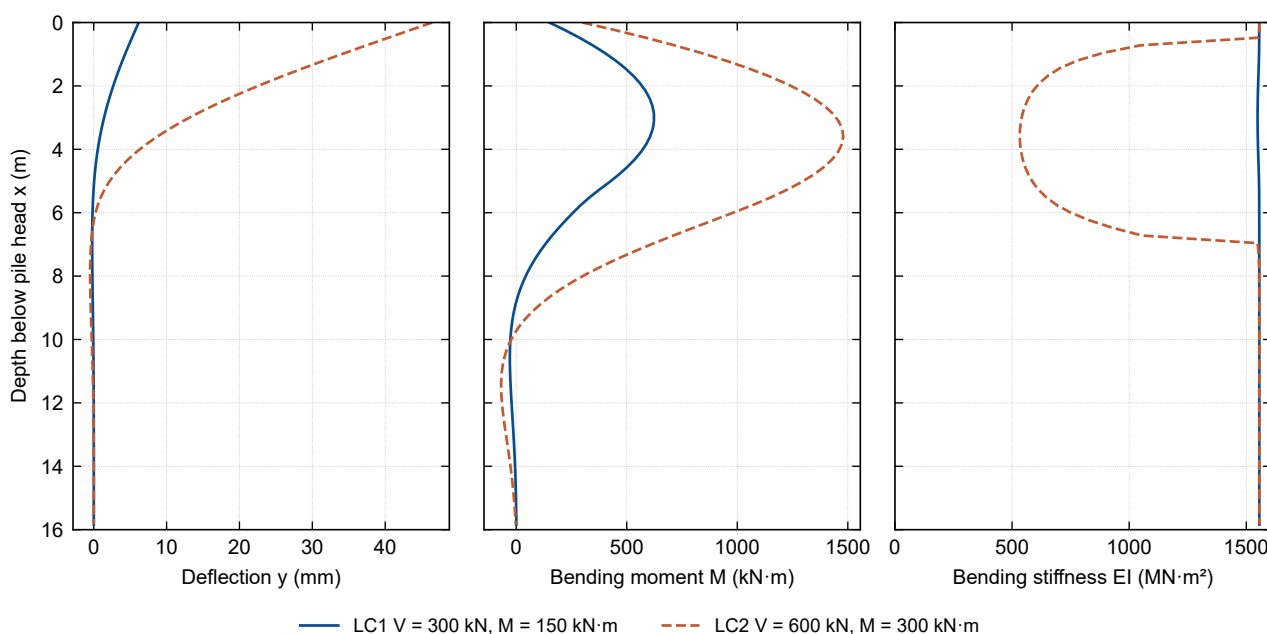


Figure 15.4 — Example 2 — deflection, moment and bending stiffness (upper 16 m)

15.2.4 Interpretation

- Under LC1 the largest moment stays below the cracking moment, the bending stiffness is practically the uncracked value over the whole pile, and the response is almost linear.
- Under LC2 the moment exceeds the cracking moment over a zone of several metres around the point of maximum moment. There the stiffness falls to about a third of its uncracked value. Doubling the load therefore

increases the head deflection by a factor of about $0.04646/0.006174$, far more than the factor of two of a linear analysis. An analysis with the uncracked stiffness would underestimate the deflection.

- The maximum moment of LC2, 1479 kN·m, is below the nominal capacity at 2500 kN, 2248 kN·m. For a design check, the factored moment must be compared with the factored capacity required by the applicable code, or the LRFD mode used.

Appendix A Section types and parameters

This appendix lists the parameters of every section type as they appear in the section window, with the key used in commands (Chapter 14), the unit in each unit system, the default value of a new section in an SI project and the accepted range. The tables are generated from the parameter registry of Solpile 1.0.0.

A.1 Elastic Section (Non-yielding)

Command key: `elastic`. No defined moment capacity. Default section type.

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>length</code>	Length of Section	m	in	0	≥ 0
<code>structural_shape</code>	Structural Shape	—	—	circular	list (12 options)
<code>aisc_family</code>	AISC Family	—	—	—	list (13 options)
<code>aisc_size</code>	AISC Section	—	—	—	list (0 options)
<code>diameter</code>	Section Diameter	mm	in	0	≥ 0
<code>struct_diameter</code>	Pole Diameter	mm	in	0	≥ 0
<code>wall_thickness</code>	Casing/Wall Thickness	mm	in	0	≥ 0
<code>width</code>	Section Width	mm	in	0	≥ 0
<code>depth</code>	Section Depth	mm	in	0	≥ 0
<code>flange_thickness</code>	Flange Thickness	mm	in	0	≥ 0
<code>web_thickness</code>	Web Thickness	mm	in	0	≥ 0
<code>corner_radius</code>	Corner Radius	mm	in	0	≥ 0
<code>stiffener_length</code>	Stiffener Length	mm	in	0	≥ 0
<code>stiffener_thickness</code>	Stiffener Thickness	mm	in	0	≥ 0
<code>auto_props</code>	Auto-compute Area & Inertia from dimensions	—	—	yes	yes / no
<code>area</code>	Area	mm ²	in ²	0	≥ 0
<code>inertia</code>	Moment of Inertia	mm ⁴	in ⁴	0	≥ 0
<code>elastic_mod</code>	Elastic Mod.	kPa	psi	0	≥ 0
<code>shear_cap</code>	Shear Capacity	kN	lbs	0	≥ 0

A.2 Elastic Section with Specified Moment Capacity

Command key: `elastic_mcap`. Elastic-perfectly-plastic via specified plastic moment capacity.

