

# B9 – Reinforced Concrete Corbel

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**material**  
C30/37  
B500A

**concr. cover**  
c = 2,5 cm

**column**  
ξs = 24,0 cm  
cs = 22,0 cm

**console**  
bk = 24,0 cm  
lk = 23,0 cm  
hk = 25,0 cm  
lkr = 21,0 cm

**slab of introduct. of load**  
ξp = 10,0 cm  
lp = 10,0 cm

**loads**  
vertical Fed = 91,50 kN a = 8,0 cm  
horizontal Hed = 20,00 kN ξs = 2,0 cm

**reinforcement**

	number	Dm	Ac [cm <sup>2</sup> ]	V
tensile stirrups	1	1U	1,2	
tensile loops	1	8	1,01	
longitud. stirrups	0	0	1,51	
web stirrups	3	6	1,70	
vert. stirrups	4	6	2,26	

distance of column lnght. rent. d = 3,0 cr

dimensions and reinforcement propose  always calc.

**edge of console**

Vzd = 51,50 kN	Myc = 11,72 kNm
Ac tension sel. 4,09	eq. 1,87 cm <sup>2</sup>
Ac splitting sel. 1,70	eq. 0,94 cm <sup>2</sup>
<b>by web stirrups</b>	

**system calculated.**

Material 28.12.2016 | 11:15



# B9 – Reinforced Concrete Corbel

*Note: The present document describes the Eurocode-specific application. Documents referring to former standards are available in our document archive at [www.friilo.eu](http://www.friilo.eu) >> Service >> Documentation >> Manuals.*

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Further information and descriptions are available in the relevant documentations:

<a href="#">FDC – Basic Operating Instructions</a>	General instructions for the manipulation of the user interface
<a href="#">FDC – Menu items</a>	General description of the typical menu items of Frilo software applications
<a href="#">FDC – Output and printing</a>	Output and printing
<a href="#">FDC - Import and export</a>	Interfaces to other applications (ASCII, RTF, DXF ...)
<a href="#">FCC</a>	Frilo.Control.Center - the easy-to-use administration module for projects and items
<a href="#">FDD</a>	Frilo.Document.Designer - document management based on PDF
<a href="#">Frilo.System.Next</a>	Installation, configuration, network, database

## Application options

The B9 application is suitable for the design of corbels with loads applying directly from above (“corbel with direct load introduction”).

Available direct loading:

- Vertical load
- Additional horizontal load

Standards:

- DIN EN 1992-1-1: 2012 + 2013 + 2015
- ÖNORM EN 1992-1-1:2011
- BS EN 1992-1-1: 2004 + 2009 + 2015
- NTC EN 1992-1-1:2008

*DIN 1045/DIN 1045-1 is still optionally.*

The following entities are determined:

- Safety against compressive web fracture
- Compressive strain under load
- Required  $A_s$  of the tensile and web reinforcement
- Anchorage and lap lengths of the reinforcement
- Internal forces in the corbel section
- Reinforcement drawing

The corbel condition  $0,3 \leq \frac{a}{h} \leq 1,0$  must be complied with.

a = distance of the vertical load from the column

h = structural height

## Basis of calculation

The calculation is based on the strut-and-tie model. The regulations of the different National Annexes are taken into account.

