

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

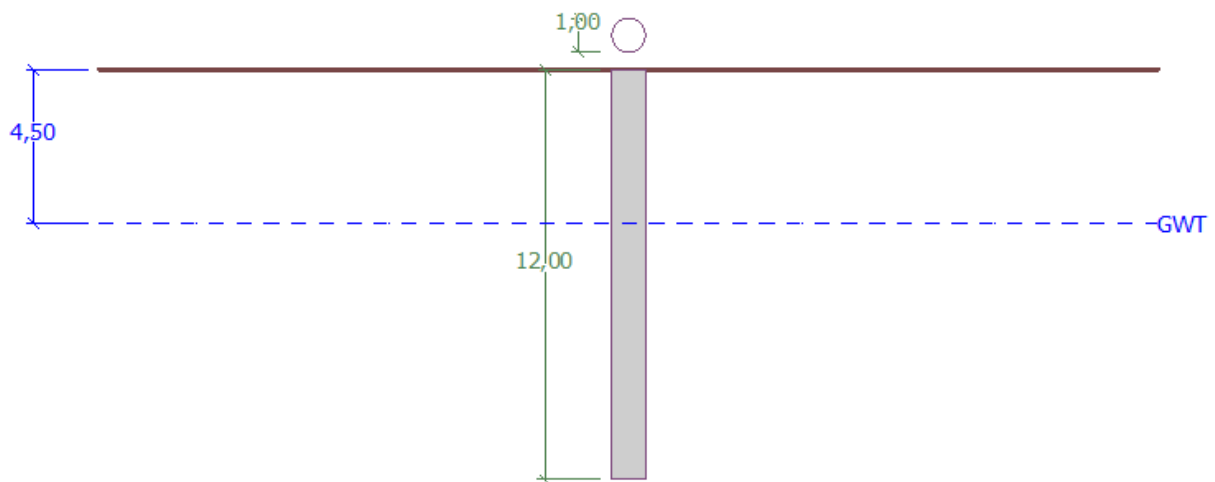
Program: Pile CPT

File: Demo\_manual\_15.gpn

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

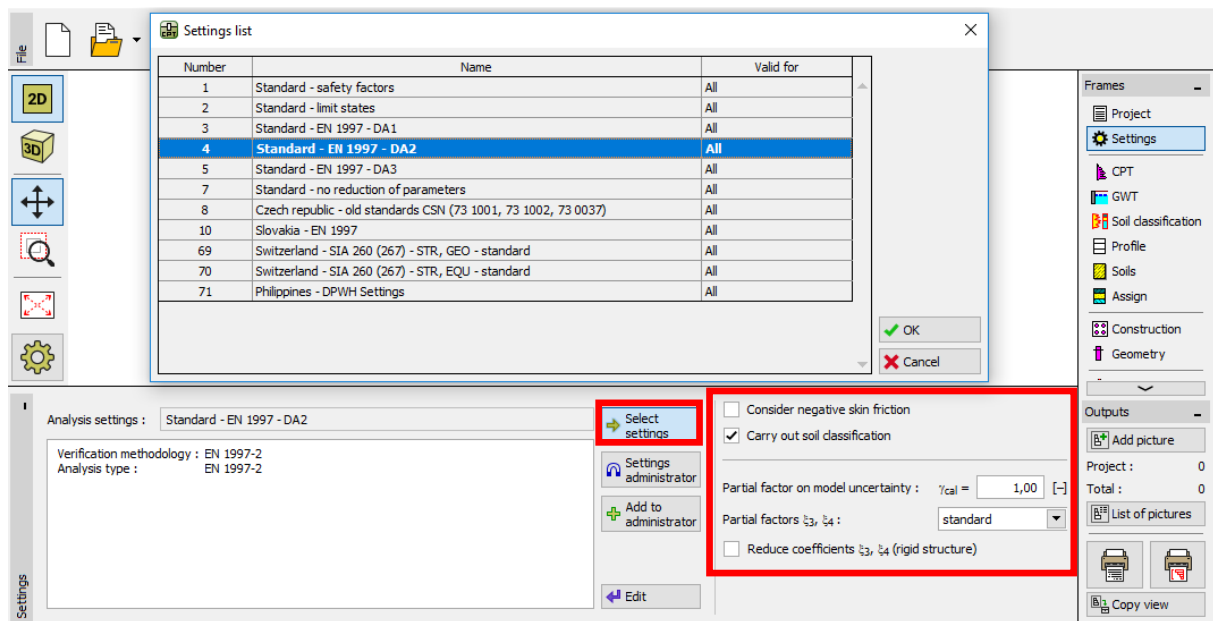


*Problem specification diagram – single pile investigated on the basis of CPT tests*

### Solution

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

In the frame “Setting”, we will click the “Select settings” button (in the middle of the bottom part of the screen). In the “Settings list” dialog window that appears, 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*.