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>length</code>	Length of Section	m	in	0	≥ 0
<code>structural_shape</code>	Structural Shape	—	—	circular	list (12 options)
<code>aisc_family</code>	AISC Family	—	—	—	list (13 options)
<code>aisc_size</code>	AISC Section	—	—	—	list (0 options)
<code>diameter</code>	Section Diameter	mm	in	0	≥ 0
<code>struct_diameter</code>	Pole Diameter	mm	in	0	≥ 0
<code>wall_thickness</code>	Casing/Wall Thickness	mm	in	0	≥ 0
<code>width</code>	Section Width	mm	in	0	≥ 0
<code>depth</code>	Section Depth	mm	in	0	≥ 0
<code>flange_thickness</code>	Flange Thickness	mm	in	0	≥ 0
<code>web_thickness</code>	Web Thickness	mm	in	0	≥ 0
<code>corner_radius</code>	Corner Radius	mm	in	0	≥ 0
<code>stiffener_length</code>	Stiffener Length	mm	in	0	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
stiffener_thickness	Stiffener Thickness	mm	in	0	≥ 0
plas_mom_cap	Plas. Mom. Cap.	kN·m	in·lbs	0	≥ 0
auto_props	Auto-compute Area & Inertia from dimensions	—	—	yes	yes / no
area	Area	mm ²	in ²	0	≥ 0
inertia	Moment of Inertia	mm ⁴	in ⁴	0	≥ 0
elastic_mod	Elastic Mod.	kPa	psi	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0

A.3 Rectangular Concrete Section

Command key: rect_concrete

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
width	Section Width	mm	in	457.2	≥ 0
depth	Section Depth	mm	in	406.4	≥ 0
fc	Compressive Strength, f _c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
plain_no_rebars	Plain Concrete – No Rebars	—	—	no	yes / no
fy	Yield Stress, f _y	kPa	psi	4.1369e+05	≥ 0
Es	Elastic Modulus, E _s	kPa	psi	1.9995e+08	≥ 0
continue_above	Continue Rebar Pattern and Size from Section Above	—	—	no	yes / no
bar_size	Bar Size	—	—	US Std. #8	list (149 options)
bar_dia	Bar Diameter	mm	in	0	≥ 0
bar_area_manual	Edit bar area manually	—	—	no	yes / no
bar_area	Bar Area	mm ²	in ²	0	≥ 0
pattern	Rebar Pattern	—	—	circle	list (3 options)
num_bars	Number of Bars	—	—	0	≥ 0
n_x	Number of Bars X	—	—	3	≥ 2
n_y	Number of Bars Y	—	—	3	≥ 2
bundle	Bar/Bundle Options	—	—	single	list (3 options)
cover	Concrete Cover to Edge of Bar	mm	in	76.2	≥ 0
ring2	Use second layer of reinforcement	—	—	no	yes / no
ring2_num_bars	Number of Bars 2nd layer	—	—	0	≥ 0
ring2_dist	Rebar Dist. (outer to inner layer, c/c)	mm	in	0	≥ 0
offset_enabled	Offset Reinforcement Pattern from Centroid	—	—	no	yes / no
offset	Offset	mm	in	0	
tr_type	Rebar Type	—	—	hoop	list (2 options)
tr_bar_size	Bar Size	—	—	US Std. #4	list (148 options)
tr_spacing	Spacing of Transv. Reinf.	mm	in	152.4	≥ 0
tr_fy	Yield Stress of Trans. Reinf.	kPa	psi	4.1369e+05	≥ 0
n_trans	Number of Transverse Reinf.	—	—	1	0 – 300
n_legs_x	Number of Legs X	—	—	2	0 – 300

Key	Parameter	SI unit	US unit	Default (SI)	Range
n_legs_y	Number of Legs Y	—	—	2	0 – 300
confined	Consider Confined Concrete (Mander et al. 1988)	—	—	no	yes / no
strain_harden	Use Strain Hardening (longitudinal)	—	—	no	yes / no
fu_fy	f_u / f_y	—	—	1.25	≥ 1
esh	ϵ_{sh} (strain at hardening)	—	—	0.0125	≥ 0
esu	ϵ_{su} (ultimate strain)	—	—	0.09	≥ 0

A.4 Round Concrete Shaft (Bored Pile)

Command key: round_concrete

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Section Diameter	mm	in	914.4	≥ 0
fc	Compressive Strength, f_c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
plain_no_rebars	Plain Concrete – No Rebars	—	—	no	yes / no
fy	Yield Stress, f_y	kPa	psi	4.1369e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
continue_above	Continue Rebar Pattern and Size from Section Above	—	—	no	yes / no
bar_size	Bar Size	—	—	US Std. #8	list (149 options)
bar_dia	Bar Diameter	mm	in	0	≥ 0
bar_area_manual	Edit bar area manually	—	—	no	yes / no
bar_area	Bar Area	mm ²	in ²	0	≥ 0
pattern	Rebar Pattern	—	—	circle	list (2 options)
num_bars	Number of Bars	—	—	0	≥ 0
bundle	Bar/Bundle Options	—	—	single	list (3 options)
cover	Concrete Cover to Edge of Bar	mm	in	76.2	≥ 0
ring2	Use second layer of reinforcement	—	—	no	yes / no
ring2_num_bars	Number of Bars 2nd layer	—	—	0	≥ 0
ring2_dist	Rebar Dist. (outer to inner layer, c/c)	mm	in	0	≥ 0
offset_enabled	Offset Reinforcement Pattern from Centroid	—	—	no	yes / no
offset	Offset	mm	in	0	
tr_type	Rebar Type	—	—	spiral	list (2 options)
tr_bar_size	Bar Size	—	—	US Std. #4	list (148 options)
tr_spacing	Spacing of Transv. Reinf.	mm	in	152.4	≥ 0
tr_fy	Yield Stress of Trans. Reinf.	kPa	psi	4.1369e+05	≥ 0
n_trans	Number of Transverse Reinf.	—	—	1	0 – 300
confined	Consider Confined Concrete (Mander et al. 1988)	—	—	no	yes / no
strain_harden	Use Strain Hardening (longitudinal)	—	—	no	yes / no
fu_fy	f_u / f_y	—	—	1.25	≥ 1
esh	ϵ_{sh} (strain at hardening)	—	—	0.0125	≥ 0
esu	ϵ_{su} (ultimate strain)	—	—	0.09	≥ 0

