

Spread footing settlement and rotation analysis

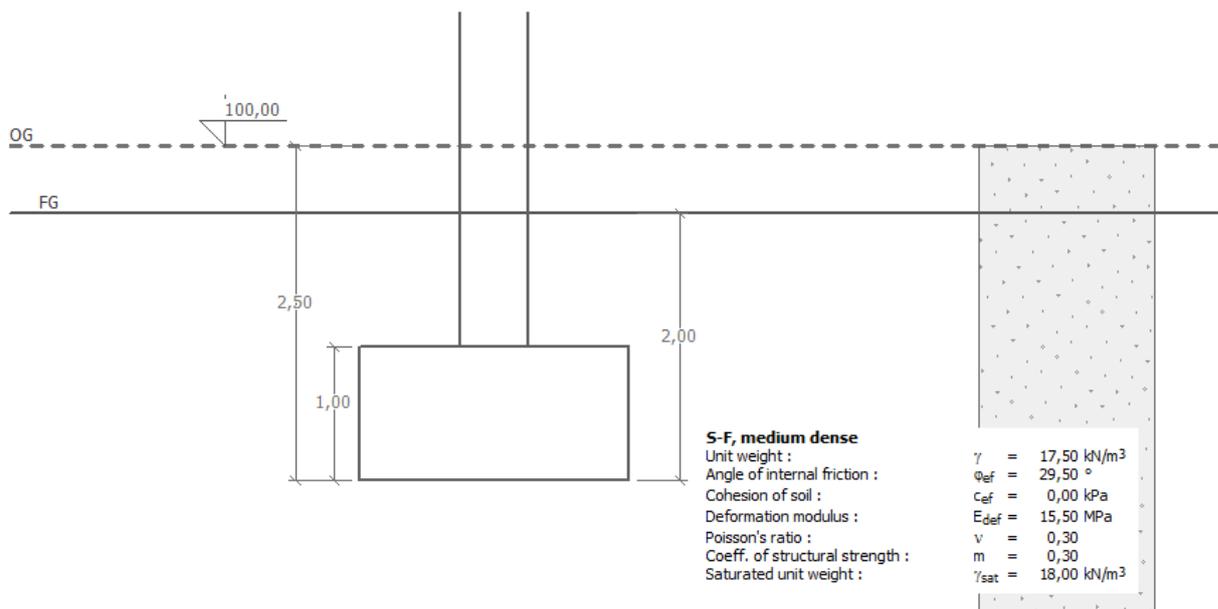
Program: Spread footing

File: Demo_manual_10.gpa

This engineering manual describes how the analysis of settlement and rotation of a spread footing is performed.

Assignment

Analyze the settlement of a centric spread footing that was designed in the last chapter (No. 9 Design of dimensions of a spread footing). The geometry of the structure, load, geological profile, and soils are all the same as in the last chapter. Perform the settlement analysis using the oedometric modulus and consider the structural strength of the soil. Analyze the foundation in terms of limit states of serviceability. For a structurally indeterminate concrete structure, of which the spread footing is a part, the limiting settlement is: $s_{m,lim} = 60,0$ mm.



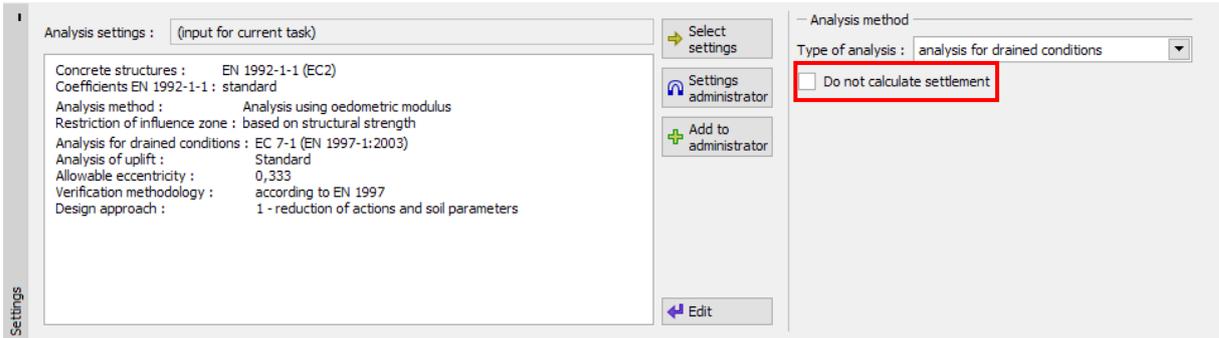
Scheme of the assignment – analysis of settlement of a spread footing

Solution

To solve this task, we will use the GEO5 Spread footing program. We will base our analysis on the task from the last chapter, where almost all the required data are already entered.

