

AXIAL PILE ANALYSIS · CAPACITY AND T-Z
METHOD

Sol-load

User Manual

Building, running and reporting axial pile analyses with
Sol-load.

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SPL-SL-002	Sol-load — User Manual	Building, running and reporting axial pile analyses with Sol-load.
SPL-SL-003	Sol-load — Technical Reference	Capacity methods, load-transfer curves, numerical solution and verification.
SPL-SL-004	Sol-load — Release Notes	Scope, requirements and known limitations of release 1.0.0.
SPL-SL-005	Sol-load — Third-Party Software Notices	Open-source components distributed with Sol-load and their licences.

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1 Introduction

1.1 Purpose and scope of this manual

This manual explains how to use Sol-load 1.0.0: how to describe a pile and the ground, how to choose the capacity methods and the load-transfer curves, how to run the analysis, and how to read, check and report the results. It is written for geotechnical and structural engineers who design piles. It assumes familiarity with axial pile design, but not with Sol-load.

The engineering model, the equations of each capacity method and load-transfer curve, and the verification of the program are described in the Technical Reference (SPL-SL-003). This manual refers to it where a choice in the program depends on the theory.

1.2 What Sol-load computes

Sol-load analyses one pile under axial load. It answers two questions, separately or together:

- **Capacity.** What axial load can the pile carry in compression or in uplift? Sol-load computes the shaft and tip resistance as a function of the penetration with one or more static methods (API, USACE, FHWA, Revised Lambda, user-defined resistances, and the CPT-based methods NGI, ICP, UWA and Fugro), and the design capacity on a nominal, allowable-stress (ASD) or load and resistance factor (LRFD) basis.
- **Load-settlement.** How does the pile move under a given load? Sol-load divides the pile into elements supported by nonlinear shaft springs (t-z curves) and a tip spring (Q-w curve), and solves the equilibrium of the pile for each load case. It reports the head and tip movement, the axial force, the pile movement and the shaft stress along the pile, and the load-settlement curve. A settlement profile of the soil can be applied to obtain downdrag (negative skin friction) and the neutral depth.

The two analyses share one model of the pile and the ground. In the combined mode the t-z and Q-w curves are scaled to the resistances of a chosen capacity method, so that the load-settlement curve approaches the computed capacity. CPT soundings can be imported and interpreted to fill soil parameters, and measured load-test data can be compared with the computed curve.

1.3 Conventions used in this manual

Table 1.1 — Typographic conventions

Convention	Meaning
File ▸ Open...	a menu command, a button or a field in the program
C:\Program Files\Solplan	a file, a folder or an address
F9	a key or a key combination
<i>t, z, Q, w</i>	a symbol of the Technical Reference

The figures show Sol-load with SI units. Notes marked as such contain information that prevents an error or explains a result that may otherwise look surprising.

1.4 Documentation set

Table 1.2 — Sol-load documents

No.	Title	Use
SPL-SL-001	End-User Licence Agreement	Terms of use, licence and session rules
SPL-SL-002	User Manual	This document
SPL-SL-003	Technical Reference	Capacity methods, load-transfer curves, numerical method, verification
SPL-SL-004	Release Notes	Content of the release, requirements, known limitations
SPL-SL-005	Third-Party Software Notices	Open-source components and their licences

2 Installation, licence and start-up

2.1 Requirements

Sol-load runs on 64-bit Windows 10 or Windows 11. The minimum and recommended configurations are listed in the Release Notes (SPL-SL-004). A display of at least 1280 × 720 pixels is needed so that every data window fits on the screen.

2.2 Installing

Install Sol-load with the Setup program supplied by Solplan (Sol-load-1.0.0-Setup.exe). Setup needs administrator rights and installs the program into C:\Program Files\Solplan\Sol-load. No separate Python installation is needed. Setup offers two options: to open .sload project files with Sol-load (on by default) and to create a desktop shortcut (off by default). The documentation is installed in the docs folder of the installation.

2.3 Licence and sign-in

Use of Sol-load is governed by the End-User Licence Agreement (SPL-SL-001). A Sol-load licence is separate from a licence of another Solplan program. The rules that affect daily work are these:

1. Each user signs in inside Sol-load with a personal solplan.id account: the e-mail address and password registered at solplan.id, or **Continue with Google**, which opens the browser to sign in there and confirm a short code. When the account holds more than one Sol-load licence, Sol-load asks which one to use.
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.
4. Sol-load 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 Sol-load 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

Licences and trials are managed under **Account ▶ Licences** at solplan.id. The type of the licence in use is shown on the right of the status bar. **Help ▶ Licence...** shows the account, the licence and its end date, and offers borrowing, returning and signing out.

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 Sol-load from the Start menu (**Solplan** ▶ **Sol-load**) or by double-clicking a .sload file. After the start screen, Sol-load asks you to sign in if no valid sign-in is stored. A new session starts with an empty SI project: one pile section, one soil, one layer and one load case, without dimensions, strengths or loads. Three filled projects are available under **File** ▶ **Input examples**; they are used in Chapter 13.

2.5 Files and folders

Table 2.2 — Files and folders used by Sol-load

File or folder	Content
*.sload	Project. A JSON text file in UTF-8 encoding, at most 20 MB. It contains the complete input, but no results: results are recomputed when the project is analysed.
*.srp	Soil-resistance file for a driving analysis in GRLWEAP (Section 12.2).
%APPDATA%\Geostruktur\Sol-load	User settings (settings.ini), the stored sign-in (encrypted for the Windows user) and the folder logs with the diagnostic log.

Saving is atomic: Sol-load writes a temporary file and replaces the previous file only when the write has succeeded. An interrupted save therefore never damages the existing project. When you close a project with unsaved changes, Sol-load asks whether to save them.

3 Modelling concepts

3.1 The analysis model

The pile is a straight member made of one or more sections stacked from the head to the tip. It may stand above the ground surface over a free length and may be inclined (battered). The ground consists of horizontal layers, each assigned to a soil material. Along the embedded length the pile is supported by shaft springs, and at the tip by a tip spring (Figure 3.1).

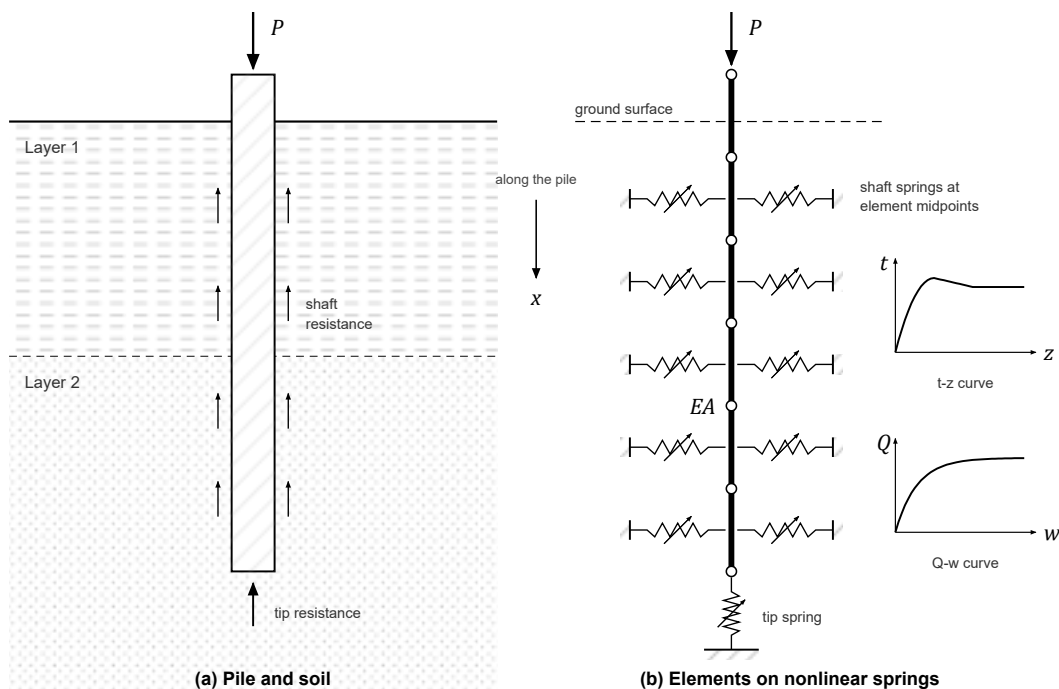


Figure 3.1 — Idealisation of an axially loaded pile

- A **t-z curve** gives the unit shaft resistance t (a stress on the pile surface) as a function of the movement z of the pile relative to the soil at that depth.
- A **Q-w curve** gives the tip force Q as a function of the tip movement w .

