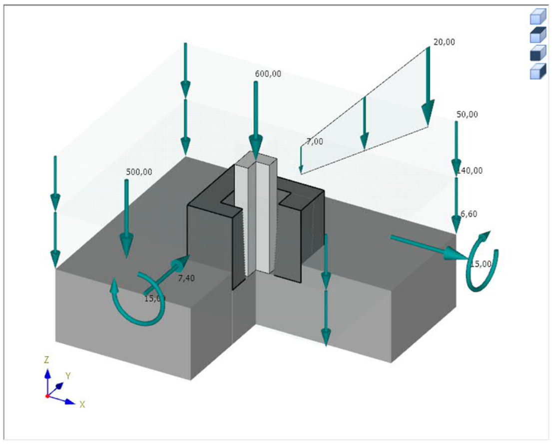
Foundation FD+ / FDB+

Contents

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.frilo.com ▸ Support ▸ Articles/Information ▸ Basic operating instructions.

Application options



The FD+ application allows you to verify squared and rectangular foundations cast with or without pocket/sleeve.
External loads can optionally apply centrically or with a uniaxial or biaxial eccentricity.

The software application calculates the soil pressure underneath the four corner points and the position of the zero-line in case of a gaping joint.

The required flexural reinforcement is calculated for the foundation and the punching shear resistance verification is performed.

You can optionally calculate the required connection reinforcement (Option "Connection Reinforcement" under ▸ Output).

The system consists of the foundation slab and an optional

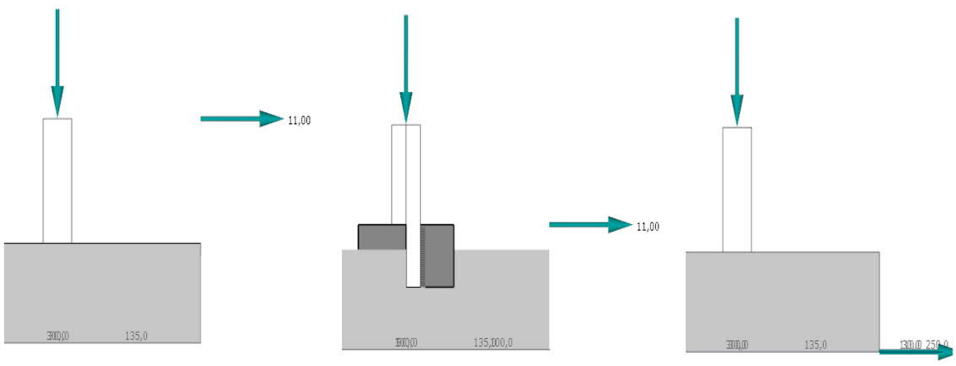
- column
- pocket

with optional eccentricity

The flexural design is performed at the centre of the column (axis) – the graph of the moment will be rounded. Optional it is performed at the column edge.

You can include the following load types in the calculation:

- Single vertical load V at the column location
- Horizontal loads Hx und Hy.
  The horizontal loads are acting (see graphic below)
  - at the top edge of footing or
  - if a column was defined, at the top edge of the column and
  - if a pocket was defined, at the top of the pocket.
  horizontal loads are generating a moment (effects in the sole)
  - as an option the horizontal loads can act directly at the sole without generating a moment.
- Outer moments Mx and My
- Earth surcharge load and additional uniformly distributed load applying to the foundation surface without column and additional vertical single loads applying at freely selectable points.



Basis of calculation

Reinforced concrete

Available standards / national annexes

- DIN EN 1992-1-1:2011/2012/2013/2015
- ÖNORM B 1992-1-1:2011/2018
- BS EN 1992-1-1:2009/2015
- PN EN 1992-1-1:2010
- EN 1992-1-1:2010/2014

- DIN EN 1997-1:2010
- ÖNORM B 1997-1:2010/2013
- BS EN 1997-1:2007/2014
- PN EN 1997-1:2011
- EN EN 1997-1:2009

Nationale Bemessungsnormen

- DIN 1054:2005/2010/2021
- DIN 4017:2006
- DIN 4019:2014
- ÖNORM B 4435-2:1999

still available:

- DIN 1045:1988
- DIN 1045-1 (2001 + 2008)
- ÖNORM B4700:2001
- DIN 1054:1976

The flexural design is performed in accordance with the kh- or kd-method.

The punching shear resistance is verified in accordance with the selected reinforced concrete standard. The constructive rules specified by the Booklets 240 and 525 issued by the German Committee for Reinforced Concrete DAfStb are considered.

The decisive reduced shear force Q_{red} is calculated by reducing the existing column load by the reaction force of the soil pressure portion attributed to the base surface of the punching cone.

The shear resistance verification is performed if the foundation geometry produces a uniaxial supporting behaviour.

For pocket foundations the following distinction is made:

- In combination with a rough/toothed pocket surface, the punching cone can be assumed outgoing from the surface of the pocket because the effect of the composite action allows such load distribution.
- In combination with a smooth pocket surface, the column base is considered to be the upper boundary of the punching cone.

- If the total bottom face of the foundation is inside the punching cone assumed with an inclination angle of 45 degrees, the verification can be dispensed with.

The column moments and horizontal forces are decomposed into the equivalent force groups *Ho* and *Hu*. An inclined strut *D* results. The inner lever arm *z* depends on the roughness of the surfaces. The limiting cases "smooth pocket surface, no bond" and "rough pocket surface, full bond" are distinguished. The lever arm *z* is assumed to be approximately 6/10 of the penetration depth *t* with no bond. With full bond, its value is multiplied with 1.4. If the bond is not ensured by appropriate measures, additional reinforcement should be installed to compensate the lower force component *Hu*.

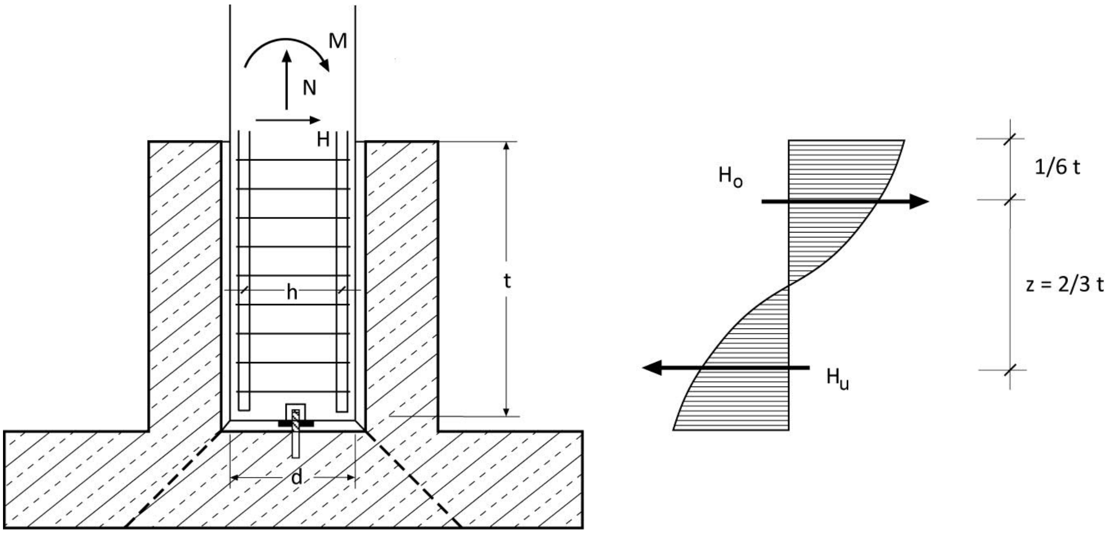


Illustration: Pocket with smooth surface

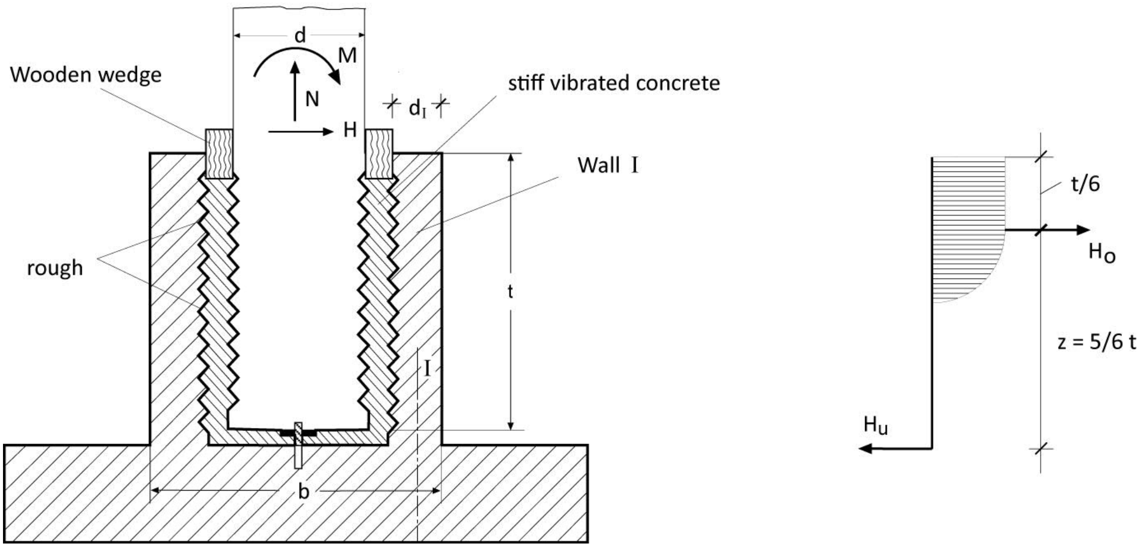


Illustration: Pocket with rough surface

Shear resistance verification

If the option "Shear force as beam" is activated in the "Design" menu, the software checks whether the foundation geometry produces a uniaxial supporting behaviour and if so, verifies the shear resistance.

This can happen in the three cases described below.

Meaning of the variables:

d	Statically effective height of the foundation
h	Foundation height (in z-direction)
a1, a2	Distances of the column to the foundation edge on the left and right (in x-direction)
a3, a4	Distances of the column to the foundation edge at the front and rear (top and bottom in the illustration, in y-direction)
cx	Column dimension in x-direction (width)
cy	Column dimension in y-direction (length)

Case 1:

The distances of two opposite column or pocket sides to the foundation edges are smaller than or equal to the statically effective height *d*. At the same time, the distance of one of the remaining sides to the foundation edge is greater than *d* (see illustration 1).

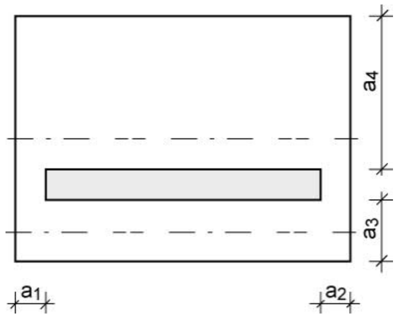


Illustration 1:

a1 and a2 <= d

a3 and/or a4 > d

In this case, only shear resistance, not punching shear resistance, is verified.

If the pressure is unevenly distributed along the shear section, the shear resistance is verified in the area with high pressure (see illustration 1a).

Shear force resultant with variable pressure distribution along the shear section.

Examined area of the resulting shear force in the shear resistance verification section

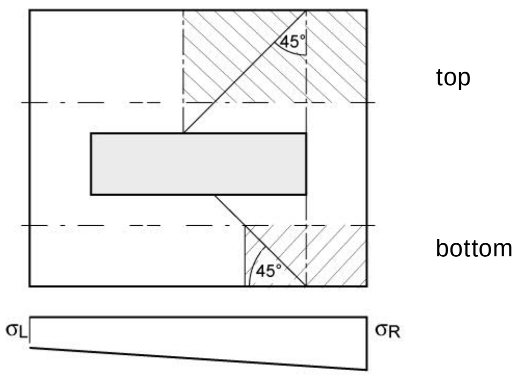


Illustration 1a

Case 2:

The dimensions of the pocket or column are comparable to those of a wall.

a1 > d and a2 > d and cx > a1 + a2 + cy + cy + Ls (Ls ≥ 1 m)

According to Booklet 240 of the German Committee for Reinforced Concrete DAfStb, the punching shear resistance for walls on stiff foundations is verified on an equivalent system where a square column (cy · cy) is positioned on a symmetrical rectangular foundation at the wall end.

The shear resistance is only verified if a wall is at least as long as the two equivalent systems at the wall ends plus an addition *Ls* (length of the shear section).

If *Ls* < 1 m, a minimum length of 1 m is taken into account (see ill. 2).

The shear resistance verification is performed in the central area of the wall between the two equivalent systems. In addition, the punching shear resistance is verified on an equivalent column with a side lengths ratio of 1:1.5.

If the foundation height h >= 1 m, the foundation height h is set for the length of the shear section *Ls*.

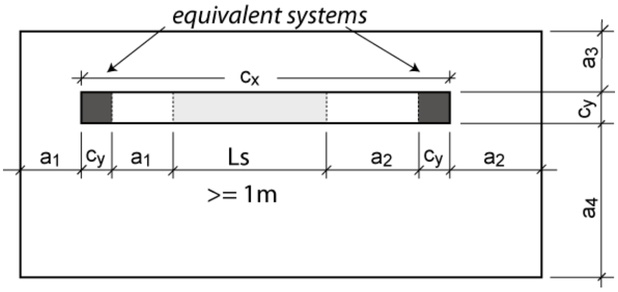


Illustration 2:

Case 3:

The distance of one side of the column or pocket to the foundation edge is smaller than *d* and the distance of at least one other side of the column or pocket to the foundation edge is greater than *d*, but the conditions of case 1 are not satisfied. At the same time, the length of the column or pocket must at least be equal to *2d* (see illustration 3).

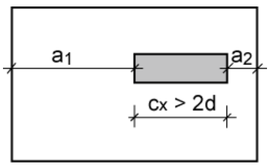


Illustration 3:

In this case, punching shear resistance is verified on an equivalent column with a side lengths ratio of 1:1.5.

The shear resistance is verified in the area of the wall.

If the pressure is unevenly distributed along the shear section in the area of the wall, shear resistance is verified in the area with high pressure (see illustration 1a).

If a wall is as long as or exceeds the minimum length defined in case 3 and is located at the edge, the software examines if the border or central area of the wall has higher shear reinforcement and perfoms a shear resistance verification in this area.

For the verification of punching shear resistance it is recommended to specify a total load factor for the punching shear load in the program.

In the standards based on the partial safety concept, the limit distance *d* specified in the cases above is defined as 1.5 · *d*.

The option “shear force as beam” in the ▸ Design menu allows you to verify shear force resistance on a beam instead of a plate.