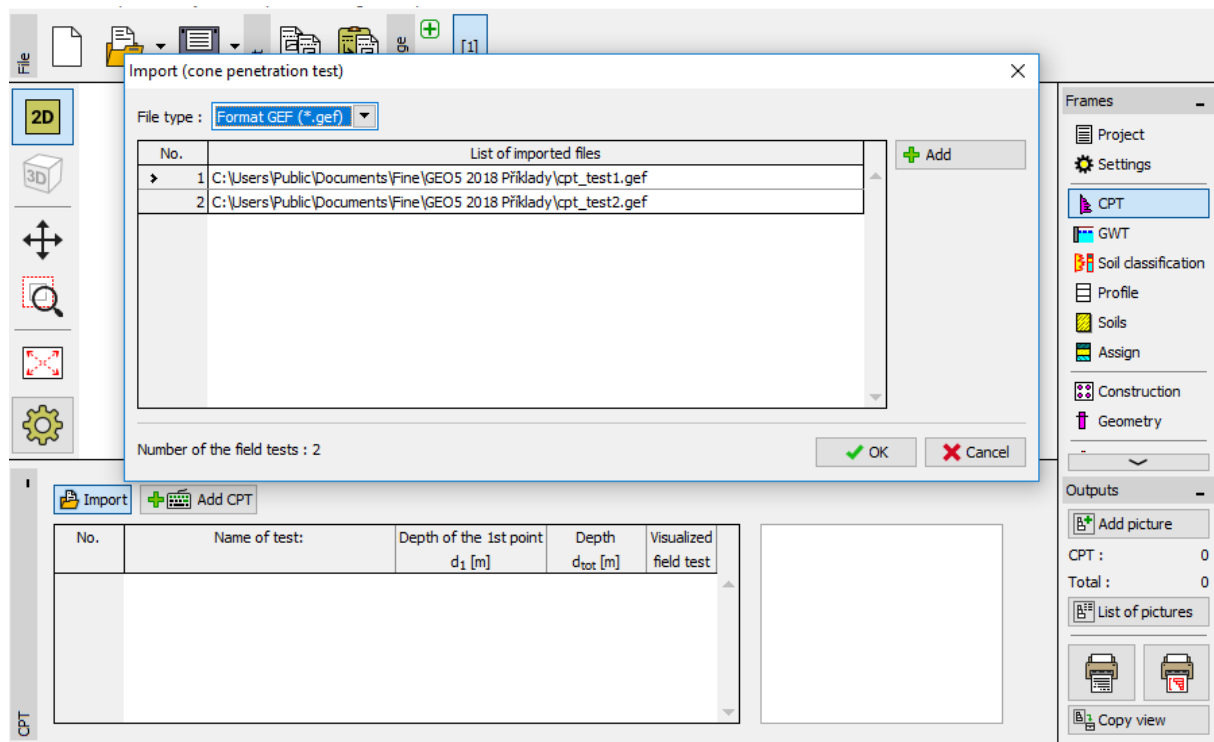
Frame "Settings"

In the first analysis, we will assess a single pile. We will therefore not specify the reduction of correlation coefficients  $\xi_3, \xi_4$ . We will not take the influence of negative skin friction into consideration. 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 – but we will use the standard value of 1.0.

We will also 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  $\xi_3, \xi_4$ , 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 correlation coefficients are smaller. In our case, 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).*

Now, we will move to the “CPT” frame. Here, we will import the completed tests into the program using the button “Import” and then “Add”.



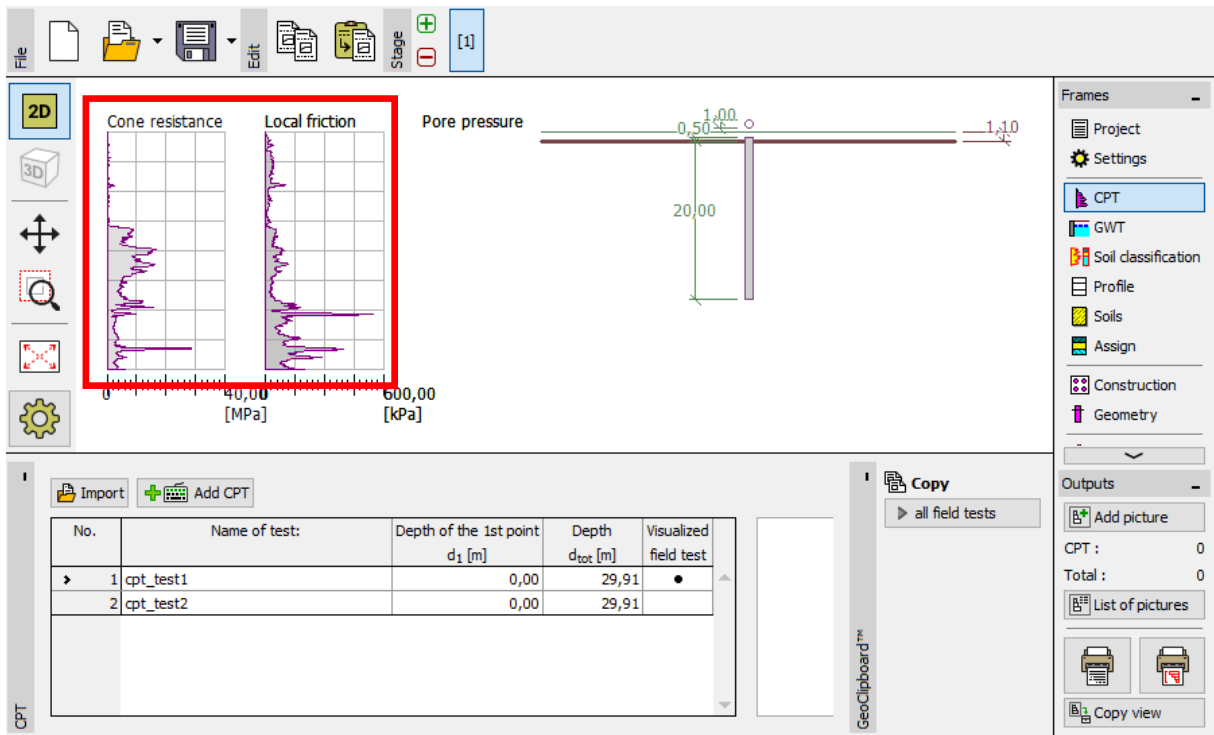
Frame “CPT”

