Analysis of vertical load-bearing capacity and settlement of piles investigated on the basis of CPT tests

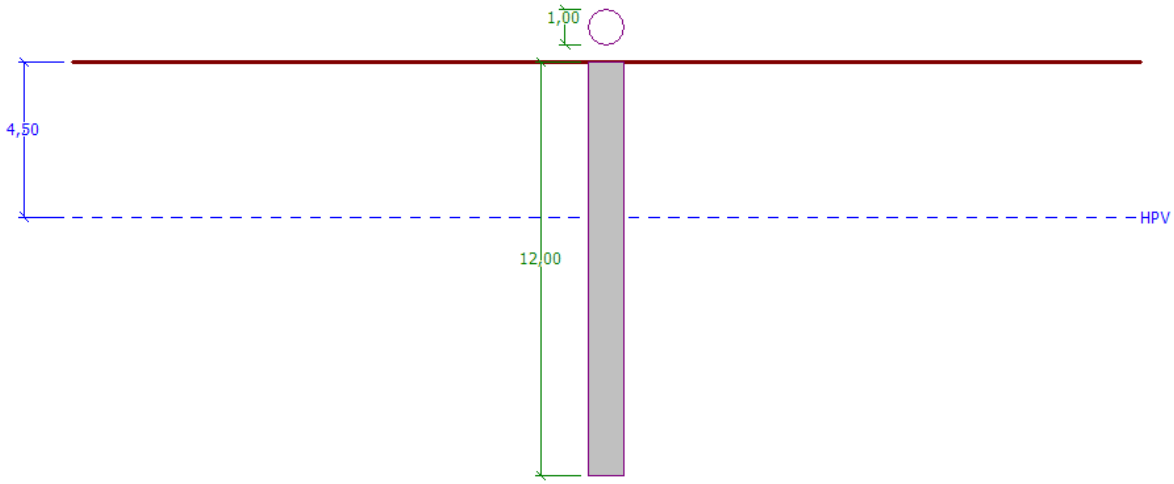
Program: Pile CPT

File: Demo_manual_15.gpn

The goal of this engineering manual is to explain the use of the GEO 5 – CPT PILE program.

Problem specification

The general specification of the problem was described in the previous chapter (*12. Pile foundations – Introduction*). Analyse the load-bearing capacity and the settlement of a single pile, or a pile group according to EN 1997-2.

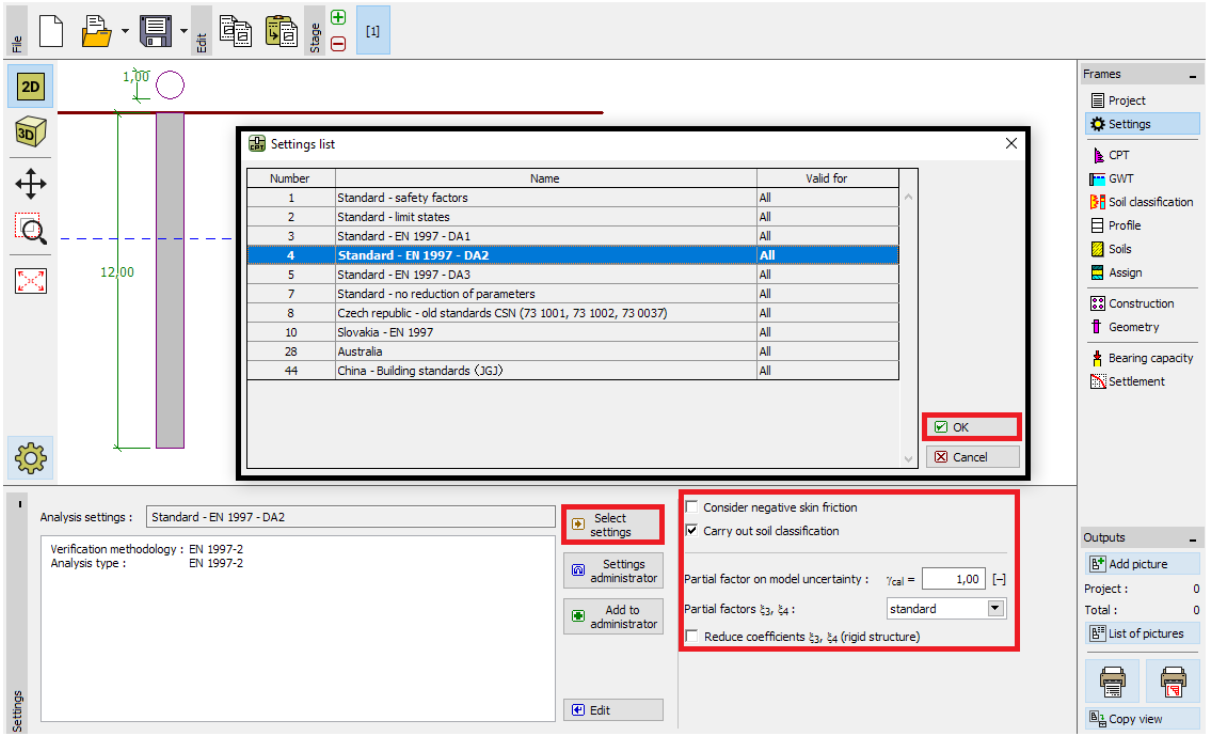


Problem specification diagram – single pile investigated on the basis of CPT tests

Solution

We will use the GEO 5 – CPT PILE program to analyse this problem. In the text below we will describe the solution to this problem step by step.

We will click the "Select setting" button (at the bottom left corner of the screen) in the "Settings list" frame and then choose the "Standard – EN 1997" analysis settings. The design approach is not important, the analysis is carried out in accordance with the *EN 1997-2* standard: *Geotechnical Design – Part 2: Ground investigation and testing*.



