GeoMechanica Desktop

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GeoMechanica Desktop

The GeoMechanica desktop is a suite of programs that were written to help increase the productivity in the GeoMechanica consulting house. In GeoMechanica, the norm was to use c# functions in all routine geotechnical calculations. Now, all code is being transformed into user friendly interfaces that can be used by all geotechnical engineers so they can focus on engineering rather than decrypting computer code. So far 4 programs have been completed with a plan to add more in the upcoming releases. The 4 programs are all for shallow foundations' bearing capacity and settlement calculations. Rafts, footing, and strip foundations can be analyzed. The GeoMechanica desktop should be used in early stage of foundation prototyping and for routine geotechnical analysis in conjunction with extensive subsurface soil investigation.

1. Shallow foundations

1.1. Elastic settlement on uniform soil

For a foundation that rests on a uniform soil with a constant modulus of elasticity as shown in figure 1.1, the settlement of the foundation can be calculated as follows,

$$S_e = q_0(\alpha B')\frac{1-\mu_s^2}{E_s}\, I_s\, I_f \qquad (1.1)$$

Where:

S_e	:	Foundation settlement
q_0	:	Foundation pressure
α	:	Factor that depends on the location of the calculated settlement. α = 4 for settlement at the center and α = 1 for settlement at the corner of the foundation.
B'	:	Adjusted width. $B' = B/2$ for settlement at the center of the foundation and $B' = B$ for settlement at the corner of the foundation.
B	:	Foundation shortest dimension
μ_s	:	Poisson's ratio of the soil
E_s	:	Elastic modulus of the soil
I_s	:	Shape factor
I_f	:	Depth factor

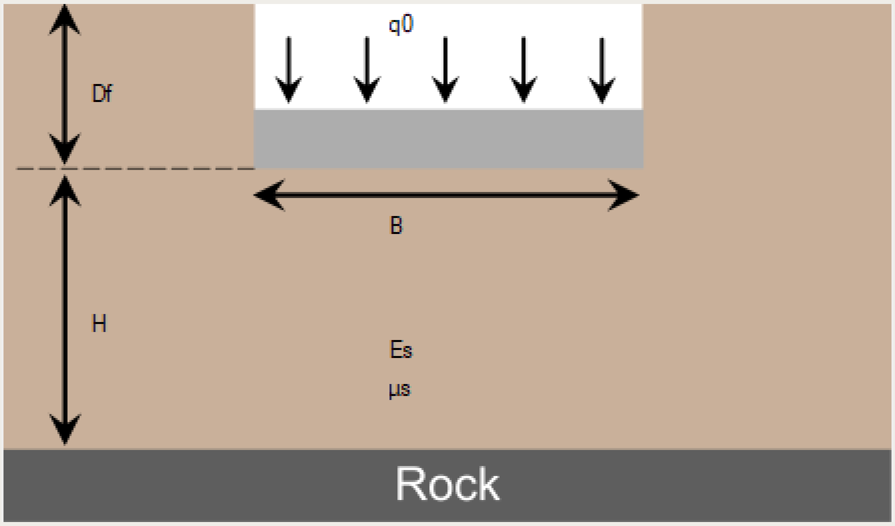


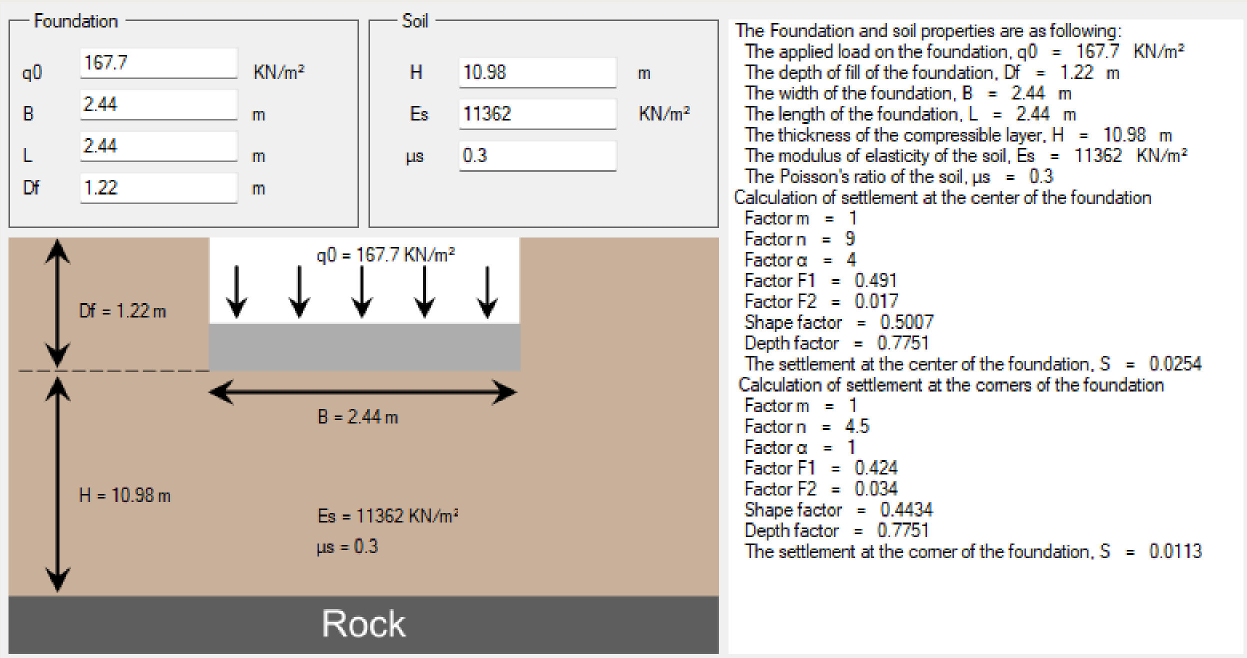
Figure 1.1: Foundation on uniform soil

1.1.1. Example on elastic settlement on uniform soil

The following examples is taken from Das Principle of Foundation Engineering 7th edition. The parameter provided in the example are given as

q_0	:	167.7 Kpa
B	:	2.44 m
μ_s	:	0.3
E_s	:	11362 KPa

The depth to bed rock or end of stress bulb, H was given as 10.98 m. the parameters are inserted in the program and the settlement at the center of the foundation was found to be 2.54 cm while at the corner, it was found to be 0.0113 m.