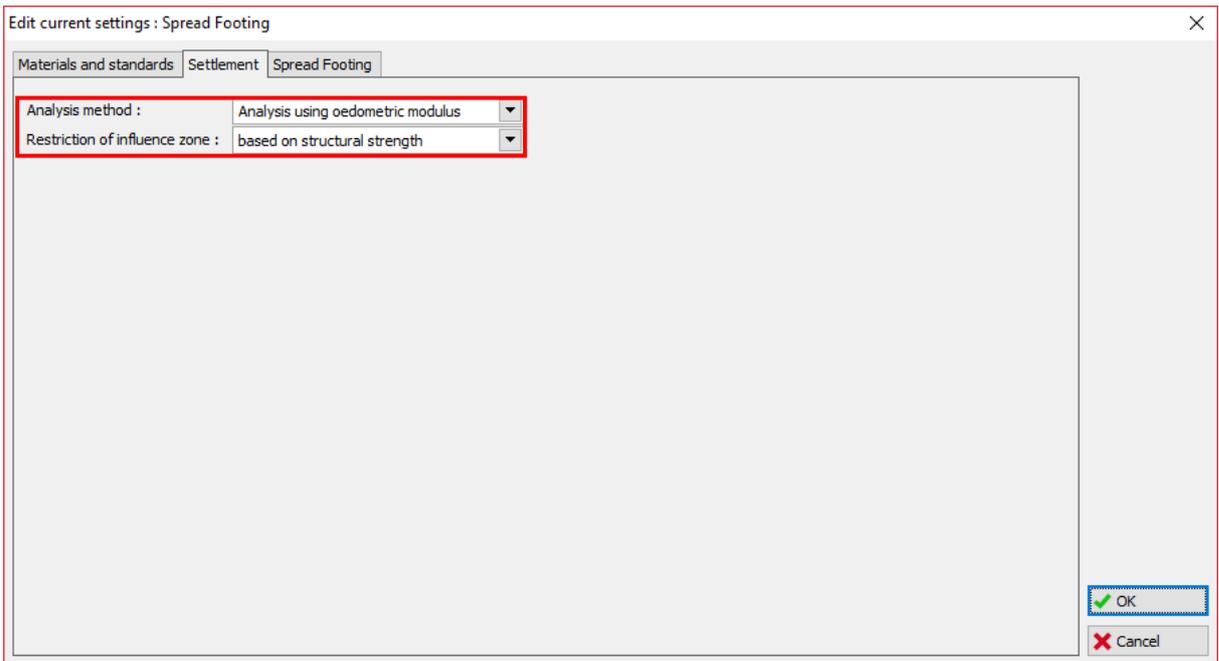
The design of a spread footing in the last task was performed using the standard EN 1997, DA1. Eurocodes do not dictate which theory for the analysis of settlement must be used, so any common settlement theory will do. In the default setting of the program, the most widely used theory is selected.

Firstly, uncheck the option “Do not calculate settlement” in the “Settings” frame.



“Settings” Frame

Then check the settings by clicking on the “Edit” button. In the “Settlement” tab select the method “Analysis using oedometric modulus” and set the Restriction of influence zone to “based on structural strength”.



“Edit current settings” Dialog window

Note: Structural strength represents the resistance of soil against the deformation from a load. It is only used in the Czech Republic and Slovakia. In other countries, the restriction of the influence zone is described by the percentage of the initial in-situ stress. The recommended values of the structural strength are from CSN 73 1001 standards (Foundation soil below the foundation)

In the next step, define the parameters of the soils for a settlement analysis in the “Soils” frame. We need to edit the existing soil and add values of the Poisson’s ratio, the coefficient of structural strength and the oedometric modulus (deformation modulus).

Table with the soil parameters

Soil, rock (classification)	Unit weight γ [kN/m^3]	Angle of internal friction φ_{ef} [$^\circ$]	Coeff. of structural Strength m [-]	Deformation modulus E_{def} [MPa]	Poisson’s ratio ν [-]
S-F – Sand with trace of fines, medium dense soil	17,5	29,5	0,3	15,5	0,3

Note: The coefficient of structural strength depends on the type of the soil (more info in F1 – HELP).