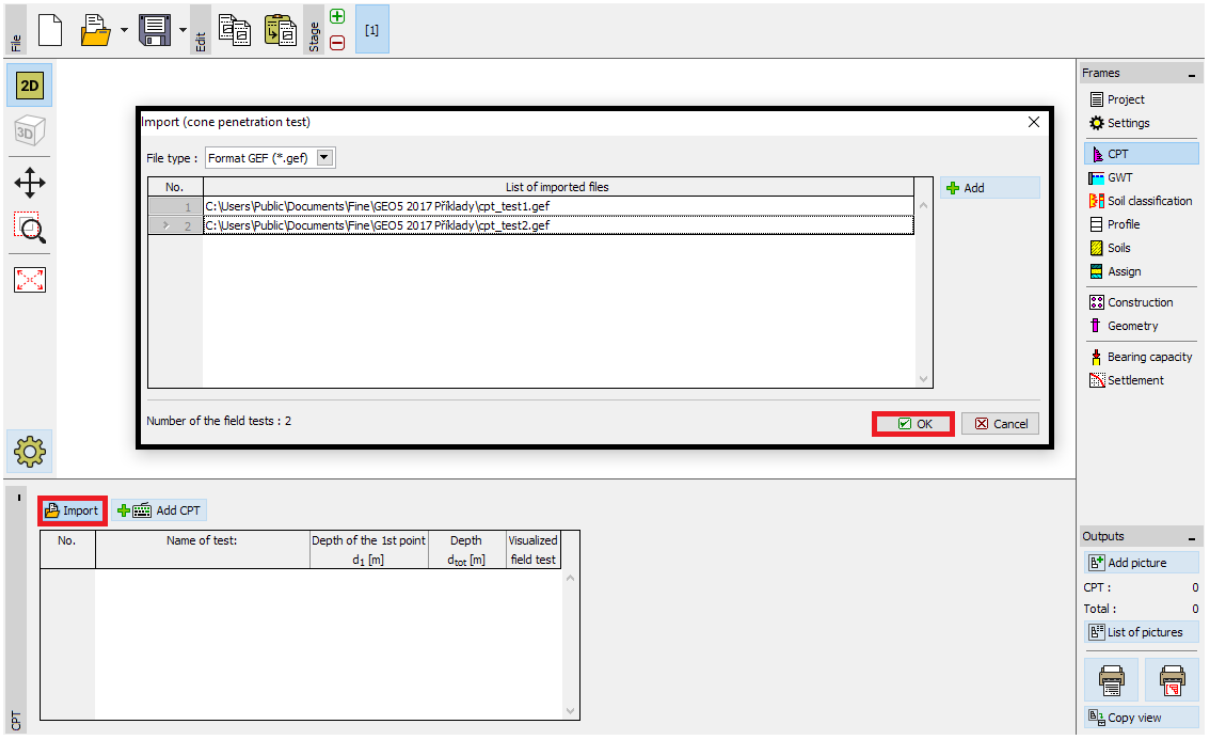
Frame "Settings"

In the first analysis, we will assess a single pile, we therefore will not specify the reduction of correlation coefficients ξ_3, ξ_4. We will not take the influence of the negative skin friction into consideration. In this frame, it is also possible to specify the *partial factor of model uncertainty,* which is used to reduce the total calculated bearing capacity of the pile – we will keep the standard value of 1.0.

In this frame, we will check the box "Carry out soil classification". This ensures that all soil parameters will be automatically assigned in the whole task as given by the performed CPT tests.

Note: Correlation coefficients ξ_3, ξ_4, and even the total bearing capacity of the pile, depend on the number of completed CPT tests. When we have more completed CPT tests available, the magnitude of the correlation coefficients is smaller. For two completed static penetration tests, the values are $\xi_3 = 1.35$, $\xi_4 = 1.27$ according to ***Table A.10*** *- Correlation coefficients for deriving characteristic values of pile capacities from ground tests presented in EN 1997-1 (Part A.3.3.3).*

In the “CPT” frame, we will import the completed tests into the program.