Basis of calculation for verifications in foundation engineering

Standards

- DIN EN 1997-1
- ÖNORM EN 1997-1
- BS EN 1997-1
- PN EN 1997-1
- DIN 1054:1976/2005/2021

Position stability

When performing the verification of the position stability in accordance with Eurocodes, the stabilising and destabilising moments are determined on the four outer edges of the foundation. If the result load cases are used instead of the characteristic ones, no reduction factors are considered in the calculation of the stabilising and destabilising moments. In this case, only self-weight is multiplied with the partial safety factors that have a favourable or unfavourable effect.

Gaping joint

Under permanent loads, no gaping joint must occur and under the total load, gaping of the foundation joint is allowed only up to the centre of gravity. In combination with Eurocodes, the calculation of the gaping joint is based on representative instead of characteristic loads.

If design values are used instead of characteristic loads (Basic parameters ▸ Type of actions), the loads are reduced to the characteristic level with the help of reduction factors before considering the gaping joint. In this connection, it is important to define whether the individual load cases are the result of permanent loads exclusively or of both, permanent and variable loads. A gaping joint up to the centre of gravity is only permitted for the combination of permanent and variable loads. It is not permitted if only permanent loads apply.

Permissible bearing pressure

For a simplified verification in standard cases, the existing bearing pressure is compared to the permissible bearing pressure. The latter can be determined automatically with the help of standardised tables for this type of verification. The permissible bearing pressure taken from the standard tables could be increased or reduced if matching boundary conditions, such as the required anchoring depth, ground water or the relation of the horizontal and vertical loads require this. In combination with Eurocodes, the calculation of the equivalent area for the design value of the bearing pressure is based on representative instead of characteristic loads.

If design values are used instead of characteristic loads the loads are reduced to the characteristic level with the help reduction of factors before considering the equivalent area. The design value of the bearing pressure is obtained by dividing the design value of the vertical loads by the representative or characteristic equivalent area. As additional information, the software determines the inclination of the characteristic or representative bearing pressure resultant in order to check whether the inclination is suitable for a simplified verification.

Stability against sliding

If horizontal forces apply, the stability against sliding is verified. The stability against sliding is considered satisfactory if $T_d \leq R_{td}$.

T_d: Design value of the loading parallel to the bottom of the foundation.

Td is calculated by the software by multiplying Tk with the partial safety factors for the decisive limit state. The software uses the partial safety factors for the permanent and quasi-permanent design situations. If you define loads applied by accidental actions or earthquakes, the accidental and seismic design situations are taken into account as well.

R_{td}: Design value of the sliding resistance.
R_{td} is calculated by dividing R_{tk} by the partial safety factor for the sliding resistance for the decisive limit state in accordance with the currently selected foundation standard.

Safety against ground/bearing resistance failure

In combination with Eurocodes, the ground failure safety is calculated with characteristic or representative values. The design values of the ground failure resistance are determined by dividing the characteristic values by the partial safety coefficients. They are compared to the design values of the actions, which are multiplied by partial safety factors. Depending on the selected design standard, the characteristic or representative ground failure safety is calculated on the basis of ÖNORM B 4435-2 or DIN 4017.
The FD+, FDB+, FDS+ and FDR+ applications always calculate the ground failure safety as an isolated foundation. FDS+ and FDR+ calculate the ground failure safety as a strip foundation if the wall length corresponds to the foundation length.
In the GBR+ application, the "strip foundation" verification type is optionally available. When you select this type of verification, the shape coefficients and the load inclination coefficients 'ma' and 'mb' are set to 1.0. Instead of the calculated equivalent width in the longitudinal wall direction (y-direction), the foundation length (y-direction) is taken into account.

The Settlements

The settlements are calculated according to DIN 4019:2014, therefore characteristic loads should be taken into account. The user can decide whether only the static loads or also the variable loads should be applied and whether the variable loads should be multiplied combination coefficients.
See DIN 1054:2010 2.4.8 A (2.8a). The settlements are calculated in characteristic point K on the surface of the foundation – that is the point, in which the settlement calculated for rigid foundation matches with the calculated settlement with an assumption of equivalent uniformly distributed load. The settlements are determined for every defined soil layer. As a result, at the printout it is pointed out whether the settlement effective depth or rather limit depth *ts* in the ground, from which additional stresses cause only negligibly small deformations in the soil, was achieved or not. The calculated module *E**, which is used as a value for the settlements analysis, can be either specified directly by the user or calculated automatically from the given stiffness value and predetermined correction coefficient. Some soil parameters are required for settlement analysis, which include: geometrical model of the ground and also the groundwater model, as well as parameters of the soil layers, which can be usually found in the geotechnical reports according to DIN EN 1997-2 or DIN 4020. Further information is required about the structure and the ground. These include the dimensions and the level of the foundation, values of the loads applied to the foundation and, if applicable, also their development and changes in time, the distance of the foundation to foundations of adjacent buildings, the geometry and loads for the adjacent buildings foundations, as well as the terrain elevation. Frequently, only some part of changeable loads is relevant for settlement analysis. For the calculations of settlements, the significant settlement effective depth is verified by the program. It is located where the perpendicular additional stresses caused by the average loads effective for settlements are equal to 20% of the effective perpendicular output stresses of the ground. These criteria are verified at the deepest point of the last defined soil layer and there is an appropriate message about it in the printout.

It can happen, that highly compressible soil layers are present below the determined settlement effective depth, therefore the depths of the layers greater than the limit depth can be defined by the program. The settlements are calculated according to DIN 4019:2014 (3) for a rigid foundation in the characteristic point (see DIN 4019:2014, figure 3).

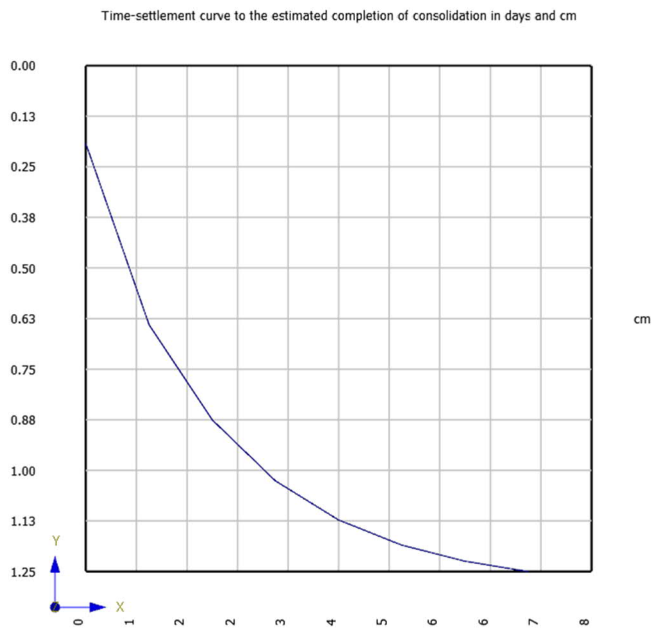
At first, the program calculates the settlement s, which consists of the immediate settlement s_0 and the consolidation settlement s_1.

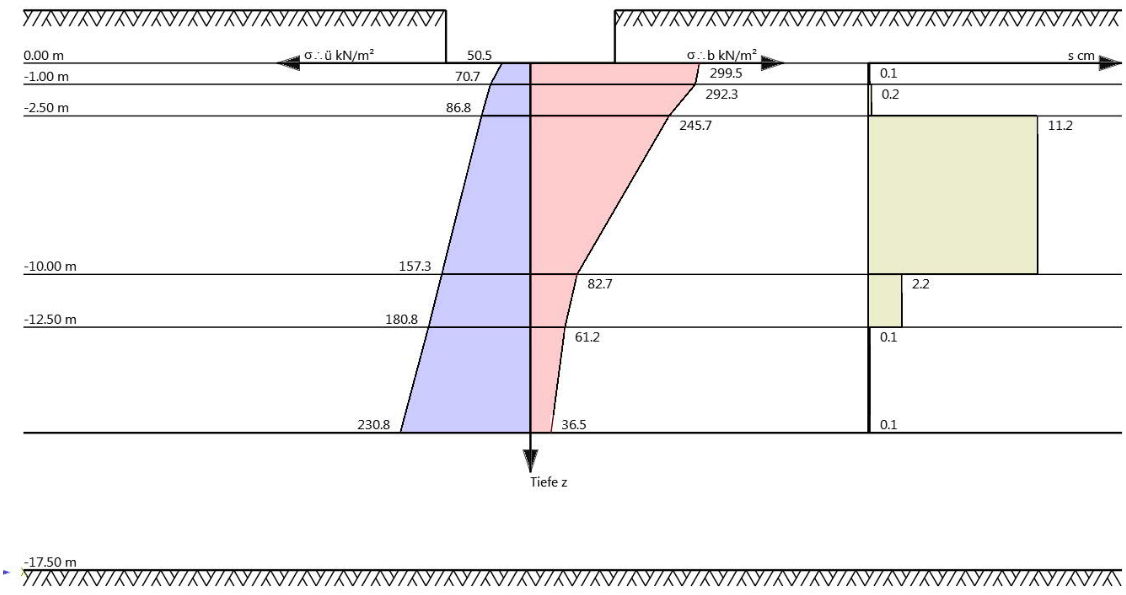
$s = s_0 + s_1$

The consolidation settlement is considered at the end of the consolidation according to DIN 4019:2014 12.2 and is determined for the point in time $\tau = 1$ and set up in a table. Additionally, the increase of settlement in time until the estimated end of consolidation is graphically presented.

Then the creep settlement for a value of $\tau \geq 1$ given by the user is calculated and that results in the total settlement value s_{ges}

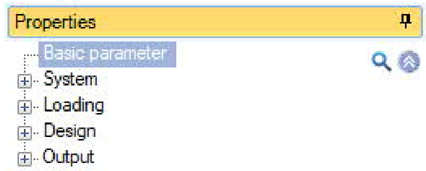
$s_{ges} = s + s_2$





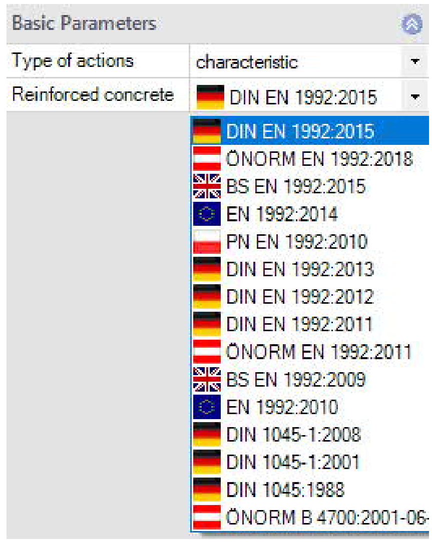
If eccentricities occur in the decisive superpositions or the significant load case for the settlement calculation, the additional settlement part *Delta S* is calculated. If there is a gaping joint, then the program reaches its applications limit for settlements calculations.

Data entry – Basic parameters



The definition of properties and control parameters is done in the menu of the left screen section. You can check the effect of the entered values in the graphical representation on the right screen section.

Prior to the first entry, the units (cm, m ...) can be customized:
File ▸ Program Options.



Wizard

The Wizard appears by default / automatically at startup, but can be switched off.

Input Options in the GUI

The input options in the GUI window are described in the document Basic operating instructions-PLUS.pdf.

Basic parameters

Type of actions

Design values	The loads are entered with their partial safety factors and reduced by the specified reducing factors in the soil engineering-specific verifications, if applicable.
characteristic	The loads are specified with the characteristic (1.0-fold) value.

Reinforced concrete

Select the desired reinforced concrete standard:

See also Basis of calculation

Soil Engineering and Bearing failure

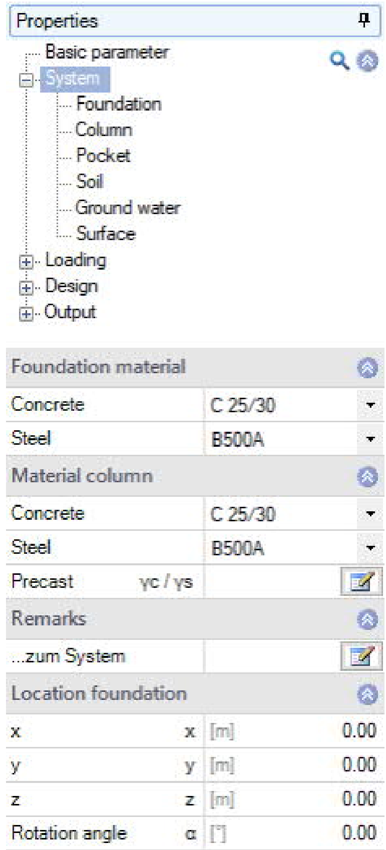
According to the selected reinforced concrete standard, the software selects the corresponding standards for soil engineering and bearing failure automatically.

System

Material

Selection of the concrete quality and reinforcement steel grade.

Via "Precast γc / γs" a dialog with options for the partial safety factors of the material is called up.



Remarks

Click on the button, to enter your own comments to the system.

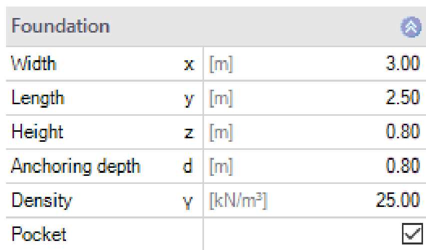
Location foundation

The global position related to the foundation axis is only required for communication with other programs such as GEO and SBR+.

Foundation

In the foundation ground plan, the x-axis (positive) runs from the left to the right and the y-axis (positive) from the bottom to the top.

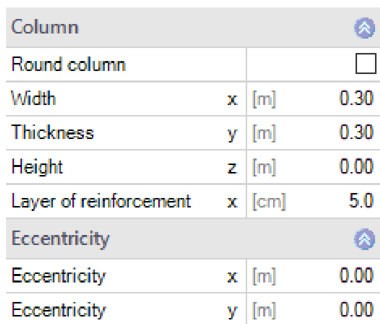
Width	x	Foundation dimension in x-direction
Length	y	Foundation dimension in y-direction
Height	z	Foundation height
Anchoring depth	d	Lowest foundation depth below the ground level or the top edge of the basement floor.
Density	γ	Weight density
Pocket		FD+: tick this option to actvate the menu “Pocket” (will be displayed under "System").