1.2. Elastic settlement on Gibson soil

Gibson soils can be defined as soils which stiffness increases in depth. Naturally as confinement increases with depth, the modulus of elasticity should increase. If foundation is placed on a soil where the modulus of elasticity increases with depth as shown in figure 1.2, its settlement can be calculated as:

$$S_e = \frac{q_0 B_e (I_G I_F I_E)(1-\mu_s^2)}{E_{s0}} \tag{1.2}$$

Where:

S_e	:	Foundation settlement
q_0	:	Foundation pressure
B_e	:	Diameter of an equivalent circle
μ_s	:	Poisson's ratio of the soil
E_{s0}	:	Elastic modulus of the soil at the bottom of the foundation
I_G	:	Factor to account for Gibson's soil
I_F	:	Factor to account for the rigidity of the foundation
I_E	:	Factor to account for the embedment of the foundation

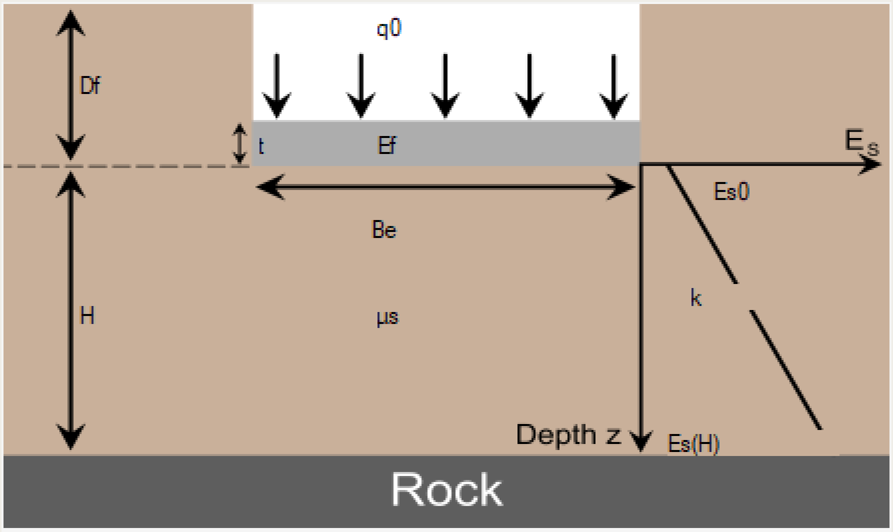


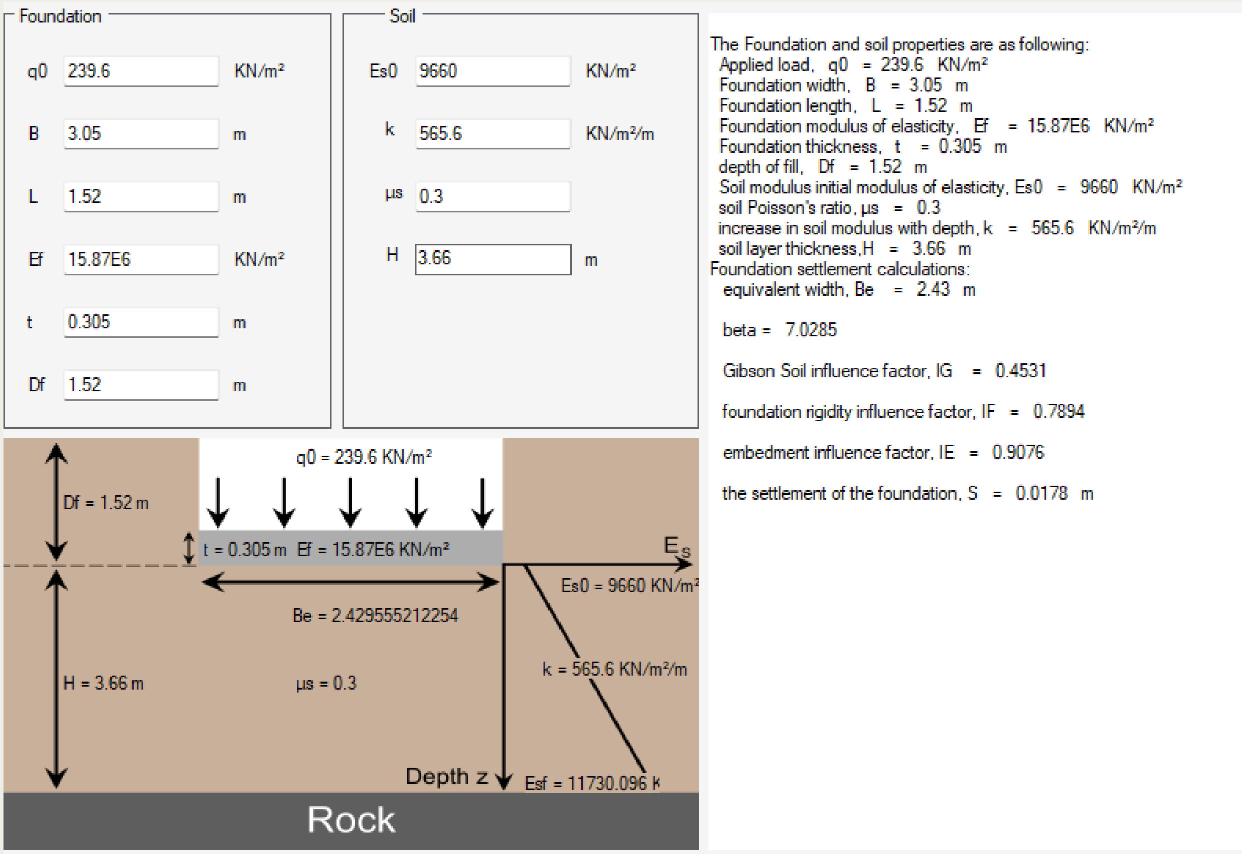
Figure 1.2: Foundation on Gibson soil

1.2.1. Example on elastic settlement on Gibson soil

The following examples is taken from Das Principle of Foundation Engineering 7th edition. The parameter provided in the example are given as

q_0 : 239.6 Kpa
B_e : 2.43 m
μ_s : 0.3
E_{s0} : 9660 Kpa

Using the software with the following input gives



The settlement differs form that found in the book, mainly because of the factor I_G. Most factors here are calculated using finite element models and not from the reference mentioned in the book.

1.3. Consolidation settlement

Consolidation settlement is a phenomenon that occurs in clay soils. It happens when saturated clay is subjected to pressure. This pressure raises the pore water pressure between the clay particles. With time the additional pore pressure dissipates, and the pressure is transferred to the clay particles. The procedure takes a long time. To calculate the consolidation settlement of a clay layer, a one-dimensional consolidation test is performed to obtain the coefficient of consolidation, coefficient of rebound and the pre-consolidation pressure if the clay is over consolidated. Over consolidated clay is that which was exposed to pressure in the past but then the pressure was removed. This pressure can be due to geologic events such as the build up of snow over a clay layer in the Ice Age. It also can be a result of human activity such as building and demolishing a structure on clay. In any case, once the clay is subjected to a certain pressure, it can be detected using the consolidation test, even if the pressure is removed from the clay.

Once consolidation tests are performed and the needed parameters are obtained the consolidation settlement can be calculated as

If the clay is normally consolidated