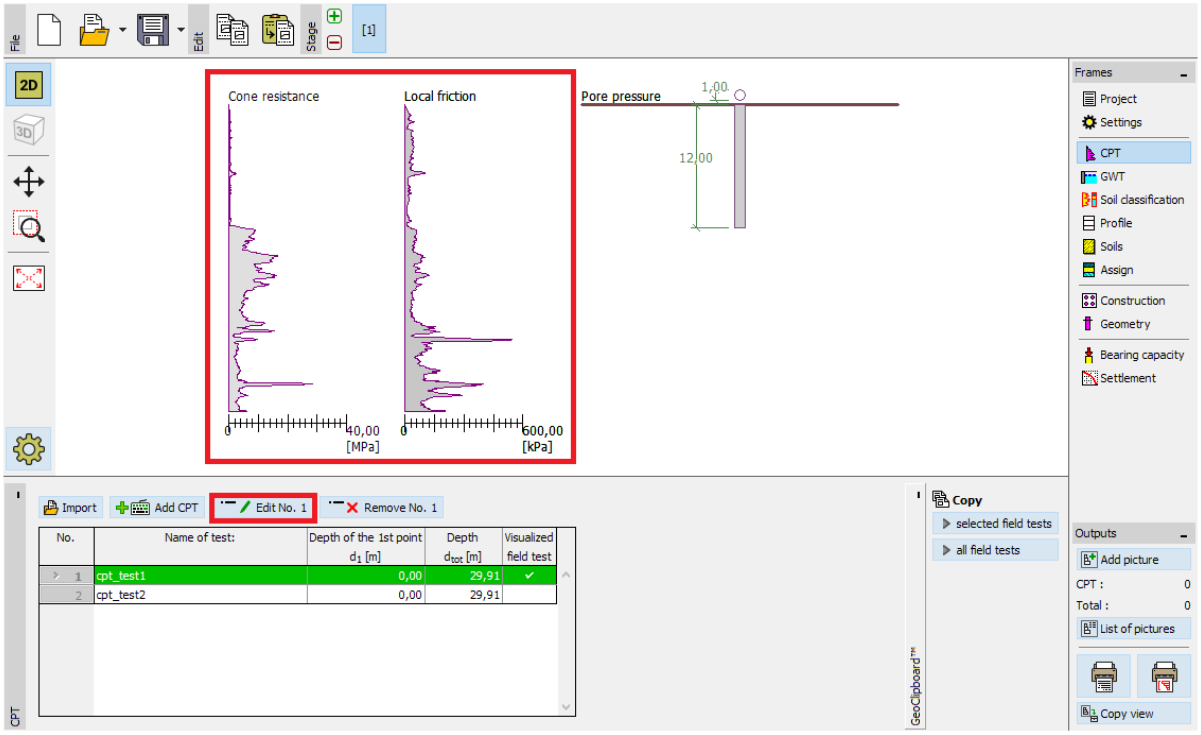
Frame “CPT“

Note: The files for import (cpt_test1.gef, cpt_test2.gef) are part of GEO5 installation and they are located in the folder FINE in public documents.

Note: The CPT tests can be imported in several formats, in our example, we will use tests in the Dutch format GEF. For more information see the program help – press F1 or online.

Note: It is also possible to enter CPT tests manually using the “Add CPT” button. Because the amount of measured points is usually large, import is frequently used instead.

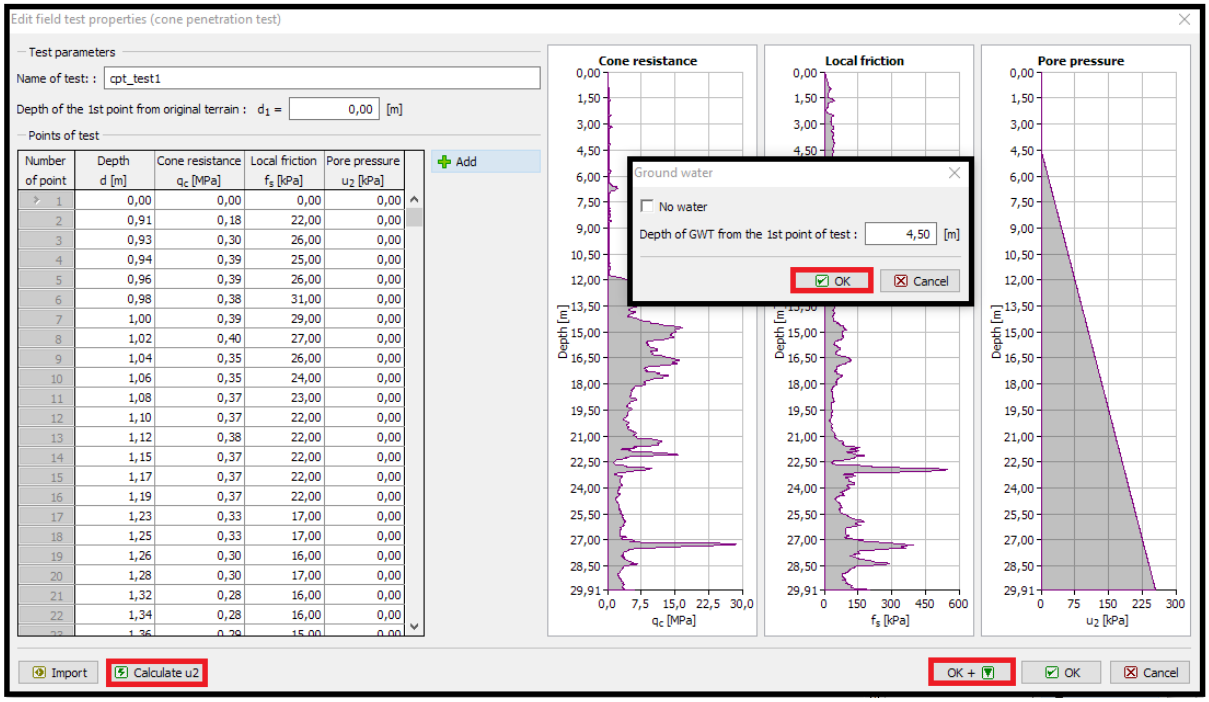
By clicking the “OK” button, the tests are loaded and the graphs of measured values are displayed on the desktop.



Frame “CPT“ – imported tests

Note: Simply put, CPT tests can be divided into two types. Standard CPT tests measure cone resistance (q_c) and skin friction (f_s). The second type is a more detailed test called CPTu, which measures the pore pressure as well. The CPTu test is more financially and technically demanding. However, the knowledge of pore pressure (u) is necessary in order to classify the soils correctly based on CPT testing. If we know the ground water table, we can let the program calculate the pore pressure automatically. This is explained above.

By pressing the “Edit” button, we display a dialog window with detailed results of the selected test.

