

# Soil Settlement - SBR+

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## Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage [www.friilo.com](http://www.friilo.com) in the Campus-download-section.

## Application options

The SBR+ program can be used to calculate the magnitude and the progression over time of settlements and foundation tilting caused by volume or shape changes in the subsoil, which occur under perpendicular, static loading. Lifting due to relief by excavation can be calculated analogously. The portions from immediate and consolidation settlements are always calculated as a standard. Optionally you can add creep settlement.

A polygonal terrain model can be automatically interpolated by defining drilling profiles. With the help of a load export, any number of foundation loads from the GEO Building Model and the FD+ Foundation can be imported and superimposed at a freely definable point for a settlement calculation.

### Geotechnical standards

- DIN EN 1997-1:2010
- DIN 1054:2010-12
- DIN 4019:2014-01
- ÖNORM B 1997-1-1
- ÖNORM B 1997-1-2
- PN EN 1997:2011
- BS EN 1997:2011

### Model

Any number of horizontal soil layers as well as a horizontal ground top edge and a horizontal groundwater level can be defined.

Any number of horizontal and polygonal soil layers and terrain levels as well as a horizontal groundwater level can be defined.

### Loading and superposition

The external loads can apply in the form of infinite perpendicular surface loads or limited block loads that apply at freely selectable positions exclusively at the level of the ground top edge. Asymmetrical trapezoidal loads with different load ordinates at the respective edges can also be modelled at any position and with variable orientation. By defining excavation areas, all loads can also be applied at a depth  $z$  below the top of the terrain. The number of ground surface loads, their type of action, as well as the limit state and the design situation to be considered can be selected as desired. Automatic superposition of the load cases according to the applicable superposition rules is also integrated.

### Result options

- The settlements can be put out for any number of freely selectable design points
- Definition of user-defined design sections
- Output of a settlement trough over the entire model area
- Stress influence coefficients  $i$  per load case and per design point
- Settlement influence depth
- Stress-settlement diagram over the depth per design point
- Stress-settlement diagram according to settlement portions  $s_0$ ,  $s_1$ ,  $s_2$  und  $s_{tot}$  per design point
- Time-settlement diagram per design point

### Time setting

An application time can be assigned to each load. In this way, the timing components of individual loads applied at different times can be superimposed. In this way, a more differentiated consideration of the time setting can be undertaken in order to obtain a realistic assessment with regard to the decay of consolidation and creep.

## Basis of calculation

### General

If necessary, a subdivision of the ground surface into partial areas is required for the settlement calculation. More information is given in the following sections. The subdivision is always carried out automatically by the SBR+ program and cannot be influenced by the user.

### Stresses in the isotropic elastic half-space

The analytical calculation method in SBR+ is based on the assumption of slack loads (structures). The method of indirect settlement calculation is used. In this approach, the foundation stresses generated by a top load in the isotropic elastic half-space are determined as a function of the depth and the foundation geometry using influence coefficients  $i$ .

The isotropic elastic half-space is created by separating in mind the three-dimensional space by means of a horizontal plane. The upper half is assumed weightless and empty, while the lower half is assumed to be filled with a homogeneous and fully elastic substance. Because of this assumption, the soil contained in the lower half has the same elasticity on all sides, which is reflected in a Poisson's ratio of  $\nu = 0.5$ .

### Calculation of the settlements from the stresses

By assuming an isotropic elastic half-space, the theory of elasticity and thus the superposition principle is fully valid. I. e. the proportional settlements at the point of consideration due to each individual load case can be superimposed by addition.

Based on the calculated settlement-generating stress behaviour in the half-space, the compression in the soil is calculated in partial layers. Real layer boundaries are taken into account. The calculation of the settlements is performed in the last step by integrating the strains over the named partial layers up to a defined limit depth. Since the superposition law is applicable, the integration can also be realised by a summation.

$$s_{\text{ges}} = \int_0^{d_s} \frac{i \cdot \sigma_1}{E_{m_z}} \cdot dz$$

### Settlement influence depth

If no defined limit depth were assumed when calculating the settlements, the stresses and thus also the settlements would continue to increase with depth and the calculated values would become too great and unrealistic. According to DIN 4019, the settlement influence depth  $t_s$  may be assumed at a level below which the vertical effective additional stress  $\sigma_z$  generated by the load effective for the settlement exceeds 20 % of the effective initial vertical stress  $\sigma_a$  in the soil. This stress criterion is automatically calculated in SBR+ and the resulting decisive settlement influence depths are considered separately for the individual design points. Alternatively, you can specify a user-defined settlement influence depth if incompressible layers are supposed to exist. This disables the automatic calculation. Practical experience has shown that this limiting depth is  $t_s \approx b$  for extended foundation slabs and  $t_s \approx 2b$  for single or strip foundations ( $b$  = foundation width).

## Elastic soil parameters

In order to be able to consider the elastic behaviour of the soil in the settlement calculation, different elastic moduli are available. Values of moduli determined from tests and observations are always to be seen as reference values which serve as a basis for the determination of an  $E^*$  value that can be used in the calculation. The calculation  $E^*$  value shall be determined in a traceable way based on a compression modulus  $E_m$ , recalculated from settlement observations, or a stiffness modulus  $E_s$ , obtained from laboratory tests. According to the theory of elasticity, the following relationships apply (equations (1) and (2) of DIN 4019):

$$E^* = \frac{E}{1-\nu^2} \quad (1)$$

and

$$E_s = \frac{1-\nu}{1-\nu-2\nu^2} \cdot E \quad (2)$$

In the isotropic elastic half-space, the Poisson's ratio  $\nu$  is set to 0.5 as mentioned before.

However, settlements calculated on the basis of the stiffness modulus  $E_s$  often deviate considerably from the actual measured settlements, because in the laboratory only a small soil volume is investigated in the form of individual random samples, which means that disturbances of the samples and test-related simplifications are unavoidable. Moreover, the stiffness modulus  $E_s$  is not a soil constant for the respective layer. It depends not only on the load magnitude, but also on the foundation area (the larger the area, the greater is also  $E_s$ ). If no compression modulus  $E_m = E^*$  is available from settlement recalculations, the calculation value of the compression modulus  $E^*$  should be obtained from a stiffness modulus  $E_s$  with consideration of correction factors to compensate for the inadequacies of the laboratory  $E_s$  values:

$$E^* = E_s / \kappa$$

with:

- $\kappa = 0.67$             for sand and clay
- $\kappa = 1.00$             for clay, simply compacted or slightly over-compacted
- $\kappa = 0.50 \dots 1.00$    for clay, strongly over-compacted

In accordance with DIN 4019, cautious estimates of the mean value or limit values should be used as decisive parameters of the compressibility  $E^*$  for the respective soil and stress area. If the range of variation is large or only few basic data are available, you should select upper and lower limit values for the parameters that allow the estimation of the maximum and minimum deformations.

## Stresses and settlements under a slack foundation body

The stress calculation is based on the calculation of the vertical stress caused by a concentrated load  $V$  acting on the surface of the half-space using the equation (A.1) of DIN 4019:2015-05 developed in accordance with Boussinesq (Boussinesq, J.: "Application des potentiels à l'étude de l'équilibre et du mouvement des solides élastiques", Gauthier-Villars, Paris (1885)):

$$\sigma_z = \frac{3 \cdot V \cdot z^3}{2\pi \cdot (z^2 + r^2)^{5/2}}$$

Steinbrenner (Steinbrenner, W.: „Tafeln zur Setzungsberechnung“. Die Straße, Heft 1 (1934)) extended this calculation method for single loads through integration via directions  $a$  and  $b$  on area loads. The subsoil stress at the depth  $z$  below the corner point of a slack (flexible) uniform area load  $\sigma_{z0}$  (rectangular load) is obtained with the influence coefficient  $i$  using equation (A.2) in accordance with DIN 4019:2015-05:

$$\sigma_z = \frac{\sigma_{z0}}{2\pi} \left[ \arctan \frac{a \cdot b}{z \cdot R_3} + \frac{a \cdot b \cdot z}{R_3} \cdot \left( \frac{1}{R_1^2} + \frac{1}{R_2^2} \right) \right] = \sigma_{z0} \cdot i_R$$

With the geometric parameters shown in Figure A.2 and the equations (A.3) to (A.5) taken from DIN 4019:2015-05:

$$R_1 = \sqrt{a^2 + z^2} \quad (\text{A.3})$$

$$R_2 = \sqrt{b^2 + z^2} \quad (\text{A.4})$$

$$R_3 = \sqrt{a^2 + b^2 + z^2} \quad (\text{A.5})$$

The described stresses  $\sigma_{z,i}$  are usually calculated for each partial layer in the centre of the layer. The compression of a partial layer is then obtained by multiplying these stresses  $\sigma_{z,i}$  by the layer thickness  $h_i$  and dividing the result by the calculated value of the compression modulus  $E^*_i$  acting on the partial layer.