$$S_c = \frac{C_c H}{1+e_0} Log \frac{\sigma_0' + \Delta\sigma_v'}{\sigma_0'} \quad (1.3)$$

If the clay is over consolidated and $\sigma_0' + \Delta\sigma_v' \leq \sigma_c'$
$$S_c = \frac{C_s H}{1+e_0} Log \frac{\sigma_0' + \Delta\sigma_v'}{\sigma_0'} \quad (1.4)$$

If the clay is over consolidated and $\sigma_0' + \Delta\sigma_v' > \sigma_c'$
$$Sc = \frac{C_s H}{1+e_0} Log \frac{\sigma_c'}{\sigma_0'} + \frac{C_c H}{1+e_0} Log \frac{\sigma_0' + \Delta\sigma_v'}{\sigma_c'} \quad (1.5)$$

Where:

S_e	:	Foundation settlement
q_0	:	Foundation pressure
B_e	:	Diameter of an equivalent circle
μ_s	:	Poisson's ratio of the soil
E_{s0}	:	Elastic modulus of the soil at the bottom of the foundation
I_G	:	Factor to account for Gibson's soil
I_F	:	Factor to account for the rigidity of the foundation
I_E	:	Factor to account for the embedment of the foundation

The consolidation settlement calculation window is very different from the previous windows shown in section 1.1 and 1.2. the window is shown in figure 1.3. the program allows for the entering multiple soil layers. In addition, each layer can be checked for consolidation settlement separately. This is important for multilayered soils where sand layers, which don't experience consolidation, might exist between clay layers. If the layer is over consolidated, a value of the pre-consolidation pressure should be input into the soil layers table if not it can be left to zero. Part 1 of the program is for foundation information. The foundation can be circular, rectangular other than a strip foundation. Choosing the proper type of foundation allows for the correct calculation of the stress on the clay layer. Part 2 is the soil layers input table. Multiple soil layers can be incorporated in the analysis. The program distinguishes between consolidated and non-consolidated layers in the analysis as per the user request. The soil properties needed as an input are:

t	:	Thickness of the soil layer
γ	:	Unit weight Foundation pressure
$e0$	:	Void ratio
Cc	:	Coefficient of consolidation
Cs	:	Swelling index or coefficient of rebound (leave empty for NC clay)

σ_c : Pre-consolidation pressure (leave empty for NC clay)

The consolidation checkbox in the table checked if the soil layer should be included in the analysis. If a layer is not included in consolidation analysis, only its thickness and unit weight are needed as an input for overburden pressure calculations. You can delete any layer by selecting it and click on the red x button. The water table level should be inputted into the textbox, a default value of 1 m below ground level is assumed. Part 3 is a 3D rendering of the foundation and the soil layers. And part 4 is the log where analysis steps and results are shown.