The curves are generated by Sol-load from the soil parameters and the load-transfer models, or entered as tables. The capacity analysis does not need the curves: it integrates the unit resistances of the chosen methods along the pile for each penetration.

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

- one pile under axial load; lateral load, bending and the interaction of the piles in a group are outside the scope of Sol-load;
- the shaft springs act independently of each other;
- loads are static; set-up, relaxation, creep and cyclic degradation are not modelled.

3.2 Analysis modes and loading

The computation mode is chosen in **Program Options** ▶ **Analysis**:

Table 3.1 — Computation modes

Mode	What is computed	Resistance of the t-z and Q-w curves
Capacity + Settlement	capacity profiles of every ticked method, and the load-settlement analysis	from the capacity method chosen as Transfer basis

Mode	What is computed	Resistance of the t-z and Q-w curves
Capacity	capacity profiles only	not used
Settlement	load-settlement analysis only	the unit shaft and tip resistances entered for each soil material

The pile installation (**Driven pile** or **Drilled shaft**) selects the load-transfer models: a drilled shaft uses the curves of Reese and O'Neill. The loading is defined by its direction and its control:

- **Direction.** **Compression** or **Uplift**, with loads entered as positive magnitudes. In the Settlement mode a third choice, **Signed**, accepts positive (downward) and negative (upward) loads in one project.
- **Control.** **Head load:** Sol-load finds the movement for each load. **Tip movement:** Sol-load applies each tip movement and reports the corresponding head load, which also allows the response beyond the peak of softening curves to be followed.

3.3 Coordinates and sign convention

Depth z is measured downwards from the ground surface. Axial force, pile movement and shaft stress are positive in compression and for downward movement; the soil settlement of a downdrag analysis is positive downwards. The convention is shown in Figure 3.2.

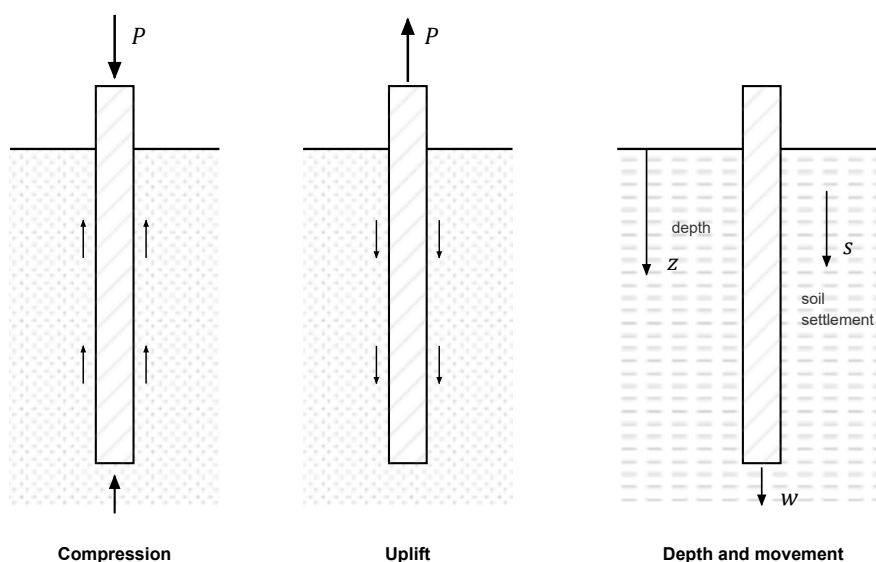


Figure 3.2 — Sign convention

In an uplift analysis the loads are entered as positive magnitudes, and the results (head load, movement, axial force) are reported with negative signs. Layer thicknesses, the water table, output depths and the tables of soil movement and modification factors are measured from the ground surface. Result profiles are plotted against depth below the ground; the part of the pile above the ground has negative depths.

With **Use elevations instead of depths (Program Options ▶ Units)** and an elevation of the soil surface, every depth input and result is shown as an elevation instead: the water table, the CPT readings, the soil movement, the modification factors, the output depths, the depths of manual t-z curves, the canvas ruler and the result profiles. Layer thicknesses and lengths along the pile are unchanged.

3.4 Units and number entry

Table 3.2 — Unit systems

Quantity	SI	US customary
Length, depth, elevation	m	ft

Quantity	SI	US customary
Diameter, wall thickness, movement	mm	in
Force	kN	kip
Stress, strength, resistance	kPa	ksf
Modulus of the pile	MPa	ksi
Unit weight	kN/m ³	pcf
Area	m ²	ft ²

Changing the unit system in **Program Options ▸ Units** converts the complete project when you click **OK** or **Apply**. Numbers are entered with the decimal character of the Windows regional settings (a point or a comma). A field that holds an invalid number is marked, and the dialog cannot be closed with **OK** until it is corrected.

3.5 Unit weight and water table

Each soil material has a total unit weight above the water table and a saturated unit weight below it. Sol-load derives the vertical effective stress from them and from the water table (**Geometry**); enter total, not buoyant, unit weights. Without a water table the total unit weight applies throughout.

3.6 How changes are applied

Every data window works on a copy of the project. **OK** applies the changes in one step and **Cancel** discards them. Each applied change can be undone with **Edit ▸ Undo** (**Ctrl+Z**) and redone with **Edit ▸ Redo** (**Ctrl+Y**).

Results belong to the input from which they were computed. When a change affects the analysis, the results are withdrawn and the status bar says **run analysis to refresh results**; a change that does not affect the analysis (for example the project title) keeps them. Sol-load never shows results that do not match the current input.

4 The workspace

4.1 Main window

The main window (Figure 4.1) consists of the menu bar and toolbar; the data sidebar on the left, the model canvas, and the status bar.