The total settlement  $s_{\text{tot}}$  ultimately results from the addition of the compressions  $h_i$  of the individual layers to:

$$s_{\text{tot}} = \sum \Delta h_i$$

## Stresses under a triangular load

The stresses in any point in the half-space below a triangular load can be calculated in accordance with Tölke [1969] using the following equation:

$$\sigma_z = \frac{\sigma_0}{\pi a} \sum_{i=1}^4 (-1)^i \cdot \left\{ \frac{(y+y_i)}{R_i} \cdot z \left[ \frac{(x+x_i)x+z^2}{(x+x_i)^2+z^2} + \frac{(x+x_i)x}{(y+y_i)^2+z^2} \right] + x \arctan \frac{(x+x_i)(y+y_i)}{zR_i} \right\}$$

In this equation is  $R_i^2 = (x+x_i)^2 + (y+y_i)^2 + z^2$ . For  $x_i$  and  $y_i$ , half the foundation widths  $a/2$  and  $b/2$  must be inserted with sign according to the following scheme:

$i=$	1	2	3	4
$2x_i$	-a	-a	+a	+a
$2y_i$	-b	+b	+b	-b

The special feature of the stress equations according to Tölke is that they consider the antimetric load case in order to calculate the stress at any point (not only below the corner point). I. e. for the stress at a freely selected point below a triangular load, this antimetric load case must be superimposed with a rectangular load case:

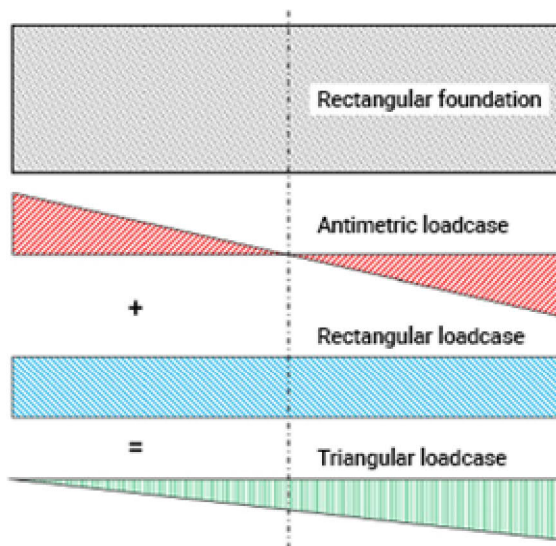


Figure 1: Calculation of a triangular stress distribution

## Stresses at a freely selected point

To calculate the stresses below any point P inside or outside the foundation area, divide it into rectangles R in such a way that all rectangles have a corner point at the point below which the stress is sought after. If the point lies outside the foundation area or outside the load application area, the foundation is extended with a hypothetical area up to this point P and the excess stress or settlement portion is then deducted again ( $R^-$ ).

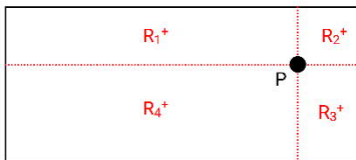


Figure 2: Design point within the foundation area

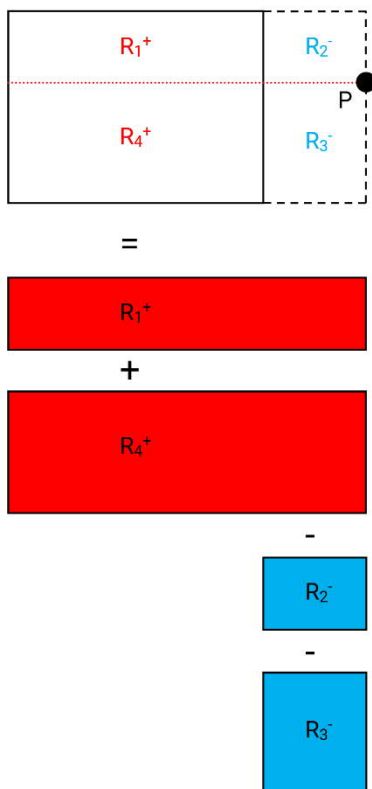


Figure 3: Design point outside the foundation area

## Stresses and settlements underneath a rigid foundation body

To assess the settlement behaviour, the stiffness of the structure or the foundation must be estimated to be able to decide whether the slack or the stiff limit case of the structure stiffness should be used in the settlement calculation.

The previously mentioned calculation methods are based on the assumption of the slack limit case. For a precise settlement analysis, the settlement values are determined and plotted at different foundation points. The connecting line or connecting plane of the settlement coordinates determined in this way provides the settlement trough, which reveals considerable settlement differences between the larger central settlement below the load centre of gravity and the smaller edge settlements.

With increasing bending stiffness of the foundation body, these differences between the settlement at the borders and in the centre become increasingly greater as the structural loads are increasingly absorbed by bending moments and shear forces in the foundation. In the other limit case - the ideally rigid structure - the stiffnesses are sufficiently great to prevent its deformation. If loading and subsoil stratification are uniform, the settlement coordinates along the entire foundation base have the same magnitude.

Certain points in the foundation area where the settlements have the same magnitude result from superposition of the settlement troughs of the slack and the rigid limit cases. These points are located at a distance of  $0.74 \cdot a/2$  or  $0.74 \cdot b/2$  to the foundation axes in the case of rectangular foundations and are referred to as distinguishing points.

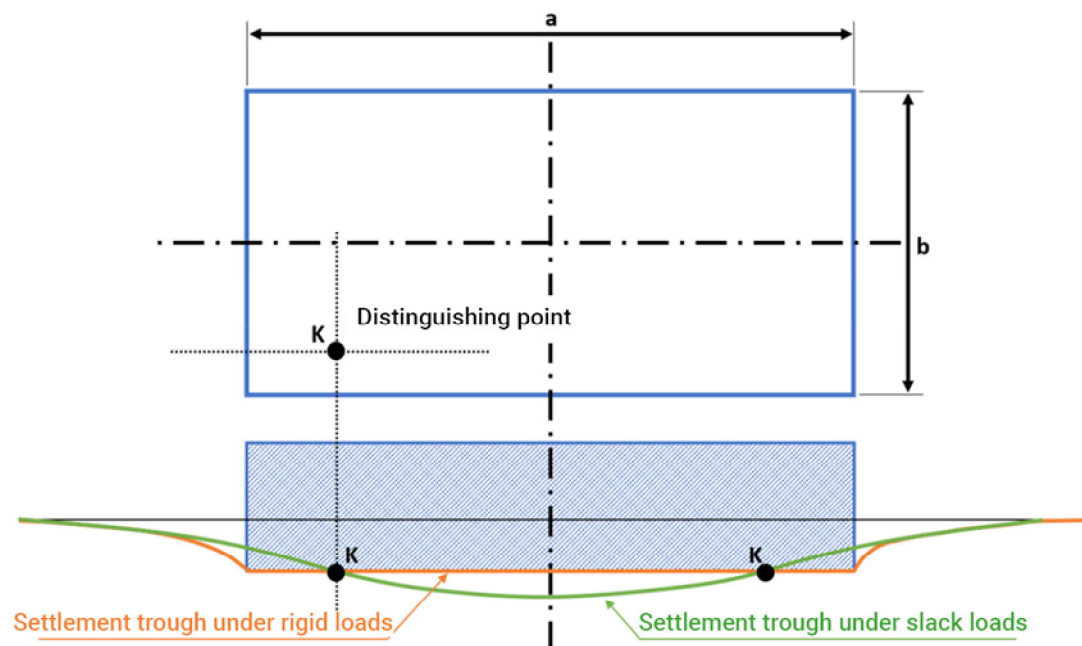


Figure 4: Settlement trough under slack and rigid loads with distinguishing point.