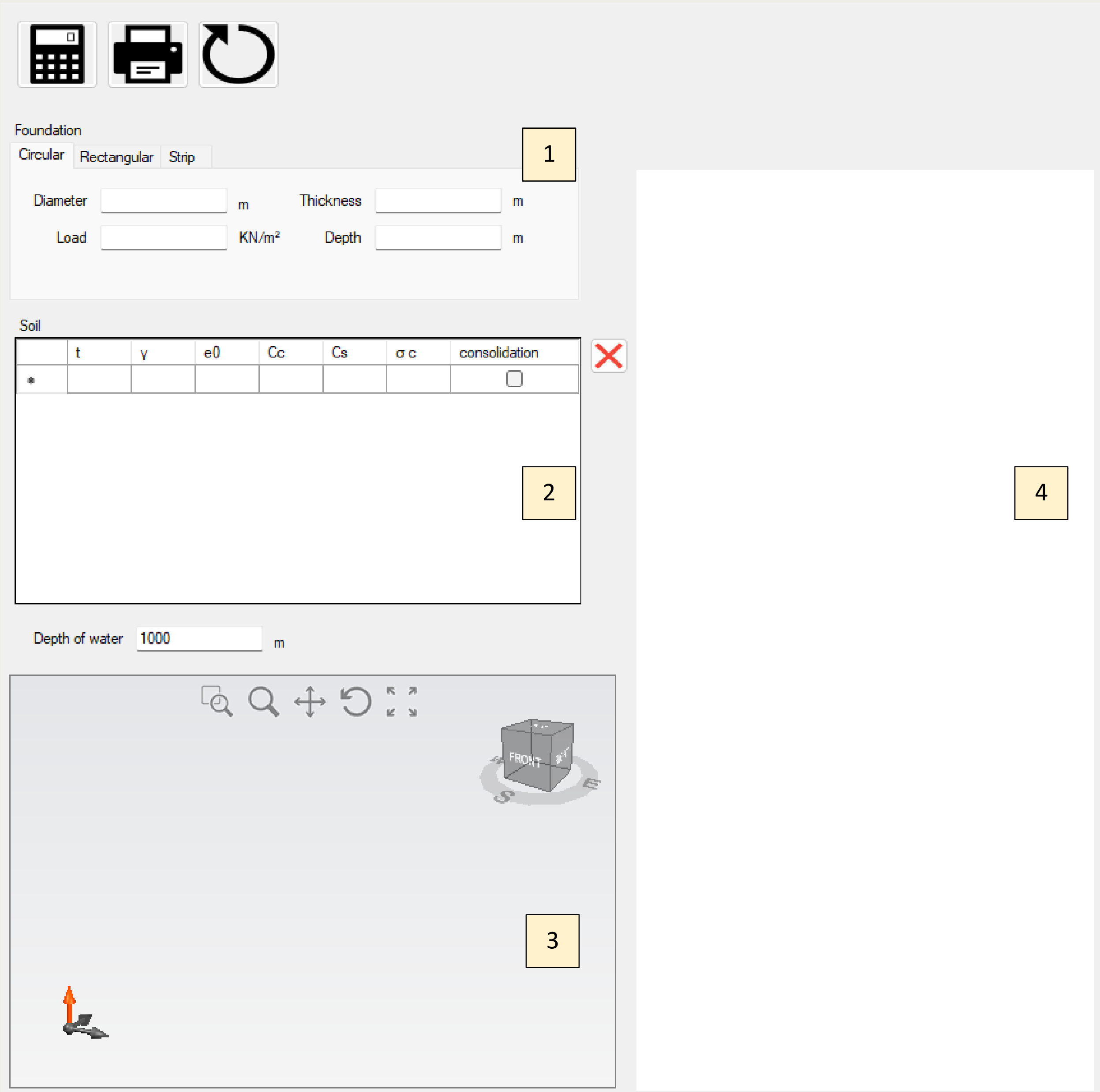
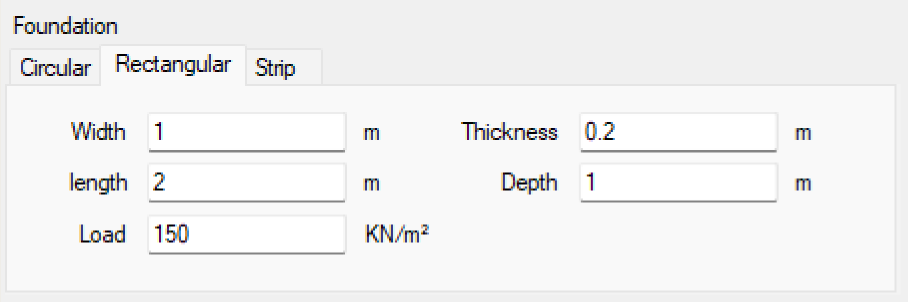


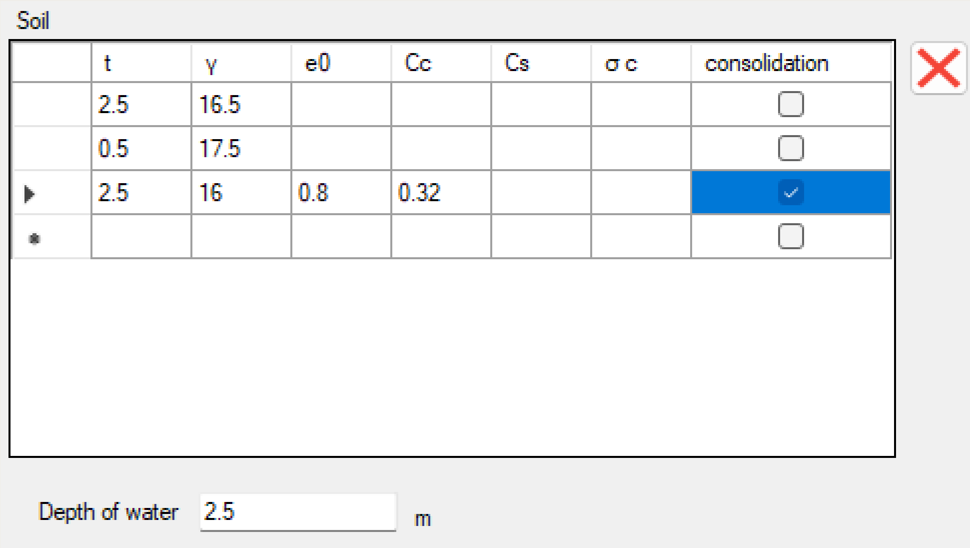
Figure 13: Program layout for consolidation settlement