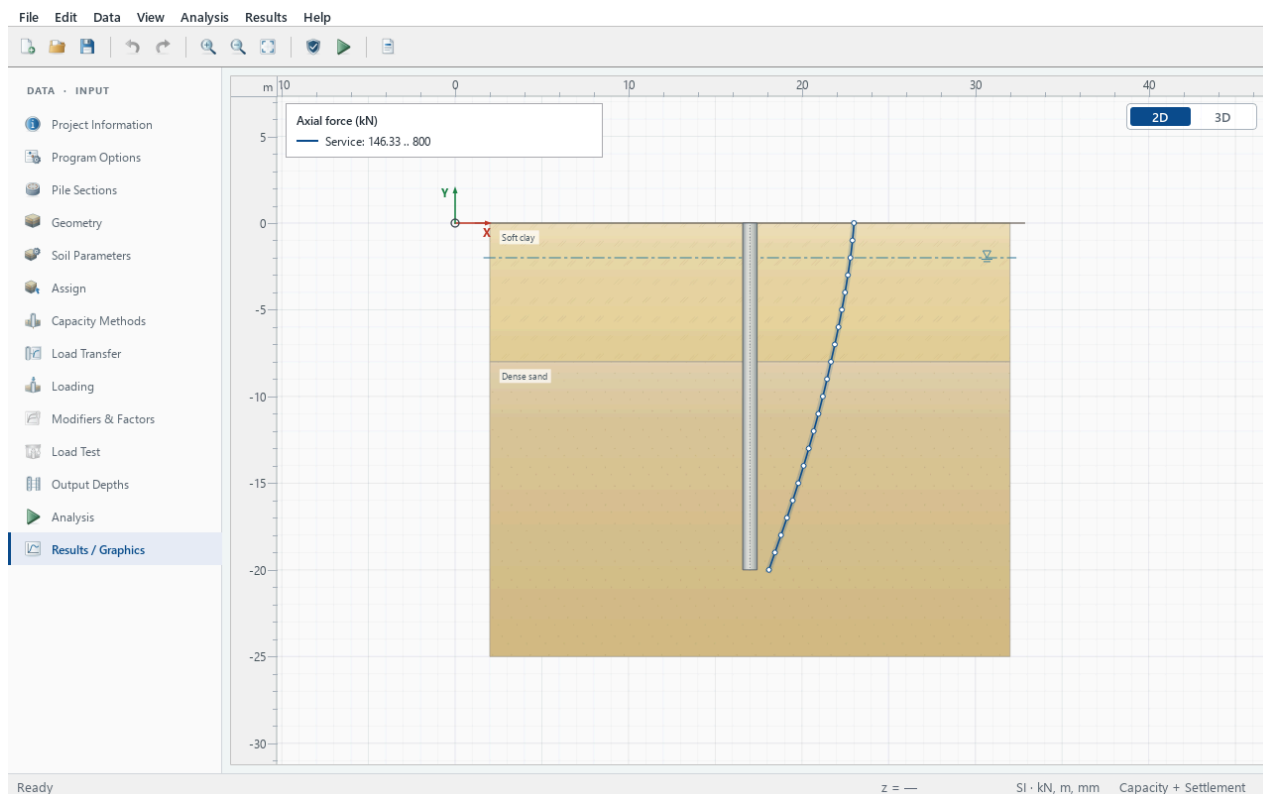


Figure 4.1 — Main window with the axial force of a load case drawn on the 2D model

- **Model canvas.** Shows the pile, the soil layers with their names, the water table and, after an analysis, the selected result profile next to the pile. The buttons **2D** and **3D** switch the view. Drag with the left mouse button to pan and use the mouse wheel to zoom; in the 3D view, drag with the middle button to rotate; **View ▸ Fit to View** (**Ctrl+0**) restores the whole model. Double-click a pile section to edit it.
- **Status bar.** Shows the last action and whether the results are current, the depth under the mouse pointer, the unit system, the computation mode and the licence in use.

4.2 Data steps

The sidebar lists the data steps in the order of a typical model. Each step opens a data window; the same windows are in the **Data** menu.

Table 4.1 — Data steps

Step	Content	Section
Project Information	title, company, description, designer, date	Section 5.2
Program Options	mode, installation, units, loading, load-transfer sources, solver, optional data	Section 5.3
Pile Sections	free length, sections, pile options	Chapter 6
Geometry	soil layers and water table	Section 7.1
Soil Parameters	soil materials	Section 7.2

Step	Content	Section
Assign	material of each layer	Section 7.3
Capacity Methods	methods, design factors, calculation settings	Section 8.1
Load Transfer	automatic models or manual t-z and Q-w curves	Section 8.2
Loading	load cases, soil movement	Section 9.1
Modifiers & Factors	modification factors of the curves	Section 9.3
Load Test	measured load–settlement points	Section 9.4
Output Depths	depths of additional t-z curves in the results	Section 9.5
Analysis	input check and run	Chapter 10
Results / Graphics	charts, tables and exports	Chapter 11

The steps **Modifiers & Factors**, **Load Test** and the **Soil Movement** tab of **Loading** are active only when the corresponding option is switched on in **Program Options**. Most data windows contain a visual guide that illustrates the current choice; it can be hidden with **Show visual guide**.

4.3 Menus and toolbar

Table 4.2 — Menus

Menu	Commands
File	New (Ctrl+N), Open (Ctrl+O), Save (Ctrl+S), Save As (Ctrl+Shift+S), Input examples, Export (report builder), Exit
Edit	Undo (Ctrl+Z), Redo (Ctrl+Y)
Data	the data steps
View	Zoom In, Zoom Out, Fit to View, Data Sidebar
Analysis	Check Input (F8), Run Analysis (F9)
Results	Results / Graphics
Help	Workflow Guide (F1), Licence, About Sol-load

The toolbar holds the most frequent commands: new, open, save, undo, redo, zoom, fit, check input, run analysis and export.

5 Building a model

5.1 Workflow

A model is built by working through the data steps from top to bottom (Figure 5.1). The order is not compulsory, but a later step often depends on an earlier one: the materials must exist before they are assigned, and the options decide which later steps are active.

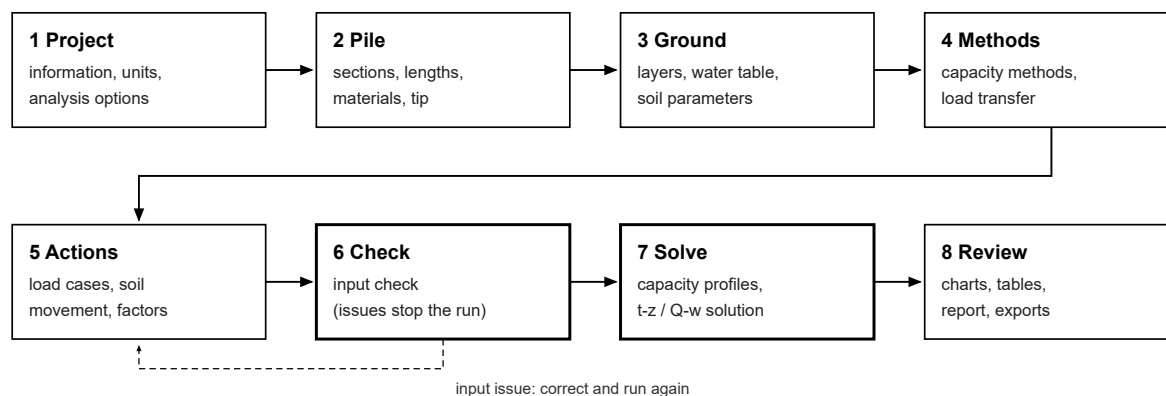


Figure 5.1 — Workflow of an analysis

5.2 Project information

Project Information holds the title, company, description, designer and date of the project. They are printed on the cover of the report and do not affect the analysis.

5.3 Program options

Program Options shows a summary of the current settings; **Edit Program Options...** opens the options dialog (Figure 5.2) with six pages:

Table 5.1 — Pages of the program options

Page	Settings
Analysis	Computation mode (Section 3.2); pile installation (driven pile or drilled shaft); the optional analyses Include Soil Settlement / Downdrag and Include Load-transfer Modification Factors .
Units	SI or US customary units; Use elevations instead of depths and the elevation of the soil surface.
Loading	Load direction (compression, uplift, or signed in the Settlement mode) and load control (loads at the pile head or tip movements).
Load transfer	Source of the shaft t-z curves and of the tip Q-w curve: generated from the soil model, or user-defined.
Solver	Number of pile increments (default 100), maximum number of iterations (default 500), convergence tolerance (relative force, default 10^{-5}), Align increments to soil boundaries and movement changes ; and the capacity settings shaft start, uplift shaft factor, capacity step and pile weight, which are also in Capacity Methods ▶ Calculation .
Data & output	Input Data from Load Test and Input CPT Measurements with the button CPT Data... (Section 7.4).

Analysis

Units

Loading

Load transfer

Solver

Data & output

Analysis

What the analysis computes, and which additional inputs it includes.