This connection is of interest insofar as the uniform settlement of a compact, centrally loaded rigid foundation can be determined by approximation as the settlement in the distinguishing point of the foundation in accordance with DIN 4019. The uniform settlement of the rigid foundation can therefore be calculated using the same approaches for the calculation of a slack load by dividing the foundation area into sub-areas as described above in such a way that the corner point of the sub-surfaces, i. e. the settlement point, coincides with the distinguishing point of the foundation area.



You can find a demo example under the main item "Examples" of the ribbon bar of SBR+, which illustrates the settlement calculation in the distinguishing point for a rigid foundation.

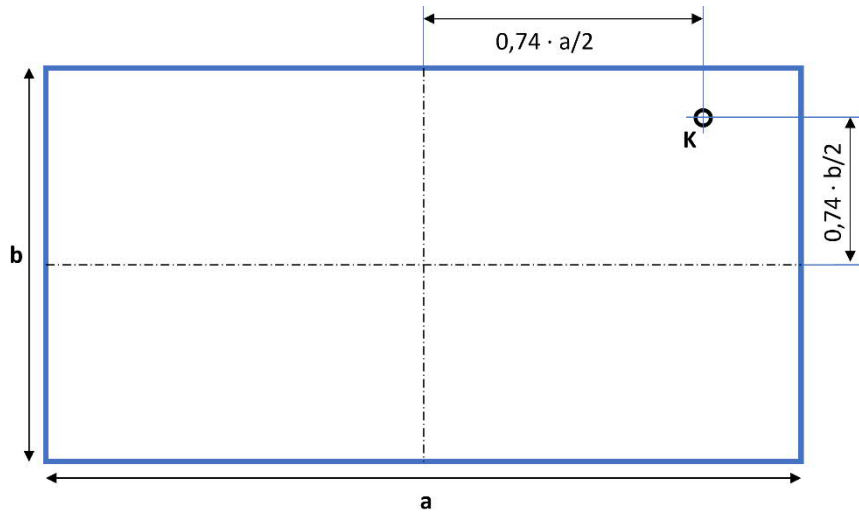


Figure 5: Distinguishing point in the rigid foundation

## Calculation of the settlement progression over time

Basically, the total settlement  $s_{tot}$  is composed of three settlement portions, which are more or less pronounced depending on the soil type (mainly cohesive or non-cohesive):

$$s_{tot} = s_0 + s_1 + s_2$$

$s_0$  = portion from immediate settlement (volume-stable shape change of water-saturated cohesive soils)

$s_1$  = portion from primary consolidation of the soil (time-delayed settlement due to the squeezing out of pore water and stress redistribution)

$s_2$  = creep settlement (secondary settlement due to creep phenomena in the soil after the consolidation settlement has subsided)

The settlement  $s$  calculated in SBR+ using stress integration corresponds to the sum of the immediate settlement  $s_0$  and the consolidation settlement  $s_1$ . For simplification, this settlement  $s$  may be distributed over the consolidation period based on the unidimensional consolidation theory, without taking the immediate settlement  $s_0$  into account separately. The calculation of the creep settlement  $s_2$  can optionally be performed in addition in SBR+.

The behaviour of the individual settlement portions over time is shown in Fig. 6 in accordance with DIN 4019 (Fig. 4). However, it is often impossible to separate the individual settlement portions when evaluating observed settlements.

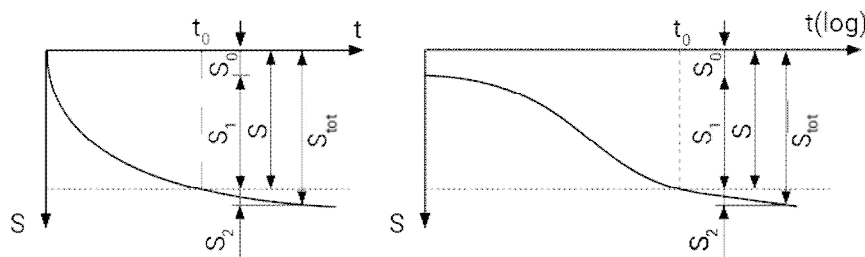


Figure 6: Time-dependent settlement portions in accordance with DIN 4019, Fig. 4

$s_{tot}$	total settlement
$s$	sum of $s_0$ and $s_1$
$s_0$	immediate settlement
$s_1$	consolidation settlement
$s_2$	creep settlement
$t$	time after the application of the load
$t_0$	time until full consolidation

For coarse-grained soils, the delay of the consolidation settlement  $s_1$  and the creep settlement  $s_2$  may be neglected for structures with typical settlement limitation requirements in accordance with DIN 4019.

## Immediate settlement

To estimate the portion of the immediate settlement  $s_0$  in the total settlement  $s_{tot}$ , the calculation value of the compression modulus  $E^*$  can be increased by the factor 1.25 and the Poisson's ratio  $\nu$  can be set to a value of 0.5. With these modified elastic soil parameters, the settlement portions  $s_0$  are then recalculated layer by layer and separated from the settlement portions  $s$  ( $s$  corresponds to the sum of immediate settlement  $s_0$  and consolidation settlement  $s_1$ ).

In SBR+, however, the immediate settlement  $s_0$  is calculated from the difference of the settlement portion  $s$  obtained via the stress integration and the portion of the consolidation settlement  $s_1$  (see the following section):

$$s_0 = s - s_1$$

## Consolidation settlement

The consolidation settlement is a time-delayed settlement due to the application of the load. The progression in time of this settlement is calculated using the equations (11) to (14) of DIN 4019:

$$\frac{s(\tau)}{s} = \left(\frac{4\tau}{\pi}\right)^{0,5} \quad \text{for } \tau \leq 0,2 \quad (11)$$

$$\frac{s(\tau)}{s} = 1 - 0,5 \cdot e^{(0,5 - 8\tau/\pi)} \quad \text{for } 0,2 < \tau \leq 1 \quad (12)$$

with  $\tau = \frac{t}{t_0}$  (13)

and  $t_0 = \frac{d^2}{c_v}$  (14)

$s$  settlement due to action of the load

$\tau$  dimensionless time

$s(\tau)$  settlement at the time  $\tau$

$t_0$  time until approximate decay of the consolidation settlements

$t$  time after the application of the load

$d$  thickness of a layer drained on one side. For a layer drained on both sides with thickness  $h$ :  $d = h/2$

$c_v$  consolidation coefficient

The consolidation coefficient is determined using equation (15) of DIN 4019:

$$c_v = \frac{k \cdot E_s}{\gamma_w} \quad \text{with}$$

$k$  permeability coefficient of the soil

$E_s$  stiffness modulus of the soil

$\gamma_w$  specific weight of the water

## Creep settlement

Creep settlement is only considered after the consolidation phase has subsided at  $\tau = 1$  and its magnitude and progression over time is calculated in accordance with DIN 4019 using the equations (16) to (18):

$$s_2(\tau) = \varepsilon_2(\tau) \cdot h \quad (16)$$

$$\text{with } \varepsilon_2(\tau) = C_\alpha / (1 + e_0) \cdot \log(\tau) \quad \text{for } \tau \geq 1 \quad (17)$$

$$\text{and } \tau = \frac{t}{t_0} \quad (18)$$

with

$e_0$  void ratio of the soil after completion of the consolidation

$C_\alpha$  creep coefficient

$h$  thickness of the layer that is capable of creep

$\tau$  dimensionless time

$t_0$  time until approximate subsidence of the consolidation settlement

$t$  the considered time

## Interpolation of the soil layers from drilling profiles

By defining any number of drilling profiles, a polygonal terrain model can be created, which is automatically interpolated from the information from the outcrops. For this purpose, the elevations of the top surface and the individual layer boundaries are defined for each drilling profile. The geotechnical parameters of the respective layers are also defined. In principle, both the layer geometries and the soil properties of an individual layer can be interpolated. This means, for example, in the case of a homogeneous stratification with constant stratum thickness in all drilling profiles, a different stiffness modulus can be defined in one and the same stratum for the settlement parameters. As a result, only the stiffness modulus in the affected layers is interpolated. In this way, different stiffness ratios can be modeled for one and the same layer. This is necessary, for example, when areas of a layer have already been exposed to geological pre-loading, while others have not and therefore different stiffnesses are required for the settlement calculation due to the different loading history. Thanks to this feature, different stiffness ratios can be recalculated from settlement observations and an existing soil model with measured settlement values can be calibrated or verified.