*Note: The files for import (cpt\_test1.gef, cpt\_test2.gef) are included in the GEO5 installation and they are located in the folder FINE in public documents.*

*Note: 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 – 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.*

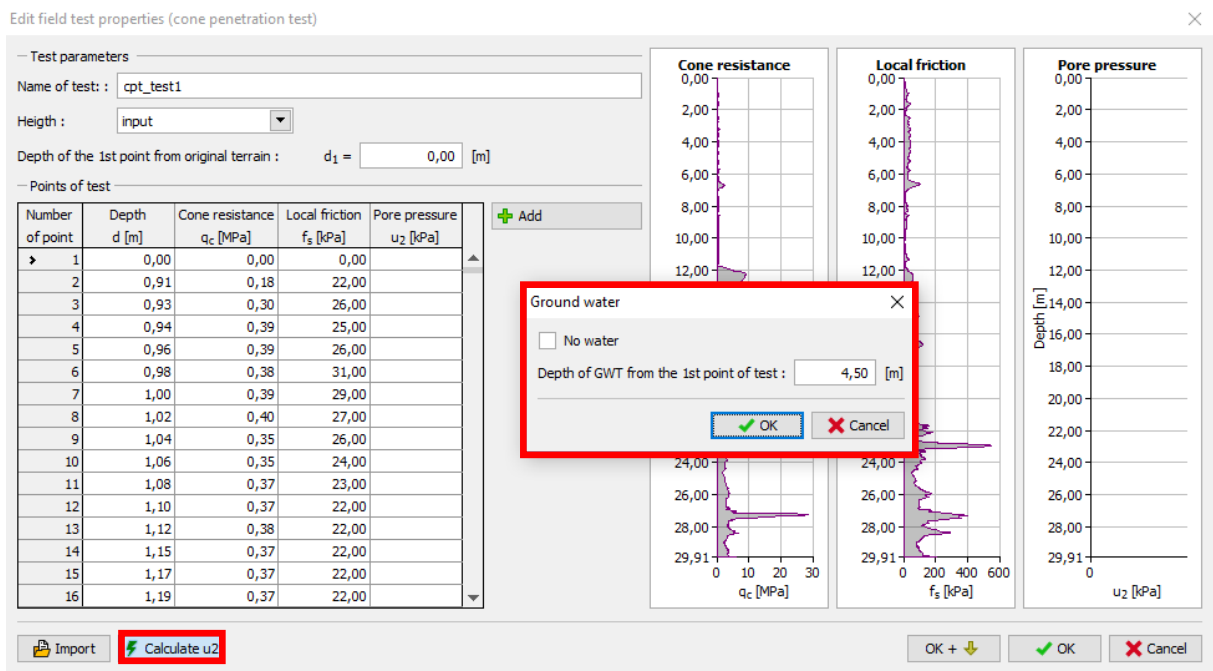
By clicking the “OK” button, the tests are loaded into the program and the graphs of measured cone resistance and local friction are displayed onscreen.



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 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 pore pressure automatically. This is explained in the following text.

Select “cpt\_test1” and click on the “Edit No. 1” button. After pressing the “Edit” button, a dialog window appears with detailed results of the selected test.

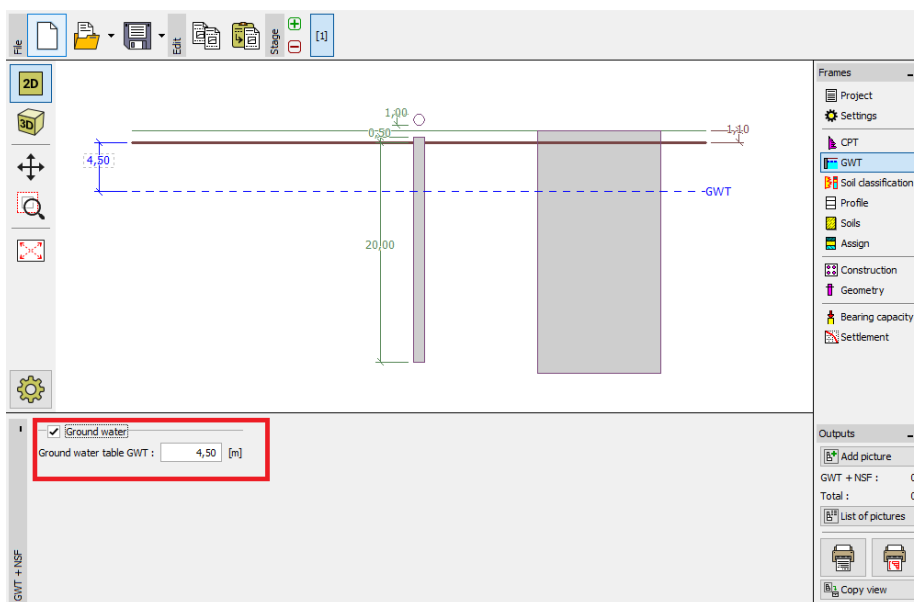


Frame “CPT” – pore pressure calculation

In this dialog window, press the “Calculate u2” button in the bottom left part of the screen and enter the supposed ground water table at 4,50 m.