1.3.1. Example on consolidation settlement

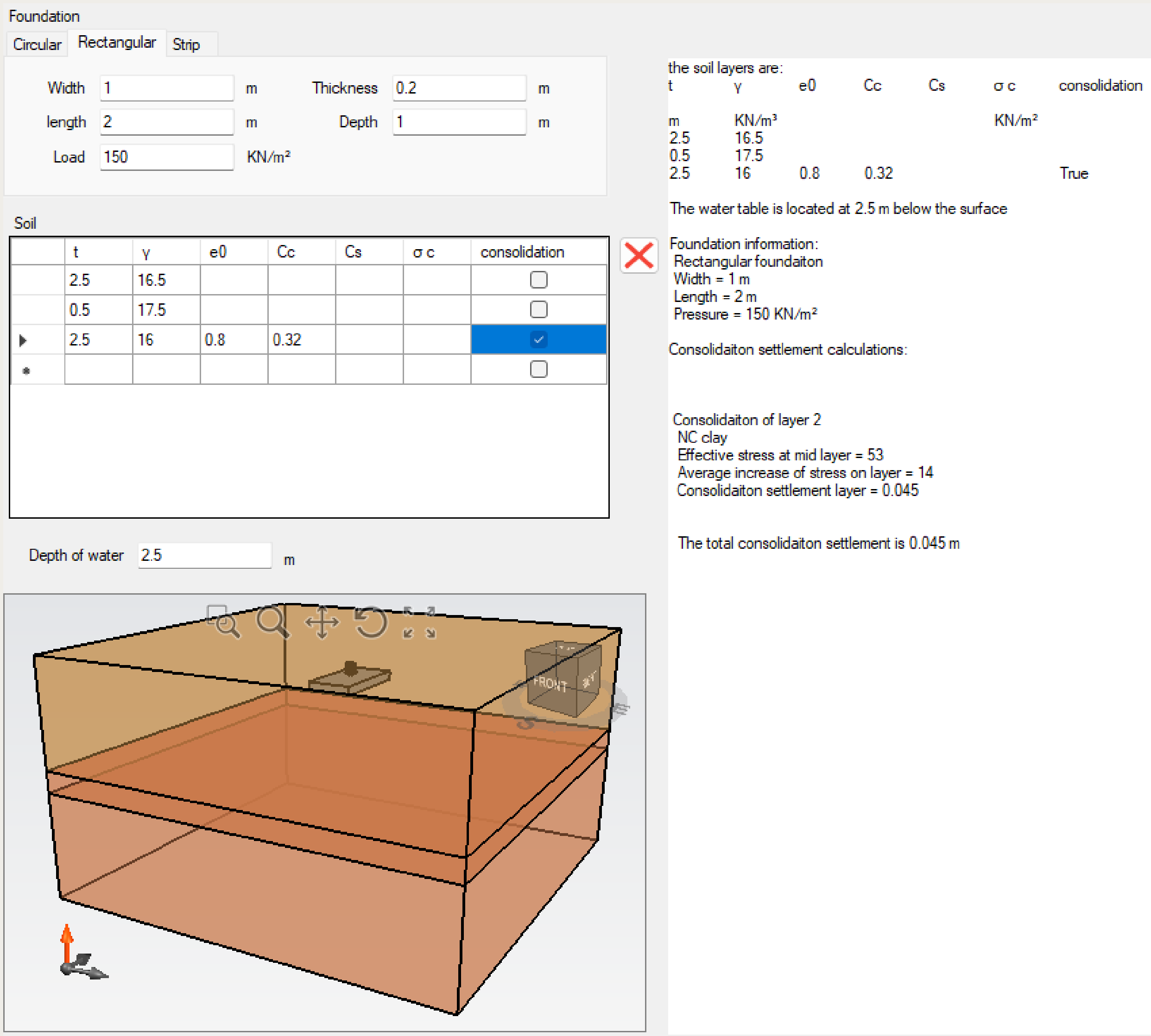
The foundation shown in figure 1.4 is being analyzed for consolidation settlement. To use the GeoMechanica Desktop, first the tab control is changed to rectangular foundation with the following input



The information of the soil is then inputted in the table of soil layers. Note that for the top sand layers, only the thickness and the unit weight are used. The other fields are left empty. For the clay layer, the initial void ration and the coefficient of consolidation are add to the table while the pre-consolidation pressure is left empty since it is a normally consolidated clay. Finally the water table level is entered to the program at 2.5 below ground level.



As simple as this, all the needed information is entered in the program and the analysis can be run. After clicking on the calculate icon the 3D model viewer and the log will be updated. The final window will look as the following,



A 3d model is added to the window and the results are shown in the log. The final settlement was found to be 0.045 m. the output in the log can be copied to be used in a report. In addition, the window can also be printed as is to a pdf document.