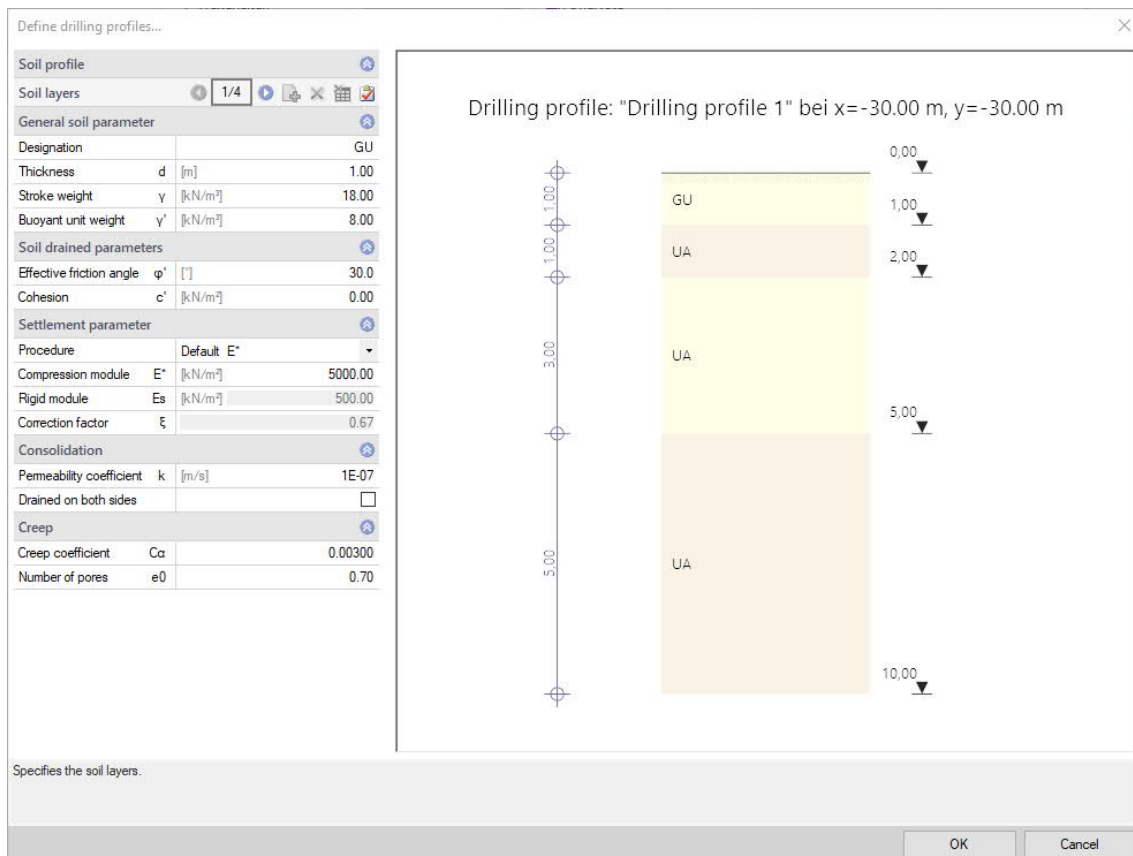


Figure 7: Definition of geometry and soil parameters in the drilling profile

A linear interpolation is used for the automatic calculation of the soil model. The influence of a drilling profile on an observed section through the terrain decreases inversely proportionally with its distance.

The size of the current layer thickness  $Z$  of a viewing point or a settlement parameter (e.g.  $E^*$ ) with constant layer thickness is calculated with a proportionality constant  $F$ , which is composed of the sum of the individual drilling profiles as follows:

$$F = \sum_{i=1}^n \left[ \frac{1}{L_i} \right] \quad (19)$$

The size interpolated at any point (in this case the layer thickness  $Z$ ) is then calculated with:

$$Z = \sum_{i=1}^n \left[ \frac{z_i \cdot \left( \frac{1}{L_i} \right)}{F} \right] \quad (20)$$

For the calculation example from Figure 8 "Influence of the layer thickness", the result for the searched layer thickness at point  $P_x$  is:

$$F = \frac{1}{L_1} + \frac{1}{L_2} = \frac{1}{2} + \frac{1}{4} = 0,75$$

$$Z_x = \frac{3,5 \cdot \frac{1}{2}}{0,75} + \frac{2 \cdot \frac{1}{4}}{0,75} = 3,00\text{m}$$

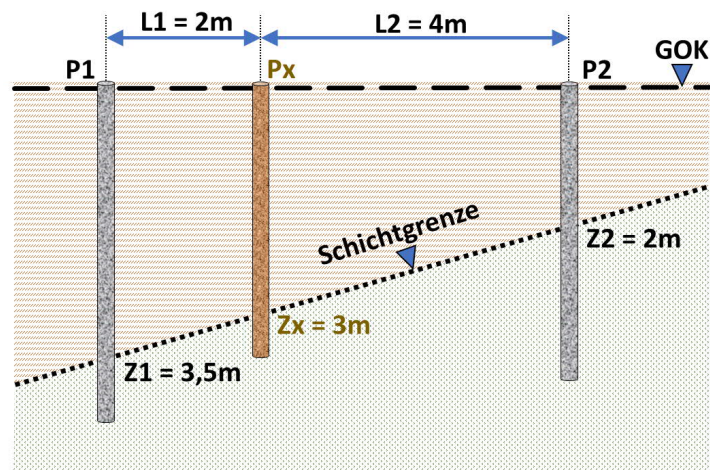


Figure 8: Influence of the layer thickness

For the calculation example from Figure 9 "Influence of the distance", the result for the sought layer thickness at point  $P_x$  is:

$$F = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} = \frac{1}{25} + \frac{1}{18} + \frac{1}{10} = 0,1956$$

$$Z_x = \frac{5 \cdot \frac{1}{25}}{0,1956} + \frac{8 \cdot \frac{1}{18}}{0,1956} + \frac{11 \cdot \frac{1}{10}}{0,1956} = 8,92\text{m}$$

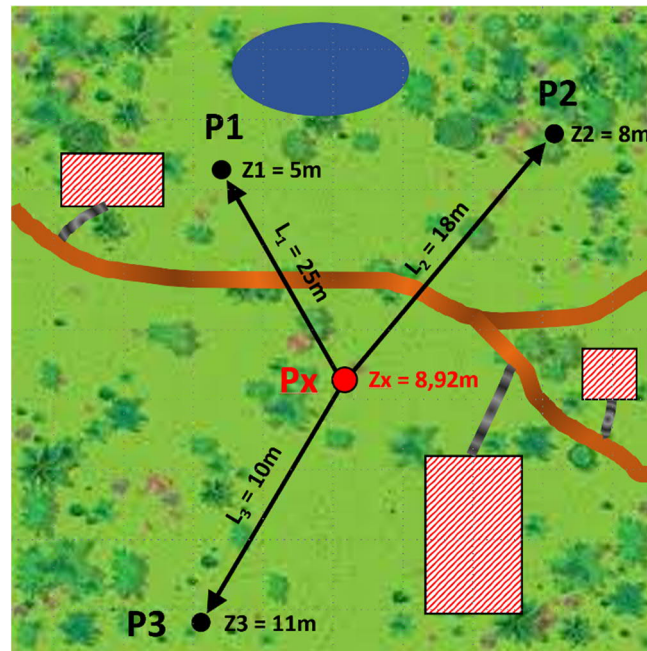


Figure 9 Influence of the distance

If the layer thickness is interpolated according to formula 20 at any number of points over a defined model area, a polygonal terrain model can be derived from this, as shown below:

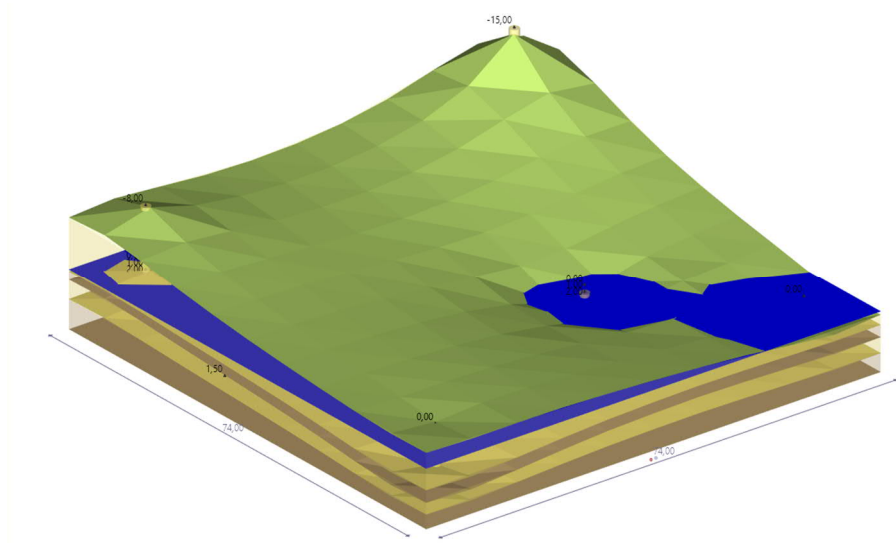


Figure 10: Polygonal terrain model

## Definition of excavation areas

For the creation of a foundation, an area of the existing site is usually first excavated. Depending on the depth and area of the foundation, these excavations can be considerable and must therefore be considered in the calculation. Therefore, any excavation area can be defined in the program.

In the area of excavation relief, negative area loads are applied in the self-weight load case, the load ordinate of which corresponds to the excavated soil. Furthermore, the excavated soil is not taken into account in the settlement calculation. The loads in the area of the excavation relief act directly on the base of the freely selectable excavation depth. The calculation of the limiting depth is not influenced by excavation relief.

If, apart from excavation relief, no further loads are defined, then the results of the settlement calculation have a negative sign and are consequently to be interpreted as uplifts as a result of the relief. Since no creep can occur in this case, the proportions of creep settlement are always ZERO (a comparable phenomenon, e.g. due to swelling, is not described in the literature).

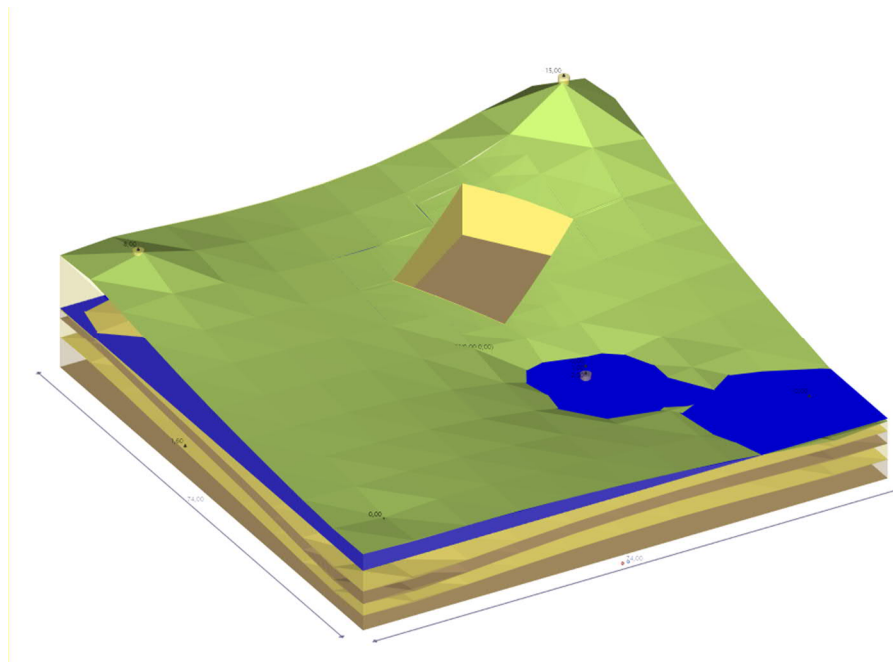


Figure 11: Terrain model with excavation relief

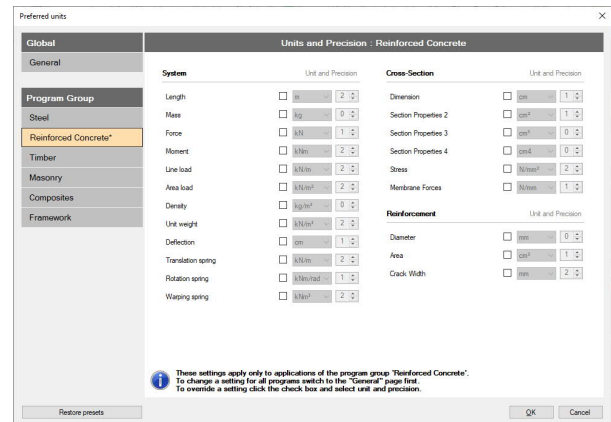


## Data entry

You can enter values and define control parameters in the menu on the left screen section. The effect of a value that you enter is immediately shown in the graphical representation on the right screen section.

Before entering any data, you can edit the dimensional units (cm, m, kN,...) via the option

File → [Settings](#) → Configure units.



## Assistant

The [assistant](#) is launched as a standard/automatically when the program starts.

With the help of the assistant, you can quickly define a basic structural system and gain a first impression of the results. Subsequently, you can adjust secondary parameters in a second step.

*Note:* You can disable the automatic start of the assistant via the corresponding option on the bottom of the window.

## Data-entry options in the three-dimensional GUI

The data-entry options in the GUI are described in the document [Basic Operating Instructions-PLUS](#).

## Basic parameters

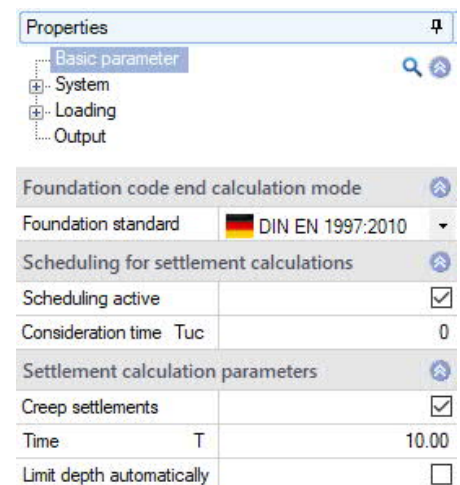
Select the desired [standard](#).

**Scheduling** If this option is activated, a consideration time can be defined for the design points. Furthermore, the load start and load duration for the [ground loads](#) as well as the excavation start and excavation duration for the [excavations](#) can be defined. The program then calculates the settlement at the consideration time, taking into account the degree of consolidation and degree of deconsolidation.

**Creep settlement** when you tick this option creep settlements are considered in the calculation of the settlement.

**t** time in years, attributed to the creep portion in the settlement calculation. The time begins after completion of the consolidation phase.

**Limit depth autom.** allows you to set whether the limit depth for the stress influence of surface loads should be determined automatically. If you untick this option, the stress influence is assumed over the entire height of each of the defined soil layers.



## Structural system

### Dimensions

Enter the dimensions and the number of subdivisions of the settlement trough.

### Design points

You can define any number of design points by entering their x/y-coordinates.

#### Current design point

In the [table bar](#), navigate to a design point (e.g. 2/2) and then mark this as the "current design point" (click on the edit symbol).

Use "Current design point" (edit-button) to define the point to which the calculation results shown in the graphics belong (the current design point is also shown in the text line at the top left of the graphic screen).










### Design cuts

Here you can create user-defined sections in order to be able to evaluate the settlement progression along these sections as required.

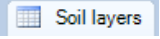
#### Current design section

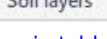
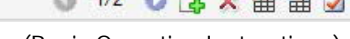
Set the current design section - as described for the current design point.


Remarks: Call up the [Remarks Editor](#).