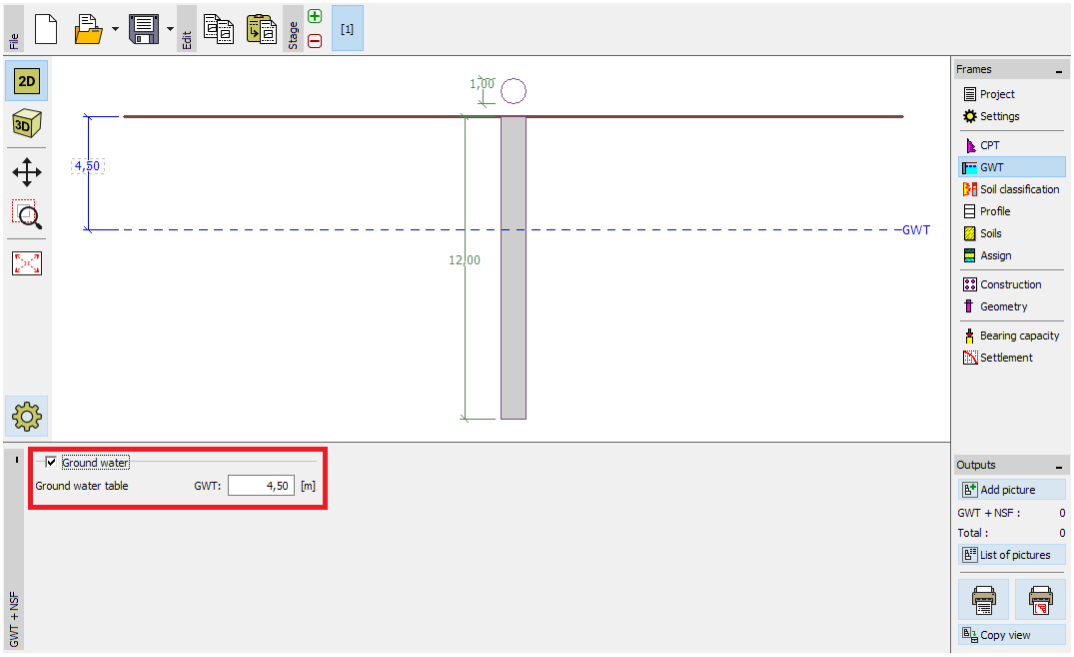


Frame “CPT” – pore pressure calculation

In this dialog window, we press the “Calculate u2” button and enter the supposed ground water table.

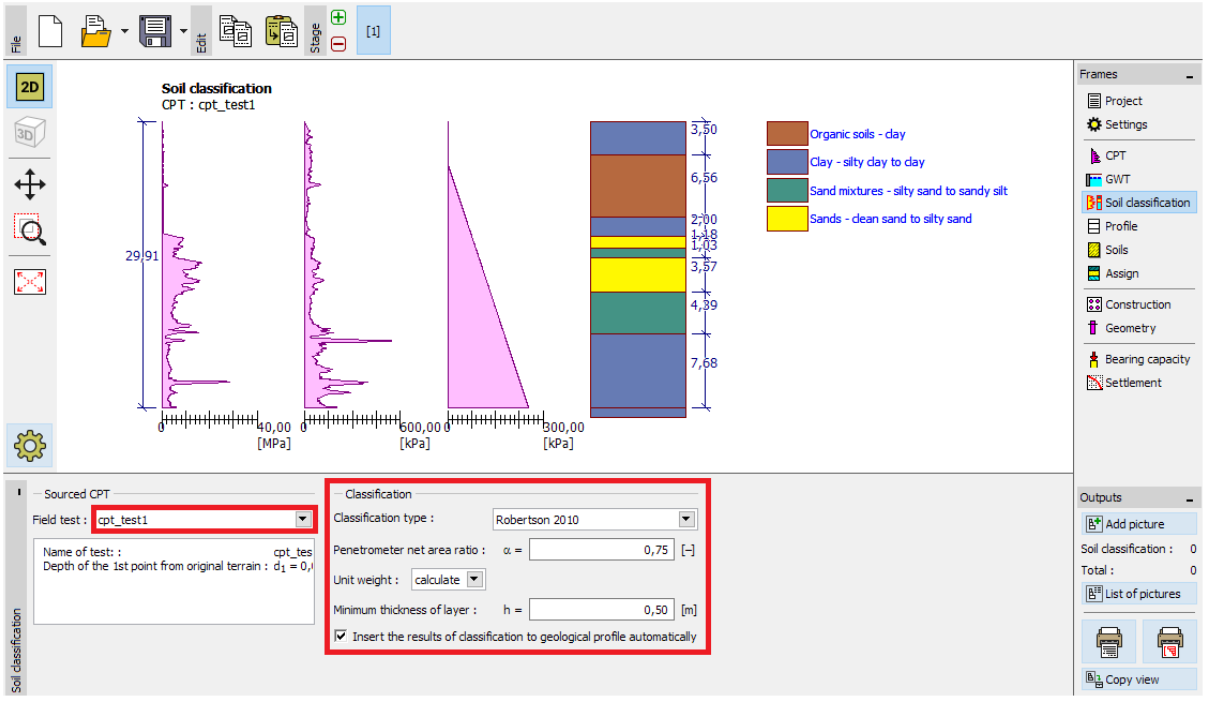
This way we perform the calculation of pore pressure for both tests.

It is necessary to enter the ground water table in the frame “GWT” as well.



Frame "GWT"

Now we move to the frame "Soil classification".



Frame "Soil classification"

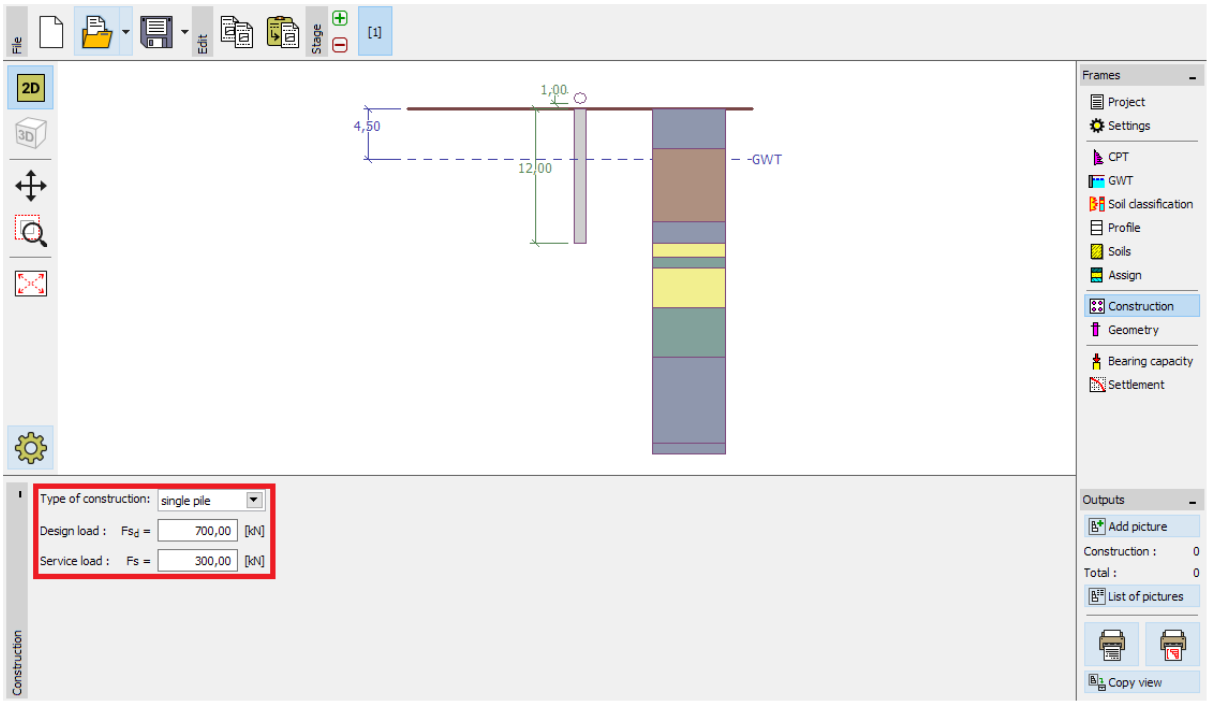
We select the classification according to Robertson (2010). The penetrometer net area ratio has a standard value of 0,75 and the unit weight is calculated using CPT tests. For more information see the program help – press F1 or online.