Computation mode

☒ Capacity + Settlement

☐ Capacity

☐ Settlement

Pile installation

☒ Driven pile

☐ Drilled shaft

Include in the analysis

☐ Include Soil Settlement / Downdrag

☐ Include Load-transfer Modification Factors

Visual guide



Capacity
Shaft + tip

Load-settlement
P
W

OK

Cancel

Apply

Figure 5.2 — Program options, page Analysis

6 Describing the pile

6.1 Pile sections

Pile Sections (Figure 6.1) lists the sections of the pile from the head down, with their top, bottom and length. Enter the free length above the ground in **Pile Length Above Ground (free)**; the total length is the sum of the section lengths. **Add Section**, **Insert Section**, **Copy Section** and **Delete Section** edit the list; **Edit Section** or a double-click opens the section dialog.

Figure 6.1 — Pile sections

6.2 Section types

Table 6.1 — Section types and their dimensions

Type	Dimensions	Notes
Circular	diameter; diameter at the section bottom (0 = straight)	solid section; may taper
Pipe	diameter, wall thickness; diameter at the bottom	open or closed tip (Section 6.3); may taper
Rectangular	section depth and width	
H section	section depth; cross-sectional area, contact perimeter, bearing area (required)	bearing area of the box enclosed by the flanges, or as judged by the engineer
User defined	cross-sectional area, contact perimeter, bearing area (0 = material area)	any other shape

A pile may not widen downwards, neither between sections nor within a tapered section. On the **Properties** tab (Figure 6.2) enter the material (concrete, steel, timber, other), the elastic modulus, the modulus at the section bottom when it varies linearly (0 = constant), the unit weight of the pile material and, for the FHWA method, the Nordlund pile type (**Automatic** chooses it from the section and material).

Name: Type: Total Length = 20 m

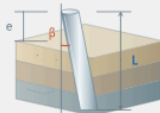
Dimensions Properties Options

Length of Section: m

Diameter: mm

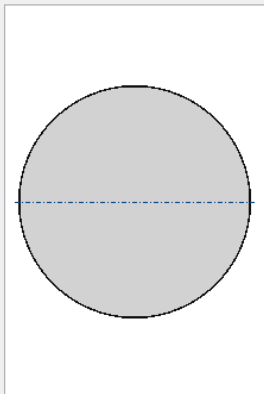
Diameter at Section Bottom (0 = straight): mm

Visual guide



L Total length
e Free length
β Batter from vertical

Section Preview



OK Cancel

Figure 6.2 — Section dialog, tab Dimensions

NOTE The material of the section sets the interface friction angle of the USACE method (0.75ϕ steel, 0.95ϕ concrete, 0.9ϕ timber) when the soil has no explicit value.

6.3 Batter and tip condition

The **Options** tab of the section dialog holds two settings that apply to the entire pile:

- **Batter from Vertical**, in degrees. Depths are measured vertically; lengths along the pile.
- **Tip Condition**: **Closed end** (the tip bears on the full base); for pipes **Open · plugged** (gross base area, no internal friction), **Open · unplugged** (annulus plus, for the CPT-based methods, internal friction of the soil column) and **Open · automatic plug** (the plug history during installation decides; see the Technical Reference, section “Open-ended piles and plugging”).

NOTE For the CPT-based methods an unplugged pile can have a higher capacity than a plugged one, because the internal friction of the full soil column is added to the annulus. Unplugged is therefore not a lower bound for these methods.

7 Describing the ground

7.1 Soil layers and water table

Geometry (Figure 7.1) lists the soil layers from the surface down by their thickness; the top and bottom depths are computed. **Add Soil Layer** and **Remove Selected** edit the list. Enter the water table as an elevation relative to the ground surface (0 or negative: -2 m is 2 m below the ground; with elevations in use, relative to the elevation of the soil surface), or tick **No water table**. The soil profile must reach at least the pile tip and, with tip averaging, the bottom of the averaging zone.

The screenshot shows the 'Geometry' dialog box. It has a title bar 'Geometry' and two buttons: 'Add Soil Layer' and 'Remove Selected'. Below these is a section titled 'Soil Layers' containing a table with four columns: 'No', 'Thickness t (m)', 'Top z (m)', and 'Bottom z (m)'. The table has two rows of data. Below the table is a summary line: 'Summary: 2 layers · total depth 25.00 m'. To the right of the table is a 'Water Table' section with a checkbox 'No water table' and a text input field for 'Water table elevation (≤ 0)' with the value '-2' and the unit 'm'. At the bottom right are 'OK' and 'Cancel' buttons.

No	Thickness t (m)	Top z (m)	Bottom z (m)
1	8.00	0.00	8.00
2	17.00	8.00	25.00

Summary: 2 layers · total depth 25.00 m

Water Table

☐ No water table

Water table elevation (≤ 0)

-2 m

OK Cancel

Figure 7.1 — Soil layers and water table

7.2 Soil materials

Soil Parameters lists the soil materials; a material can be assigned to several layers. **Add Soil**, **Edit Soil** and **Delete Soil** edit the list, and the status column shows whether the material is complete for the current analysis. The soil dialog (Figure 7.2) holds the name, colour, axial soil model and unit weights, and the main parameters of the model. The **Load-transfer Preview** shows the t-z curve that the current input gives in each layer that uses the material.

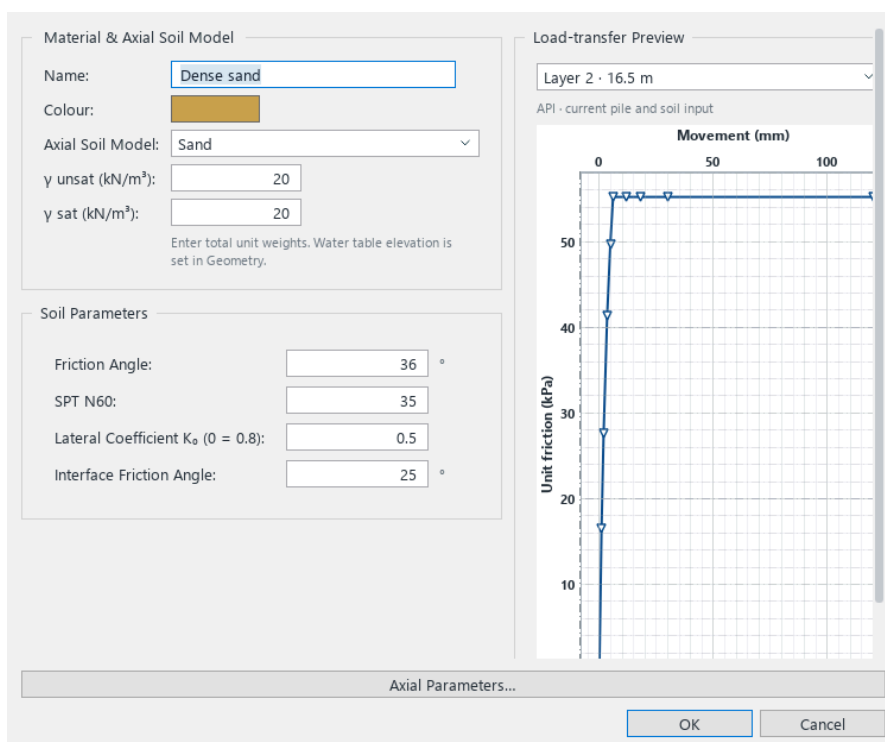


Figure 7.2 — Soil dialog of a sand, with the preview of its API t-z curve

Table 7.1 — Axial soil models and their main parameters

Model	Main parameters
Clay	undrained strength at the top and bottom of the layer; OCR or yield stress ratio; adhesion factor α (0 = Tomlinson chart for FHWA)
Sand	friction angle or SPT N60; lateral coefficient K_0 (0 = 0.8); interface friction angle
Silt	the parameters of clay and of sand together
Rock, User defined	unit shaft resistance and unit tip resistance

Axial Parameters... opens the detailed parameters on four tabs:

- **Transfer.** Unit shaft and tip resistance (in the Settlement mode these are the resistances of the curves; in the combined mode a positive value caps the capacity method), API peak movement and clay residual ratio, clay strain ε_{50} , the t-z law of this layer (**Automatic** follows the project), the toe law used with Mosher t-z curves, and the critical toe movement.
- **Capacity.** Remoulded strength for the plug, explicit values that replace the charts of the methods (API N_q , USACE N_q , K and critical depth, FHWA N'_q , α , Tomlinson graph, Nordlund K_δ and C_f , tip coefficient α_t and limiting tip resistance), interface friction angle, LRFD resistance factors of the layer, the unit resistances of the user-defined method, and **USACE long-pile adhesion**.
- **Layer bottom.** With **Vary parameters through each assigned layer**, values at the layer bottom; the program interpolates linearly between top and bottom.
- **CPT parameters.** Plasticity index, yield stress ratio and interface dilation of the CPT-based methods.