A.5 Round Concrete Shaft with Permanent Casing

Command key: round_casing

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Section Diameter (casing OD)	mm	in	914.4	≥ 0
casing_wall	Casing Wall Thickness	mm	in	12.7	≥ 0
casing_fy	Casing Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
casing_Es	Casing Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
fc	Compressive Strength, f _c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
plain_no_rebars	Plain Concrete – No Rebars	—	—	no	yes / no
fy	Yield Stress, f _y	kPa	psi	4.1369e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
continue_above	Continue Rebar Pattern and Size from Section Above	—	—	no	yes / no
bar_size	Bar Size	—	—	US Std. #8	list (149 options)
bar_dia	Bar Diameter	mm	in	0	≥ 0
bar_area_manual	Edit bar area manually	—	—	no	yes / no
bar_area	Bar Area	mm ²	in ²	0	≥ 0
pattern	Rebar Pattern	—	—	circle	list (2 options)
num_bars	Number of Bars	—	—	0	≥ 0
bundle	Bar/Bundle Options	—	—	single	list (3 options)
cover	Concrete Cover to Edge of Bar	mm	in	76.2	≥ 0
ring2	Use second layer of reinforcement	—	—	no	yes / no
ring2_num_bars	Number of Bars 2nd layer	—	—	0	≥ 0
ring2_dist	Rebar Dist. (outer to inner layer, c/c)	mm	in	0	≥ 0
offset_enabled	Offset Reinforcement Pattern from Centroid	—	—	no	yes / no
offset	Offset	mm	in	0	

A.6 Round Shaft with Casing and Core/Insert

Command key: round_casing_core

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Section Diameter (casing OD)	mm	in	914.4	≥ 0
casing_wall	Casing Wall Thickness	mm	in	12.7	≥ 0
core_type	Core/Insert Type	—	—	steel_pipe	list (10 options)
core_filled	Fill Core with Concrete	—	—	no	yes / no
core_diameter	Core/Insert Outer Diameter	mm	in	457.2	≥ 0
core_wall	Core Wall Thickness	mm	in	12.7	≥ 0
core_aisc_family	Core AISC Family	—	—	HP	list (14 options)
core_aisc_size	Core AISC Section	—	—	—	list (0 options)
core_depth	Core Section Depth	mm	in	0	≥ 0
core_bf	Core Flange Width	mm	in	0	≥ 0
core_tf	Core Flange Thickness	mm	in	0	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
core_tw	Core Web Thickness	mm	in	0	≥ 0
casing_fy	Casing Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
casing_Es	Casing Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
core_fy	Core Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
core_Es	Core Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
fc	Compressive Strength, f _c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
plain_no_rebars	Plain Concrete – No Rebars	—	—	no	yes / no
fy	Yield Stress, f _y	kPa	psi	4.1369e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0
continue_above	Continue Rebar Pattern and Size from Section Above	—	—	no	yes / no
bar_size	Bar Size	—	—	US Std. #8	list (149 options)
bar_dia	Bar Diameter	mm	in	0	≥ 0
bar_area_manual	Edit bar area manually	—	—	no	yes / no
bar_area	Bar Area	mm ²	in ²	0	≥ 0
pattern	Rebar Pattern	—	—	circle	list (2 options)
num_bars	Number of Bars	—	—	0	≥ 0
bundle	Bar/Bundle Options	—	—	single	list (3 options)
cover	Concrete Cover to Edge of Bar	mm	in	76.2	≥ 0
ring2	Use second layer of reinforcement	—	—	no	yes / no
ring2_num_bars	Number of Bars 2nd layer	—	—	0	≥ 0
ring2_dist	Rebar Dist. (outer to inner layer, c/c)	mm	in	0	≥ 0
offset_enabled	Offset Reinforcement Pattern from Centroid	—	—	no	yes / no
offset	Offset	mm	in	0	

A.7 Steel Pipe Section

Command key: steel_pipe

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Outer Diameter	mm	in	609.6	≥ 0
wall_thickness	Wall Thickness	mm	in	12.7	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.8 Steel H Section Strong Axis

Command key: steel_h_strong

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
depth	Section Depth	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
web_thickness	Web Thickness	mm	in	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.9 Steel H Section Weak Axis

Command key: steel_h_weak

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
depth	Section Depth	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	2.4821e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.10 Steel C Section (Strong Axis)

Command key: steel_c

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
depth	Section Depth	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
corner_radius	Corner Radius	mm	in	0	≥ 0
stiffener_length	Stiffener Length	mm	in	0	≥ 0
stiffener_thickness	Stiffener Thickness	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	3.4474e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.11 Steel T Section (Weak Axis)

Command key: steel_t

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
depth	Section Depth	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	3.4474e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.12 Steel Box Section

Command key: steel_box

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
depth	Section Depth	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
corner_radius	Corner Radius	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	3.4474e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.13 Steel AISC Section Strong Axis

Command key: aisc_strong

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
aisc_family	AISC Family	—	—	HP	list (14 options)
aisc_size	AISC Section	—	—	—	list (0 options)
depth	Section Depth	mm	in	0	≥ 0
wall_thickness	Wall Thickness	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
area	Area	mm ²	in ²	0	≥ 0
inertia	Moment of Inertia	mm ⁴	in ⁴	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	3.4474e+05	≥ 0
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.14 Steel AISC Section Weak Axis