We set the minimum thickness of a layer as 0,5 m to get a clearer picture of the geological profile.

Note: Soil classification is always performed just for one CPT test – it is necessary to specify it in the box "Sourced CPT".

The frames "Profile", "Soils" and "Assignment" can be skipped – everything is filled automatically based on the values from the CPT tests.

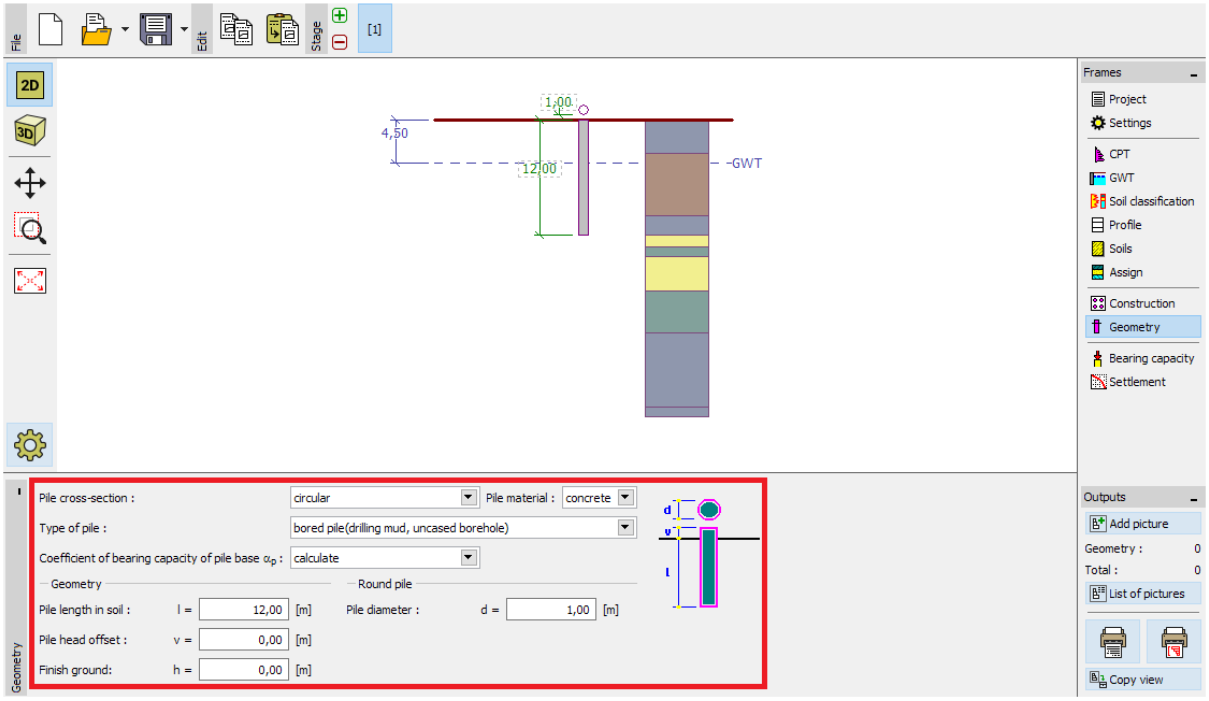
In the "Construction" frame we choose the "single pile" option. Then we enter the maximum magnitude of the vertical load acting on the pile. The design load is used for pile bearing capacity analysis and the service load for pile settlement analysis.



Frame "Construction"