A zero in a field marked "0 = ..." selects the default stated in its label. An explicit value always takes precedence over a chart or a default.

7.3 Assigning materials

Assign lists the layers with their depths; choose the material of each layer.

7.4 CPT data

With **Input CPT Measurements** ticked, **CPT Data...** (**Program Options** ▸ **Data & output**) opens the window **CPT Measurements**. The readings (depth, cone q_c , sleeve f_s and pore pressure u_2) are typed, pasted, or read with **Import CPT Data...** from a text file, choosing the column and unit of each quantity, the first and last row, the decimal character and the delimiters. **Interpret CPT...** opens the interpretation with a depth profile, the soil behaviour type charts and the table of interpreted parameters; there the net area ratio, N_{kt} and the friction-angle correlation are chosen. **Fill layers with CPT data...** shows the values it proposes for each layer for review and writes unit weight, friction angle, undrained strength, N60 and q_c into the materials. The CPT-based capacity methods use the readings directly. The interpretation is described in the Technical Reference, chapter “Cone penetration test data”.

NOTE	Filled values are end-point values of each layer, not averages. Review them against the sounding before using them for design.
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8 Capacity methods and load transfer

8.1 Capacity methods

Capacity Methods (Figure 8.1) has three tabs.

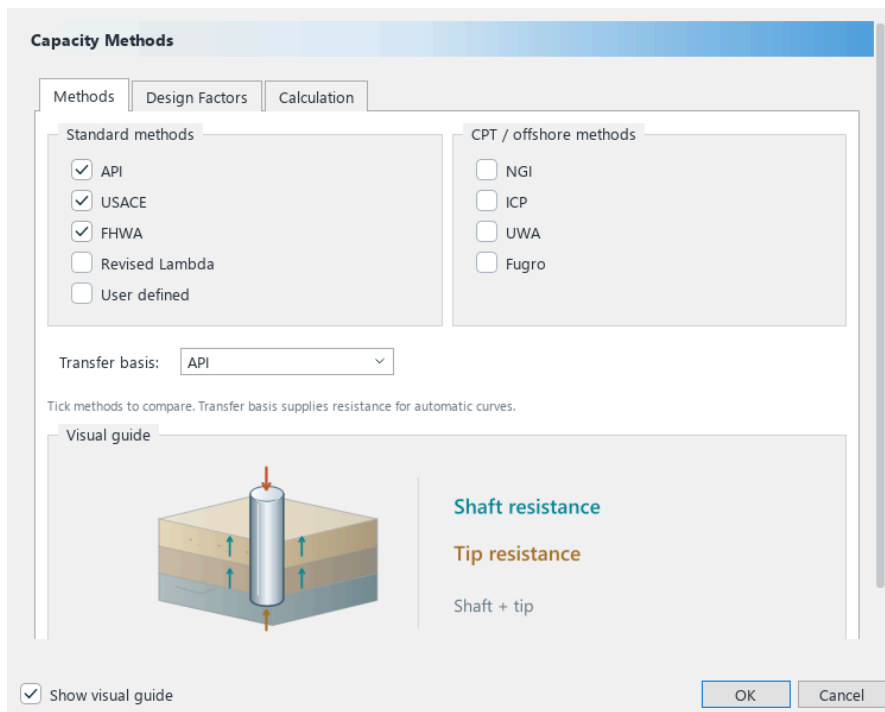


Figure 8.1 — Capacity methods

- **Methods.** Tick the methods to compute: the standard methods API, USACE, FHWA, Revised Lambda and User defined, and the CPT / offshore methods NGI, ICP, UWA and Fugro. Each ticked method gives its own capacity profile. In the Capacity + Settlement mode, **Transfer basis** selects the method whose resistances scale the t-z and Q-w curves.
- **Design Factors.** Design basis (nominal, ASD or LRFD), load direction, and the factors: ASD safety factor (default 2.5), LRFD shaft and tip resistance factors (defaults 0.55 and 0.5), and, in uplift, the uplift shaft reduction (default 0.8, not applied to the CPT-based methods).
- **Calculation.** **Ignore shaft resistance above** a depth; **Capacity step** (0 = pile length divided by the number of increments); **Print every N capacity steps**; tip averaging radius (none, $\pm 1.5D$, $\pm 3D$); USACE critical depth (10/15/20B by friction angle, or the depth of 3 500 psf effective stress); the drained or undrained clay toe of ICP, Fugro and UWA; and **Include pile weight and buoyancy**.

The factors of the design basis act on the capacity only. The load-settlement analysis always uses nominal (unfactored) resistances.

8.2 Load transfer

Load Transfer (Figure 8.2) selects the source of the shaft t-z curves and of the tip Q-w curve, each **Automatic** or **Manual**.

Load Transfer

Shaft t-z curves: Automatic

Tip Q-w curve: Automatic

Automatic models

Model: Soil models

Clay: API

Sand: API

USACE needs Capacity + Settlement mode with USACE as the reference method; the clay / sand choices then do not apply.
Combined mode uses the capacity reference for resistance levels.

Visual guide

☒ Show visual guide

OK Cancel

Figure 8.2 — Load transfer

- **Automatic models.** For a driven pile, **Soil models** uses the clay model (API or Coyle & Reese) and the sand model (API or Mosher); **USACE** uses Coyle & Reese in clay, Mosher in sand and the USACE tip curve, and requires the Capacity + Settlement mode with USACE as transfer basis. A drilled shaft always uses Reese & O'Neill. A layer whose material has its own t-z law uses that law.
- **Manual shaft t-z.** A table of curves, each at a depth below the ground, with its points of movement z and unit friction t (**Edit t-z...**). Between two depths the curves are interpolated; above the first and below the last the nearest curve applies.
- **Manual tip Q-w.** Points of tip movement w and total tip force Q (**Edit Q-w...**).

Every curve starts at zero and keeps its last value beyond its last point. The shapes of the automatic curves are given in the Technical Reference.

9 Describing the actions

9.1 Load cases

Loading ▸ Pile Head (Figure 9.1) holds the direction and the control of the loading and the table of load cases: a name and either the head load or the tip movement, according to the control. Loads and movements are entered as positive magnitudes (in the signed mode, negative values are upward).

Loading

Pile Head

Direction: Compression

Control: Head load

Compression / uplift use positive magnitudes. Signed mode: positive down, negative up; Settlement only, with symmetric t-z curves (the uplift shaft factor applies to Uplift only).

Additional tip-movement profiles...

Add Row Insert Row Delete Row

	Load case	Head load (kN)
1	Service	800
2	Test	1200

Visual guide

☒ Show visual guide OK Cancel

Figure 9.1 — Load cases

Additional tip-movement profiles... lists tip movements at which Sol-load also computes complete profiles of force and movement. Nine steps from 0.0001 to 5 in are preset; they also extend the load–settlement curve beyond the load cases.

9.2 Soil movement (downdrag)

With **Include Soil Settlement / Downdrag** ticked, the tab **Soil Movement** holds the settlement of the soil as a table of depth and movement (positive downwards), with a preview of the profile. Between the rows the movement is interpolated linearly. Where the soil settles more than the pile, the shaft resistance acts downwards on the pile.