Column

Specification of the following dimensions:

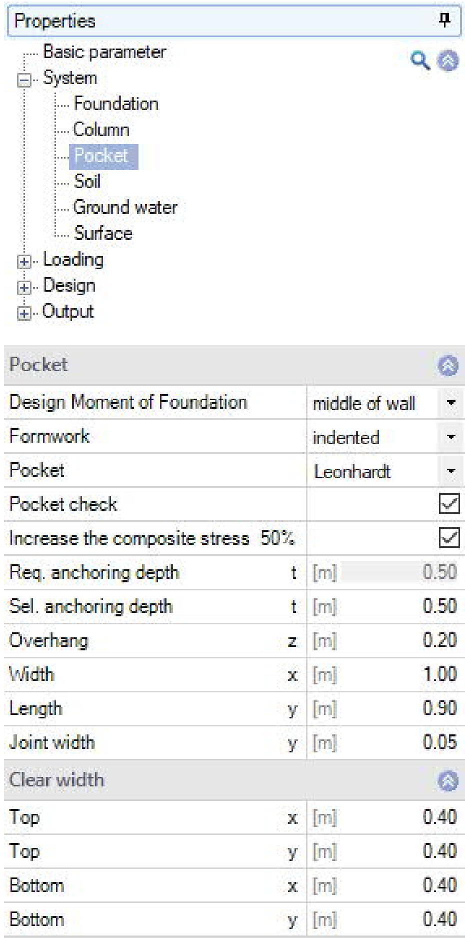
Round column	Option for round columns
Width x	Width of the column
Thickness y	Thickness of the column
Height z	Height of the column
Layer of Reinforcement	Reinforcement layer in the column



Eccentricity

Eccentricity x	Column eccentricity in x-direction
Eccentricity y	Column eccentricity in y-direction

Pocket



FD+: *The "Pocket" menu is only available if the option "Pocket" (menu "foundation") was selected.*

Pocket

Design Moment of Found..	Middle of the wall, pocket axis (FD+), Wall cut part. Specify here in which sections the bending design of the foundation should be performed. The bending moment is rounded for design sections in the pocket center line but not in the wall axis of the pocket or in the section of the wall of the pocket.
Formwork	FD+: indented (toothed) or smooth; FDB+: toothed. *Note for surfaces with indentations:* *Column base and pocket wall are manufactured with serrated formwork (profile depth at least 10 mm) - see examples to design according to Euro code 2, Volume 1 and EC2-1-1, 6.2.5 and 10.9.6.2*
Pocket	Calculation according to Leonhardt or Schlaich/Schäfer.
Pocket check	If the option is activated, the required anchoring depth is calculated and displayed. The geometry test takes place according to DAfStb booklet 399 p.64-66 and Leonhardt part 3 16.3.3 as well as examples for dimensioning DIN 1045 p.237. The anchoring depth corresponds to 1.5 times the column width with related moments M/(N*d) of less than 0.15. With related moments of M/(N*d) of more than 2, the anchoring depth is twice the column width. Intermediate values are interpolated. The anchoring depth is at least 50 cm. For smooth formwork surfaces in the pocket, the anchoring depth increases by a further 40% according to Leonhardt Part 3 16.3.3.2. In the reinforcement dialog, the program also offers the option of dimensioning the column and pocket reinforcement to match the anchorage and lap lengths.
Increase composite stress 50%	When calculating the lap joint 'I0' between the longitudinal column reinforcement and the vertical pocket reinforcement a bond stress increased by 50 % may be assumed in accordance with booklet 399 due to the existing transversal pressure.
... anchoring depth t	The required/selected anchoring depth.
Overhang	Absolute distance between the top edge of the foundation and the top edge of the pocket. For recessed pockets, the pocket overhang should be set to "0".
Width/Length	FD+: pocket dimensions in x/y-direction
Joint width	Width of the joint underneath the column base.

Clear width

Top / Bottom	FD+: clear width at pocket top/bottom edge in x / y-direction
Width	FDB+: clear width of the pocket in x / y-direction

Mounting panel (FDB+)

Width x / y	Width of the mounting panel in in x/y-direction.
Joint width y	Joint width beneath the column base.

Anchoring depth pocket

The program determines the required anchoring depth according to " Vorlesungen über Massivbau Teil 3 [Fritz Leonhardt] 16.3.3 page 228". It should be noted that the anchoring depth according to " Heft 411 [DAfStb] 7.1 Page 31" is 1.5 ds instead of 1.2 ds. Thereafter, a pocket depth of 1.5 times the column width is sufficient for existing friction to safely accommodate high bending stressed and reinforced columns. A pocket with an anchoring depth of 1.2 times the column width appears to achieve lower breaking loads, leads to slippage in the tensile reinforcement of the column and creates high strains in the stirrups.
The anchoring depth depends on the referenced eccentricity e/d:

For $\frac{e}{d} < 0.15$: $\quad TB = 1.5 \cdot d$

For $\frac{e}{d} > 0.15$: $\quad TB = 1.5 \cdot d + 0.5 \cdot d \cdot \frac{\frac{e}{d} - 0.15}{1.85}$

The required anchoring depth is limited by the program to 2 times the column width.

With smooth concrete surfaces, the minimum anchorage depth is increased by 40 %. Furthermore, the anchoring depth is defined by the program to at least 50 cm.

The calculated anchoring depth is displayed and you should select a value that is at least as high as the specified one.

Also smaller values can be entered if this is appropriate due to smaller moments. A corresponding note is displayed in the output.

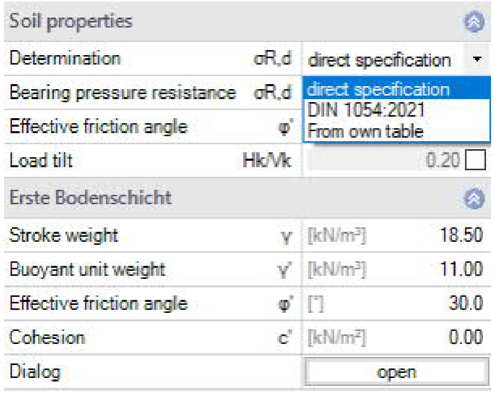
Furthermore, it is possible to exclude the determination of the required anchoring depth and to define column reinforcement and pocket reinforcement in the reinforcement dialog and to control the calculation of the anchorage lengths and lap lengths via the output options "Reinforced concrete / Text Reinforcement" and, if applicable, "Anchoring details".

The clear widths must exceed the column dimensions by one centimetre at least.
The minimum outer dimensions result from the selected clear dimensions plus 0.5 x column width for the walls (Booklet 399, page 66).

The wall thickness must amount to 1/3 of the lowest pocket opening width at least. The distance of the column to the edge must be at least 10 cm at the upper pocket opening and 5 cm at the lower pocket opening. These geometrical conditions are verified during the definition of the column and adjusted, if required.

Soil

Soil properties

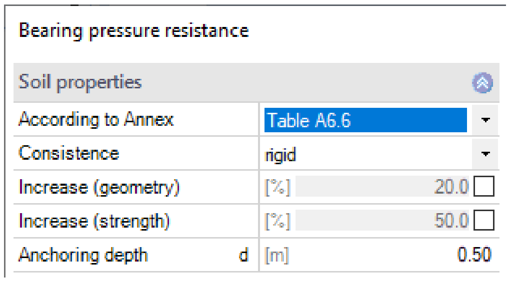


Determination σR,d — Select whether the design value of the bearing resistance should be entered directly, or to come from a standard table (DIN 1054) or from a user defined (own) table - see section below.

Bearing pressure resistance — Specification of the permissible bearing pressure $\sigma_{R,d}$
In the case of "direct specification", input of the design value of the bearing pressure resistance σR,d for the permanent design situation BS-P. For the design situations BS-A, BS-E and BS-T, the design value is increased according to the ratio of the partial safety factors of the bearing capacity. For example 1.4/1.2 = approx. 116% or 1.4/1.3 = approx. 107%.

Eff. friction Angle φ´ — Angle of the inner friction underneath the foundation base.

Load tilt — Enter the maximum tilt of the characteristic or representative bearing pressure-resultant H/V, which should be checked in the case of simplified verification. Otherwise, default values are used.



Dialog — If the determination σR,d is not specified directly, the design value of the bearing pressure resistance is taken from a table (standard or user defined)
Click the "open" Button to open the tabledialog.

Parameters by standard table DIN 1054:

According to Annex — The soil pressure is taken from the corresponding table in the soil engineering standard or its National Annex.

Consistence — consistency of soil: rigid, half-solid, solid – only with tables A6.6. to A6.8.

Increase (geometry) — The permissible bearing pressure can be increased by 20 % if the relevant border conditions (b/d) specified by the applicable standard are satisfied. By ticking this option the value can be edited.

Increase (strength) — The permissible bearing pressure is increased by 50 %, if the soil is sufficiently solid. By ticking this option the value can be edited.
Note: The values are added up under particular conditions (70 %).

Anchoring depth d — Lowest foundation depth below the ground level or the top edge of the basement floor.

Define own table:

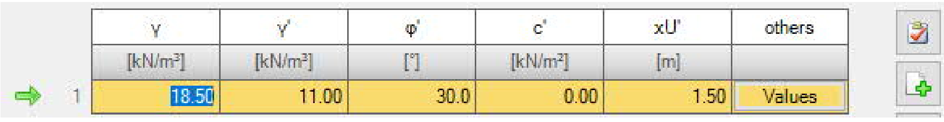
For the self-defined table, you can use the button to create a new entry and enter the design value of the bearing pressure resistance σRd. This value should come from a geotechnical report and should have sufficient guarantees against ground failure and a sufficient limitation of settlements. Furthermore, the corresponding foundation width and anchoring depth must be specified. The meaning of the other buttons can be seen from the Tooltips.

First soil layer

In this section you can enter the values of the first soil layer.
For additional soil layers click the Button “Dialog – open”.

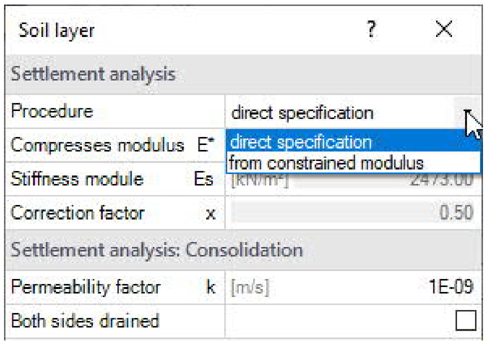
Stroke weight	γ	Specific weight of the soil.
Buoyant unit weight	γ'	Specific weight of the soil layer under buoyancy. This value is only used if groundwater was defined (▸ System ▸ Soil)
Friction angle	φ'	Friction angle of the soil in this layer.
Cohesion	c'	Soil cohesion.

Further soil layers / additional values (▸ Dialog „open“)



xU Thickness of the soil layer. Soil layers below 0.10 m cannot be defined.

Click the Button “Values” to open the dialog for additional parameters.



Settlement analysis

Procedure	Direct specification or from constrained modulus: To define the compressibility of the soil (*Em*-module) select - directly in E* or - from the constrained modulus - *Em* will be calculated from stiffness/constrained modulus *Es* and correction factor *x* (from DIN 4019 T1).
E*	Compression modulus. The compressibility of the soil can be specified by a pressure settlement line or calculated from the constrained modulus in connection with a correction factor.
Es	Constrained modulus.
x	Correction factor.

Settlement analysis: Consolidation

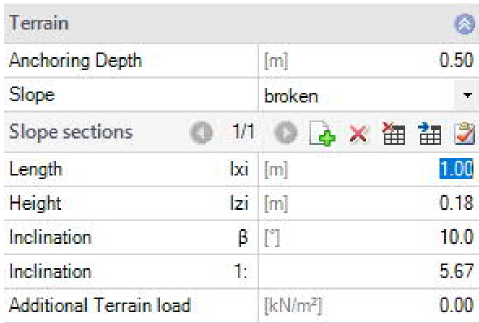
k	Permeability coefficient of the rate of consolidation. The value can be extracted from the soil report.
Both sides drained	For the calculation of the time to approximate decay of consolidation settlement in unilateral drainage the full layer thickness is set, in bilateral drainage only half the layer thickness.

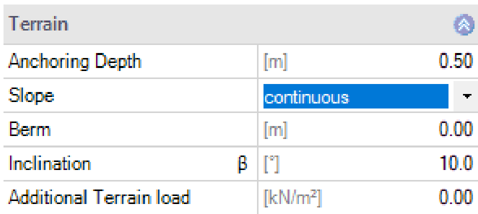
Ground water

Ground water existing This option allows you to define whether groundwater exists (displays the entry "Ground water").

Ground water Only if ticked option "Ground water existing".
Absolute depth of the groundwater below the bottom edge of the foundation body. Negative values can be used to define a groundwater level below the base of the foundation.

Surface





Anchoring depth Anchoring depth of the foundation body.

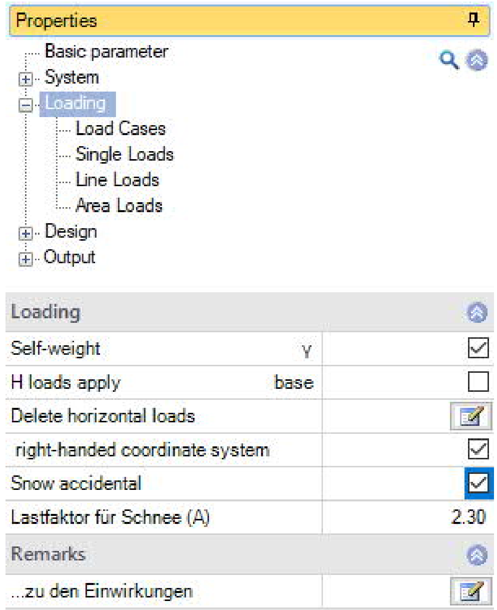
Slope The ground level can be modeled as horizontal, with a continuous slope, or with a broken embankment.

<u>Continuous:</u>
Here you can define a berm and the slope - see advanced foundation dialog.

<u>Broken:</u>
Input of the embankment sections. The "+" symbol creates a new table row for a further section. Parameters are length, height or inclination or rise (the height adjusts automatically to the incline).

Additional Terrain load Additional characteristic permanent area load on the bearing failure figure, which increases the characteristic punching shear resistance.

Loads



Self-weight γ

Automatic consideration of the self-weight. If the groundwater is above the base of the foundation, the self-weight cannot be deactivated.

H loads base

Option not ticked:
The horizontal loads apply at the top edge of the base and generate a moment with a particular lever arm

Option ticked:
The horizontal loads apply directly in the base joint without generating a moment

Delete horizontal loads

Delete all horizontal loads with one click! This is useful if many load cases from other applications (GEO, B5...) have been imported.