1.4. Bearing capacity of shallow foundations

This program uses the general equation of Meyerhof to calculate the bearing capacity of shallow foundations The general bearing capacity equation is written as follows:

$$q_u = cN_cF_{cs}Fc_dF_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \frac{1}{2}\gamma B'\gamma N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i} \quad (1.6)$$

Where:

q_u	:	Ultimate bearing capacity of the foundation
c'	:	Cohesion of the soil
B'	:	Effective foundation width
q	:	Effective stress at the foundation level
γ	:	Unit weight of the soil
N_c, N_q, N_γ	:	Bearing capacity factors
$F_{cs}, F_{qs}, F_{\gamma s}$	:	Shape factors
$F_{cd}, F_{qd}, F_{\gamma d}$	:	Depth factors
$F_{ci}, F_{qi}, F_{\gamma i}$	:	Load inclination factors

The program considers the effect of water table below or above the foundation level. If water table exists above the foundation level, both the value of q and γ in equation 1.6 should be changed accordingly. If the water table is below the foundation at a depth that is less than the foundation width, only the value of γ in equation 1.6 needs to be reduced.

The program also takes into account the eccentricity of the loading either one way or two-way eccentricity. Two-way eccentricity is delt with as per AASHTO LRFD bridge design specification Article 10.6.1.3. The width and the length of the foundation are reduced as:

$$B' = B - 2e_B \quad (1.7)$$

$$L' = L - 2e_L \quad (1.8)$$

The value of the effective width and length are used in calculation of the shape factors and in equation 1.6. These values are not used in calculation of depth factor and effect of water table.

1.4.1. Example on bearing capacity calculation of a shallow foundation

The example shown in figure 1.4 will be solved using the GeoMechanica Desktop. Nor eccentric loading neither was a water table below the ground were reported.

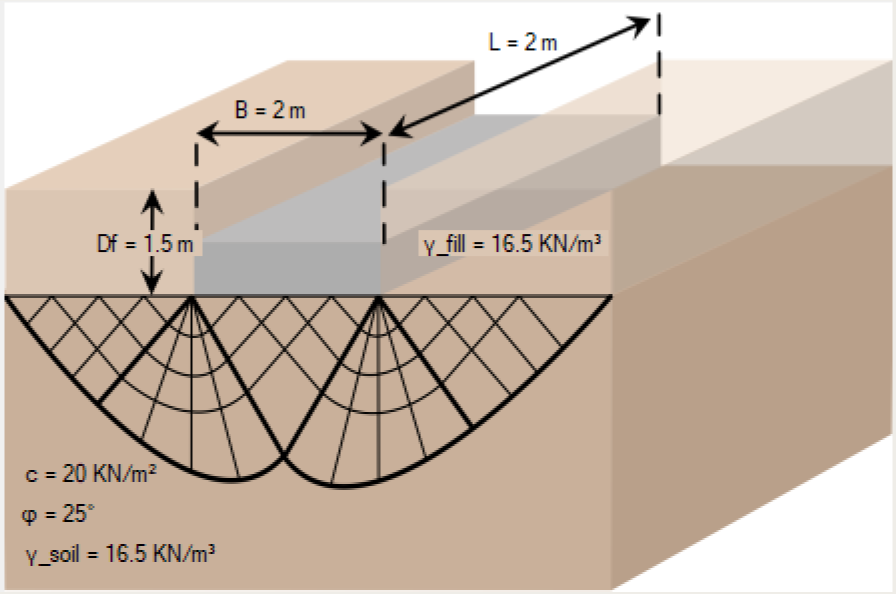
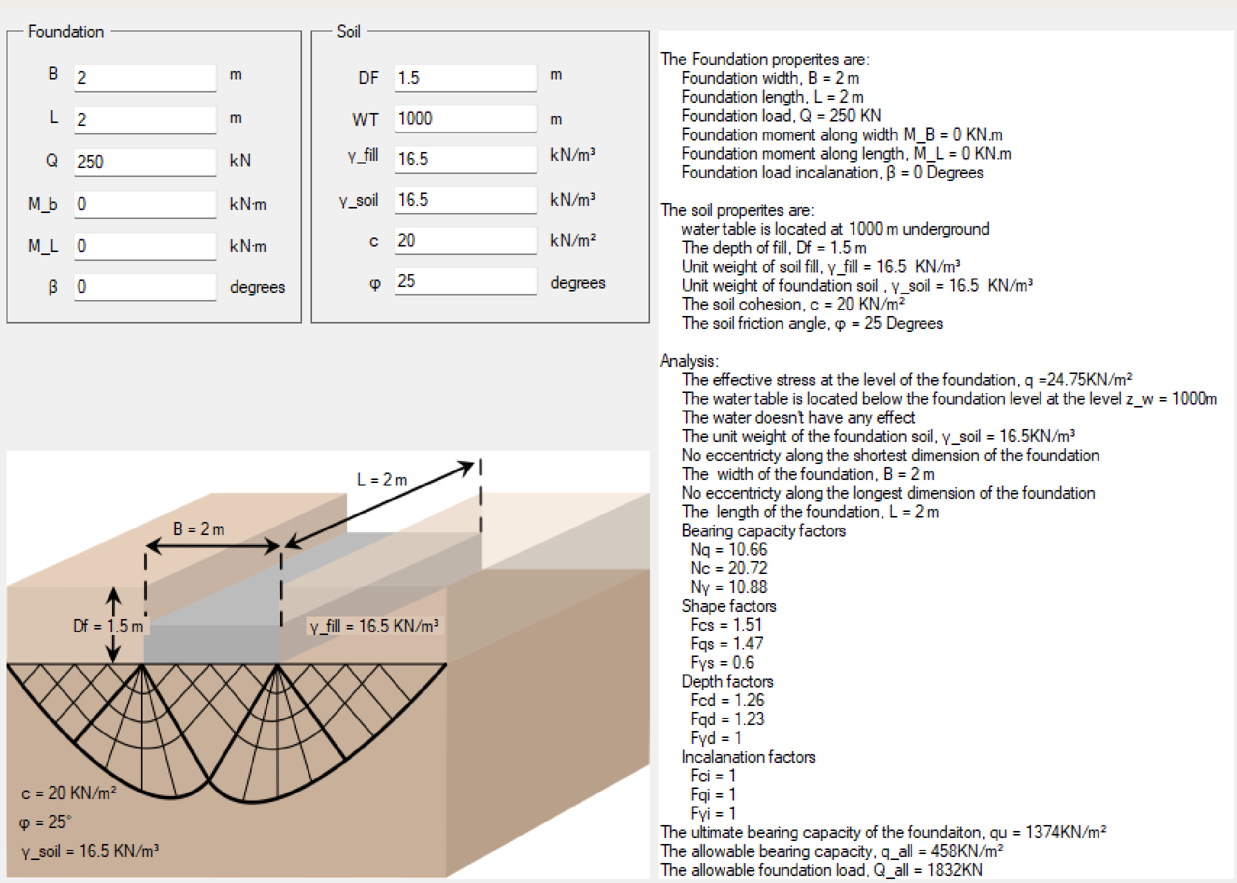