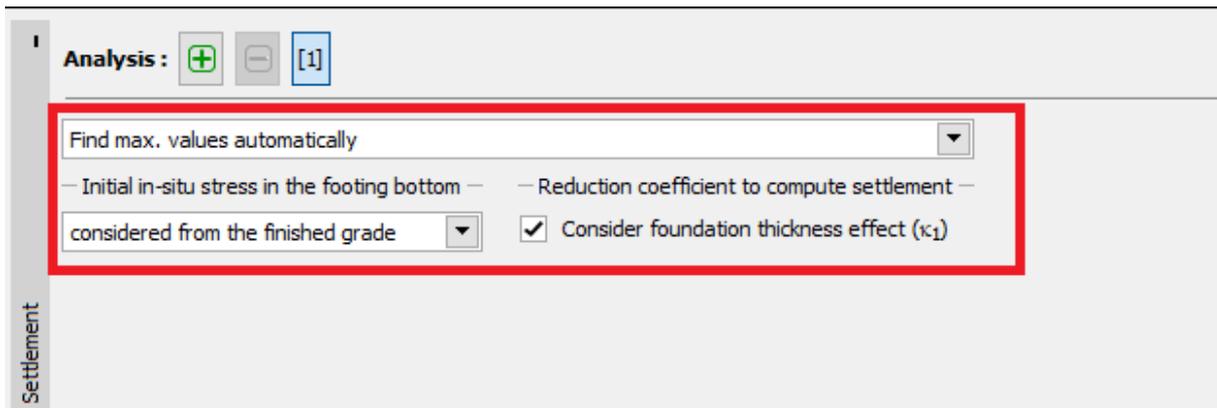
The screenshot shows the "Edit soil parameters" dialog window. The "Name" field is "Sand with trace of fines (S-F), medium dense". The "Basic data" section includes: Unit weight $\gamma = 17,50$ [kN/m^3], Angle of internal friction $\varphi_{ef} = 29,50$ [$^\circ$], Cohesion of soil $c_{ef} = 0,00$ [kPa]. The "Settlement - oedometric modulus" section includes: Poisson's ratio $\nu = 0,30$ [-], Type E_{oed} : constant, Settlement analysis: insert Edef, Deformation modulus $E_{def} = 15,50$ [MPa]. The "Settlement - influence zone computation" section includes: Coeff. of structural strength $m = 0,30$ [-]. The "Uplift pressure" section includes: Calc. mode of uplift: standard, Saturated unit weight $\gamma_{sat} = 18,00$ [kN/m^3]. The "Draw" panel shows Pattern category: GEO, Subcategory: Soils (1 - 16), Pattern: 9 Sand, Color: (dark blue), Background: automatic, Saturation <10 - 90>: 50 [%].

“Edit soil parameters” Dialog window

Analysis

Now, we will run the analysis in the “Settlement” frame. The settlement is always analyzed for the **service** load. We first need to input some other parameters in the bottom left part of the screen:

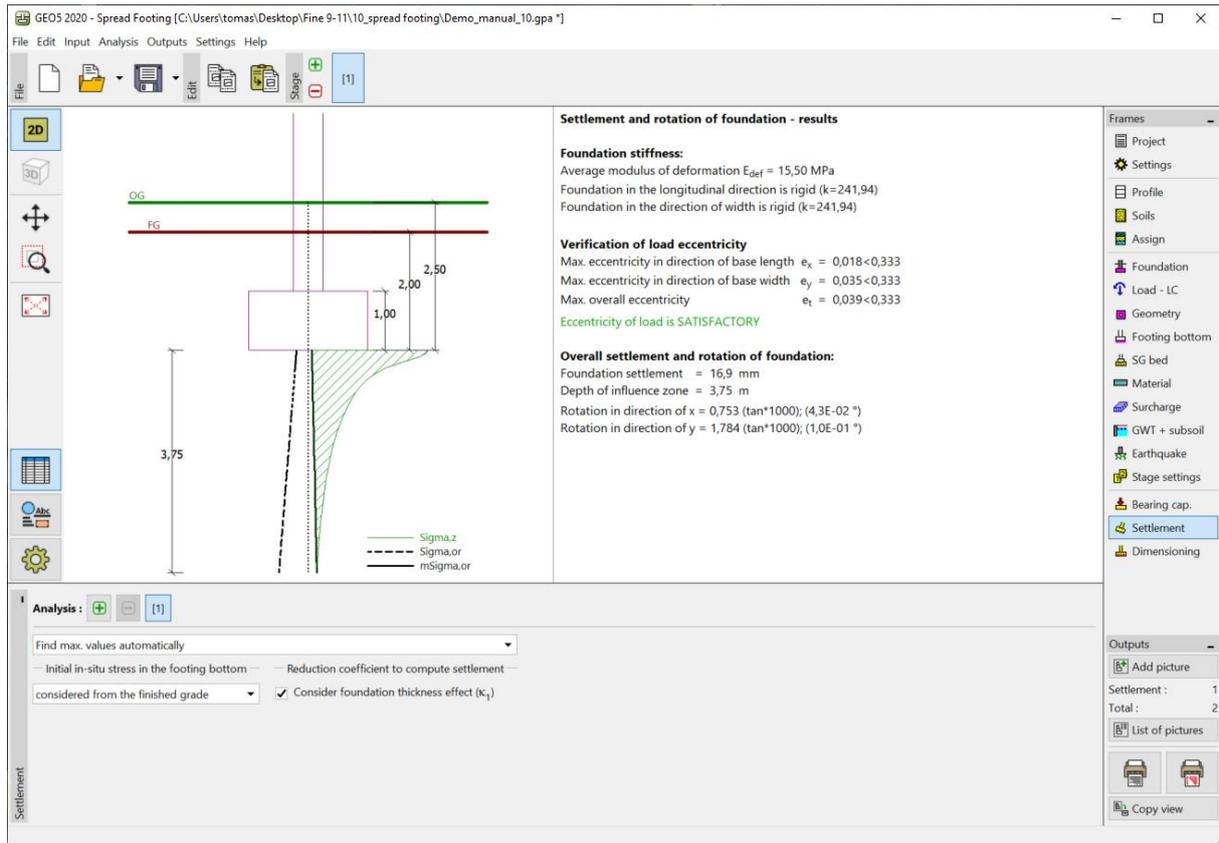
- **Initial in-situ stress** in the footing bottom is considered from the finished grade
- In the **Reduction coefficient to compute settlement**, select the option “Consider foundation thickness effect (κ_1)”.