Right-hand coordinate system (new standard)

Coordinate system based on the right-hand rule, also referred to as right-hand coordinate system. The signs comply with the sing definitions in engineering mechanics. Positive moments about the x-axis generate pressure on the bottom and/or in the negative area of the foundation. Positive moments about the y-axis generate pressure on the right and/or in the positive X-area of the foundation. If this option is unchecked (default setting until recently) positive moments generate pressure on top right and/or in the positive X/Y-area of the foundation. In the graphic representation, both variants are shown with their absolute values. The arrows indicate the actual direction of action. The values in the data entry fields and in the output documents are indicated with their signs. If you change the sign definition, the sign of the moments about the y-axis changes as well.

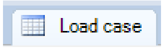
Accidental snow load

When you check this option, snow loads are automatically included as accidental action in addition to the typical design situations. The user can either specify a freely selectable load factor for the accidental snow loads or have it determined automatically by the software. The default value is 2.3

Remarks

The remarks editor is called up via the button. This text appears in the output.

Load Cases

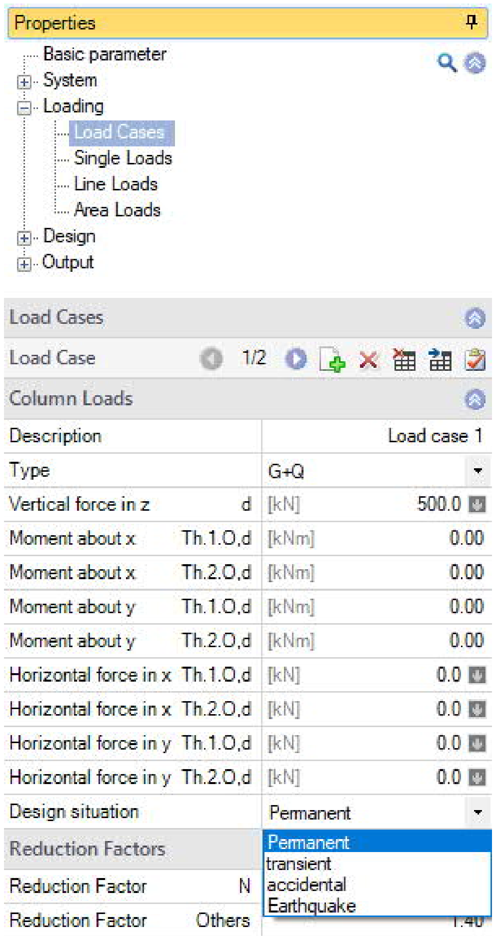
Enter the data of the first load case via the data-entry mask or directly in the load case table, which can be displayed by activating the  tab (below the graphic).

Load case toolbar:  - see Data entry via tables

To add additional load cases, click on the button once more (a new empty input mask is displayed each time).

Tip: *A description is displayed in the status line each time you click into an input field.*

Column Loads



Description	Optional text to the selected action can be entered. This text is included in the output.
Action	The appropriate actions can be selected from a list: Permanent loads ... seismic loads (calculation method "characteristic").
Vertical force in Z	Vertical force in the centre of the column
Moment about x/y	Positive moments generate pressure on top right or in the positive x/y section of the foundation.
Horizontal Force in x/y	Horizontal loads apply to the top edge of the foundation or the top edge of the column, if a column height was defined. These horizontal loads generate moments on their way down to the foundation base, which are taken into account automatically by the software.

Standard for the load input are characteristic (1.0 times) values from the support of the column or the wall. Alternatively, the type of stress can be changed to 'design values' in the basic parameters – see ill. right.

By clicking on the arrow icon you can access a load value summary - see the description of the LOAD+ application.

Design situation

The selection of the design situation is displayed if "Design values" has been selected under
▸ Basic Parameters ▸ Type of actions. In the accidental design situation, the option "foundation checks" appears.

Foundation checks

Here you can disregard the foundation design for individual load cases of the accidental design situation (remove check mark). For different situations, such as impact from forklifts, it may be useful to have a load case for the safety checks in earthworks and foundation engineering (gaping joint, positional safety, simplified detection, ground breaking, sliding and subsidence) and in concrete (bending, shear force and punching) disregarded. In this case, only the connection reinforcement or the pocket are dimensioned in connection with this load case.

Note: *According to DIN 1055-9: 2003-08, para. 6.2 (6), the effects of impacts in general structural engineering are not to be passed on to the foundation. With reference to the explanations to the inquiries of the building law authorities and inspecting persons at the working meeting of the union of the test engineers for structural engineering Baden-Wurttemberg from 14.11.2013 can with use of DIN EN 1991-1-7 NDP to 4.1 (1), note 3 it can be assumed from the same point of view.*

Reduction Factors

These input fields are enabled if "Design values" was selected as calculation method.

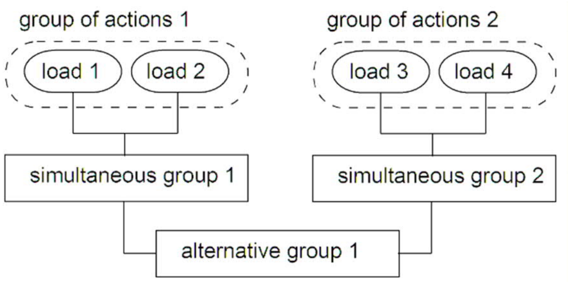
Reduction Factor N	Reduction coefficient for the forces acting in the z-direction (axial force in the column) and loads (additional concentrated loads, line loads and surface loads).
Reduct. Factor Others	Reduction factors for other internal forces. If a column was designed in a second order analysis, the internal forces are only available on the design level. In order to make verifications in soil engineering available on the characteristic level, the reduction factors are used to adjust the internal design forces to a characteristic level. When using the characteristic calculation method (▸ Basic parameters ▸ Calculation method) in combination with first-order columns, the afore-mentioned situation does not occur.

Group membership

The assignment to a group is displayed if "characteristic" has been selected under ▸ Basic parameters ▸ Type of actions.

<u>Simultaneous (concurrent) group</u>

Loads of a particular action group can be defined as "always acting simultaneously"
by assigning them to simultaneous (concurrent) groups.



Ill.: *Example for the functioning of alternative and simultaneous groups*

<u>Alternative group</u>

Different variable load cases with similar actions can be assigned to an alternative load case group via the allocation of an <u>alternative group number</u>. Only the decisive load case of this alternative load case group is invoked in the superposition.

Bearing pressure / Actions from the column

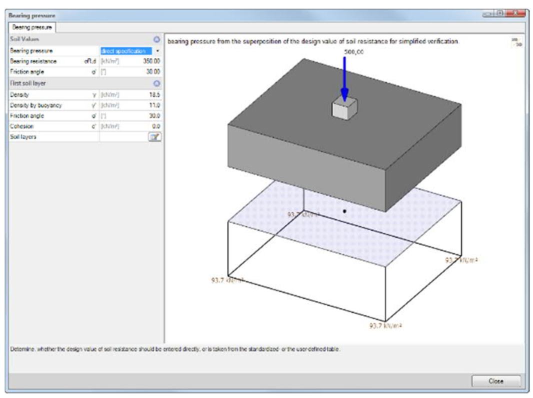
<u>Display of the bearing pressure pattern</u>

To ensure traceability, the bearing pressure pattern with stress can be shown for all load cases and superpositions decisive in the verifications. Click the symbol “Bearing pressure” to display the graphic in a popup window. See also ▸ Design ▸ Soil Engineering.

Explanation:

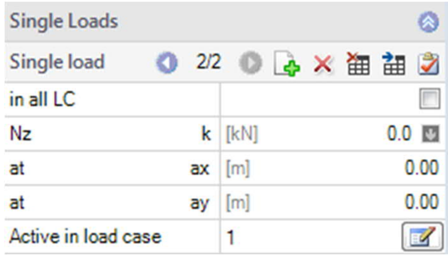
Positive moments Mx and My generate compressive strains in the foundation joint in the right top corner and/or the positive x/y section.

The moment Mx rotates about the x-axis and the moment My about the y-axis; the horizontal forces Hx and Hy act in direction of the axes. Hx generates a moment My and Hy a moment Mx.



The moments resulting from first and second order calculations are used for all verifications. The scope of data to be put out is defined in the Output profile.

Single Loads



Define a new concentrated (single) load by activating the button (the corresponding input mask is displayed).

Activating the Single load tab displays the "Single load table" giving an overview of the defined loads.

Toolbar: 1/2 - see also Data entry via tables

Tip: A description is displayed in the status line each time you click into a particular input field.

In all LC:	If you tick this option, the corresponding single load acts in <u>all</u> load cases.
Nz	Value of the axial force of the additional single load. By clicking on the arrow icon you can access a load value summary - see the description of the LOAD+ application.
at ax/ay	Position of the additional single load in x or y direction referenced to the foundation centre.
Active in LC	Assignment of the additional single load to load cases. Activating the button displays a dialog with the corresponding options.

Notes: *If a single load is assigned to one or several load cases it acts only in combination with the load case(s.*
In the case of the calculation method design values single loads are processed with the corresponding reduction factors.
Single loads that are not assigned to load cases are <u>not</u> taken into account in the calculation.

All verifications are referenced to the column loads. Additional single loads are defined only to check the effects on the bearing pressure, tilting, position stability, sliding and ground failure.

For the verification of punching shear resistance, the loads that apply in the area of the punching cone must be summarized to a resulting load, because the shear design would be unsafe otherwise.

With foundations for twin columns you should combine both columns to a single column instead of defining the second column as an additional single- or line load. Otherwise, you will obtain incorrect results in the verification of punching shear resistance .

Line Loads

General operation as described under single loads.

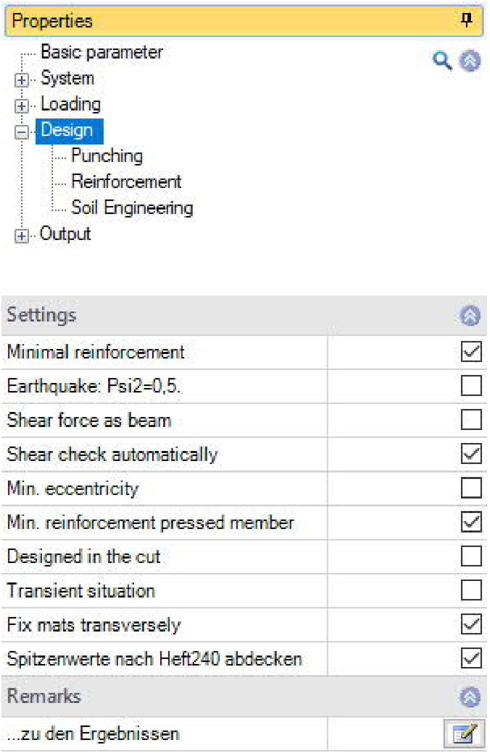
In all LC:	Option ticked: the load acts in all load cases
P1	Value at the begin of the line load
at x1/y1	Position of P1 relative to the foundation center
P2	Value at the end of the line load
at x2/y2	Position of P2 relative to the foundation center
Active in load case	As described under single loads

Area Loads

Loads by soil on the foundation	Height of the earth surcharge, if applicable. In combination with the weight density γ, the soil load generates an area load on the foundation, which is taken into account in the calculation. *Explanatory note: The earth surcharge load refers to the top edge of the foundation. If a wall, column, wall base or pocket exists, the earth surcharge load is reduced in accordance with the geometry of the structural component.* *Note: This value has nothing to do with the self-weight of the foundation.*
Density γ,k	Weight density of a possible soil load.
Area Load q,k	Additional area load on the foundation body. *Explanatory note: The area load acts on the surface of the foundation. If a wall, column, wall base or pocket exists, the area load is reduced in accordance with the geometry of the structural component. If a top-mounted pocket exists, the area load also acts on the pocket, but not in the area of a column casted in the pocket. See the description of the option "Earth surcharge height" for more information.*
Active in load case	Assignment of the additional area load to load cases. Activating the button  displays a dialog with the corresponding options.

Design / Verifications

Settings - Program settings

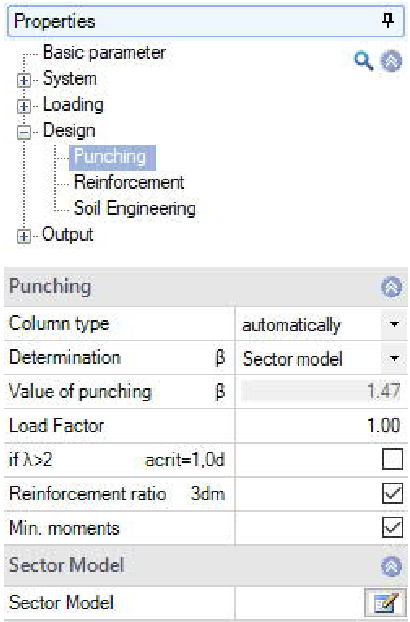


Minimum reinforcement	Ductility reinforcement in accordance with the selected reinforced concrete standard
Earthquake: Psi_2=0.5	In accordance with the introductory decree of DIN 4149 for Baden-Württemberg, the combination coefficient Psi2 = 0.5 for snow loads should be used in the superpositions with seismic loads.
Shear force as beam	Specification whether the shear resistance should be verified on a slab or a beam.
Shear check automatically	With this option, the program will decide in accordance with the defined geometry, whether to print out a check of punching shear, a shear force or both.
Minimum eccentricity	Considering minimum eccentricities for compression member by EN 1992-1-1 6.1 (4).
Minimum reinforcement pressed member	This option allows you to take a minimum reinforcement for compression members into account.
Design in contact surface	When you check this option, the bending moment for the foundation design is determined at the edge of the column (in the contact surface). When the option is left unchecked, the moment is calculated in the system axis and the moment curve is radiused. If a pocket was defined, this option is not displayed. You must select the design section in the pocket dialog in this case.
Transient situation	When you check this option, the transient design situation is used. When you uncheck the option, the persistent situation is used. The accidental situation and the seismic situation are automatically considered if corresponding actions have been defined.
Include transverse fabrics	Using fabrics increases the specified reinforcement (existing as). If you check this option, the ‘existing as’ is also increased for fabrics in the transverse direction. When you use stirrup fabrics, it might be reasonable to exclude transverse fabrics, for instance.
Peak values according to booklet 240	Selection of whether you want to cover the peak values with different reinforcement distributions as an enveloping value curve according to booklet 240 or simply want to distribute the distribution according to booklet 240 differently.

Remarks

The remarks editor is called up via the  button. This text appears in the output.

Punching



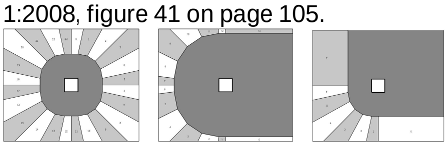
The Eurocodes provide several methods for the punching shear analysis. In accordance with DIN 1045, constant β-coefficients are used in the punching shear analysis.