Command key: aisc_weak

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
aisc_family	AISC Family	—	—	HP	list (14 options)
aisc_size	AISC Section	—	—	—	list (0 options)
depth	Section Depth	mm	in	0	≥ 0
wall_thickness	Wall Thickness	mm	in	0	≥ 0
flange_width	Flange Width	mm	in	0	≥ 0
flange_thickness	Flange Thickness	mm	in	0	≥ 0
web_thickness	Web Thickness	mm	in	0	≥ 0
area	Area	mm ²	in ²	0	≥ 0
inertia	Moment of Inertia	mm ⁴	in ⁴	0	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
fy	Yield Stress, f _y	kPa	psi	3.4474e+05	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
Es	Elastic Modulus, Es	kPa	psi	1.9995e+08	≥ 0

A.15 Round Prestressed Concrete

Command key: round_ps

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Diameter	mm	in	609.6	≥ 0
fc	Compressive Strength, f'c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.16 Round Prestressed Concrete with Void

Command key: round_ps_void

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Diameter	mm	in	609.6	≥ 0
void_diameter	Diameter of Core Void	mm	in	304.8	≥ 0
fc	Compressive Strength, f'c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.17 Square Prestressed Concrete

Command key: square_ps

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
width	Width	mm	in	457.2	≥ 0
chamfer	Corner Chamfer	mm	in	25.4	≥ 0
fc	Compressive Strength, f'c	kPa	psi	27579	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.18 Square Prestressed Concrete with Void

Command key: square_ps_void

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
width	Width	mm	in	457.2	≥ 0
chamfer	Corner Chamfer	mm	in	25.4	≥ 0
void_diameter	Diameter of Core Void	mm	in	254	≥ 0
fc	Compressive Strength, f _c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.19 Octagonal Prestressed Concrete

Command key: oct_ps. Corner chamfer computed internally to form the octagon.

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
width	Width (across flats)	mm	in	457.2	≥ 0
fc	Compressive Strength, f _c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no

Key	Parameter	SI unit	US unit	Default (SI)	Range
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.20 Octagonal Prestressed Concrete with Void

Command key: oct_ps_void. Corner chamfer computed internally to form the octagon.

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
width	Width (across flats)	mm	in	457.2	≥ 0
void_diameter	Diameter of Core Void	mm	in	254	≥ 0
fc	Compressive Strength, f_c	kPa	psi	27579	≥ 0
agg_max	Max. Coarse Aggregate Size	mm	in	19.05	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
strand_type	Prestressing Strand Type	—	—	g300	list (7 options)
strand_size	Strand/Bar Size	—	—	1/2" 7-wire A=0.153	list (25 options)
n_strands	Number of Strands/PS Bars	—	—	8	0 – 150
ps_force	Prestress Force Before Losses	kN	lbs	0	≥ 0
ps_loss_frac	Fraction of Loss of Prestress	—	—	0.15	0 – 1
ps_cover	Cover Over Strands	mm	in	38.1	≥ 0
ps_auto	Automatically position strand	—	—	yes	yes / no
ps_pattern	Strand Pattern	—	—	circle	list (3 options)

A.21 User Defined Non-linear Bending Section

Command key: user_nonlinear. User supplies nonlinear bending data per axial thrust: choose the data type, add axial thrust values, then enter the curve for each thrust.

Key	Parameter	SI unit	US unit	Default (SI)	Range
length	Length of Section	m	in	0	≥ 0
diameter	Width/Diameter (for p-y)	mm	in	609.6	≥ 0
shear_cap	Shear Capacity	kN	lbs	0	≥ 0
mphi_type	Type of Nonlinear Bending Input Data	—	—	m_vs_phi	list (2 options)

A.22 Options tab (all section types)

These keys belong to every section, for example set `sections[1].params.use_eq_diameter_py` yes.

Key	Parameter	SI unit	US unit	Default (SI)	Range
adjust_softening	Adjust Softening of Moment Curvature	—	—	yes	yes / no
caltrans_eq	Compute Equivalent Elastoplastic Moment Curvature (CALTRANS)	—	—	no	yes / no
estimate_resistance	Estimate Resistance Factors and Shear Capacity	—	—	no	yes / no
use_eq_diameter_py	Use Equivalent Diameter for p-y Calculations	—	—	no	yes / no
eq_diameter_py	Equivalent Diameter	mm	in	0	≥ 0
eq_diameter_py_bottom	Equivalent Diameter at Bottom	mm	in	0	≥ 0

Appendix B Soil models and parameters

Parameters of the p-y models, generated from the registry of Solpile 1.0.0. Every soil material also has the total unit weights γ (above the water table, key `gamma_unsat`) and γ_{sat} (below it, key `gamma_sat`). A default of zero for ϵ_{50} or k means that Solpile assigns a value (Section 7.2).

B.1 Soft Clay (Matlock)

Command key: `soft_clay`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, c_u	kPa	psi	0	≥ 0
eps50	Strain factor, ϵ_{50}	—	—	0	0 – 0.2

B.2 API Soft Clay (user-defined J)

Command key: `api_soft_clay_j`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, c_u	kPa	psi	0	≥ 0
eps50	Strain factor, ϵ_{50}	—	—	0	0 – 0.2
J	Empirical constant, J	—	—	0.5	0 – 1

B.3 Stiff Clay with Free Water (Reese)

Command key: `stiff_clay_fw`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, c_u	kPa	psi	0	≥ 0
eps50	Strain factor, ϵ_{50}	—	—	0	0 – 0.2
k	Subgrade modulus, k ($E_s = k \cdot x$)	kN/m ³	pci	0	≥ 0

B.4 Stiff Clay without Free Water (Reese)

Command key: `stiff_clay_nfw`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, c_u	kPa	psi	0	≥ 0
eps50	Strain factor, ϵ_{50}	—	—	0	0 – 0.2