“Settlement” Frame – analysis settings

Note: The value of the in-situ stress in the footing bottom influences the amount of settlement and the depth of the influence zone – a larger initial in-situ stress means less settlement. The option of in-situ stress acting on the footing bottom depends on how long the footing bottom is open. If the footing bottom is open for a longer period of time, the soil compaction will be smaller and it is not possible to consider the original stress conditions of the soil.

Note: The coefficient “ κ_1 ” takes into account the influence of the depth of the foundation and gives more realistic results of the settlement. When using this coefficient, the so-called substitute value of depth under the footing bottom z_r is used.



“Settlement” Frame – analysis results

Results of the analysis

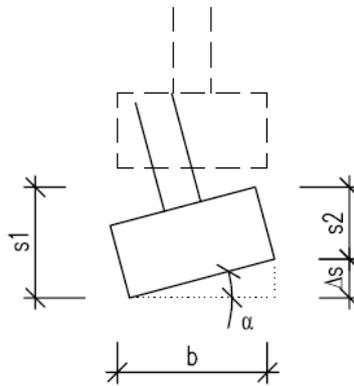
The final settlement of the structure is 16,9 mm. Using an analysis of limit states of serviceability, we can compare the values of the analyzed settlement with the limit values, which are permissible for the structure.

*Note: The stiffness of the structure (soil foundation) has a major influence on the settlement. This stiffness is described by the coefficient k – if k is greater than 1, the foundation is considered to be stiff, and the settlement is calculated under a **characteristic point** (located in $0,37l$ or $0,37b$ from the center of the foundation, where l and b are the dimensions of the foundation). If the coefficient k is smaller than 1, the settlement is calculated under the **center of the foundation**.*

- The analyzed stiffness of the foundation in direction is $k = 241,94$. Therefore, the settlement is computed under a characteristic point of the foundation.

Note: Informative values of allowable settlement for different kinds of structures can be found in various standards – for example, in the CSN EN 1997-1 (2006) “Design of geotechnical structures”.

The Spread footing program also provides results for the rotation of the foundation, which is analyzed using the difference in settlement of the centers of each edge.



$$\Delta s = s_1 - s_2$$

$$rotation = \frac{\Delta s}{b} (\tan * 1000)$$

$$\alpha = \arctan \frac{\Delta s}{b} [^\circ]$$

Rotation of the foundation – analysis principle

- Rotation in direction x : $0,753 \cdot (\tan \cdot 1000) = 0,043^\circ$
- Rotation in direction y : $1,784 \cdot (\tan \cdot 1000) = 0,1^\circ$

Note: Rotation of the foundation is very important when analyzing the foundation of special structures – e. g. bridge abutment, high columns, chimneys, pylons, etc.

Conclusion

This spread footing satisfies the evaluation criteria in terms of the settlement.

$$\text{Settlement: } s_{m,lim} = 60,0 \geq s = 16,9 \text{ [mm].}$$