Column type:

Selection of the type of column:
- automatically
- inner column,
- outer (edge) column in the x- or y-direction and
- corner column.

This setting affects the way how the control perimeters are generated.

If you activate the "Automatic" option, the type of column is determined as specified by DIN 1045-1:2008, figure 41 on page 105.



inner column *edge column* *corner column*

Determination β

Selection how to define the punching shear coefficient:
- ductile shear force distribution
- sector model
- constant values
- user-defined value

In combination with plastic shear stress distribution, the selected column type is used for the calculation of the β coefficient in order to take dynamically unbalanced loading in the critical perimeter into account. The static moments of the line of gravity of the critical perimeter are calculated using the set of formulae specified in Booklet 600:2012, table H6.4, page 96. The β-value that is used subsequently in the punching shear analysis results from this calculation.
When using the sector model, the selected column type is not of importance. The application program checks automatically which shape of critical perimeter produces the shortest perimeter length and whether the perimeter intersects the foundation edge in its shortest version. The punching shear analysis is based on the maximum stress of the decisive sector.
See → Notes concerning the sector model.
For constant values, the β-value specified in the design code for the selected column type is used.

User-defined: the "Value of punching/Punching shear coefficient β" entry field is enabled.

Punching shear coefficient β:

You can manually set the coefficient for dynamically unbalanced loading in the critical perimeter. It is used in combination with the selected column type in the punching shear analysis with constant factors.

Calculation as per:

This option is only enabled in combination with DIN 1045-1.
Selection of the desired punching shear analysis:
in accordance with DIN 1045-1 or DAfStb* Booklet. When selecting Booklet 525, a calculation as a compact foundation can be imposed.

Load factor:

The design value of the shear force in the punching shear analysis is multiplied with this factor. It allows you to increase the punching shear load in order to take dynamically unbalanced flexural loading into account, for instance.

if $\lambda > 2{,}0$ $a_{crit} = 1.0 \cdot d$ — according to DIN EN 1992-1-1 NA a constant perimeter at a distance of 1.0·d may be assumed to facilitate the calculation of floor slabs and slender foundations with $\lambda > 2.0$.

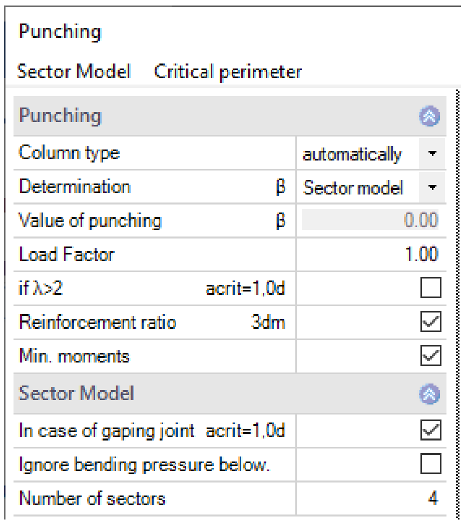
Reinforcement ratio — The degree of reinforcement relative to the anchored tensile reinforcement is generally to be calculated as a mean value taking into account a plate width corresponding to the support dimension plus 3d per side. Decide whether this simplification should be used.

Min. moments — In order to ensure the transverse load carrying capacity, the plates in the area of the supports are to be dimensioned for minimum moments, if the shear forces determination does not lead to higher values. Decide whether the minimum moments are to be included in the reinforcement distribution.

Ignore κ_{Red} — *Only DIN 1045-1:* disregard the reduction factor κ_{Red} specified in Booklet 525 [2010] page 98.

Sector model

Activating the button displays a dialog with the corresponding options.



... gaping joint — If a gaping joint occurs under the design loads, the radius of the punch cone is set to 1.0 · d and instead of the punching shear resistance the transverse force resistance is used. In addition, an analysis of shear resistance is performed at the distance 1.0 · d.

Ignore bending pressure below — disregards sectors with bending compression stresses at the bottom (lifted parts in case of a gaping joint or additional concentrated loads).

Load case number — when not equal to 0: only this load case is considered for punching shear.

Number of sectors — specify the number of sectors for the curve area of the control perimeters.

Explanations concerning the fully plastic distribution of shear stresses

The calculation of the total load factor β in accordance with the method of fully plastic shear stress distribution is optionally available. The moments applying at the column base MEx,col and MEy,col are used to calculate ß. These moments are internally converted to the centre of gravity of the critical perimeter. In the iteration process to determine the critical perimeter, the load factor ß is re-determined in each iteration. For corner columns, punching shear resistance is verified on all four corners; for outer columns in the x-direction or y-direction, punching shear resistance is only verified on the two decisive facing sides. Inner columns cannot have an eccentric position. Outer columns can have an eccentric position on the respective axis and corner columns on both axes. The calculation of β is based on equation NA.6.39.1 in the National Annex for Germany. You can optionally transfer the decisive superposition and/or the decisive load case to the B6+ application.

Notes concerning the sector model

When using the sector model, the foundation body is divided into sectors. These sectors are located between the critical perimeter and the outer edge of the foundation or a gaping joint.

The stress over the sector section bordering the perimeter and over the statically effective height is calculated from the resulting shear force in the sector.

The maximum stress in a sector at the perimeter border divided by the average stress at the perimeter gives the β-coefficient, which is provided here just for information.

The punching shear resistance is verified with the maximum stress at the perimeter. The maximum stress is obtained by dividing the shear force of the decisive sector by the length of the sector section bordering the perimeter and by the statically effective height of the foundation.

The lowest possible value resulting from the calculation is $\beta = 1.0$.

The minimum value may result if the column has a circular cross-section, the foundation is loaded double-symmetrically and has a circular base area. Relevant standards assume a minimum value of $\beta = 1.1$ because a completely symmetrical case as previously described cannot occur in practice according to these codes. Therefore, FD+ always uses a β-value of 1.1 minimum.

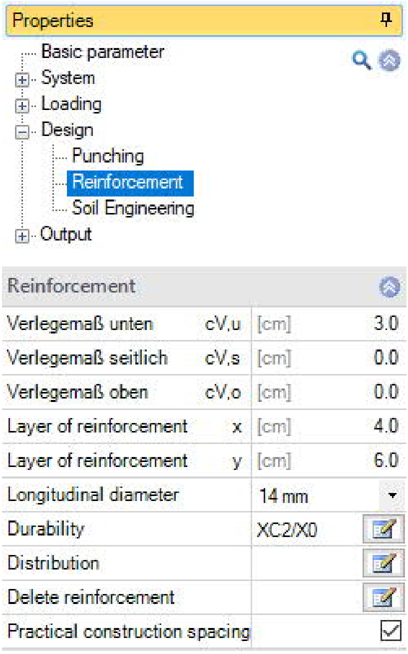
Handling of the sector model in the application program

First, the geometry of the sectors is calculated.

The user can pre-set the number of sectors per quadrant in a range of 1 to 100. The default in FD+ is four sectors for each corner of the column.

The sectors in the corner area have constant inner angles. Only in the special case of three sectors per corner area, angles of 33.75° + 22.5° + 33.75° = 90° are used in Germany as recommended in the comment to Eurocode 2.

Reinforcement



You can define up to 2 mats and 2 layers of steel rods over the whole upper foundation area.
Lower layer: 2 mats and one layer of steel rods in the X- and Y- direction according to the selected distributuion of the reinforcement (acc. to booklet 240 or variants of it).
See also „chapter „Distribution / extended reinforcement” dialog.

cV,u Laying dimensions of the specified reinforcement on the underside of the foundation. The specified reinforcement is designed into the foundation body according to this laying dimension. Based on this, 2D and 3D graphics are created.

cV,s Laying dimensions of the specified reinforcement on the outside of the foundation.

cV,o Laying dimensions of the specified reinforcement at the top of the foundation.

x reinforcement layer for the moments around the y-axis

y reinforcement layer for the moments around the x-axis

Longitudinal diameter select the longitudinal diameter for the reinforcement. The software uses this diameter to calculate a reinforcement that covers the requirements. If the minimum and maximum spacing cannot be realised with the initially defined diameters, higher diameters are used.

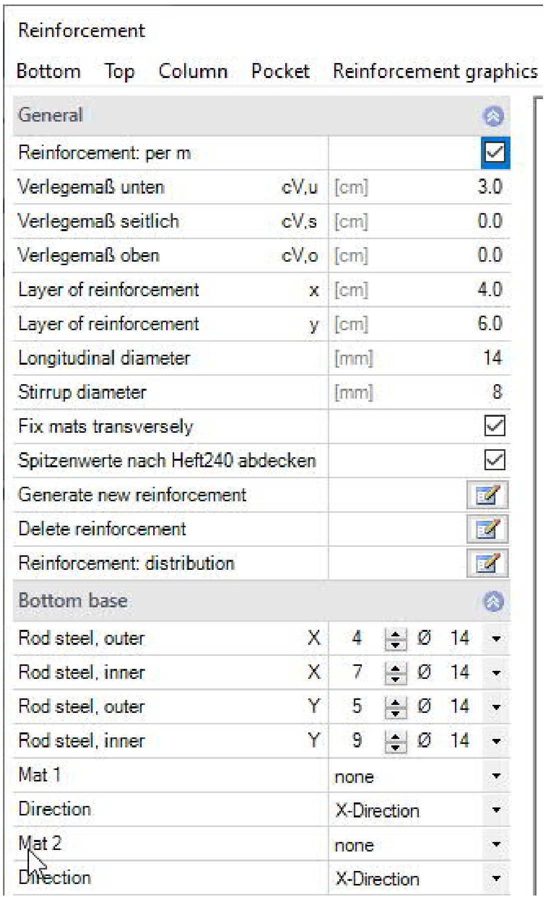
Durability: activating the button displays the Durability dialog. When you confirm your settings in this dialog with OK, the concrete cover, reinforcement layers and their diameter are checked and adjusted accordingly.

Distribution enhanced reinforcement dialog ( ).

Delete reinforcement deletes the defined reinforcement

Practical construction spacing By default, the bar spacing is defined "exactly", i.e. the resulting bar distances are determined on 1 mm accuracy. When this option is ticked, the bar spacing is adjused to 5, 6, 7, 7.5, 8, 9, 10, 12.5, 15, 17.5, 20, 22.5, 25, 27.5 or 30 cm.

Enhanced reinforcement dialog



Click on this symbol 

for the extended reinforcement dialog.

In addition to the registers for the lower and upper reinforcement, the register "Column" is displayed. If a pocket has been defined (▸ System - Foundation), tab "Pocket" appears.

General

Reinforcement: per m — Selection whether the reinforcement should be put out per metre or as an absolute value referenced to one eighth.

Laying measure — Actual concrete cover of the specified reinforcement on the bottom side of the foundation (cV,u) or at the outer sides (cV,s) and on the top side (cV,o). The specified foundation is constructed inside the foundation body in accordance with the specified actual cover. The generated 2-D and 3-D representations are based on this construction.

Layer of reinforcement — See chapter "Reinforcement".

Longitudinal diameter: — See chapter "Reinforcement".

Stirrup diameter — Select the stirrup diameter to generate the required reinforcement. If the minimum and maximum bar spacing is not feasible, larger diameters are used.

Fix mats transversely — ... see also Design/Settings - Program settings.

Peak values according to booklet 240 ... see also Design/Verifications.

Generate new reinforcement — A reinforcement is calculated which covers a minimum of the required reinforcement and a reinforcement for the punching verification without stirrups, as long as the compression strut remains stable (punching shear resistance verification) and the maximum possible bending reinforcement for punching shear resistance verification is not exceeded.
If the minimum and maximum bar spacings are not feasible with this longitudinal diameter, larger diameters are used.

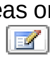
If the defined reinforcement is deleted or modified, the automatic generation of reinforcement is disabled and the defined reinforcement remains.

Should this be insufficient, the program issues a warning.

If no reinforcement is specified, no warning will be shown.

With the automatic generation of reinforcement, the program begins with the specified longitudinal diameter.
With a new generation of the reinforcement an automatic optimization is executed.

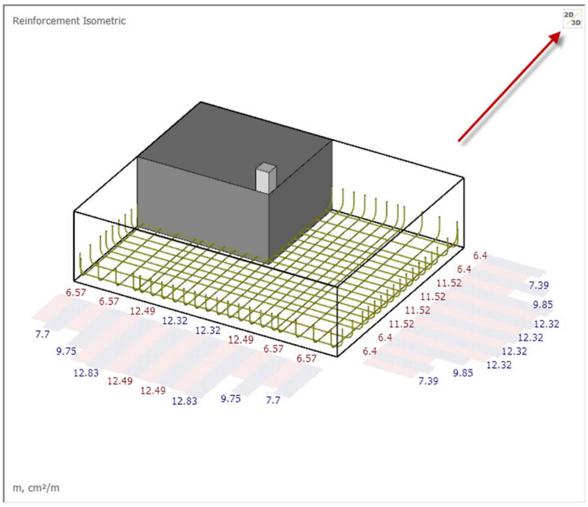
Delete reinforcement — Deletes the defined reinforcement. Only the required reinforcement will be taken into account.

Reinforcement distribution — Area selection in X/Y-direction acc. to booklet 240 DAfStb.
When selecting areas only the type of reinforcement distribution is adjusted.
Click on the button  to open the selection dialog for the area selection.
See also chapter area selection.

Bottom / Top base

Rod outer/inner — Definition of number (1. column) and diameter (2. column) of rods/steel bars.

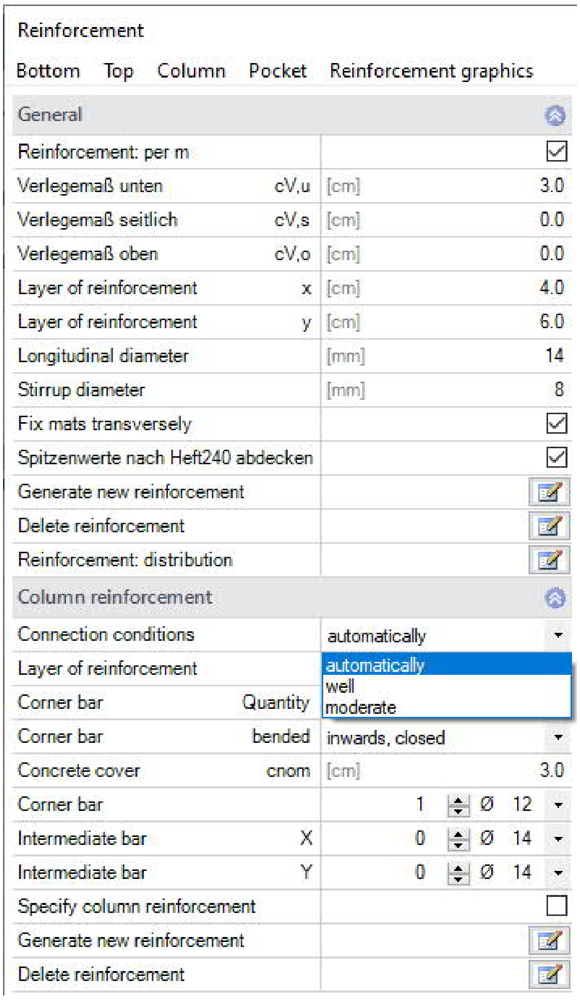
Mat 1/2, Direction — Selection of rebar mats in x/y-direction.