9.3 Modification factors

With **Include Load-transfer Modification Factors** ticked, **Modifiers & Factors** holds a table of depths with four multipliers: t (shaft resistance), Q (tip resistance), z (shaft movement) and w (tip movement). A value of 1.0 leaves the curve unchanged. The shaft factors apply within the tabulated depth interval; the tip factors are evaluated at the tip. The factors change the curves only, not the capacity profiles, and are separate from the ASD and LRFD factors.

9.4 Load-test data

With **Input data from load test** ticked, **Load Test** holds measured points of load and settlement. They are plotted with the computed load–settlement curve for comparison and do not affect the analysis.

9.5 Output depths

The results always contain t-z curves at the top, middle and bottom of each layer (an **Offset inside layer ends** keeps the top and bottom curves inside the layer). **Output Depths of t-z Curves...** adds curves at further depths.

10 Checking and running the model

10.1 Input check

Analysis ▸ **Check Input** (**F8**) opens the step **Analysis**. It lists every input that needs attention, with the data step it belongs to; double-click a row to open that step. Typical issues are a pile longer than the soil profile, a layer without a material, a material without the parameters of a ticked method, a manual curve with fewer than two points, or a load case without a load. When the list is empty, the check reports **Input complete** and the analysis can be started.

NOTE “Input complete” means that the input can be analysed. It does not establish that the parameters are appropriate, that the capacity is adequate, or that the settlement is acceptable.

10.2 Running the analysis

Analysis ▸ **Run Analysis** (**F9**) checks the input, then computes the capacity profiles of the ticked methods and solves each load case. A progress window shows the current step and can cancel the run. When the run has finished, the results open in **Results / Graphics**. The analysis runs in the background, so the window stays responsive; while it runs, the input cannot be changed.

10.3 Convergence and messages

For a head load, Sol-load searches the tip movement at which the head load equals the target (Technical Reference, section “Load control”). A solution is accepted only when the head load differs from the target by no more than the convergence tolerance times the larger of 1 kN and the load. If no solution is found, the analysis stops with a message that names the load case:

- **The load exceeds the axial resistance of the pile.** The message gives the largest head load that the pile reaches on the first loading branch and the tip movement at which it occurs. Reduce the load, or check the resistances: in the Settlement mode they are the unit shaft and tip resistances of the materials; in the combined mode, those of the transfer basis method.
- **The force tolerance was not met.** The response is too steep to resolve at that load, usually because of a very stiff manual curve or a very low pile modulus. Check the units of manual curves and of the modulus.

To follow the response beyond a peak (softening curves), use tip-movement control. Very stiff springs combined with long elements are subdivided automatically; this changes no input.

11 Results

11.1 Results / Graphics

Results / Graphics (Figure 11.1) lists the results on the left under **Choose result**; the right side shows a chart and its table. **Detailed columns** shows all columns of the tables, in groups. Cells selected in a table are copied with **Ctrl+C** for pasting into a spreadsheet (not with a trial licence).

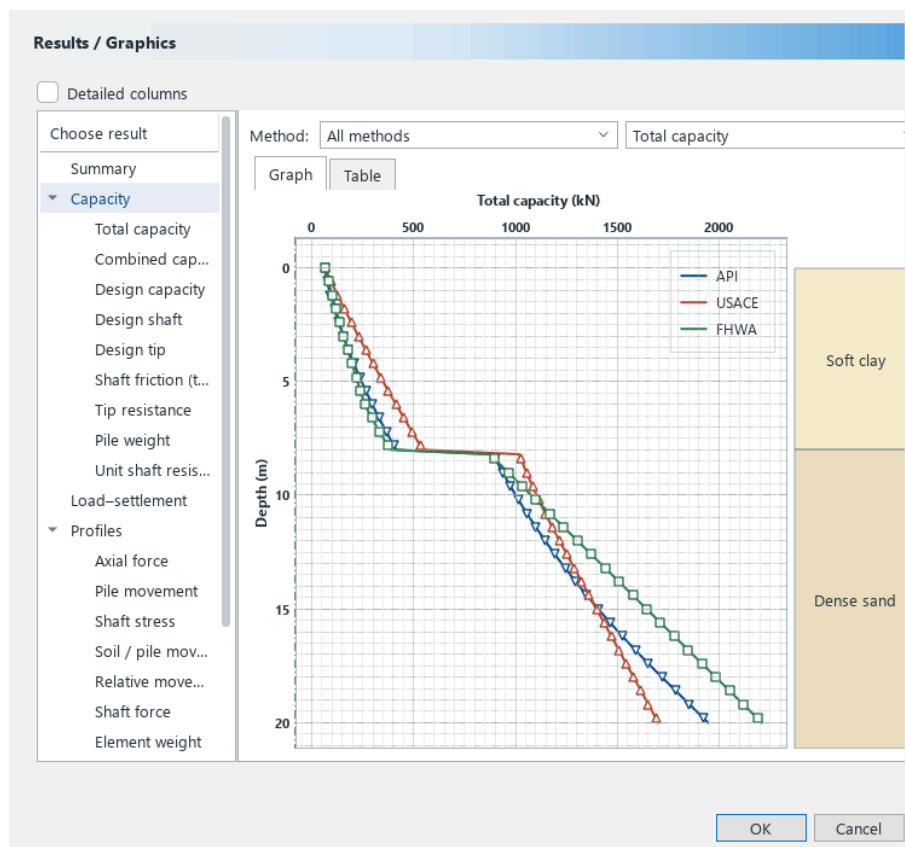


Figure 11.1 — Capacity profiles of three methods (Example 1)

Table 11.1 — Result pages

Page	Content
Summary	Capacity of each method at the pile tip (shaft, tip, weight, nominal and design capacity), the results of the load cases (head and tip load and movement), and the notes of the analysis.
Capacity	Profiles against depth, for all methods or one: total capacity, combined capacity (shaft, tip and total of one method), design capacity, design shaft and tip, shaft friction, tip resistance, pile weight, unit shaft resistance and, for open piles, plug length and internal resistance.
Load-settlement	Head load against head movement: the computed curve, the load cases, and the measured load-test points.
Profiles	For each load case and tip-movement step: axial force, pile movement, shaft stress, soil and pile movement, relative movement, shaft force and element weight, and a combined force and movement chart.
Transfer curves	The t-z curves at the layer top, middle and bottom and at the output depths, and the Q-w curve of the tip.
Neutral Plane (FHWA)	When FHWA is ticked and the load is not uplift: enter the penetration of the toe (0 = pile tip) and the permanent load; the chart and table give the neutral plane, the maximum axial load and the drag force for 100, 50 and 0 % mobilised tip resistance.
Export	Opens the report builder (Chapter 12).