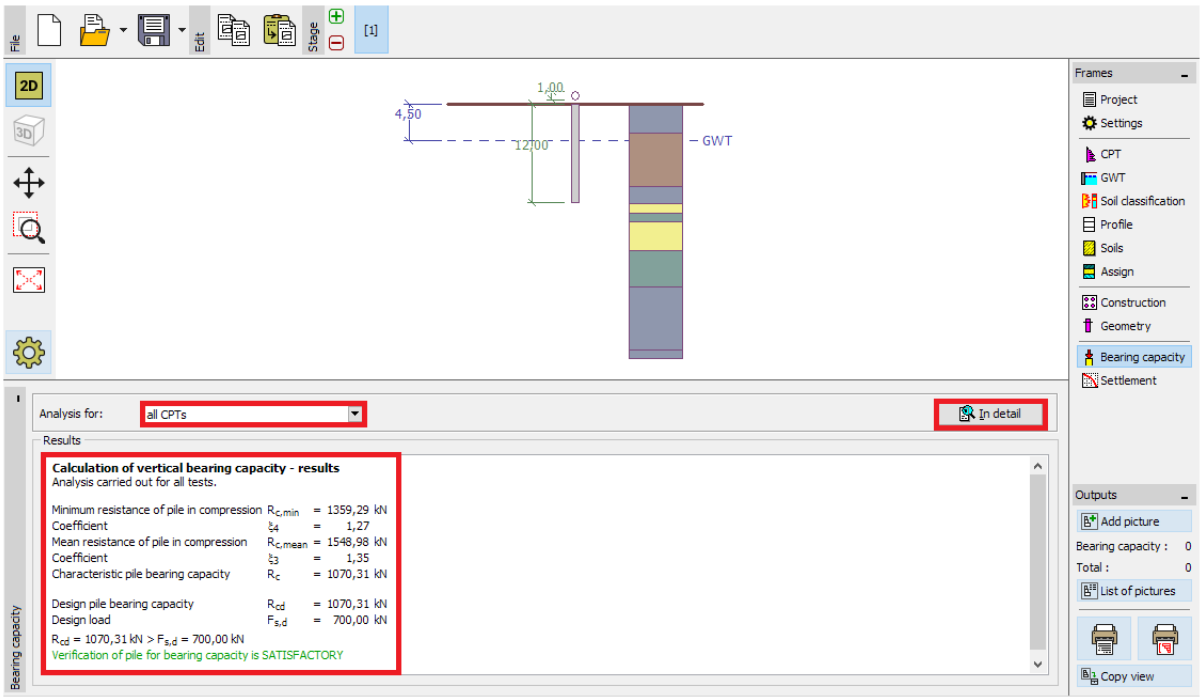
In the “Geometry” frame, we will enter the pile material and the cross-section, specify the basic dimensions, i.e. the pile diameter and its length in soil. Subsequently, we will define the pile execution technology. In this particular case, we have bored piles with the borehole uncased or stabilised with drilling mud.

The coefficient of bearing capacity of pile base α_p is calculated automatically.



Frame “Geometry“

Now we will go over to the verification of a single pile using the “Bearing capacity” frame, in which we will check the calculation results.



Frame “Bearing capacity”

By clicking on the “In Detail” button, we can see the intermediate results of the vertical pile bearing capacity analysis.

Calculation of vertical pile bearing capacity - intermediate results

Pile diameter	d_{eq}	= 1,00 m
Pile diameter at base	$d_{s,eq}$	= 1,00 m
Pile area at base	A_b	= 0,79 m^2
Coeff. of reduc. of pile base bear. capacity	α_p	= 0,50
Coeff. of influence of pile shape	s	= 1,00
Coeff. of influence of pile widened base	β	= 1,00

Calculation of vertical bearing capacity - results

Analysis carried out for all tests.

Minimum resistance of pile in compression	$R_{c,min}$	= 1359,29 kN
Coefficient	ξ_4	= 1,27
Mean resistance of pile in compression	$R_{c,mean}$	= 1548,98 kN
Coefficient	ξ_3	= 1,35
Characteristic pile bearing capacity	R_c	= 1070,31 kN
Design pile bearing capacity	R_{cd}	= 1070,31 kN
Design load	$F_{s,d}$	= 700,00 kN

R_{cd} = 1070,31 kN > $F_{s,d}$ = 700,00 kN

Verification of pile for bearing capacity is SATISFACTORY

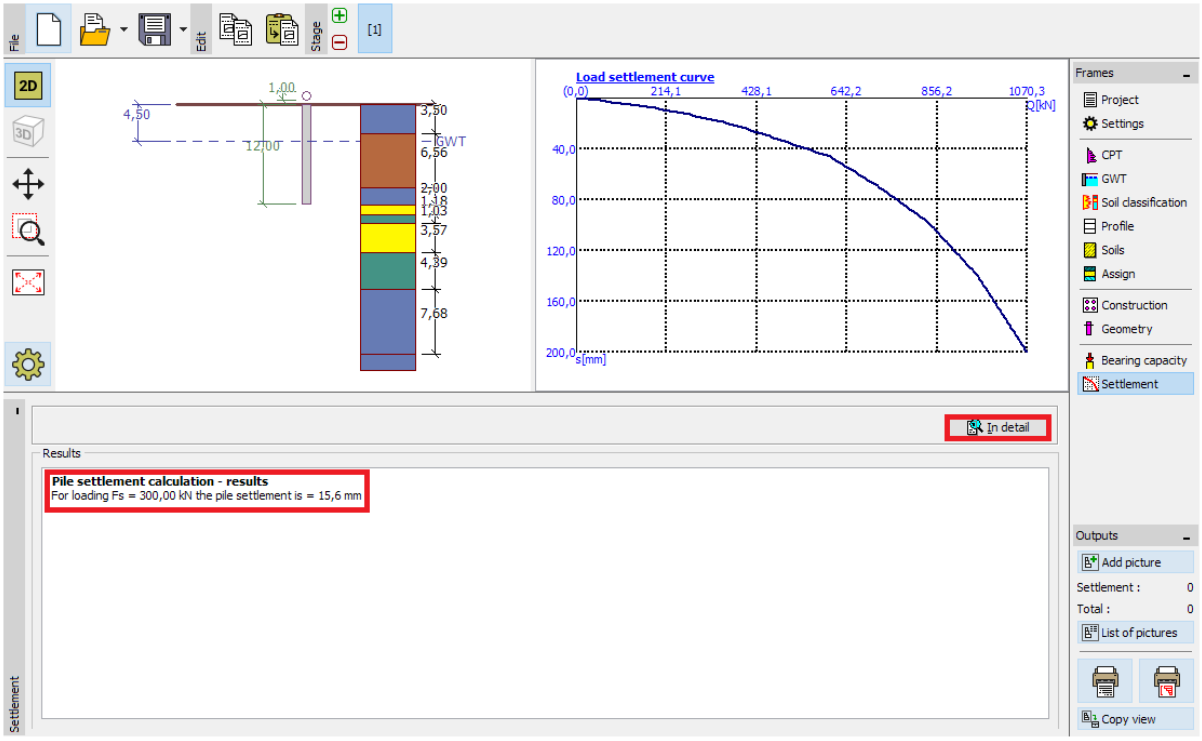
Dialog window “Verification (detailed)“ – Vertical bearing capacity

Note: Bearing capacity analysis can be carried out for one specific test or for all tests.