Bar graphs: — see adjacent illustration: As per 1/8th-region

In this graphic you can see the amount of defined (blue) an required (red) reinforcement. Therefore click on the 2D/3D-symbol.

Column / connection



Connection conditions — Bonding conditions for the column according to NCI Re 8.4.2, Figure 8.2 (automatic, good, moderate). The good bond range may be assumed to be 300 mm high in the lower component area, i.e. Figure 8.2b: h ≤ 300 mm, Figure 8.2c: h > 300 mm. The good bond range can also be assumed for horizontally manufactured rod-shaped components (e.g. supports) that are compacted with an external vibrator and whose external cross-sectional dimensions do not exceed 500 mm.

Layer of reinforcement — Selection:
As spread over side Ali = Are
As spread over side Asu = Aso
As spread over corner 4 * 1/4
As spread over perimeter
As spread over perimeter each As/4

Corner bar quantity — Number of bars.

Corner bar bended — Bending shape of the bars in the column (outwards / inwards, closed / inwards, open / straight bars)

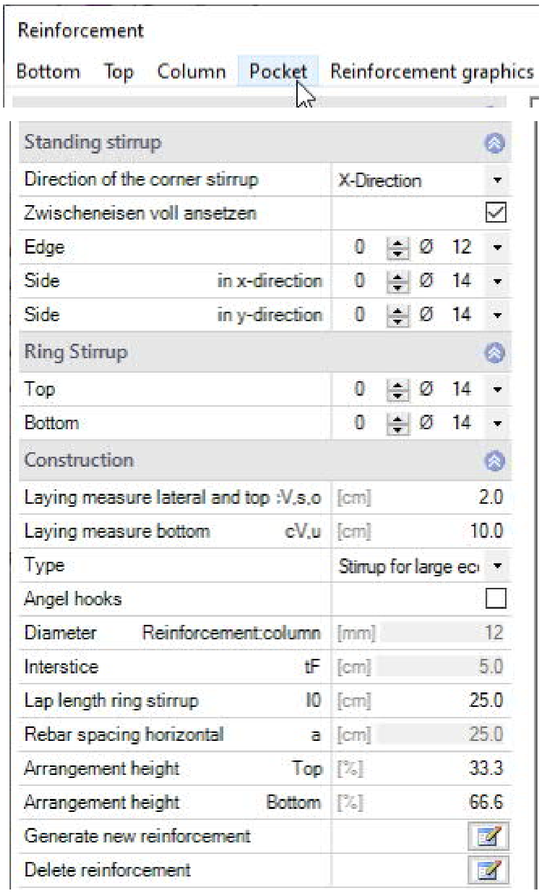
Corner bar — Number and diameter of the corner bars.

Intermediate bars — You can define intermediate bars for the column reinforcement with their vertical legs and hooks arranged parallel to the x-axis that bear torques about the y-axis. The intermediate bars are arranged in groups of up to five bars between the corner bars. The number of groups is determined by the maximum bar spacing and the selected number of intermediate bars.

Specify column reinforcement — Checking this option allows you to specify the required column reinforcement.

Pocket reinforcement

Note: some parameters only apply to FD+ or to FDB+, not to both.



Vertical (Standing) stirrup

Direction corner stirrups	Direction in which the horizontal legs of the vertical stirrups in the corners should be oriented.
Apply intermediate bars fully	If the option is selected, the intermediate bars are applied completely when calculating the lap length for a 2-axis reinforcement arrangement - otherwise only in the plane of the considered center of gravity of the column reinforcement.
Corner	Number and diameter of vertical stirrups in the corners of the pocket. (*only in FD+*)
Side X,Y	Number and diameter of vertical stirrups in the side walls of the pocket.

Ring Stirrup

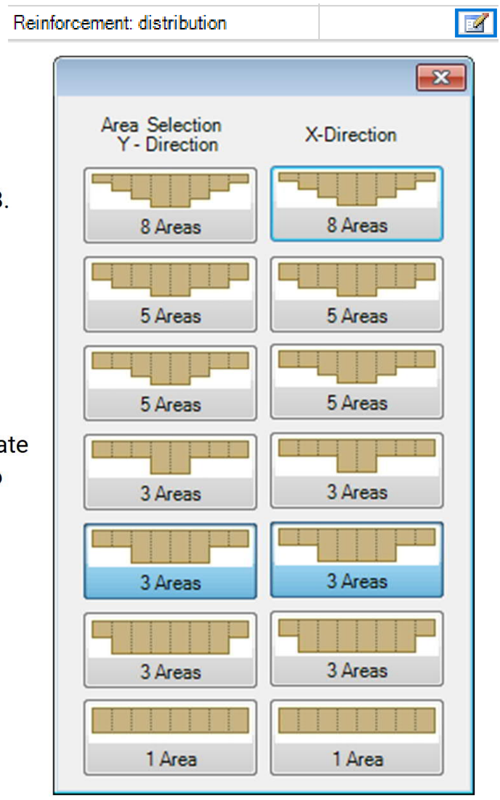
Number and diameter of ring stirrups (in the bottom and in the top of the pocket).

Construction

Laying measure... cV	Position of the reinforcing steel in the pocket (actual concrete cover).
Type	Type of the pocket reinforcement. There are various types for larger and smaller eccentricities.
Angel hooks	Check this option if the vertical stirrup should be equipped with an anchoring hook.
Diameter	Informative display.
Interstice tF	Displays the resulting distance between the column edge and the wall of the pocket.
Lap length ring stirrup	Lap length of the ring stirrups themselves.
Rebar spacing horiz.	Horizontal distance *a* between column reinforcement and the connection reinforcement. a = d1,col + tF + cnom + ds,fd/2
Arrangement height	Percentage of the distribution height of the top/bottom horizontal stirrups relative to the anchorage depth of the column in the pocket.

Area selection

Areas in the x- and y-directions

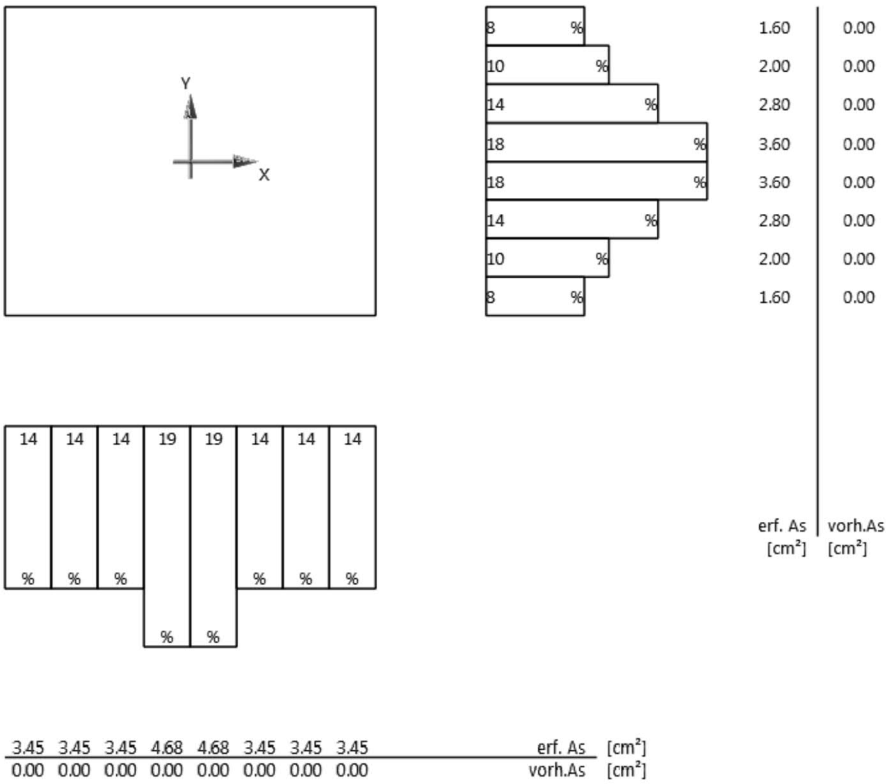


The area selection only determines the way the defined reinforcement will be distributed. Reinforcement is only generated when you activate the button "Generate new reinforcement" or when you define reinforcement.

8 areas: correspond to the distribution of the reinforcement in accordance with Booklet 240 of the German Committee for Reinforced Concrete DAfStB. Additional options: 5 / 3 / 1 area(s).

When selecting the number of areas, the peak values of the distribution specified in Booklet 240 of the German Committee for Reinforced Concrete DAfStB are covered.

In the illustrated example, the distribution of the reinforcement over three areas in the y-direction produces a rate of 122 % (= 14+14+14+19+19+14+14+14) of the reinforcement to be distributed. This rate is higher than the rate required by the standards, but distribution is easier to realise then.



Ill.: Example of reinforcement distribution

Notes concerning the selected reinforcement

Reinforcement ratios

The software calculates the absolute reinforcement quantities in eighth-part stripes in the x- and y-directions of the foundation body in accordance with the requirements specified by Booklet 240 of the German Committee for Reinforced Concrete DAfStB. In this calculation, the individual rebars in an eighth-part area are NOT added up but the quantity of reinforcing steel per metre of the reinforcement object in the area of one eighth is added up. See also the following calculation example.

Calculation example

See the illustration on the previous page.

The eighth-part area of a foundation with a width of 2 m has a width of 25 cm. The reinforcement object defined in this area consists of 10 bars with a diameter of 14 mm each. The spacing of the bars from axis to axis is 10 cm. The object covers a total width of 1 m. The width from the first bar to the last amounts to 90 cm. 5 cm on each side (half the bar spacing of 10 cm) must be added because of the affected width of the first and last reinforcement bar of the item. The total width is consequently 1 m. This object produces the following reinforcement portion:

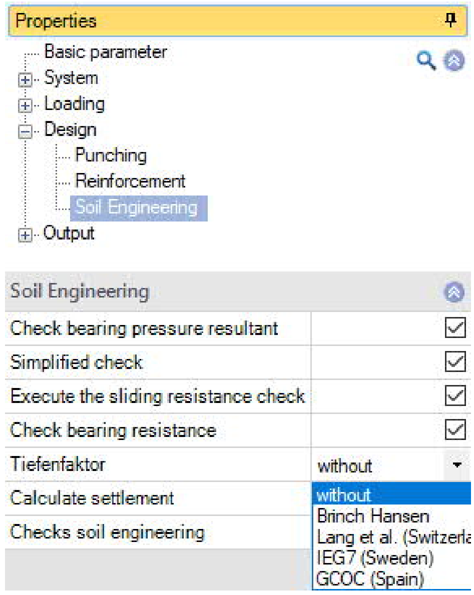
$As = [1.4\ cm \cdot 1.4\ cm \cdot \pi\ / 4] \cdot 10\ bars\ / 1\ m = 15.4\ cm^2/m.$

Due to the edge distance of this object of 17.5 cm (rounded to 0.18 m), it extends only 12.5 cm into the eighth-part with a width of 25 cm. The value of 12.5 cm is obtained by deducting the affected width of the last rebar of 5 cm due to a bar spacing of 10 cm from the edge distance: 17.5 cm – 5 cm = 12.5 cm. Therefore, only a reinforcement portion of 15.4 cm²/m · 0.125 m = 1.92 cm² results for this object in the eighth part.

The existing and required reinforcement quantities in the eighth parts are represented graphically and in the form of text in the data entry and output sections, optionally in cm² or cm²/m – see
▸ Reinforcement ▸ Distribution.

The reinforcement in the eighth parts is also used in the shear force resistance verification and in the punching shear analysis. All reinforcement quantities in the eighth parts of the examined perimeters are added up and converted to ratios. If the existing reinforcement quantity exceeds the required quantity, it is used instead. The resulting reinforcement ratios are limited by the maximally permissible reinforcement ratios for the shear force and punching shear analyses.

Soil engineering



Check bearing pressure resultant
Requirement for the simplified verification: the inclination of the characteristic or representative bearing pressure resultant complies with the condition H/V <0.2.

Simplified check
The verifications for the limit states ground failure, sliding and serviceability (verification of the settlement) are replaced by empirical design values of the base pressure resistance.

Execute sliding resistance check
When the load vector is not perpendicular to the base surface, the resistance of the foundations against sliding in the base area must be verified.

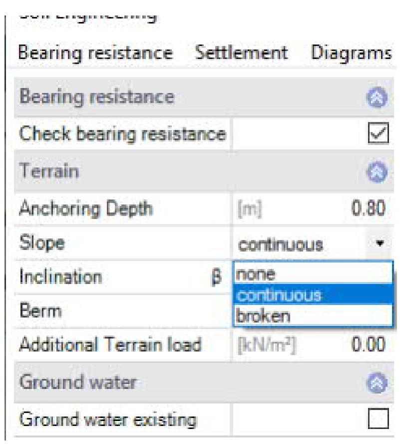
Check bearing resistance
In the ground failure analysis the shear resistance of the soil below the foundation level are considered.
The soil layers above the foundation level are considered as a top load when the soil plane and the ground top level are horizontal.

Depth coefficients (Tiefenfaktor)
The depth coefficients take into account the favorable influence of the shear strength in the fracture joint above the foundation base in the ground failure verification. In some European countries, this effect can be taken into account with coefficients > 1.

Calculate settlement
For the settlement analysis, the compression of the soil should be taken into account down to the settlement influence depth ts. The depth ts may be assumed at the level at which the additional perpendicular stress generated by the mean settlement effective load has an amount of 20% of the effective vertical output stress of the soil.

Verifications soil engineering
Click on this symbol to open the extended dialog with graphical illustrations for bearing failure, bearing pressure and settlements.

Bearing resistance (Ground failure)



Anchoring depth
Lowest depth of foundation below the ground surface or the top edge of the basement floor.

Slope
The ground level can be horizontal, with a continuous slope, or with a broken embankment.

Inclination β
Indicates the angle of inclination of a slope from the defined berm. The inclination affects the ground failure verification and defines exclusively downsloping terrain.

Berm
The width of berm is the distance between the outer edge of the foundation and the beginning of the slope.