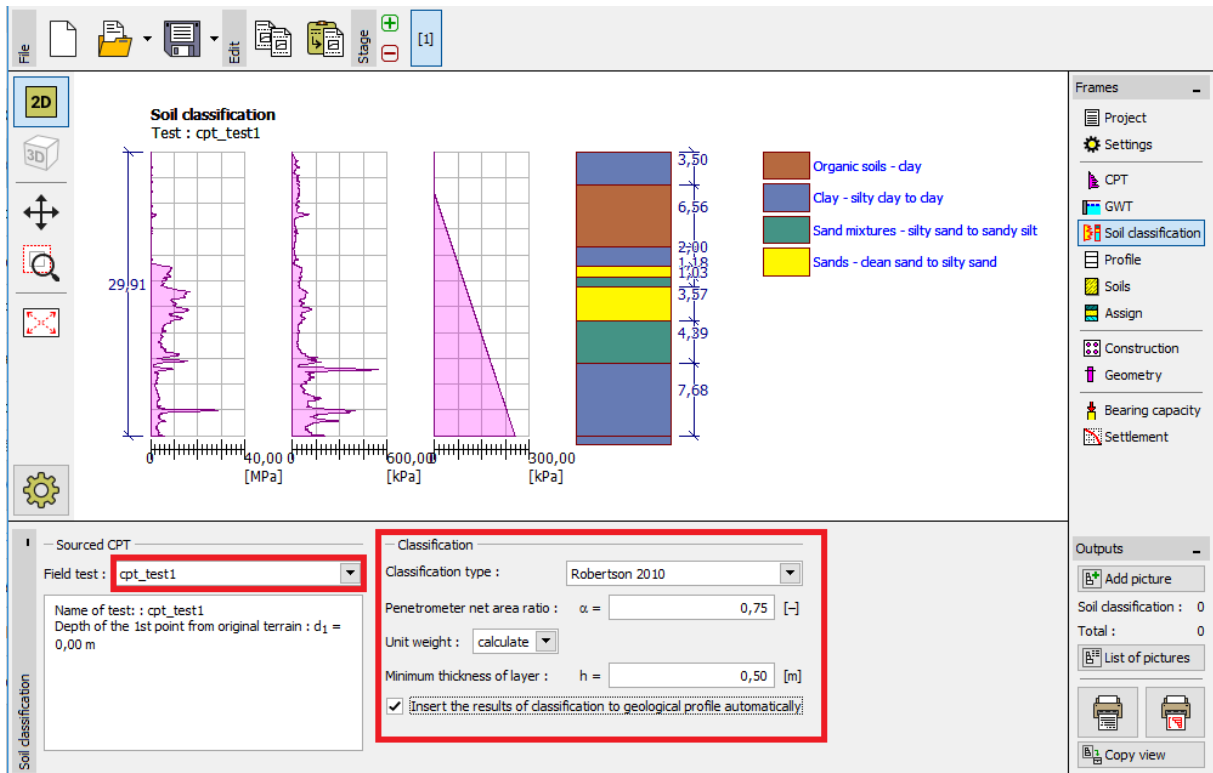
We will perform the calculation of pore pressure for both tests in this way.

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”. We select the classification according to Robertson (2010). The penetrometer net area ratio has a standard value of 0,75. Select option “calculate” to calculate the unit weight using the CPT tests. Lastly, set the minimum thickness of layer to 0,50 m to get a clearer picture of the geological profile. For more information see the program help – F1 or [online](#).