Figure 1.4: Foundation problem for example 1.4.1

The input and output of the program for this problem should look like



A value of water table level of 1000 m was used to indicate that water had no effect. The bearing capacity of the foundation is $1374\ KN/m^2$, the allowable load shouldn't exceed $1832\ KN$.

1.4.2. Example on bearing capacity calculation of a shallow foundation with water table

The example shown in figure 1.4 will be solved using the GeoMechanica Desktop. The water table was reported at 0.61 meters below ground.

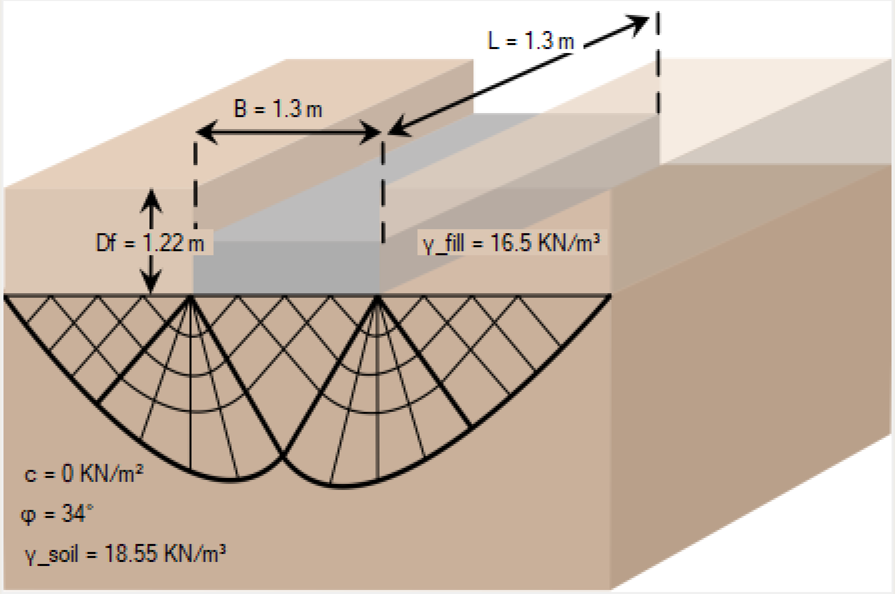
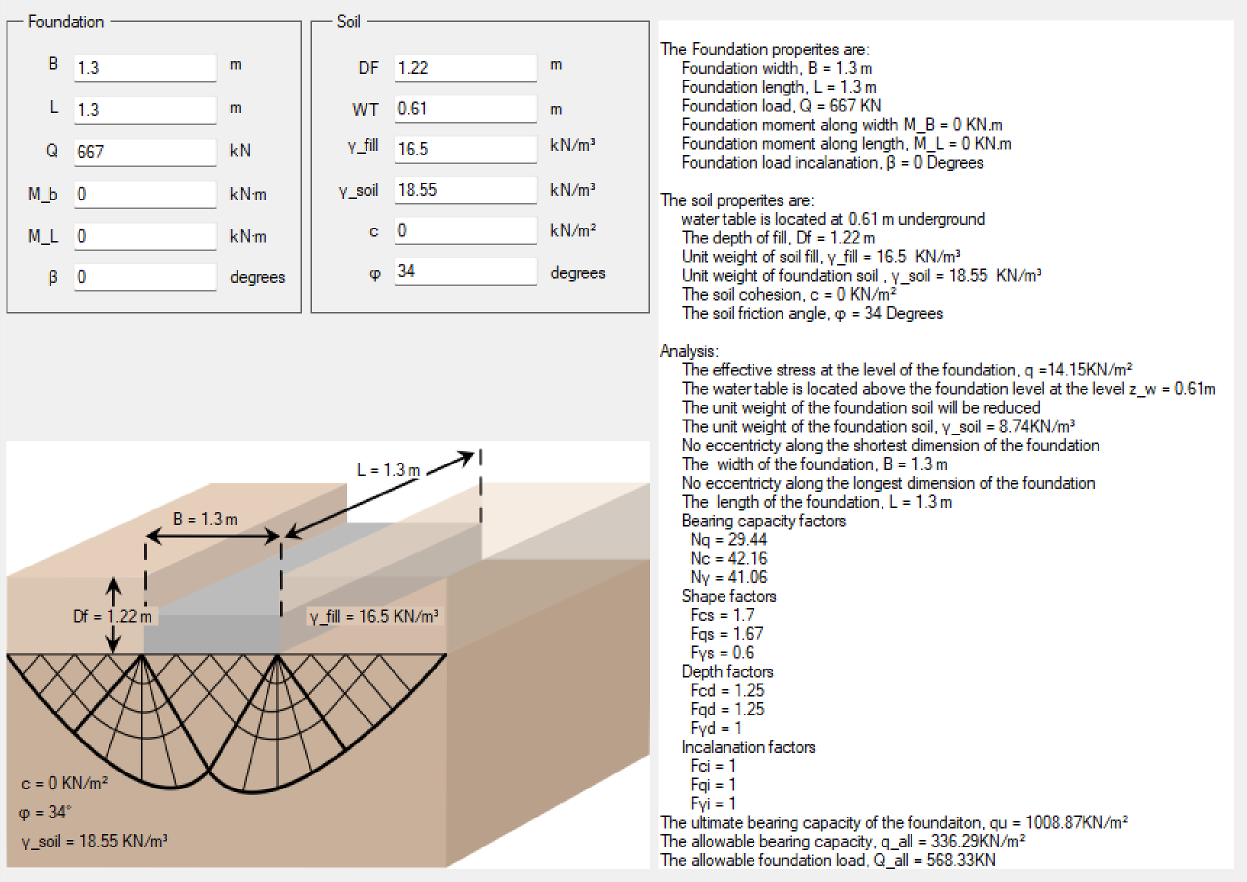
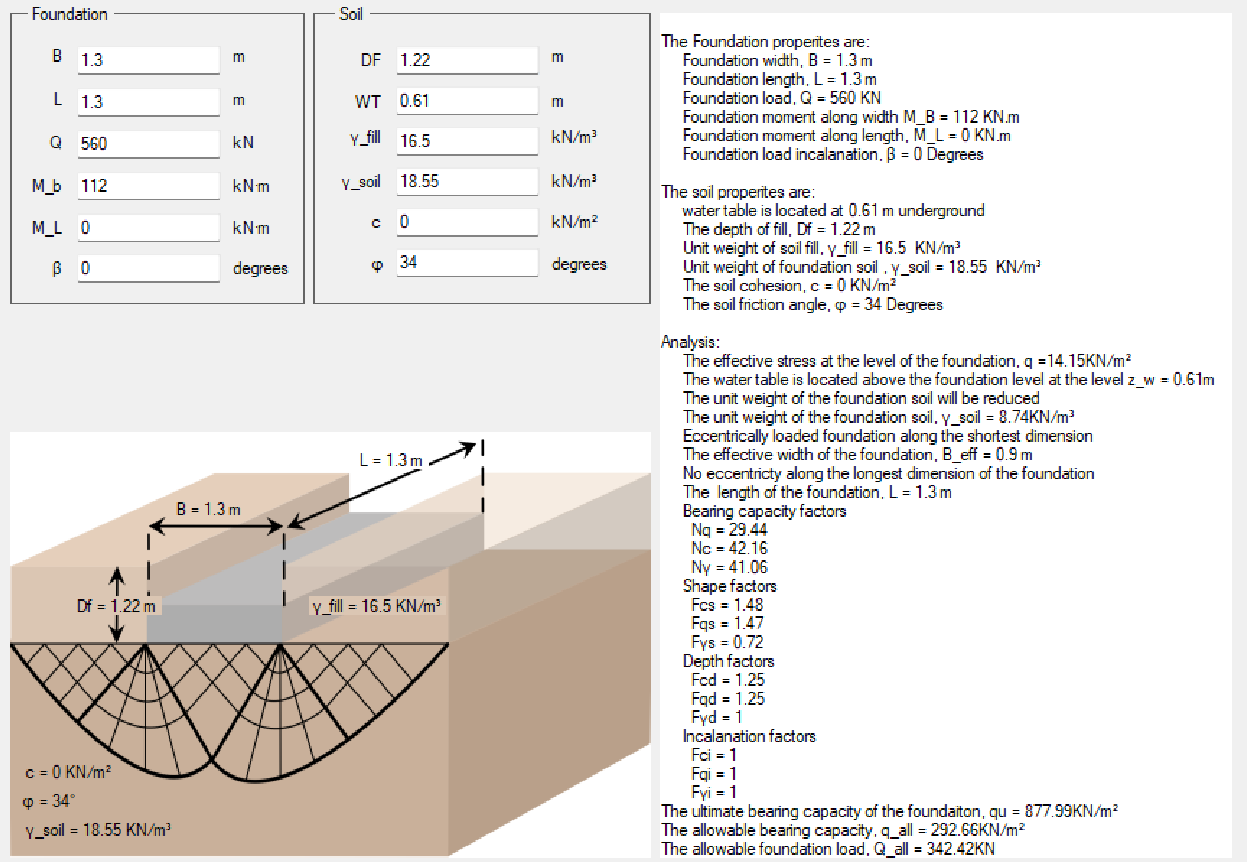


Figure 1.5: Foundation problem for example 1.4.2

The program input and output would look like



Note that the allowable load is less than the applied. The applied load was adjusted to a value equal to the allowable load and a moment acting on the shortest dimension was added and its value is 112 KNm. The program input and output would look like the following:



The allowable load was further reduced due to the moment acting on the foundation.