The vertical bearing capacity of a pile $R_{c,d}$ is the sum of the skin friction and pile base resistance (for more details visit Help – F1). To meet the reliability condition, its value must be higher than the magnitude of the acting design load $F_{s,d}$.

– **EN 1997-2**: $R_{c,d} = 1070{,}31\,kN > F_{s,d} = 700{,}0\,kN$ SATISFACTORY

Then we will go over to the "Settlement" frame, where the ultimate loading curve for the pile and the results of the pile settlement calculation are displayed. The total pile settlement is $w_{1,d} = 15{,}6\,mm$ for service load $F_s = 300\,kN$.



Frame "Settlement"– Ultimate loading curve (working diagram) of a pile

Detailed results are available by clicking the "In detail" button.

Settlement calculation:

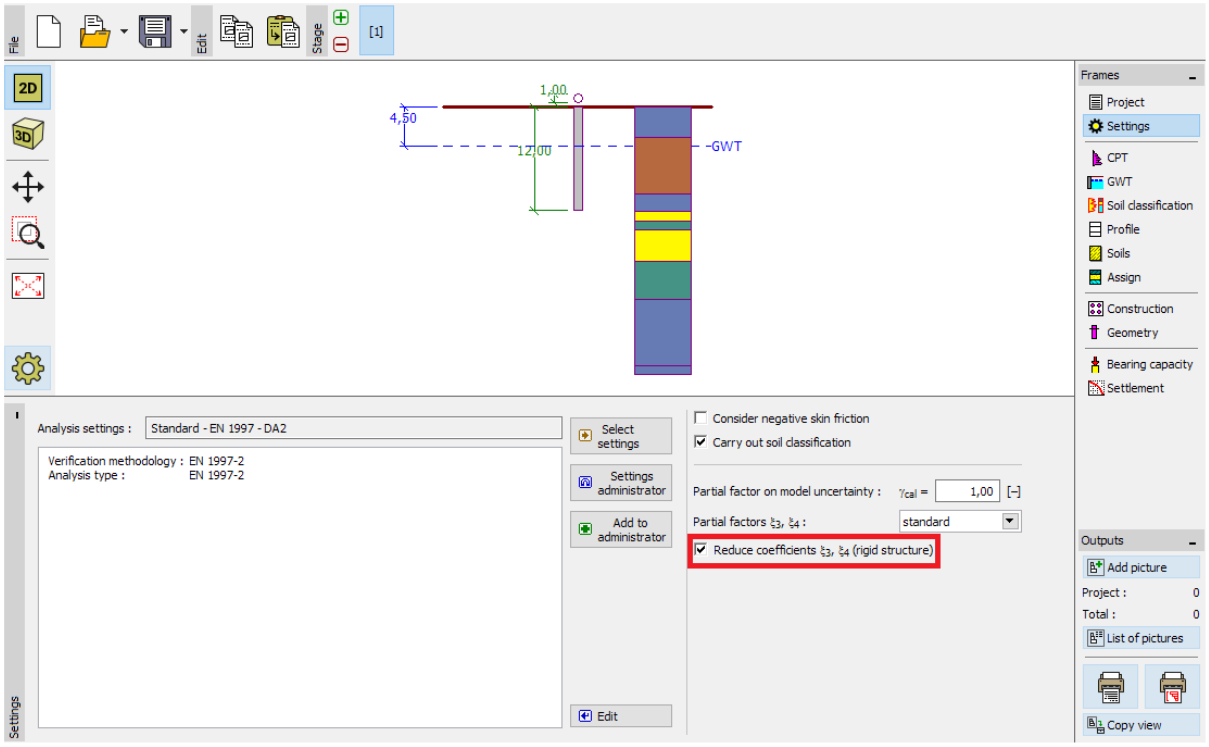
Service load	F_s	= 300,00	kN
Skin bearing capacity	R_s	= 119,11	kN
Bearing capacity at base	R_b	= 180,89	kN
Pile base settlement	w_{base}	= 15,4	mm
Elastic deformation of pile	$w_{el,d}$	= 0,2	mm
Overall settlement	$w_{1,d}$	= 15,6	mm

Pile settlement calculation - results
For loading Fs = 300,00 kN the pile settlement is = 15,6 mm