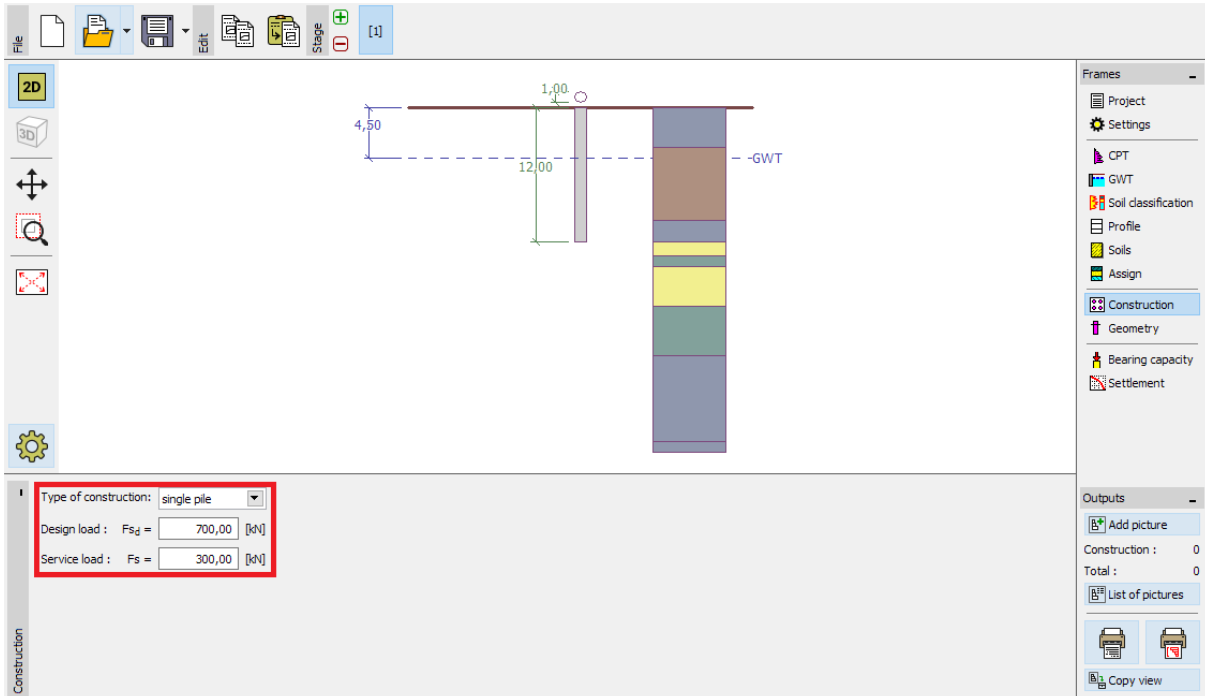


Frame “Soil classification”

*Note: Soil classification is always performed for just 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 inputted automatically based on the values from the CPT tests.

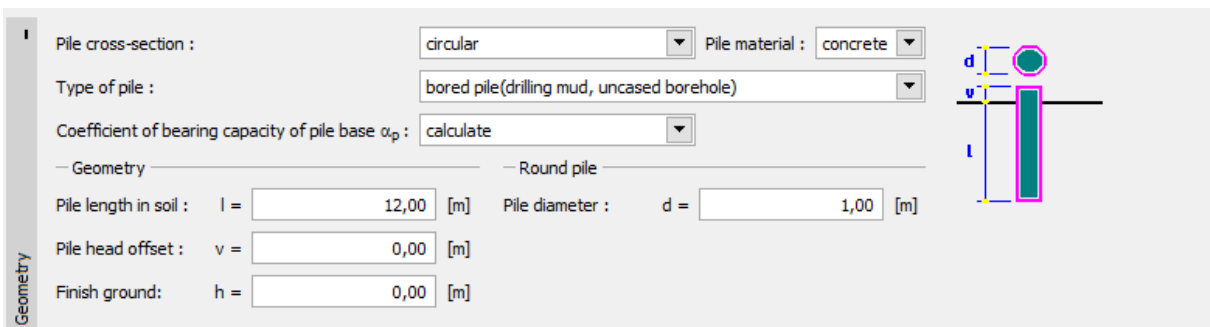
In the “Construction” frame we will choose the “single pile” option. Then we enter the maximum magnitude of the vertical load acting on the pile as shown in the figure below. The design load is used for pile bearing capacity analysis and the service load is used for pile settlement analysis.



Frame “Construction”

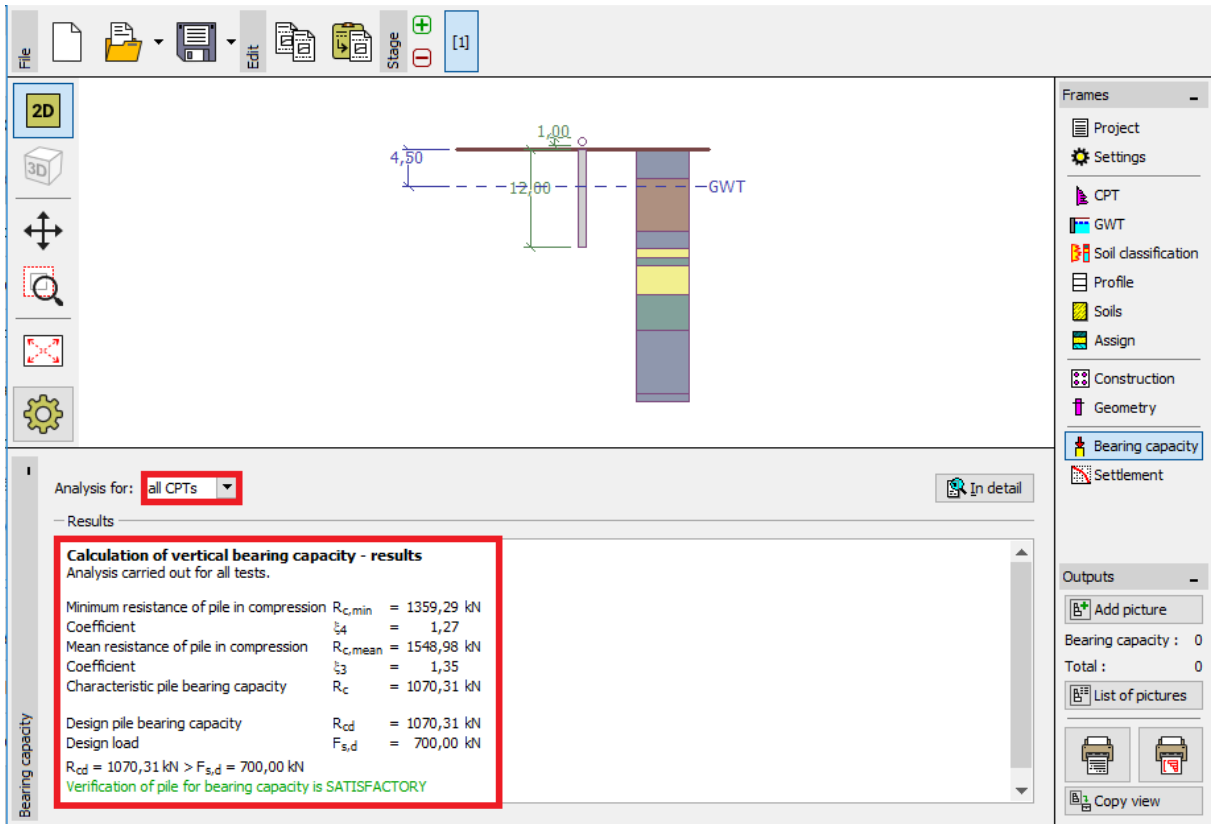
In the “Geometry” frame, we will enter the pile material and the cross-section, specify the basic dimensions, i.e. the pile diameter and its length in soil. Subsequently, we will define the pile execution technology. In this particular case, we have bored piles with the borehole uncased or stabilised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