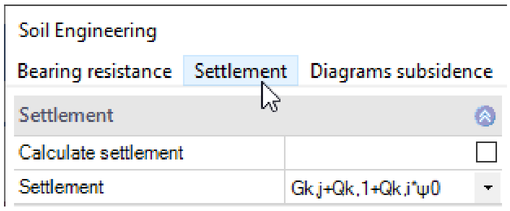
Additional Terrain load
Additional characteristic permanent area load of the ground failure mode which increases the characteristic punching resistance.

Groundwater exists
Tick this option if groundwater exists in the area.

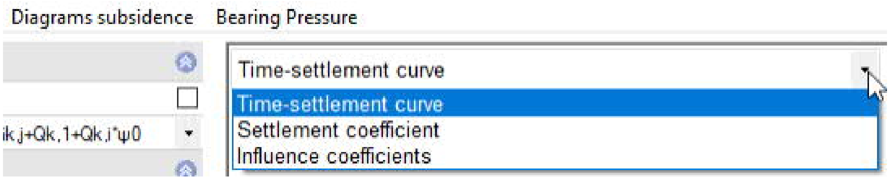
Groundwater Depth
Absolute depth of the groundwater measured from the bottom edge of the foundation.

Settlement

Calculate settlement	See page before.
Settlement	Settlements can be calculated with permanent loads or with permanent and variable loads. You can use combination coefficients for variable loads in characteristic load cases. See also DIN 1054:2010 2.4.8 A (2.8a).



Diagrams subsidence



Bearing pressure

Display of the bearing pressure graphic. The input fields are explained in the chapter Soil.

Pocket (Sleeve) foundation

Two different calculation methods are available for the calculation of a sleeve with rough formwork:

- Schlaich/Schäfer: “Konstruieren im Stahlbetonbau”; BK 2001/2 4.7.3 analogously to “Beispiele zur Bemessung nach Eurocode 2” Volume 1, Chapter 12
- Leonhardt and Mönning: "Vorlesungen über Massivbau”, Part 3, page 227 and subsequent pages, analogously to “Beispiele zur Bemessung nach DIN 1045“

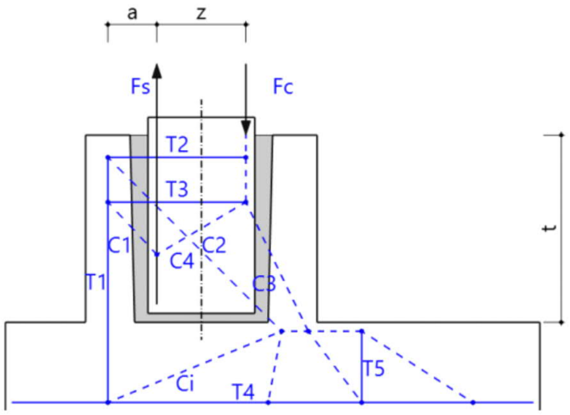
The following calculation method is available for the calculation of a sleeve with smooth formwork:

- Leonhardt and Mönning: "Vorlesungen über Massivbau”, Part 3, page 227 and subsequent pages, analogously to “Beispiele zur Bemessung nach DIN 1045“

Calculation in accordance with "Beispiele zur Bemessung nach Eurocode 2", Volume 1, Chapter 12

The prerequisite for the calculation based on this method is that the column base, the sleeve filling concrete and the foundation interact like a monolithic structure. The moment and the longitudinal forces generated by the column are transferred via vertical shear stresses to the sleeve. To ensure this, the sleeve and the column need profiling of at least 10 mm. The filling concrete must have the same quality as the foundation concrete. If the required embedment depth is calculated with the help of the anchoring depths and/or the lap lengths, the value of 1.5 times the column width prescribed by DIN EN 1992-1-1/NA 10.9.6.3 (1) is on the safe side and therefore recommendable. The bending design in connection with the sleeve can be performed in the sleeve axis with rounding of the moment or in the centre of the sleeve wall or in the contact surface of the sleeve.

The calculation is based on the following framework model:



The following verifications are performed:

Introduction of the shear force V_{Ed} into the sleeve via the tensile force T2 → horizontal stirrups

$T_2 = V_{Ed}$

$Req.A_{s,horizontal} = T_2/f_{yd}$

Absorption of the tensile force T1 caused by Fs and T2 → vertical stirrups

Portion T_1 from deflection of T_2

t = sleeve embedment depth plus joint underneath the column

a_w = spacing of the sleeve wall axes

T_1 =T_2*t/a_w = portion of the tensile force due to the deflection of T_2

d_w = sleeve wall thickness

t_f = joint between the sleeve wall and the column

d_1 = centre of gravity of the reinforcement in the column

a = d1 + t_f + d_w/2=offset of the reinforcement

z = internal lever arm of the column reinforcement

Req.$A_{s,F}$ = assumed column reinforcement

F_s = req.As,F * f_{yd} = tensile force of the column

T_1 = F_s*z/(a+z) + T_2*t/a_w

Req. $A_{s,z}$ = T_1 / f_{yd}

Absorption of the tensile force T3 due to the expansion effect of the compression struts C1 and C2 → horizontal stirrups

tanΘ = [exist.$_{l0}$-0.5($_{l0,z1}$+$_{l0,z2}$)]/a

T_3 = C_1 = T_1 / tan θ

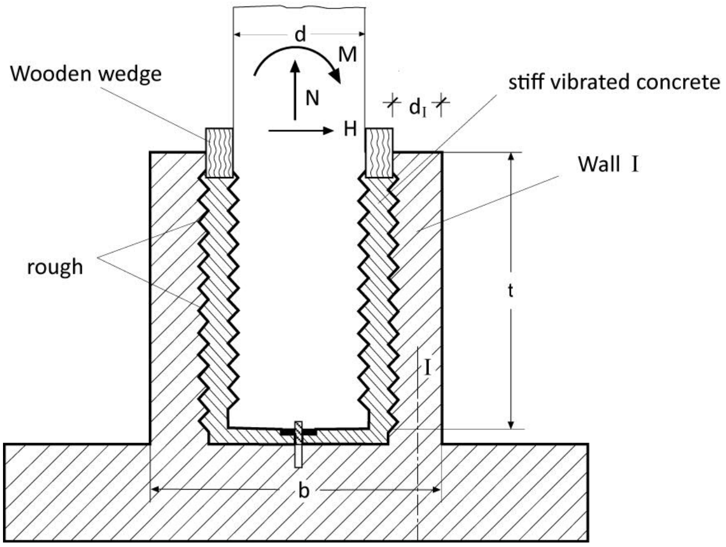
Req.$A_{s,horizontal}$ = T_3/f_{yd}

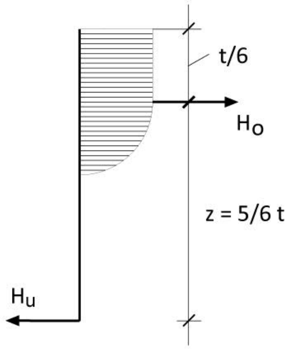
The required horizontal stirrups are to be distributed over the lap lengths of the vertical stirrups l_0.

Calculation in accordance with Leonhardt and Mönning

"Vorlesungen über Massivbau", Part 3, page 227 and subsequent pages, analogously to "Beispiele zur Bemessung nach DIN 1045"

Rough formwork





Introduction of the shear force V_{Ed} and the moment M_{Ed} into the sleeve

M_{St} = design moment of column base

H_{st} = V_{Ed}

H_o = 6/5 MSt + 6/5HSt = horizontal force on top

H_o = 6/5 MSt + 1/5HSt = horizontal force on bottom

z = 5/6 t = lever arm

d_w = sleeve wall thickness

a_0 = sleeve wall width

d_w = sleeve wall thickness

tan α = $z / (a_0 - 0.15a_0 - d_w/2)$

Z_h = h_o

Z_v = Z_h tan α

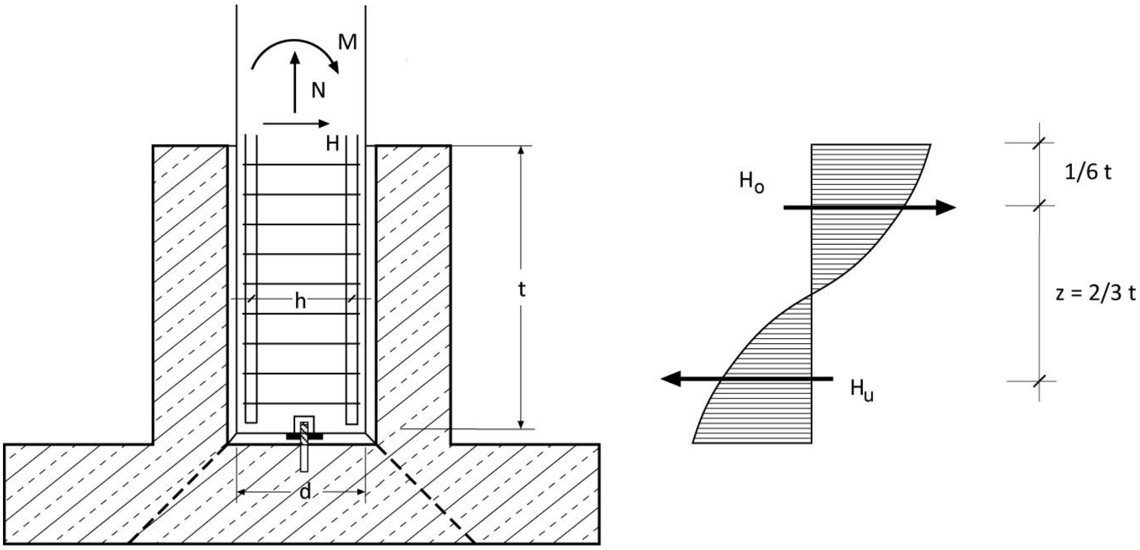
Vertical sleeve reinforcement:

Req.$A_{s,z}$ = Z_v / f_{yd}

Horizontal sleeve reinforcement:

Req.$A_{s,horizontal}$ = T_3/f_{yd}

Smooth formwork



Introduction of the shear force V_{Ed} and the moment M_{Ed} into the sleeve

M_{St} = design moment of column base

H_{st} = V_{Ed}

H_o = 3/2 MSt + 5/4HSt = horizontal force on top

H_o = 3/2 MSt + 1/4HSt = horizontal force on bottom

z = 2/3 t = lever arm

d_w = sleeve wall thickness

a_0 = sleeve wall width

d_w = sleeve wall thickness

tan α = $z / (a_0 - 0.15a_0 - d_w/2)$

Z_{Ho} = H_o

Z_{Hu} = H_u

Z_v = Z_h tan α

Vertical sleeve reinforcement

Req. $A_{s,z} = Z_v / f_{yd}$

Horizontal sleeve foundation on top

Req.$A_{s,horizontal} = T_3/f_{yd}$

Horizontal sleeve foundation on bottom

Req.$A_{s,horizontal} = T_3/f_{yd}$

Anchorage of the tension rods in the column for the tensile force Fs

The required anchorage length for the tension and compression bars of the column reinforcement is calculated and compared to the existing anchoring length. The existing anchoring length is determined by the embedment depth minus the actual concrete cover. It is assumed that the column reinforcement can also be a compressive reinforcement. In combination with the German standard, hooks, angular hooks and loops are not allowed. Therefore, straight bars are used in the calculation, $\alpha_1 = 1.0$.

$l_{b,rqd}$ = $(d_s/4) / (\sigma_{sd}/f_{bd})$ = basic value of the anchoring length

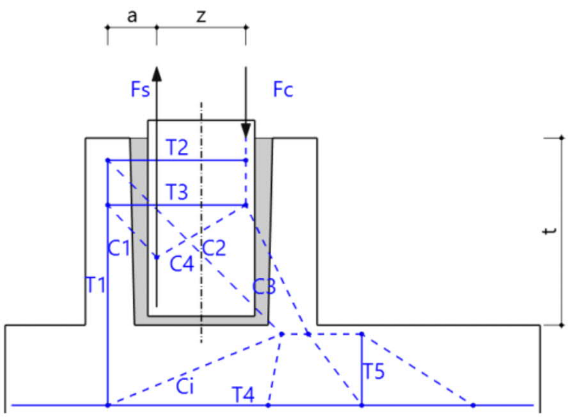
$l_{bd,erf.}$ = $\alpha_1 * l_{b,rqd} * (A_{s,req..} / A_{s,exist.})$ = required anchorage length

$l_{bd,vorh.}$ = $t – c_v$ = existing anchorage length

Anchorage of vertical stirrups in the sleeve

The required anchorage length of the vertical stirrups in the sleeve is calculated and then compared to the existing anchorage length which is obtained by deducting the concrete cover from the foundation height.

Lapping of the perpendicular stirrups and the vertical tensile reinforcement in the column

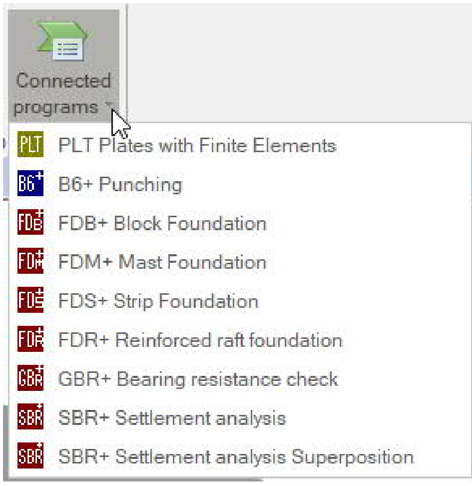


The lap lengths of the column reinforcement and the vertical sleeve reinforcement are calculated. The required lap length is decisive in this connection. When calculating the lap length of the column reinforcement, the fact that only the tensile force portion that is transferred via the compression strut C1 is transmitted via the lap joint is taken into account. When calculating the lap joint l_0 a bond stress increased by 50 % is assumed in accordance with Booklet 399 due to the existing transversal pressure.

Output

If you have checked the options “Text on reinforcement” and “Details of anchorage” in the in the Scope of the output menu, the equations and intermediate results of the sleeve calculation are put out.

Block Foundation



Block foundations can be calculated in program “FDB+”.

You can access the program FDB+ directly from the FRILO Control Center or from the program Isolated Foundation – FD+ under the item “Connected Programs” (assuming that the FDB+ program is installed on your computer).

The calculation is performed in accordance with the method described in "Deutscher Beton- und Bautechnik-Verein E.V. - Beispiele zur Bemessung nach Eurocode 2".

A block foundation is a foundation, in which the pocket is embedded.

A block foundation is characterized by an appropriate connection between the bottom part of the column and the walls of the pocket, due to which a monolithic work of the foundation with the column can be assumed.