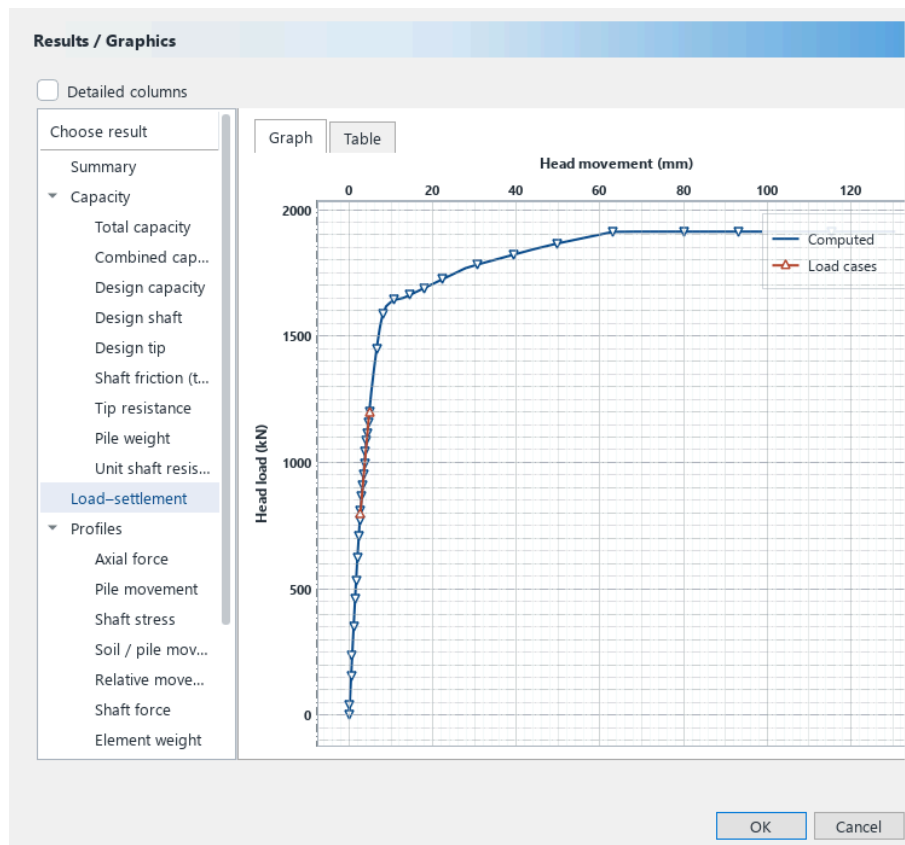


Figure 11.2 — Load-settlement curve and load cases (Example 1)

11.2 Results on the model

When a capacity profile or a load-case profile is selected, it is also drawn next to the pile on the model canvas, with a legend that gives its range (Figure 4.1). The drawing remains while the results are current.

11.3 Notes of the analysis

The summary lists notes that the analysis produced, for example when a default value was used where a method recommends another; when a shaft capacity profile was continued because a formula would decrease with penetration, when the cone resistance was estimated from SPT N60, or when a method is applied near the limit of its range. Read them before using the results.

11.4 Checking the results

A converged analysis is not necessarily a correct one. Before relying on a result, check at least the following:

1. The model on the canvas shows the intended pile, layers and water table; the depths and the free length are right.
2. The capacity profiles change where the layers change, and the methods give capacities of a similar order. Large differences between methods are common, but each should be explicable by the method and the parameters.
3. The tip resistance is not governed unintentionally by a unit tip resistance entered as a limit for the material.
4. In the combined mode the load-settlement curve approaches the nominal capacity of the transfer basis method at large movement; in the Settlement mode it approaches the sum of the entered resistances.
5. The axial force decreases from the head to the tip (in compression without downdrag), and the tip load is consistent with the tip curve at the reported tip movement.
6. Where measured load-test data are available, the computed curve has been compared with them.

12 Reports and data exchange

12.1 Report builder

File ► **Export...** opens the report builder (Figure 12.1). The left side lists what the report contains; the right side shows a preview with up to 30 rows per table (the export contains every row).

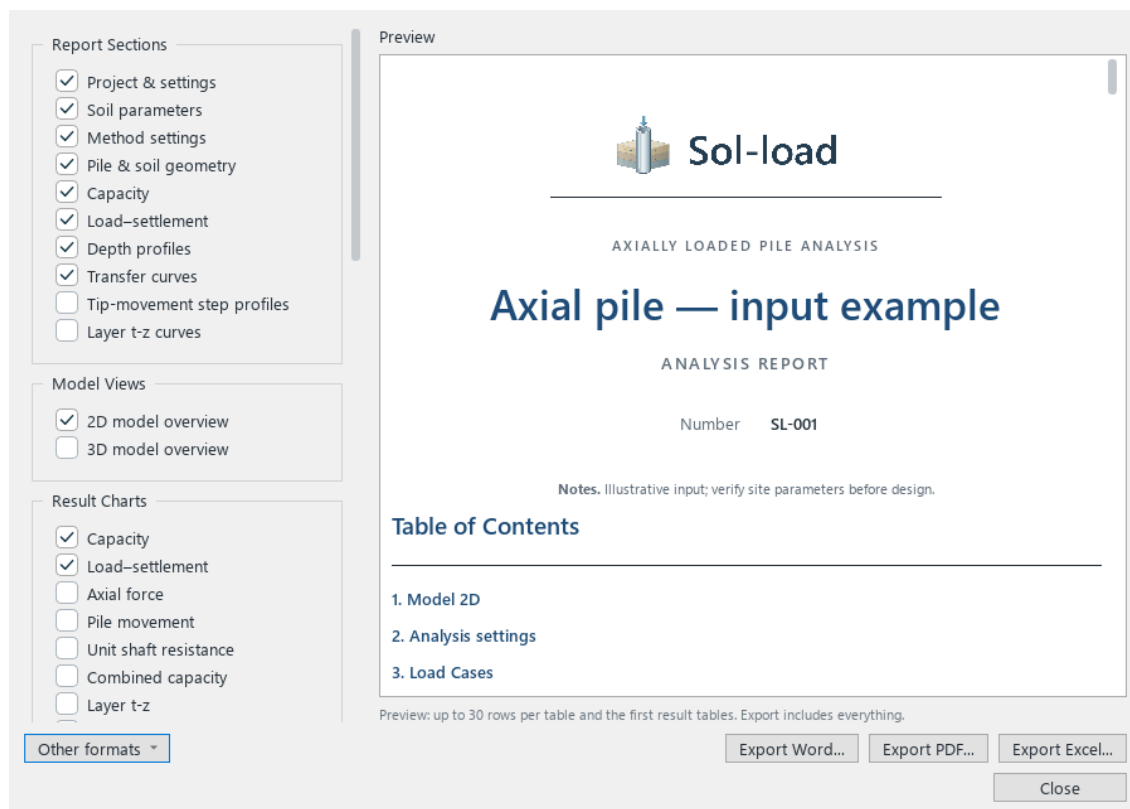


Figure 12.1 — Report builder

- **Report Sections:** project and settings (with soil parameters and method settings), pile and soil geometry, capacity, load-settlement, depth profiles, transfer curves, tip-movement step profiles and layer t-z curves.
- **Model Views:** 2D and 3D overview of the model.
- **Result Charts:** capacity, load-settlement, axial force, pile movement, unit shaft resistance, combined capacity, layer t-z, shaft t-z and tip Q-w.
- **Result Tables:** each result table, grouped under its section. A table is available only while its section is ticked.
- **Additional Data:** an appendix with the stored input, and calculation details.

The selection is saved with the project. **Export Word...**, **Export PDF...** and **Export Excel...** write the report; **Other formats** offers HTML, an image of the model, and the result files described below. Reports of an Academic licence are marked “Student version”. A trial licence does not export.

12.2 Other exports

Table 12.1 — Data exports

Export	Content
CSV	All result tables in one text file at full precision, in SI units with a point as decimal character, preceded by the project data and the notes of the analysis.
JSON	The complete result of the analysis in SI units, with the input fingerprint, for archiving or further processing.

Export	Content
GRLWEAP	A soil-resistance file (.srp) for a driving analysis: choose the capacity method, the set-up factors of clay and sand, the set-up time, the limit distance and the shape factor.
Model image	The model canvas, including the drawn result profile, as a PNG image.

13 Examples

The three examples are the projects under **File** ▶ **Input examples**. Their parameters are illustrative and are not recommendations for design. The numbers in this chapter were computed with Sol-load 1.0.0.