B.5 Modified Stiff Clay without Free Water

Command key: `mod_stiff_clay_nfw`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, c_u	kPa	psi	0	≥ 0
eps50	Strain factor, ϵ_{50}	—	—	0	0 – 0.2
k	Subgrade modulus, k ($E_s = k \cdot x$)	kN/m ³	pci	0	≥ 0

B.6 ISO Clay (ISO 19901-4)

Command key: `iso_clay`

Key	Parameter	SI unit	US unit	Default (SI)	Range
cu	Undrained shear strength, s_u	kPa	psi	0	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
test_type	Type of strength test	—	—	dss	list (6 options)
gapping	Gapping effect	—	—	auto	list (3 options)
PI	Plasticity index, PI	—	—	0	0 – 200
OCR	Over-consolidation ratio, OCR	—	—	1	1 – 100
te_ratio	TE/DSS strength ratio	—	—	0	0 – 2
z_rot	Depth of rotation (cyclic)	m	in	0	≥ 0
design	Design condition (cyclic)	—	—	gom	list (3 options)

B.7 Sand (Reese)

Command key: sand_reese

Key	Parameter	SI unit	US unit	Default (SI)	Range
phi	Friction angle, ϕ'	—	—	0	0 – 60
k	Subgrade modulus, k ($E_s = k \cdot x$)	kN/m ³	pci	0	≥ 0
enhanced	Enhanced sand option	—	—	no	yes / no
alpha	Wedge angle, α	—	—	0	0 – 45
K_0	Earth pressure coefficient, K_0	—	—	0	0 – 3
m	Depth exponent of Epy, m	—	—	0	0 – 3
n	Diameter exponent of Epy, n	—	—	0	0 – 3

B.8 API Sand (O'Neill)

Command key: api_sand

Key	Parameter	SI unit	US unit	Default (SI)	Range
phi	Friction angle, ϕ'	—	—	0	0 – 60
k	Subgrade modulus, k ($E_s = k \cdot x$)	kN/m ³	pci	0	≥ 0
enhanced	Enhanced sand option	—	—	no	yes / no
alpha	Wedge angle, α	—	—	0	0 – 45
K_0	Earth pressure coefficient, K_0	—	—	0	0 – 3
m	Depth exponent of Epy, m	—	—	0	0 – 3
n	Diameter exponent of Epy, n	—	—	0	0 – 3

B.9 Small Strain Sand

Command key: small_strain_sand

Key	Parameter	SI unit	US unit	Default (SI)	Range
phi	Friction angle, ϕ'	—	—	0	0 – 60
k	Subgrade modulus, k ($E_s = k \cdot x$)	kN/m ³	pci	0	≥ 0
G_0	Small-strain shear modulus, G_0	kPa	psi	0	≥ 0
a	Constant a	—	—	0.8	0 – 5
b	Constant b	—	—	1	0 – 5
e	Option 2 · void ratio, e	—	—	0	≥ 0
Cu	Option 2 · uniformity coefficient, Cu	—	—	0	≥ 0

B.10 Liquefied Sand (Rollins)

Command key: `liquefied_sand`. No strength parameters are needed: this is an empirical p-y curve for fully liquefied sand (Rollins et al. 2005), and it depends only on depth and pile diameter. The unit weights set the equivalent depth when the liquefied layer lies below other soil. Recommended down to 6 m (20 ft). If you have SPT or residual strength data, use the Liquefied Sand Hybrid model instead.

No parameters: the curve is entered as a table of points (user-input p-y) or computed from depth alone.

B.11 Liquefied Sand Hybrid Model

Command key: `liquefied_sand_hybrid`

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>pu_res</code>	Residual undrained shear strength, S_{ur}	kPa	psi	0	≥ 0
<code>n160cs</code>	$(N_1)_{60-CS}$	—	—	0	0 – 60
<code>eps50</code>	ϵ_{50} (residual)	—	—	0.02	0.0005 – 0.5

B.12 Weak Rock (Reese)

Command key: `weak_rock`

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>qu</code>	Uniaxial compressive strength, q_u	kPa	psi	0	≥ 0
<code>Eir</code>	Initial mass modulus, E_{ir}	kPa	psi	0	≥ 0
<code>rqd</code>	Rock quality designation, RQD	—	—	0	0 – 100
<code>krm</code>	Strain factor, k_{rm}	—	—	0.0005	5e-05 – 0.0005

B.13 Strong Rock (Vuggy Limestone)

Command key: `strong_rock`

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>qu</code>	Uniaxial compressive strength, q_u	kPa	psi	0	≥ 0

B.14 Piedmont Residual

Command key: `piedmont`

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>piedmont_test</code>	Field-test input	—	—	direct	list (5 options)
<code>Em</code>	Initial p-y modulus, E_{si}	kN/m ³	pci	0	≥ 0
<code>spt_n60</code>	Corrected SPT blow count, N_{60}	—	—	0	≥ 0
<code>cpt_qc</code>	Cone tip resistance, q_c	kPa	psi	0	≥ 0
<code>dmt_ed</code>	Dilatometer modulus, E_{dmt}	kPa	psi	0	≥ 0
<code>pmt_ep</code>	Menard pressuremeter modulus, E_{pmt}	kPa	psi	0	≥ 0

B.15 Massive rock

Command key: `massive_rock`

Key	Parameter	SI unit	US unit	Default (SI)	Range
<code>sci</code>	Uniaxial compressive strength, σ_{ci}	kPa	psi	0	≥ 0
<code>mi</code>	Hoek-Brown index, m_i	—	—	10	4 – 32
<code>nu</code>	Poisson's ratio, ν	—	—	0.25	0 – 0.5
<code>gsi</code>	Geologic strength index, GSI	—	—	50	0 – 100
<code>Ei_intact</code>	Intact rock modulus, E_i	kPa	psi	0	≥ 0