The coefficient of bearing capacity of pile base  $\alpha_p$  is calculated automatically.



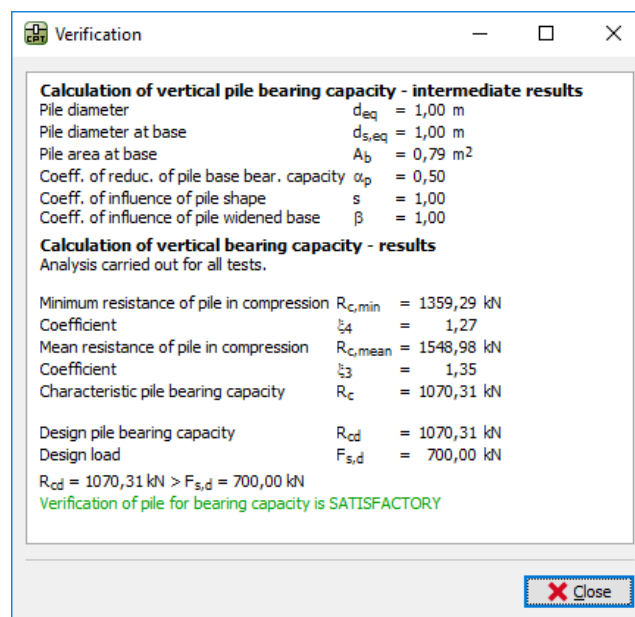
Frame “Geometry”

Now we will go over to the verification of a single pile in the “Bearing capacity” frame. This frame shows us 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.



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

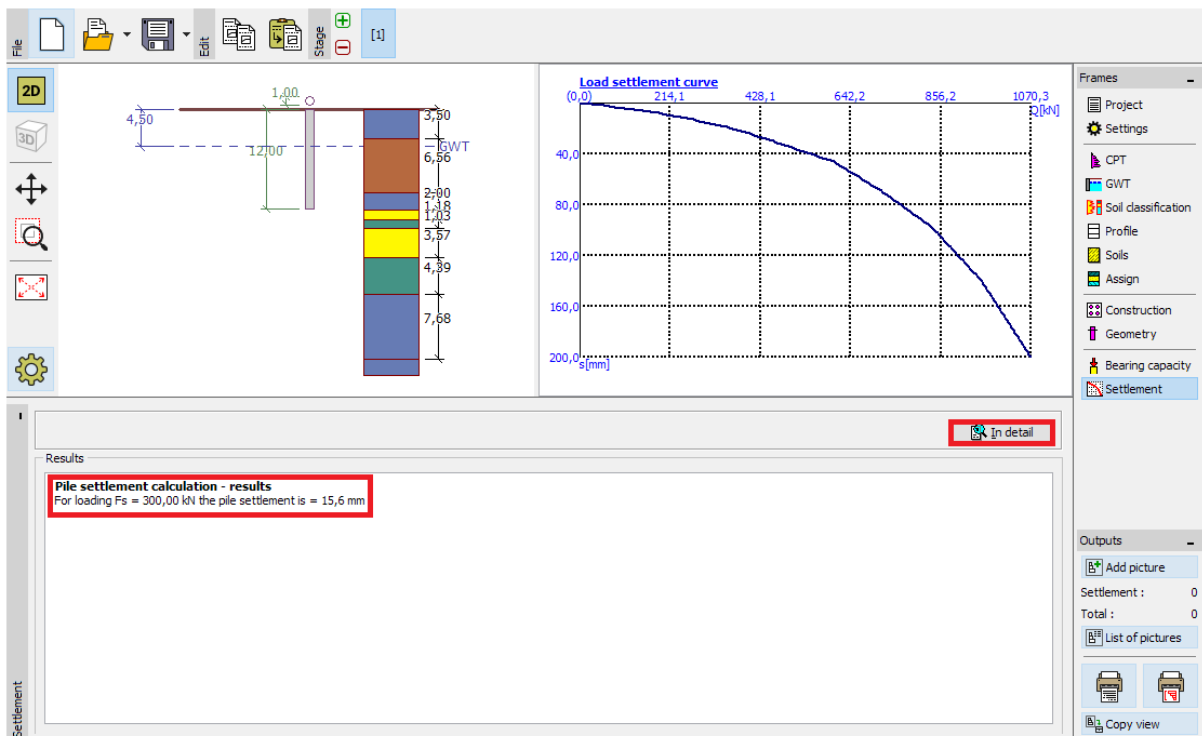


Note: Bearing capacity analysis can be carried out for one specific test or for all tests.