13.1 Example 1: driven pile, capacity and settlement

Open **File** ▶ **Input examples** ▶ **Driven pile**. The project describes a closed concrete pile of 0.6 m diameter and 20 m length ($E = 30\,000$ MPa, unit weight 24 kN/m^3) driven through 8 m of soft clay into dense sand, with the water table 2 m below the ground:

Table 13.1 — Example 1: soil materials

Layer	Depth (m)	$\gamma / \gamma_{\text{sat}}$ (kN/m ³)	Strength	Limits t / q (kPa)
Soft clay	0–8	18 / 20	$s_u = 25$ kPa at the top, 40 kPa at the bottom	60 / 2 000
Dense sand	8–25	20 / 20	$\phi = 36^\circ$, $K_0 = 0.5$, $\delta = 25^\circ$	60 / 2 000

The analysis mode is Capacity + Settlement with API as the transfer basis, and two load cases are defined: Service (800 kN) and Test (1 200 kN). To compare methods as in this example, open **Capacity Methods** and tick **USACE** and **FHWA** in addition to **API**. Then press **F9**.

Capacity. The capacity at the pile tip is:

Table 13.2 — Example 1: nominal capacity at the pile tip

Method	Shaft (kN)	Tip (kN)	Total (kN)
API	1379	565	1944
USACE	1135	565	1700
FHWA	1643	565	2209

In the clay the methods differ through their adhesion factors on the undrained strength; in the sand they diverge further, because their earth-pressure, interface and critical-depth assumptions differ (Figure 13.1a). The tip resistance is the same for all three because each method's unit tip resistance exceeds the limit of 2 000 kPa entered for the sand: the limit governs. Remove the limit (enter 0) to see the tip resistance of each method itself.

Load-settlement. Under the service load the head settles 2.69 mm and the tip carries 146 kN; under the test load the head settles 4.80 mm with 178 kN at the tip. Most of the load is carried by the shaft at these loads; the tip is mobilised later, as the curve bends towards the capacity (Figure 13.1b). The curve flattens slightly below the API capacity because the API clay t - z curves soften to 90 % of their peak after the peak movement.

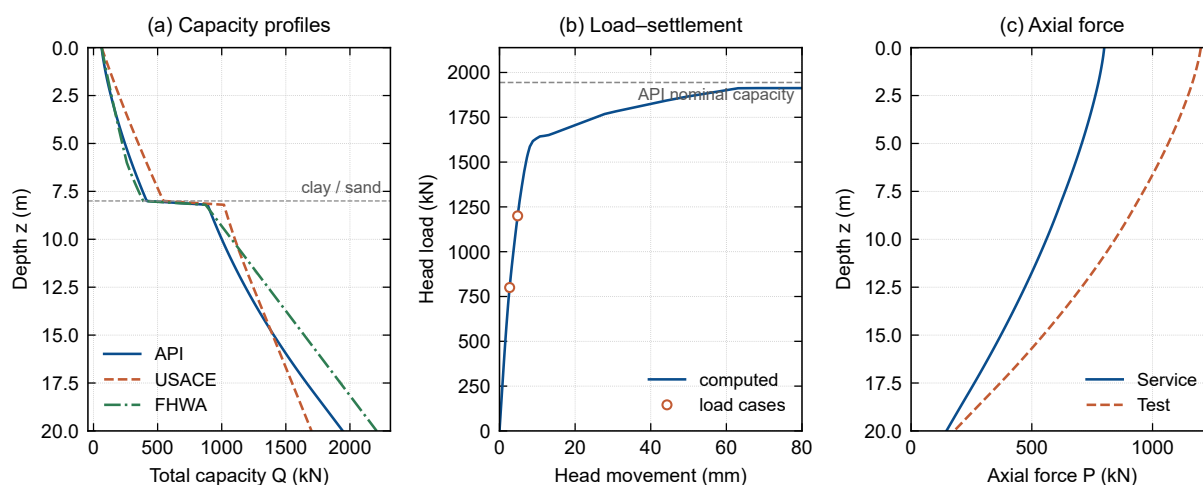


Figure 13.1 — Example 1: capacity profiles, load-settlement curve and axial force

13.2 Example 2: drilled shaft, settlement only

Open **File** ▸ **Input examples** ▸ **Drilled shaft**. The soil and the loads are those of Example 1; the pile is a drilled shaft of 1.0 m diameter, and the mode is Settlement. The load-transfer curves are those of Reese and O'Neill, scaled to the unit shaft and tip resistances entered for the materials (60 kPa and 2 000 kPa). Under the service load the head settles 0.69 mm, and under the test load 1.03 mm, with 38 kN at the tip.

The stiff shaft curves of a drilled shaft mobilise the shaft at very small movements, and the tip curve needs movements of several per cent of the diameter to reach its resistance; the tip therefore carries little load at service. In the Settlement mode the resistances come only from the material inputs: check them against a capacity analysis of the same shaft.

13.3 Example 3: downdrag

Open **File** ▸ **Input examples** ▸ **Pile with downdrag**. The model is that of Example 1, with **Include Soil Settlement / Downdrag** ticked and a soil settlement of 30 mm at the surface decreasing linearly to zero at 8 m, the base of the clay (**Loading** ▸ **Soil Movement**).

The settling clay drags the upper part of the pile down. Above the neutral depth the soil moves more than the pile and the shaft stress is negative; below it the pile moves more and the shaft resists the load (Figure 13.2). The axial force therefore increases from the head to the neutral depth and decreases below it:

Table 13.3 — Example 3: downdrag results

Load case	Head load (kN)	Neutral depth (m)	Maximum axial force (kN)	Head settlement (mm)
Service	800	6.90	1006	4.86
Test	1 200	6.08	1369	8.13

A larger head load pushes the pile down further, so the neutral depth moves up and the drag force decreases relative to the load. The maximum axial force, not the head load, governs the structural design of the pile in this case.

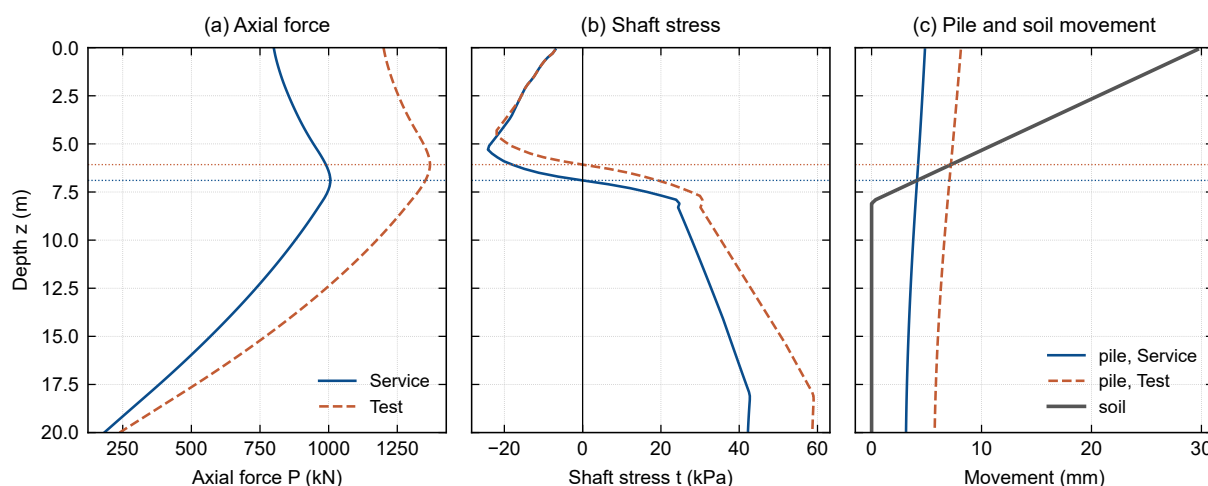


Figure 13.2 — Example 3: axial force, shaft stress, and pile and soil movement; dotted lines mark the neutral depths

For the same project, the page **Neutral Plane (FHWA)** of the results gives the neutral plane of the FHWA method when FHWA is ticked. That analysis uses the capacity profile and a permanent load, not the load-transfer curves, and therefore gives a different depth; the two answer different questions and are both used in practice.

END OF DOCUMENT