Dialog window "Verification (detailed)" – Settlement

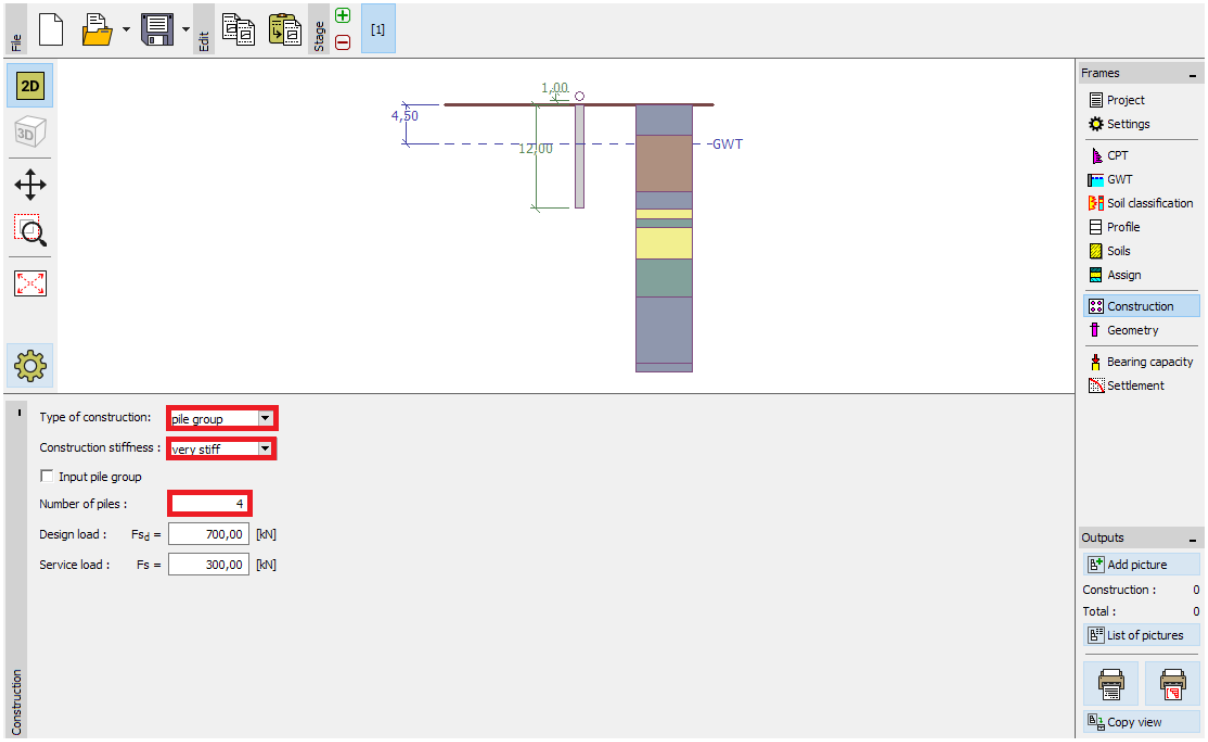
Pile group

Now we will carry out the assessment of a pile group with a rigid grid. In the “Settings” frame, we will choose the option “Reduce coefficients ξ_3, ξ_4 (rigid structure)“.



Frame “Settings“

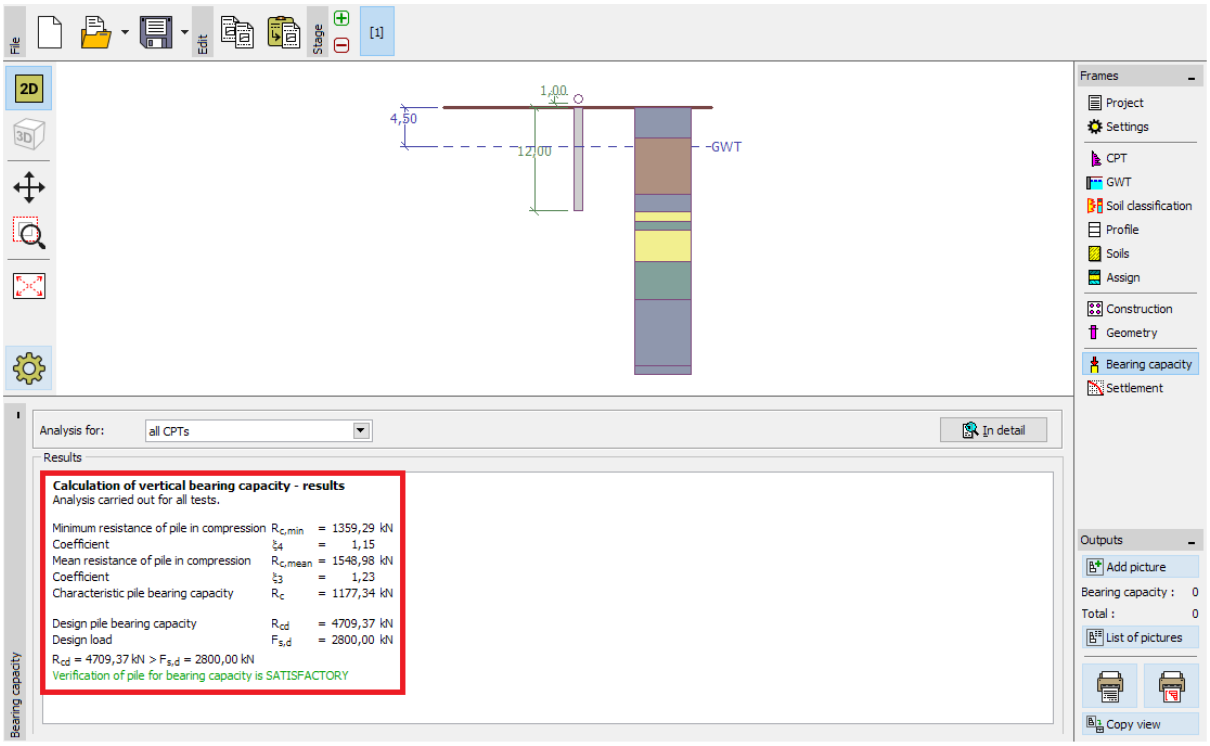
Then we will move over to the "Construction" frame, where we will define the parameters required for pile group analysis. We will consider the pile foundation (pile cap with piles) to be a **rigid structure**, where it is assumed that ***all piles settle equally***. Furthermore, we will set the number of piles to $n = 4$.



Frame "Construction"

The other frames will remain unchanged.

Now we will go back to the “Bearing capacity” frame, where the assessment results are displayed.



Dialog window “Verification (detailed)“ – Vertical bearing capacity

– **EN 1997-2**: $R_{c,d} = 4709.37\ kN > F_{s,d} = 2800.0\ kN$ SATISFACTORY

Conclusion

The vertical bearing capacity of the pile or the pile group being assessed is satisfactory. The main advantage of the analysis based on CPT tests is its speed and clarity. This procedure is accurately defined in *EN 1997-2: Geotechnical Design – Part 2: Ground investigation and testing* and thus the oftentimes ambiguous definition of strength-related parameters is not necessary.