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 the program help – F1). To meet the reliability condition, its value must be higher than the magnitude of the acting design load  $F_{s,d}$ .

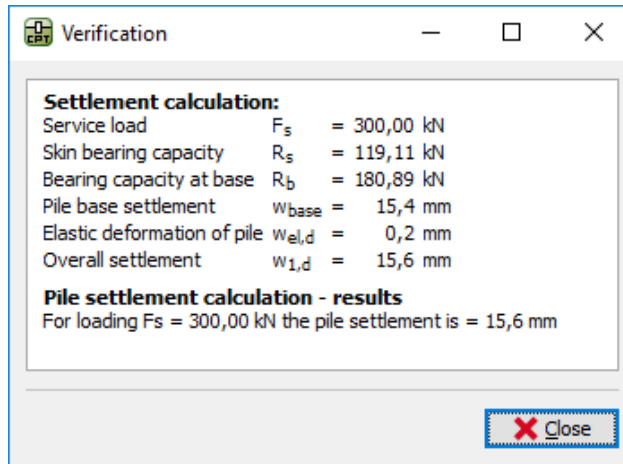
– **EN 1997-2:**  $R_{c,d} = 1070,31 \text{ kN} > F_{s,d} = 700,0 \text{ kN}$  SATISFACTORY

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  $w_{1,d} = 15,6 \text{ mm}$  for service load  $F_s = 300 \text{ kN}$ .



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

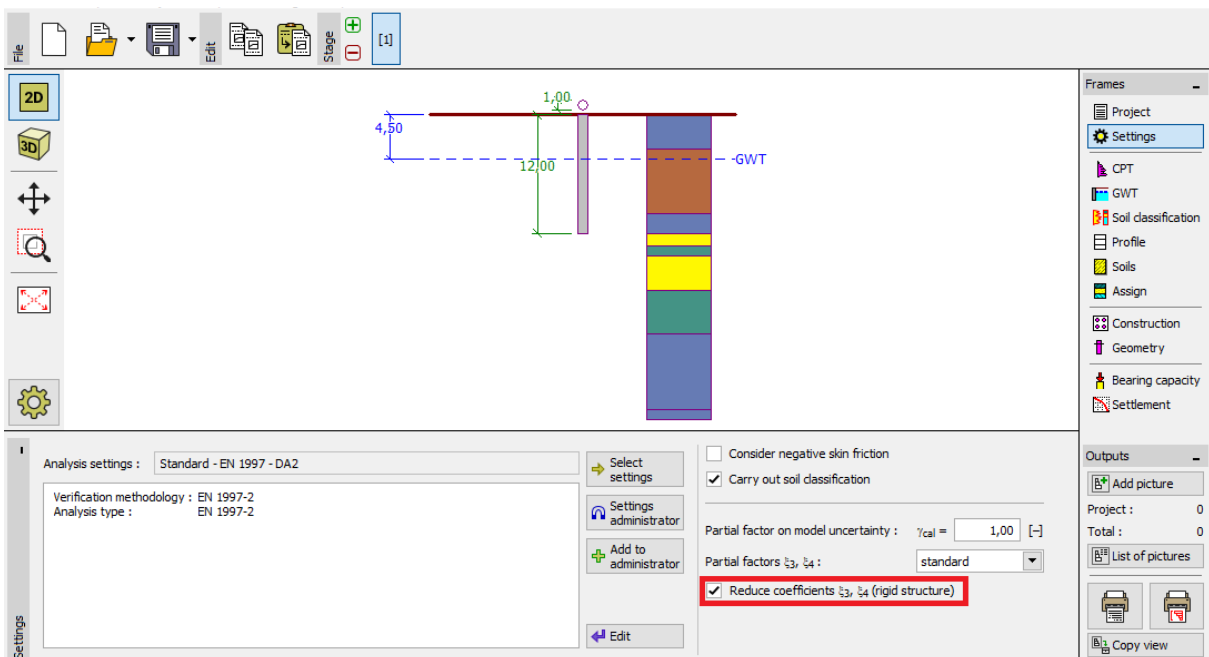
Detailed results are available by clicking the “In detail” button.