Key	Parameter	SI unit	US unit	Default (SI)	Range
Er _m	Rock mass modulus, E _{rm}	kPa	psi	0	≥ 0

B.16 Loess

Command key: loess

Key	Parameter	SI unit	US unit	Default (SI)	Range
q _c	CPT cone tip resistance, q _c	kPa	psi	0	≥ 0

B.17 Silt (Cemented Soils)

Command key: silt_cemented

Key	Parameter	SI unit	US unit	Default (SI)	Range
c _u	Undrained shear strength, c _u	kPa	psi	0	≥ 0
φ _i	Friction angle, φ'	—	—	0	0 – 60
ε _{s50}	Strain factor, ε ₅₀	—	—	0	0 – 0.2
k	Subgrade modulus, k (E _s = k · x)	kN/m ³	pci	0	≥ 0

B.18 Calcareous Rock (weak carbonate rock)

Command key: calcareous_rock

Key	Parameter	SI unit	US unit	Default (SI)	Range
φ _{i_res}	Residual friction angle, φ _r	—	—	0	0 – 60
q _u	Uniaxial compressive strength, q _u	kPa	psi	0	≥ 0
f _{drop}	Displacement factor after peak	—	—	0	0 – 1

B.19 Calcareous Sand (CPT)

Command key: calcareous_sand

Key	Parameter	SI unit	US unit	Default (SI)	Range
q _c	CPT cone tip resistance, q _c	kPa	psi	0	≥ 0
s _f	Stiffness factor E _s /q _c	—	—	0	≥ 0

B.20 Elastic Subgrade

Command key: elastic_subgrade

Key	Parameter	SI unit	US unit	Default (SI)	Range
E _s	Subgrade reaction modulus, E _s	kN/m ³	pci	0	≥ 0

B.21 User-input p-y curves

Command key: user_py. Enter at least two p-y points. Rows are evaluated in the entered order; starting at y = 0 with increasing y is recommended.

No parameters: the curve is entered as a table of points (user-input p-y) or computed from depth alone.

Appendix C Model-check messages

The model check reports findings with a code. Errors (E) stop the analysis; warnings (W) do not. Some findings are issued after the run, when the result shows the condition.

Table C.1 — Codes of the model check

Code	Level	Condition	Action
Pile and sections			
PILE-LENGTH-ZERO	E	Total pile length is zero	Enter section lengths
SECTION-DIMENSION	E	A dimension, area or inertia is zero	Enter the dimension in Pile Sections
SECTION-MATERIAL	E	A material strength or modulus is zero	Enter the material property
SECTION-VOID	E	The void is not smaller than the section	Reduce the void or enlarge the section
ELASTIC-PROPS	E	An elastic section has no valid area, inertia or modulus	Correct the elastic properties
COVER-D2	E	The cover leaves no room for reinforcement	Reduce the cover
REBAR-MAX / BUNDLE-MAX	E	More than 300 bars, or more than 3 bars per bundle	Reduce the number
STRAND-MAX	E	More than 150 prestressing strands	Reduce the number
BAR-GT-PILE, BAR-GT-SECTION, STRAND-GT-SECTION	E	A bar or strand is larger than the section	Check the bar or strand size and the section dimensions
SECTION-CHAMFER	E	The corner chamfer exceeds half of the width	Reduce the chamfer
SECTION-CASING-WALL	E	The casing wall is not smaller than half of the casing diameter	Correct the wall thickness or the diameter
CONF-SPACING	E	Confined section without transverse spacing	Enter the spacing or switch confinement off
REBAR-OVERLAP	W	Bars on a circle overlap	Check bar number and size
MANUAL-BAR-EDGE	W	Manually placed bars touch the concrete face	Check the bar coordinates
CONF-MANUAL-DEGENERATE	W	Confinement combined with a manual bar layout	Check the moment–curvature curve
MPHI-EPS003	W	Peak moment reached before a concrete strain of 0.003	Check reinforcement or prestress
MPHI-POINT-LIMIT	W	Moment–curvature curve reached its point limit	Review the section at that thrust
CURVATURE-LIMIT	W	The computed curvature exceeds the moment–curvature curve (after the run)	The section is beyond its capacity; revise section or loads
SECTION-GEOMETRY	E	The plates of a steel C, T or box section do not fit together (thickness, corner radius or stiffener)	Check the plate dimensions
BAR-AREA-GT-SECTION	E	A bar area is larger than the section	Check the bar area and the number of bars
BAR-SIZE-UNKNOWN	E	A bar size is in neither the bar catalogue nor the custom rebar catalogue of this computer	Add the bar in Tools ▸ Edit Custom Rebar Data, or choose a catalogue size
PS-COVER-ZERO	E	The cover over the prestressing strands is zero	Enter a positive cover