Properties		
Basic parameter		
System		
Soil layers		
Borehole profile		
Ground water		
Excavation areas		
Loading		
Output		
Dimensions settlement trough		
Length in x	[m]	20.00
Length in y	[m]	20.00
Subdivisions in x.		10
Subdivisions in y		10
Design points in settlement trough		
Design point	2/2	  
x-coordinate	x [m]	3.00
y-coordinate	y [m]	3.00
current design point		
Design cuts in settlement depression		
Design section	1/1	  
General		
Name		S1
Starting point		
x-coordinate	x [m]	3.00
y-coordinate	y [m]	3.00
End point		
x-coordinate	x [m]	6.00
y-coordinate	y [m]	6.00
Others		
Subdivision	n	3
Current design section		
Remarks		
... about the system		

## Soil layers

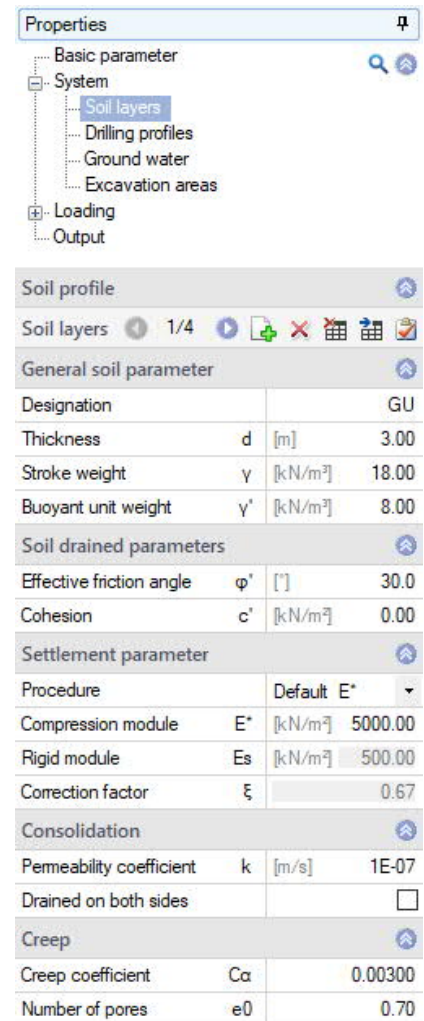
Enter the data of the first soil layer either in the corresponding data-entry mask or directly in the table, which you can display below the graphic by activating the  button.

Soil profile  
  
 Toolbar:  1/2  see [Data entry via tables](#) (Basic Operating Instructions).

To add soil layers, always set up a new entry first by activating the  button (an empty data-entry mask is displayed each time).

*Tip:* A description is displayed in the status line each time you click into a data-entry field.

Designation	name of the respective layer.
Thickness	thickness of the soil layer
Friction angle	characteristic value of the internal friction angle of the drained soil.
Cohesion	cohesion of cohesive soils in drained condition.
Procedure/Method	select whether you want to specify a user-defined compression modulus $E^*$ (pressure settlement line) or have it calculated using the stiffness modulus and the correction factor.
$k$	coefficient of permeability for the consolidation speed. You can take the value from a soil expertise.
Drained on both sides	for the approximative calculation of the time until the consolidation settlement has subsided, the full layer thickness is taken into account with drainage on one side. With drainage on both sides, only half of the layer thickness is considered.
$C_\alpha$	you can determine the creep coefficient $C_\alpha$ in a time-settlement test according to DIN 18135. Usual value range is from 0.001 to 0.00001.
$e_0$	void ratio of the soil after completion of the consolidation. Usual value range is from 0.5 to 1.1.



The screenshot shows the 'Properties' panel on the right side of the software interface. The 'Soil layers' section is expanded, showing a table for 'Soil profile' data entry. The table includes the following parameters and values:

General soil parameter		
Designation		GU
Thickness	d [m]	3.00
Stroke weight	$\gamma$ [kN/m <sup>3</sup> ]	18.00
Buoyant unit weight	$\gamma'$ [kN/m <sup>3</sup> ]	8.00
Soil drained parameters		
Effective friction angle	$\phi'$ [°]	30.0
Cohesion	$c'$ [kN/m <sup>2</sup> ]	0.00
Settlement parameter		
Procedure	Default $E^*$	
Compression module	$E^*$ [kN/m <sup>2</sup> ]	5000.00
Rigid module	$E_s$ [kN/m <sup>2</sup> ]	500.00
Correction factor	$\xi$	0.67
Consolidation		
Permeability coefficient	$k$ [m/s]	1E-07
Drained on both sides		<input type="checkbox"/>
Creep		
Creep coefficient	$C_\alpha$	0.00300
Number of pores	$e_0$	0.70

## Drilling profiles

Enter the first drilling profile directly in the input mask or, alternatively, directly in the table, which you can display via the "Drilling profiles" tab under the graphic.

See also [table entry](#) (operating instructions)

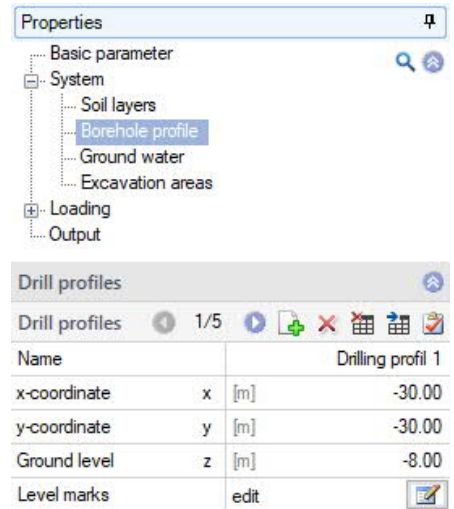
For each additional drilling profile, first create a new profile using the symbol



(a new, empty input mask is displayed).

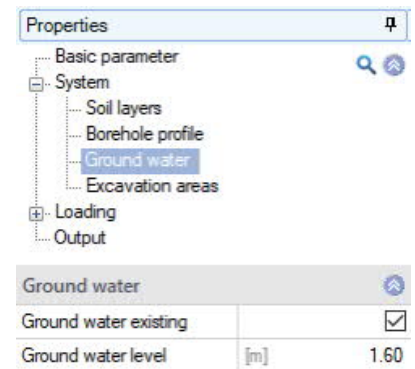
*Tip:* The explanation of the individual input fields is displayed in the status line as soon as you click in an input field.

Name	Designation for this drilling profile
x-coordinate	The global x-coordinate of the drilling profile
y-coordinate	The global y-coordinate of the drilling profile
Ground level	defines the z-coordinate of the ground level of the drilling profile
Level marks	Calling up a dialog for defining the individual layers within a drilling profile. In addition to general soil parameters such as specific gravity and layer thickness, special settlement, consolidation and creep parameters can also be set (see Figure 7)



## Groundwater

Groundwater existing	check this option if groundwater is present.
Groundwater level	depth of the groundwater level, measured from the ground top edge.



## Excavation areas

Enter the first excavation area directly in the input mask or, alternatively, directly in the table, which you can display via the "Excavation areas" tab under the graphic.

See also [table entry](#) (operating instructions)

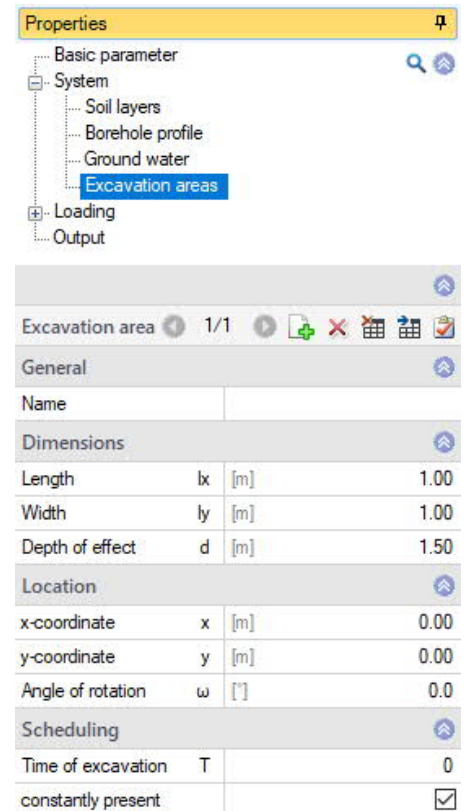
For each additional excavation area, first create a new area using the symbol



(a new, empty input mask is displayed).