Dialog window “Verification (detailed)” – Settlement

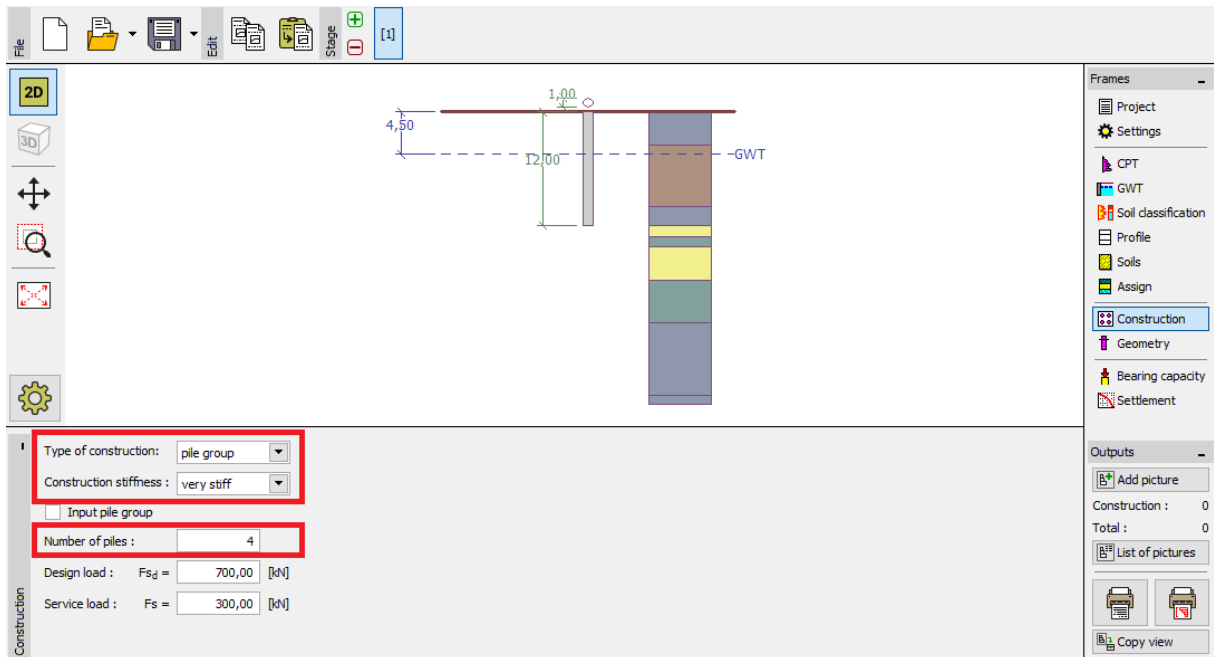
## Pile group

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  $\xi_3, \xi_4$  (rigid structure)”.



Frame “Settings”

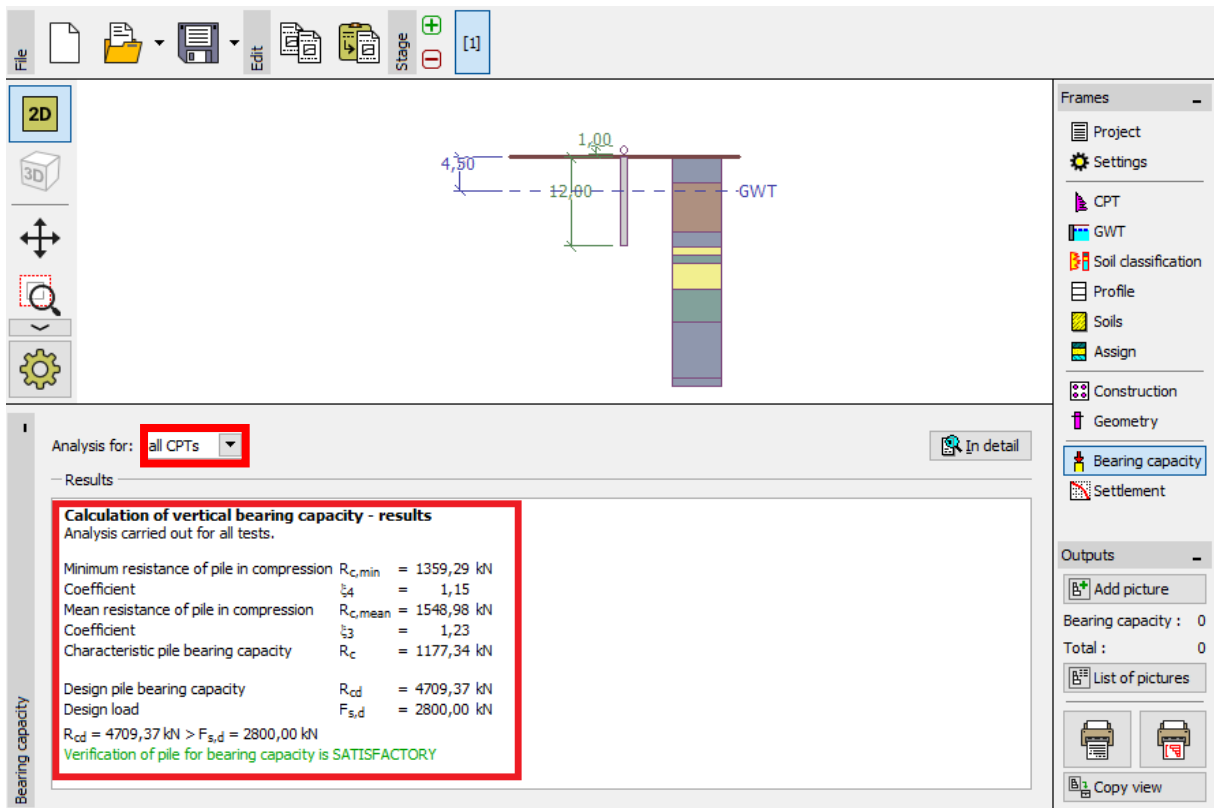
Then we will move over to the “Construction” frame, where we will define the parameters required for pile group analysis. We will consider the pile foundation (pile cap with piles) to be a **rigid structure**, where it is assumed that **all piles settle equally**. Furthermore, we will set the number of piles to 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:**  $R_{c,d} = 4709.37 \text{ kN} > F_{s,d} = 2800.0 \text{ kN}$  **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 so the often ambiguous definition of strength-related parameters is not necessary.