Code	Level	Condition	Action
EQ-DIAMETER	E	Use Equivalent Diameter for p-y Calculations with an equivalent diameter that is not greater than zero	Enter the diameter in the Options tab, or clear the option
USERMPHI-EMPTY-CURVE, USERMPHI-ZERO-CURVATURE	E	A thrust of a user-defined nonlinear section without a bending curve, or a point with zero curvature and a non-zero moment	Complete or correct the curve
USERMPHI-ONE-THRUST	W	Bending data for one axial thrust only, while the analysis uses several axial loads	Enter curves for at least two thrusts
USERMPHI-THRUST-DIFF	W	User-defined nonlinear sections with different thrust values; those of the last section are used	Press OK in the first such section to copy its thrusts
Soil			
LAYER-NO-MATERIAL	E	A layer has no soil material	Assign a material
PROFILE-ABOVE-TIP	E	The soil profile ends above the pile tip	Extend the lowest layer
SOIL-STRENGTH-ZERO	E	A required strength parameter is zero	Enter positive strengths
SOIL-VALUE-NEGATIVE	E	A strength or modulus is negative	Enter zero or positive values
SOIL-NO-RESISTANCE	W	A layer gives no lateral resistance	Enter parameters or confirm intent
SSS-G ₀ -ZERO	W	Small Strain Sand without G ₀ ; the layer is computed as API Sand	Enter G ₀ , or select API Sand
SSS-G ₀ -LOW	W	G ₀ below 1 MPa (it is entered in kPa or psi)	Check the value, for example 90 MPa = 90,000 kPa
MODEL-UNAVAILABLE	E	A p-y model is not available	Choose another model
USERPY-POINTS	E	A user p-y table has fewer than two valid points	Complete the table
USERPY-ORDER	W	A user p-y table does not start at y = 0 or is not increasing	Reorder the table
SOFT-CU-HIGH, STIFF-FW-CU, STIFF-NFW-CU, MODSTIFF-CU, WEAKROCK-QU, SAND-PHI, API-PHI, VUGGY-QU-RANGE	W	A strength parameter lies outside the range of the test data behind the model	Check the parameter and the choice of model
SAND-KPHI, API-KPHI	W	Default k requested for a friction angle outside 29°–41°	Enter k explicitly
KRM-RANGE	E	Weak rock k_{rm} outside (0, 0.01]	Use 0.00005 to 0.0005
ROCK-MODULUS-RATIO, ROCK-MASS-MODULUS-RATIO	W	Unusual ratio of rock modulus to strength	Check the rock data
GAMMA-SOIL, GAMMA-ROCK	W	Unit weight outside the usual range for soil or rock	Check the unit weights
PIEDMONT-MASSIVE-NODE	E	The boundary between a Piedmont residual soil or hybrid liquefied sand layer and the massive rock directly below it falls exactly on a pile node	Adjust a layer thickness or the increment count slightly
LOESS-CYCLES	E	Loess with more than 10 cycles	Use 10 cycles or fewer
LOESS-ALL-LAYERS	W	All embedded layers use the loess model	Use another model for at least one layer
LIQ-DEPTH, LIQ-LAYER-DEPTH, LIQ-PY-NORMALIZED	W	Liquefied sand deeper than the recommended limit	Review the applicability
LIQ-HYBRID-SPT-SU	W	Both SPT and residual strength given for the hybrid model	The residual strength is used
SOIL-VALUE-BLANK	E	A soil parameter has no value	Enter the value

Code	Level	Condition	Action
PHI-VS-ANGLE	E	The ground slope, the pile batter or their combined angle is not smaller than the friction angle of a sand (larger than that of a cemented silt)	Increase the friction angle, or reduce the slope or batter
ENH-ALPHA	E	Enhanced sand with a wedge angle α of 45° or more	Enter α below 45°, or 0 for $\phi/2$
CALC-QU-RANGE	W	Calcareous rock with q_u outside 0.5–5 MPa	Check the strength and the choice of model
PIEDMONT-MASSIVE-PRINT	E	A p-y output depth lies exactly on the boundary between a Piedmont residual soil or hybrid liquefied sand layer and the massive rock below it	Move the output depth slightly
Options, modifiers, tip			
INCR-MIN / INCR-MAX	E	Fewer than 40 or more than 500 increments	Use 40 to 500 (100 or more recommended)
ITER-RANGE	E	Iteration limit outside 30–1000	Correct the limit
TOL-MAX	E	Convergence tolerance too large	Use a smaller tolerance
DEFL-ZERO	E	Deflection limit is zero	Enter a positive limit
CYCLES-RANGE	E	Number of cycles outside 2–5000	Correct the number of cycles
PYMULT-ABOVE-GROUND	E	First multiplier row above the ground surface	Start at the ground surface or deeper
PYMULT-P / PYMULT-Y	E	Negative p-multiplier, or y-multiplier not positive	Correct the multiplier
TIP-SHEAR-TABLE / TIP-MOMENT-TABLE	E	Tip table not starting at zero or not increasing	Correct the table
PYOUT-ABOVE-GROUND / PYOUT-BELOW-TIP	E / W	Output depth above the ground surface / below the tip	Use depths along the embedded pile
Loading and special analyses			
SEP-DIST-INCOMPLETE, SEP-MOVE-INCOMPLETE, SEP-CONC-INCOMPLETE	E	Loads along the pile defined per load case, but missing for some load cases	Define them for every load case, or use one definition for all
TOPY-BC	W	Length sweep requested for a load case with prescribed deflection	Use head type 1, 2 or 3
VARLEN-COUNT	E	Variable pile length with no length to analyse	Enter at least one length, or an increment
VARLEN-RANGE, VARLEN-INC	W	Maximum length not larger than the minimum, or a zero increment that repeats the same length	Check the length settings; pressing OK in the dialog derives the increment
VARLEN-PROFILE	E	The soil profile ends above the tip of the longest pile in the sweep	Extend the lowest layer or reduce the maximum length
KMAT-BC, KMAT-V0, KMAT-M0	E	Head stiffness needs load case 1 of type 1 with non-zero V and M	Correct load case 1
KMAT-STEPS, BUCK-STEPS, PUSH-STEPS, VARLEN-COUNT-MAX	E	Number of loading steps or pile lengths outside 2–101 (pushover steps and pile lengths: 1–101)	Enter a number in the range
KMAT-DIST, KMAT-LRFD	W	Head stiffness combined with distributed load or LRFD	Compute the stiffness separately
BUCK-PMIN, BUCK-PMAX, BUCK-PORDER, BUCK-NOLOAD, BUCK-PCAP	E	Invalid buckling thrust range, no lateral load, or thrust above the section capacity	Correct the buckling controls