*Tip:* The explanation of the individual input fields is displayed in the status line as soon as you click in an input field.

Name	Designation for this excavation area
Width ly	Length of the excavation area in the y-direction
Depth of effect	Depth of the excavation area (dimension in z-direction)
x-coordinate	Position of the excavation area in the x-direction, based on the center of the excavation area
y-coordinate	Position of the excavation area in the y-direction, based on the center of the excavation area
Angle of rotation	Angle of rotation in the horizontal x-y plane to determine the position of the excavation area in relation to the global axes of the coordinate system
Scheduling	With activated option "Scheduling" – see <a href="#">Basic parameters</a> .

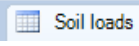



Properties			
... Basic parameter			
System			
... Soil layers			
... Borehole profile			
... Ground water			
Excavation areas			
Loading			
... Output			
Excavation area 1/1			
General			
Name			
Dimensions			
Length	lx	[m]	1.00
Width	ly	[m]	1.00
Depth of effect	d	[m]	1.50
Location			
x-coordinate	x	[m]	0.00
y-coordinate	y	[m]	0.00
Angle of rotation	$\omega$	[°]	0.0
Scheduling			
Time of excavation	T		0
constantly present			<input checked="" type="checkbox"/>


## Loading

Remarks: Call up the [Remarks Editor](#).

### Terrain loads

Enter the data of the first ground surface load either in the corresponding data-entry mask or directly in the table, which you can display below the graphic by activating the  **Soil loads** tab.


Toolbar:  see [Data entry via tables](#) (Basic Operating Instructions).

To define another load, insert a new row first by activating the  button.

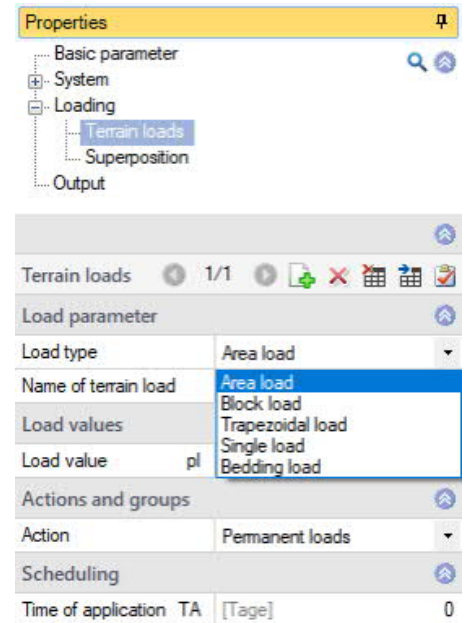
**Load type** you can select among area load, block load, trapezoidal load, single load and bedding load.

Bedding loads (Subgrade reaction loads) consist of a point load cloud for calculating settlements from floor slabs.

**Load values** the available data-entry fields depend on the selected load type.

By clicking on the arrow icon  you can access a [load value compilation](#).

**Scheduling** With activated option "Scheduling" – see [Basic parameters](#).



### Superpositions

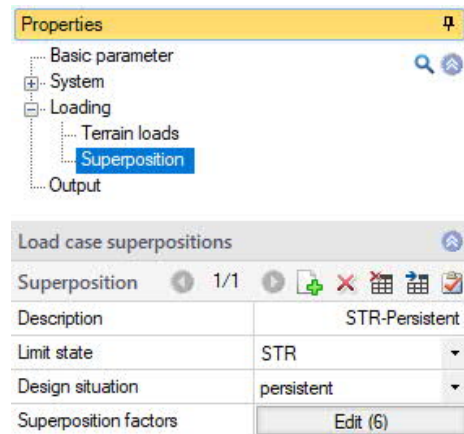
See also [Data entry via tables](#) (Basic Operating Instructions).

You can enter a name for each superposition.

**Limit state** select the limit state on which the current superposition should be based (EQU, STR, GEO, SERV).

**Design situation** select the design situation among persistent, transient, accidental, fire, seismic.

**Superposition factors** allows you to call up a dialog where you can edit factors that are applied to the load cases in the current superposition ( $\gamma_{Inf}$ ,  $\gamma_{Sup}$  or user-defined factor).



## Affiliated Programs

### Load transfer from the FD+ Foundation

After calculating a foundation in FD+, all information required for the settlement calculation can be forwarded to SBR+ via the menu item "Connected programs". For this it is absolutely necessary that the global position of the foundation is defined in the system input in FD+:

1. Foundation length in x-direction  $l_x$
2. Foundation width in y-direction  $l_y$
3. The foundation depth  $z$
4. Angle of rotation  $\alpha$  in the plane if  $l_x$  and  $l_y$  are not parallel to the global x or y axis

In the target file in SBR+, an excavation area is defined by default, which corresponds to the global foundation dimensions (see points 1 to 4 above).

When importing into an existing SBR+ position, an import dialog also appears in which the data to be imported can be explicitly activated or deactivated again (see Figure 13). This is necessary because the data from the different programs, e.g. on groundlayers, groundwater levels, etc., can be fundamentally different. Possibly, in the event of a load collision, the existing load data can also be deleted and overwritten with the new loads to be imported.

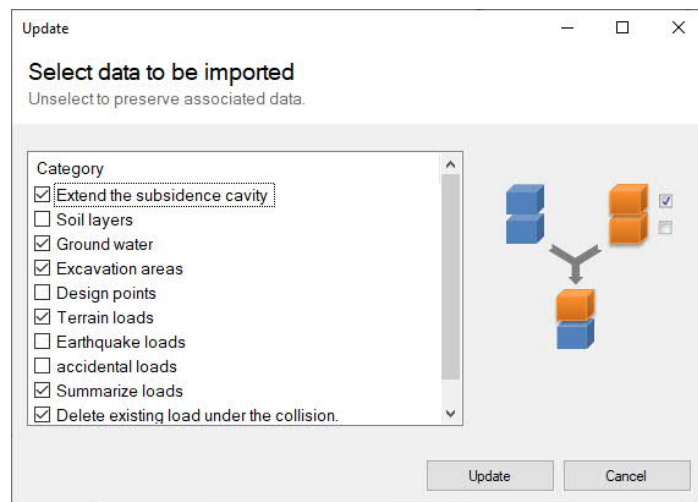


Figure 12: Selection of the data to be imported into an existing SBR+ model.

In principle, any number of foundation positions can be exported to SBR+. For this, however, it is also necessary that a [item coupling](#) to the target position in SBR+ has been defined for each individual foundation position in FD+.

In this way it is possible to create a holistic calculation model for the settlement calculation at any point under the influence of several foundations, foundation loads and additional surface or existing loads.

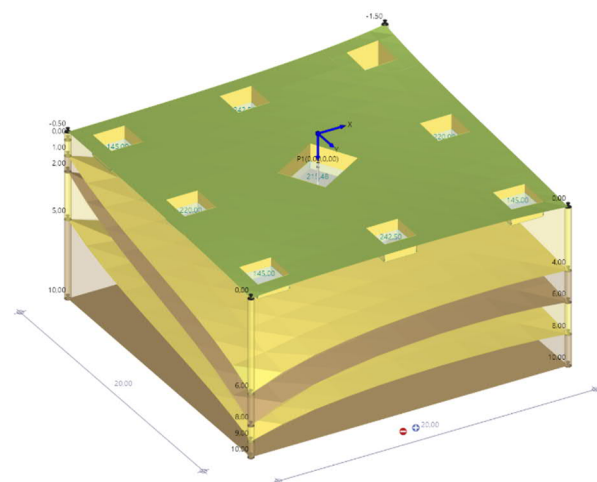


Figure 13: Importing several foundations from FD+

## Load transfer from the GEO Building Model

Everything mentioned under the two items "[Item coupling](#)" and "[Load transfer from the FD+ Foundation](#)" applies analogously to the load transfer from the Building Model. Therefore, only the special features of load transfer from GEO will be discussed at this point.

Foundation loads from single and strip foundations as well as foundation slabs can be transferred to SBR+.