The flexural design of a block foundation, in contrary to an isolated foundation, is conducted for a cross-section along the edge of a column. The resulting flexural design is made according to Heft 240, T 2.10. The task is made separately for x and y directions. Connection reinforcement in the foundation, as well as anchorage and overlapping lengths of the column reinforcement and the connection reinforcement are determined.

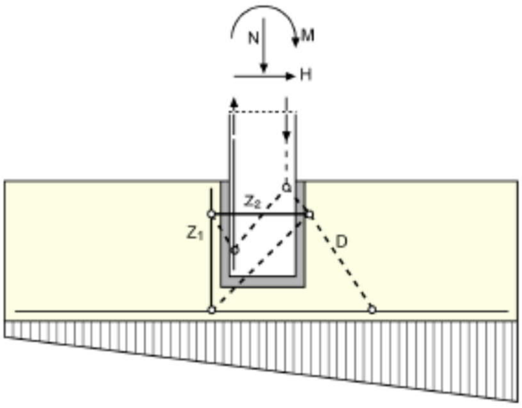


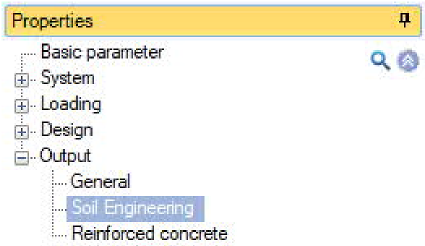
Fig.: *Determination of the vertical stirrups Asv with tensile force Z_1, determination of the horizontal stirrups Ash with tensile force Z_2*

The punching shear analysis is performed for:

- the erecting stage (for the self-weight of the column, which is applied during assembly)

- the final stage

Output



Output scope / Options

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

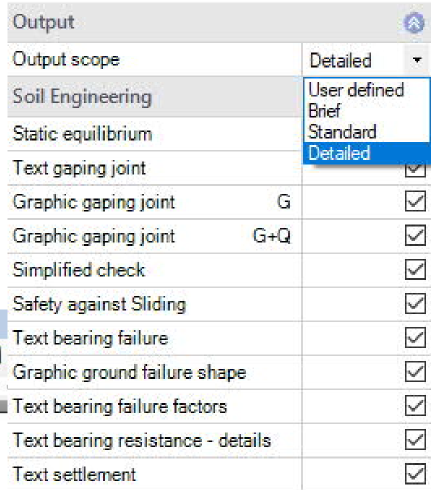
Output as PDF

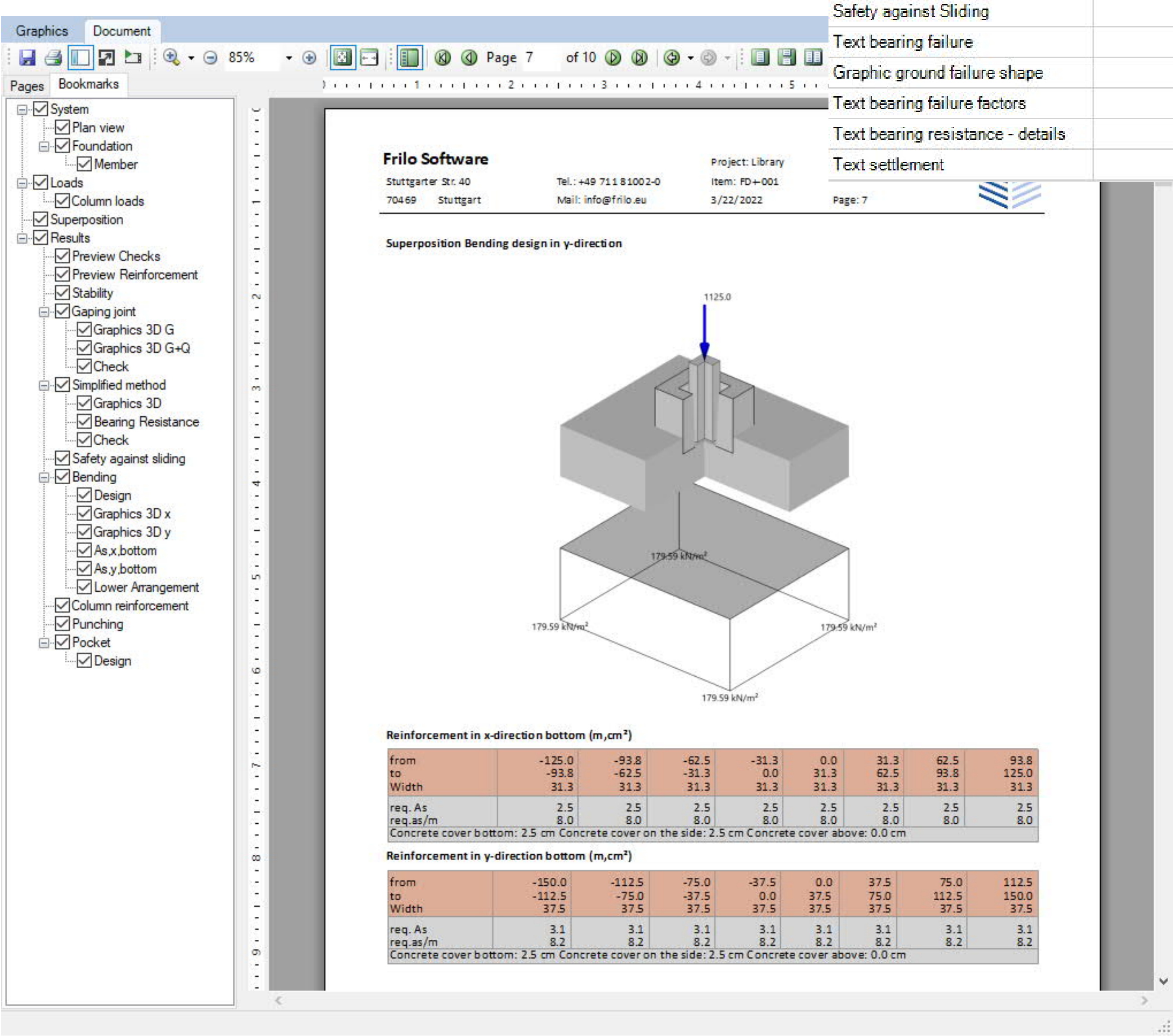
The Document tab displays the document in PDF.

See also Output and printing.

Export to Allplan

The menu option ‘File’ - ‘Export’ allows you to export a suitable file to Allplan.





Explanatory notes on the output of the results (table)

Output of the reinforcement

Reinforcement in x-direction bottom (m,cm²)

from to Width	-1250 -938 313	-938 -625 313	-625 -313 313	-313 0 313	0 313 313	313 625 313	625 938 313	938 1250 313
X-Direction	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150	R188-A 2Ø14/150
req. As exist.As req.as/m exist.as/m	2.5 3.6 8.0 11.6	2.5 3.7 8.0 11.7	2.5 3.7 8.0 11.7	2.5 3.7 8.0 11.7	2.5 3.7 8.0 11.7	2.5 3.7 8.0 11.7	2.5 3.7 8.0 11.7	2.5 3.6 8.0 11.6
Concrete cover bottom: 25 mm Concrete cover on the side: 25 mm Concrete cover above: 25 mm								

Reinforcement in y-direction bottom (m,cm²)

from to Width	-1500 -1125 375	-1125 -750 375	-750 -375 375	-375 0 375	0 375 375	375 750 375	750 1125 375	1125 1500 375
X-Direction	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125	R188-A 3Ø14/125
req. As exist.As req.as/m exist.as/m	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4	3.1 5.0 8.2 13.4
Concrete cover bottom: 25 mm Concrete cover on the side: 25 mm Concrete cover above: 25 mm								

Note: The existing reinforcement is not the result of an addition of individual rebars. It is determined by the rebar diameter and the bar spacing per m of the reinforcement area (e.g. the eighth part). The eighth parts at the edges of the foundation are not considered with their full width because of the concrete cover. Therefore, the reinforcement totals in the areas close to the edges may differ even though the reinforcement per m is the same. In the example, there is a difference in the x-direction between the existing reinforcement As = 3.6 cm² in the first eighth part and 3.7 cm² in the second and 3.7 cm² third eighth parts.

The reinforcement is put out in a table. If no type of reinforcement is selected, the existing reinforcement is put out. In the upper table section, the coordinates and the widths of the individual areas are indicated. In the middle part of the table, the selected rebars and fabrics are specified. In the lower part of the table, the required and the existing reinforcement are represented in cm² and cm²/m.

If detailed presetting was selected, a first table gives an overview of the required and the existing reinforcement in each eighth part. In a second table underneath, the used reinforcement objects are listed.

Evaluation of the results

The flexural reinforcement is calculated for the greatest Mx and My moments and the required reinforcement referenced to the foundation width is put out.

The decisive flexural moments are calculated in the following expressions:

For centrically loaded foundations, the design moment is determined in accordance with Booklet 240 in the following expression:

$$M = N \cdot b \frac{1 - \frac{d}{b}}{8}$$

b refers to the foundation width and *d* to the column width.

With uniaxially loaded foundations, the edge pressure is determined as follows

$$\sigma = \frac{N}{A} \pm \frac{M}{W} \text{ or } \sigma = 2 \cdot \frac{N}{3 \cdot b \cdot c}$$

The resulting stresses are used to calculate the moments MS around the column axes. The design moments result from the expression:

$$M = MS - N \cdot \frac{d}{8}$$

With biaxially loaded foundations, the foundation is separated in strips and the internal moments are calculated as on uniaxially loaded foundations. The sum of these moments reduced by the portion N *· d/8* constitutes the design moment.

In general, design is done in the column axis. As this approach is too far on the safe side for stiff pockets, a section through the centre of the pocket wall can optionally be selected with pocket foundations.

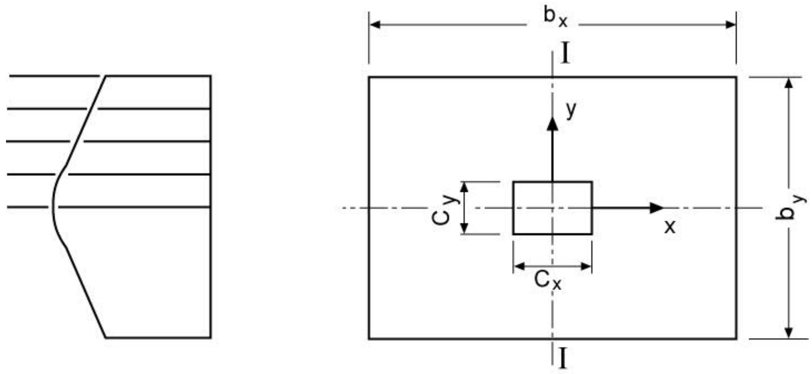
A proposal for the selection of the reinforcement is displayed in addition.

With centrically loaded or uniaxially but eccentrically loaded foundations, the distribution of the reinforcement is represented in accordance with Booklet 240, part 2.10. Separate values for the x- and y-direction are put out. If need be, the required upper reinforcement is calculated in addition.

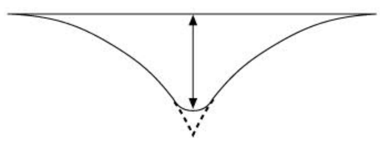
Distribution of *Mx* in the section I-I

cy/by	0,1	0,2	0,3
Percentages of the total moment	7	8	9
	10	10	11
	14	14	14
	19	18	16
Sum	50	50	50

Illustration: Behaviour and distribution of the flexural moments



Behaviour of Σ *Mx*



The reinforcement proposal is based on a bar spacing of 15 cm at least. Where squared foundations are concerned, the same bar diameter is selected in both directions.

In accordance with EN 1992-1-1, 9.2.1.1 (1), a minimum reinforcement transverse to the main loading direction is taken into account.

Output: Punching shear resistance verification

The following calculation results are put out for this verification:

- Diameter of the punching cone in the centre of the foundation dr and the base dk
- average existing µ in the area dr from the flexural design
- vertical force Q and decisive punching force Qred
- calculated shear stress τ_R
- shear stress limits $\kappa_1 \cdot \tau_{01}$ compared to τ_R and $\kappa_2 \cdot \tau_{02}$ compared to τ_R.

If $\tau_R < \kappa_1 \cdot \tau_{01}$, shear reinforcement is not required.

If $\kappa_2 \cdot \tau_{02} > \tau_R > \kappa_1 \cdot \tau_{01}$, the reinforcement ratio µ must be increased or shear additions must be installed alternatively. The software puts both values out. For the shear additions, an inclination of 45 degrees is assumed.

If $\tau_R > \kappa_2 \cdot \tau_{02}$, the reinforcement ratio µ must be increased so that the condition $\tau_R < \kappa_2 \cdot \tau_{02}$ is satisfied at least. The resulting reinforcement is put out.

Reinforcement either consisting of additional longitudinal reinforcement or shear addition must be installed in addition. Both values are put out.

For the pocket, the required horizontal As for the force Ho and the required vertical reinforcement for the vertical component of the compression strut are calculated. With cast-in pockets, the reinforcement should be arranged laterally next to the opening and anchored thoroughly.

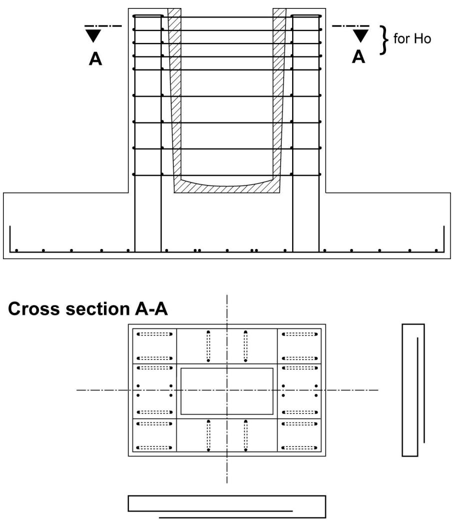


Illustration: Pocket with rough surface

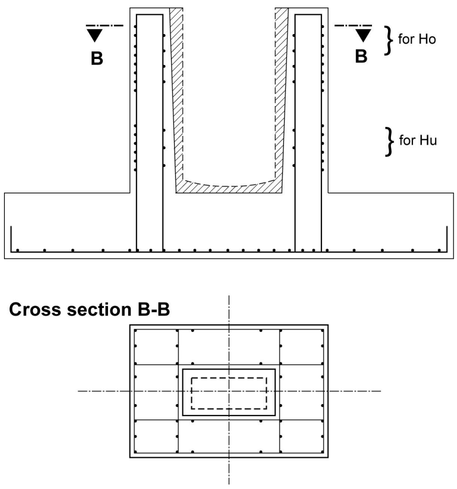


Illustration: Pocket with smooth surface