Code	Level	Condition	Action
BUCK-PMAX-LIMITED	W	Maximum buckling thrust limited to the axial capacity	Accept or reduce the range
LRFD-FACTORS-ZERO	E	A combination has all factors zero	Enter load factors
LRFD-ELASTIC	W	LRFD check of an elastic section without moment capacity	Use a nonlinear section or a moment capacity
LRFD-DIST	W	Conventional distributed load in LRFD mode	Enter it on the LRFD loads
LRFD-CAPACITY	W	One or more combinations fail (after the run)	Review the failing combinations
ELASTIC-SHEAR-COMPLEX	W	Many soil layers combined with varying elastic geometry, shear deformation and cyclic loading, soil movement or concentrated loads	Results are computed; review them with particular care
LC-MAX, LRFD-LOADS-MAX, LRFD-CASES-MAX	E	More than 100 pile-head load cases, unfactored LRFD loads or LRFD combinations	Remove rows, or split the analysis into two projects
LC-NONE-RUN	W	Run Analysis is No for every load case	Set Run Analysis to Yes for the load cases to analyse
MOVE-ONE-POINT	E	A soil movement profile with a single point	Enter at least two points
MOVE-SIDERES	W	Soil movement combined with the side-resistance moment: the movement does not load the pile	Switch the side-resistance moment off if the movement is to load the pile
VARLEN-NOT-SET	W	Variable pile length without a maximum length; 100 % to 20 % of the pile length is used	Enter the lengths, or switch the option off
VARLEN-MANUAL-EMPTY	E	Manual variable pile lengths without a positive length	Enter the lengths
PUSH-LC1-NOLC, PUSH-LC1-FACTORS, PUSH-LC1-STEPS	E	Pushover by factors on load case 1 without load case 1, without a positive factor, or with more than 101 factors	Correct the pushover settings
SD-LENGTHS, SD-MOVE-EMPTY, SD-COUNT-MAX	E	Shear demand without a section length below the ground surface, without soil movement, or with more than 101 lengths	Correct the shear demand settings
SD-INC, SD-MOVE-ZERO	W	Shear demand with a zero length increment, or with zero soil movement at the surface and at the tip	Check the shear demand settings
LRFD-PHI-MOMENT, LRFD-PHI-SHEAR	E	A combination with a resistance factor of zero or below	Enter positive resistance factors
INPUT-DATA	E	A value in the project file cannot be read	Correct the indicated field
After the run			
RUN00009	E	No solution: the pile-head deflection exceeds the deflection limit	Check the loads and the soil; if they are correct, enlarge the pile
RUN00010	E	No solution: the iteration did not converge	Follow the advice shown with the message (iteration limit, tolerance, or a load beyond the capacity)
RUN00011	E	No solution: near-zero pivot, usually soil that cannot resist the load	Reduce the load, or enlarge the pile
RUN00028	E	No solution: no bending curve of a user-defined nonlinear section for the axial load of a load case	Check the thrust values against the axial loads
RUN00045, KMAT-NOSOL	E	Pile-head stiffness stopped at the iteration limit, or without solution at a loading step	Increase the iteration limit, or lower the loading of load case 1

Code	Level	Condition	Action
RUN00048, PUSHOVER-NOSOL	E	Pushover stopped at the iteration limit, or without solution at a step; earlier steps are reported	Increase the iteration limit, or lower the largest deflection
PUSHOVER-LC1-NOSOL	W	Pushover by factors on load case 1 stopped at a factor without solution	Lower the largest load factor
SHEARDEMAND-NOSOL	W	Some shear demand lengths have no converged solution	Check the soil movement and the loading for those lengths
VALIDATOR-ERROR	W	A result check of the report could not be completed	The results themselves are unaffected

Appendix D Keyboard shortcuts

Table D.1 — Keyboard shortcuts

Keys	Action
F9	Run Analysis
Ctrl+N · Ctrl+O	New project · Open project
Ctrl+S · Ctrl+Shift+S	Save · Save As
Ctrl+Z · Ctrl+Y	Undo · Redo
Ctrl+0 · Ctrl++ · Ctrl+-	Fit to View · Zoom In · Zoom Out
F5	Redraw
F1	Solpile Manuals
Ctrl+Q	Exit
Esc	Close a data window without applying its changes

Appendix E Symbols and terms

Table E.1 — Symbols

Symbol	Meaning	SI unit
b, D	pile width or diameter used for the p-y curves	m
c_u	undrained shear strength	kPa
E_s	secant modulus of the p-y curve, p/y	kN/m ²
EI	bending stiffness of the pile	kN·m ²
k	rate of increase of the initial p-y modulus with depth	kN/m ³
k_h	modulus of subgrade reaction (elastic subgrade model)	kN/m ³
M	bending moment	kN·m
p	soil reaction per unit length of pile	kN/m
p_u	ultimate soil reaction	kN/m
P	axial thrust, compression positive	kN
P_m, Y_m	p-multiplier, y-multiplier	—
q_u	uniaxial compressive strength of rock	kPa
S	slope of the pile axis, dy/dx	rad
V	shear force	kN
x	depth below the pile head	m
y	lateral deflection	m
y_{50}	deflection at half the ultimate soil reaction (clay models)	m
$\gamma, \gamma_{sat}, \gamma'$	total, saturated and effective unit weight	kN/m ³
ϵ_{50}	strain at half the maximum deviator stress	—
ϕ'	effective friction angle	°

Table E.2 — Terms

Term	Meaning
Free length	Length of pile above the ground surface
Head condition	The pair of boundary conditions at the pile head (Table 8.1)
Increment	One of the equal segments into which the pile is divided for the finite-difference solution
Layering correction	Adjustment of the p-y curves of a layer for the different layers above it
Load case	One independent analysis with its own head conditions and axial thrust
p-y curve	Soil reaction as a function of deflection at one depth
Section	A length of pile with uniform cross-section type and properties
Soil material	p-y model, unit weights and parameters, assignable to layers

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