The [item coupling](#) can be reached in the Building Model via the upper menu ribbon using the following path:

Options ▶ Settings - GEO Building Model  
▶ Coupling items

Figure 14: Menu for item coupling in GEO

After the Building Model has been calculated, all foundation loads can then be exported to SBR+ via the point [Design check in FRILO](#)  
▶ Soil Settlement SBR+

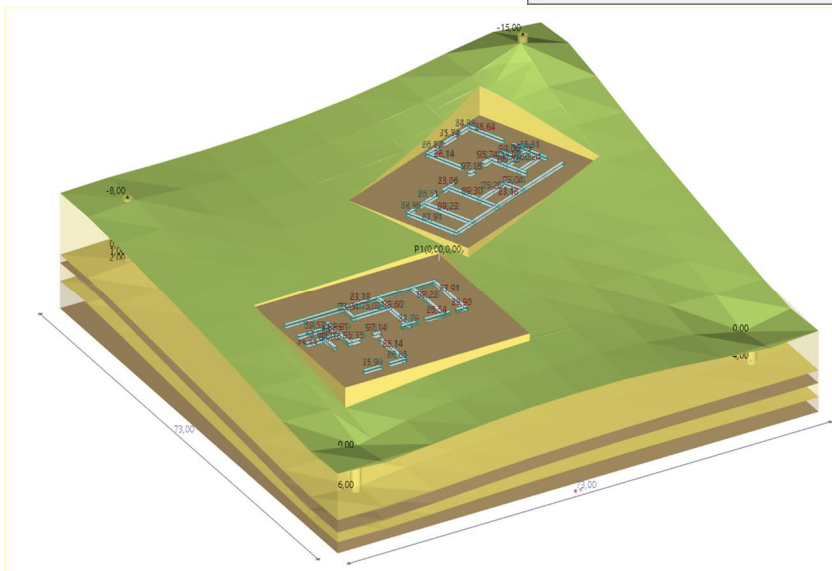
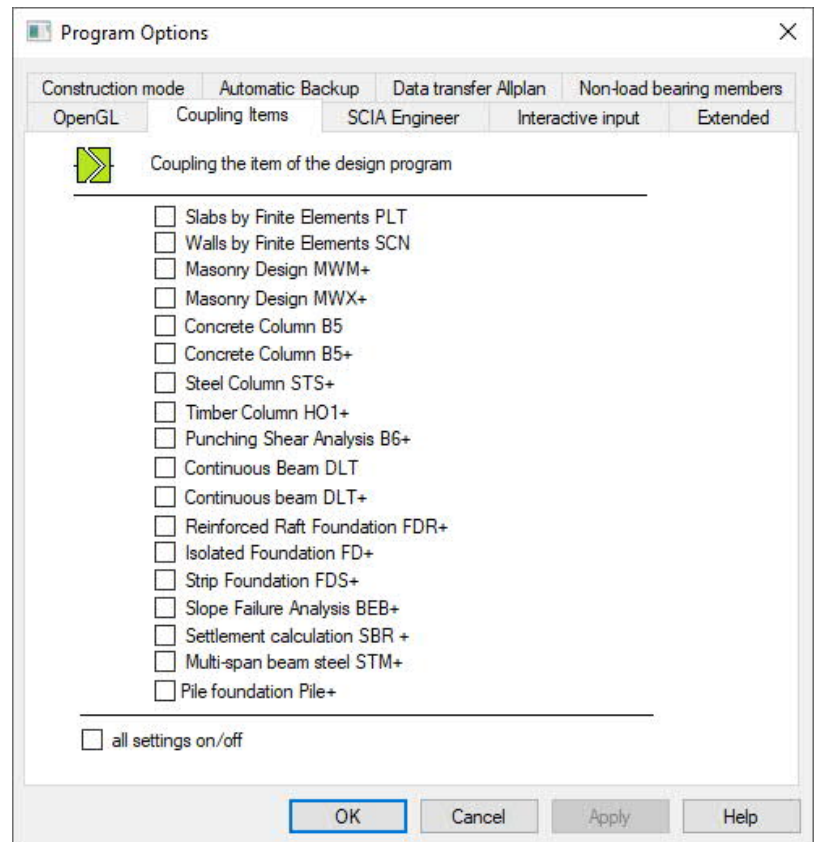


Figure 15: Import of several buildings from GEO



## Item coupling

When transferring from the GEO or FD+ programs, you can use the item coupling dialog (see following figure) to decide whether the foundation or foundation data should be imported into an existing SBR+ item or a new SBR+ item. An existing item coupling will later also be shown in the FRILO Control Center (FCC) in order to graphically illustrate the load transfer.

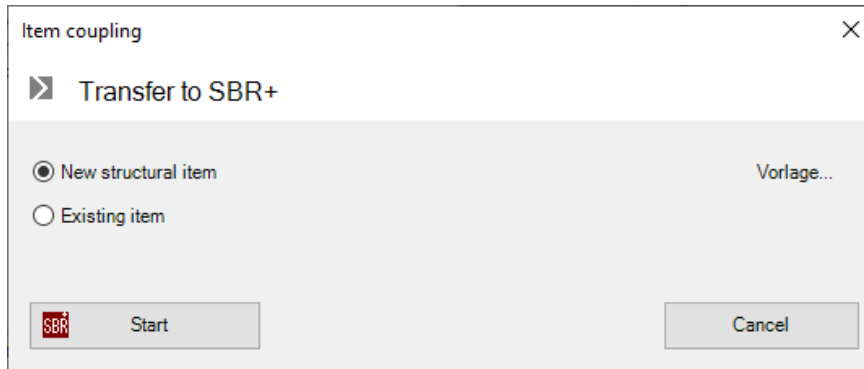


Figure 16: Item coupling between FD+ and SBR+

If several building models or foundations are to transfer their loads in an SBR+ model, this item coupling must be created separately for each exporting item.

### !!! Please note !!!

A change in the coupled higher-level item does not result in an automatic update of the foundation data and loads in the connected SBR+ item. In this case, the load forwarding must be carried out again manually. In this case, however, the connected SBR+ item is already preset as an existing item for the export.

# Output

## Scope of the output and options

By checking the desired options, you can determine the scope of texts to be put out.

## Output as a PDF document

On the "Document" tab, a PDF document is displayed.

See also the document "[Output and Printing](#)".

## Results

The icons in the "Results" tab can be used to display the various result graphics.

**Properties**

- Basic parameter
- System
- Loading
- Output**

---

**Output layout**

Output is running ... Standard

Legends

**Output system**

Calculation parameter

Soil profile

Scale auto

Ground water

Terrain

**Output of terrain loads**

Actions

Soil loads

SBR+ SBR+ -005-Landscape with Groundwater (Project: DLT Continuous Beam Ausgabe ENG)

**File Start Results Help**

Design points Design sections Settlement Time-settlement diagram Setting points Settlement cuts Cutting diagram Settlement trough Influencing values

Settlement

Scaling settlement depression

The stress-settlement diagrams scale 1:100

**Graphic Document**

50% Page 2 of 3

Pages Bookmarks

- Calculation parameter
- System
  - System graphic
  - Borehole profile
- Load cases
- Superposition
  - STR-Persistent
    - Settlement trough
    - Design point 1

**Borehole profile**  
Borehole 1' at x = -3000 m and y = -3000 m

No.	Designation	d [m]	$\gamma$ [kN/m <sup>3</sup> ]	$\gamma'$ [kN/m <sup>3</sup> ]	$q'$ [']	$c'$ [kN/m <sup>2</sup> ]
1	GU	3.00	18.00	8.00	30.0	-
2	UA	3.00	18.00	8.00	30.0	-
3	UA	2.00	18.00	8.00	30.0	-
4	UA	2.00	18.00	8.00	30.0	-

No.	$E_s$ [kN/m <sup>2</sup> ]	$E_{s0}$ [kN/m <sup>2</sup> ]	$\zeta$	$k$ [m/s]	on both sides	$C_u$	$eo$
1	5000.00	-	-	0.0000001000	no	0.003000	0.70
2	5000.00	-	-	0.0000001000	no	0.003000	0.70
3	5000.00	-	-	0.0000001000	no	0.003000	0.70
4	5000.00	-	-	0.0000001000	no	0.003000	0.70