### Calculation in accordance with EN 1992-1-1

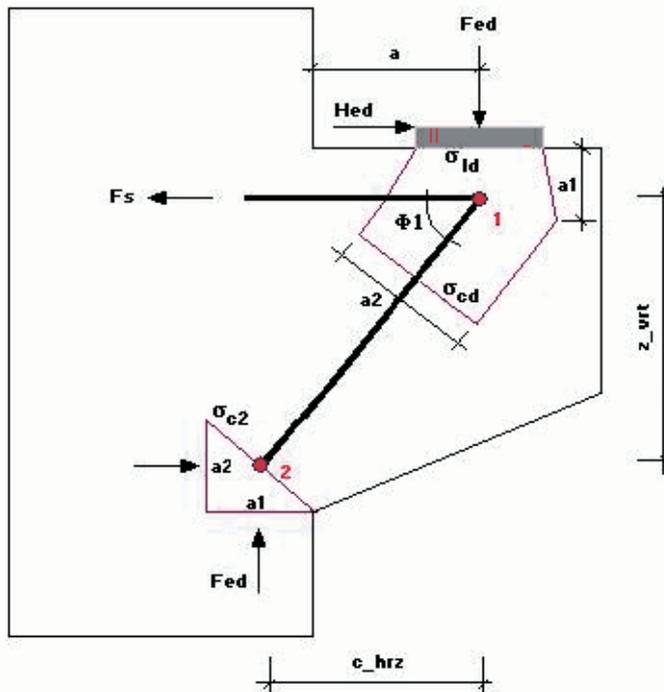


Illustration 1

The calculation is based on a simplified strut-and-tie-beam model in accordance with illustration 1. A prerequisite to the application of this method is that the corbel loads are transferred downwards in the column and that the corbel condition  $a/h \leq 1.0$  is complied with.

The software applies this method to corbels with a relation of  $a/h \geq 0.3$  in accordance with reference /4/. Otherwise, a differentiated model with multiple tie beams would be produced depending on the column forces.

**Note:** Booklet 600 DAfStb requires the inclusion of an additional horizontal force of  $H_{ed} = 0.2 \cdot F_{ed}$  in order to account for restraint effects that are not considered in the calculation (ÖNorm B 1992-1-1:  $H_{ed} = 0,1 \cdot F_{ed}$ ).

#### Strut-and-tie-beam model

First, the geometry of the strut-and-tie-beam model is determined in accordance with illustration 1. It is assumed that  $a_1$  in node 2 can bear the force  $F_{ed}$ . Based on this prerequisite and the given corbel condition,  $a_2$  in node 2 and consequently the exact strut location can be determined.

According to ÖNorm B 1992-1-1 Sect. 25.4.2, the length of the hypotenuse of the node 2 (compression - compression node) is limited to 25% of the static height of the console.

$$a1(2) = \frac{F_{ed}}{(b_K \cdot k_1 \cdot v' \cdot f_{cd})}$$

a1 at node 2,  $k_1 = 1.1$ , NA as per DIN EN 1992-1-1, 6.5.4 (4),

$k_1 = 1.25$ , ÖNorm B 1992-1-1, otherwise according to the corresponding (NA)

$$a2(2) = h - \sqrt{h^2 - \frac{2 \cdot c_{hrz} \cdot F_{ed}}{b_K \cdot k_1 \cdot v' \cdot f_{cd}}}$$

a2 at node 2,  $k_1$ : see above

with

$$h = h_K - d_1$$

effective height

$$c_{hrz} = a + a1(2)/2$$

It follows that:

$$z_{vrt} = h - 0,5 \cdot a2(2)$$

Verification of the strut inclination:

$\Phi_1$  is limited in accordance with en 1992-1-1, Annex J.3.

$$\phi_1 = \text{atn} \left( \frac{z_{vrt}}{c_{hrz}} \right)$$

When  $\Phi_1$  is too large, a2(2),  $z_{vrt}$  and D are calculated with the condition  $\Phi_1 = \Phi_{max}$ .

#### Beam tie force $F_s$

$$F_s = \max \left( \left( F_{ed} \cdot \frac{c_{hrz}}{z_{vrt}} \right), (0,4 \cdot F_{ed}) \right) + H_{ed} \cdot \frac{h_s + d_1 + z_{vrt}}{z_{vrt}}$$

#### Compressive strut force $F_c$

$$F_c = F_{ed} \cdot \sqrt{1 + \frac{c_{hrz}^2}{z_{vrt}^2}}$$

Internal forces at the corbel face:

$$z_0 = h - \left( a1(2) \cdot \frac{z_{vrt}}{c_{hrz}} \right)$$

$$M = F_{ed} \cdot a + H_{ed} \cdot (h_s + d_1 + z_0)$$

$$V = F_{ed}$$

Variables used:

$b_K$  corbel width

$d_K$  (total) corbel height

$l_p$  load plate length

$b_p$  load plate width

$d_1$  centre of gravity of the reinforcement at the upper edge of the corbel

$f_{cd}$  design value of the concrete compression force

$f_{yd}$  design value of the yield point of the reinforced concrete

Other values, see [illustration 1](#)

### Tensile reinforcement

It is determined with the help of the tie beam force  $F_S$ :

$$\text{req. } A_{s,\text{tension}} = \frac{F_S}{f_{yd}}$$

### Tensile splitting reinforcement

The reinforcement for the compensation of tensile splitting forces is estimated as follows in accordance with reference /6/ Booklet 600 DAfStb and the corbel condition  $a/h$ :

For ( $a/h \leq 0.5$ ) and ( $F_{ed} > 0.3 \cdot VR_{d,\max}$ )

$A_{s,\text{tensile splitting}} = 0.5 \cdot A_{s,\text{tension}}$  with closed horizontal stirrups

For ( $a/h > 0.5$ ) and ( $F_{ed} > VR_{dc}$ )

$A_{s,\text{tensile splitting}}$  from  $F_{b\ddot{u}} = 0.7 \cdot F_{ed}$  with closed vertical stirrups

$A_{s,\text{tensile splitting}} = F_{b\ddot{u}} / f_{yd}$

The calculation of  $vR_{d,\max}$  can be carried out optionally:

- as per Booklet 600 DAfStb eq. (H.J-4):

$$V_{Rd,\max} = 0.5 \cdot v \cdot b \cdot z \cdot (f_{ck} / \gamma_c) \quad \text{with } v \geq (0.7 - f_{ck}/200) \geq 0.5 \text{ and } z = 0.9 d, \text{ or}$$

- as per EN 1992-1-1, 6.2.3 (3) eq. (6.9)

$$V_{Rd,\max} = \frac{\alpha_{cw} \cdot b_K \cdot z_{vrt} \cdot v_1 \cdot f_{cd}}{\left( \left( \frac{c_{hrz}}{z_{vrt}} \right) + \left( \frac{z_{vrt}}{c_{hrz}} \right) \right)} \quad \text{with } \alpha_{cw} = 1.0, v_1 = 0.75 \cdot v_2, v_2 = (1.1 - f_{ck}/500) \leq 1.0 \text{ according to NA Germany, otherwise according to the corresponding (NA)}$$

$$V_{Rd,c} = \left( 0.1 \cdot \kappa \cdot \eta_1 \cdot (100 \cdot \rho_1 \cdot f_{ck})^{\frac{1}{3}} - 0.12 \cdot \sigma_{cd} \right) \cdot b_K \cdot h$$

Design value of the bearable shear force without shear reinforcement as per EN 1992-1-1. 6.2.2 (1)

$$\kappa = 1 + \sqrt{\frac{200}{h}} \leq 2.0$$

$\eta_1 = 1.0$  for standard concrete

$$\rho_1 = \frac{\text{erf. } A_{s,\text{zug}}}{b_K \cdot h} \leq 0.02$$

$$\sigma_{cd} = \frac{H_{ed}}{b_K \cdot d_{ka}}$$

$d_{ka}$  is taken as the height of the corbel cross section under vertical load (at a distance  $a$  from the corbel cross section) and  $H_{ed} < 0$  with compression loading.

### Verification of the load-bearing capacity of the compressive concrete strut

Compliance with the following condition must be verified:

$$F_{ed} \leq V_{rd\_max}$$

Prerequisite is  $\cot(\Phi_1) > 0.58$  (see strut-and-tie-beam model) and

$V_{rd,max}$  as per EN 1992-1-1 (see tensile splitting reinforcement).

### Verification of the bearing stress under $F_{ed}$

The verification of the compressive stress underneath the load plate (node 1 in illustration 1) is based on Schlaich/Schäfer or EN 1992-1-1:

With the following conditions underneath the load plate:

$$\sigma_{ld} = \frac{F_{ed}}{l_p \cdot b_p} \leq \sigma_{rd} = 0,85 \cdot f_{cd} \quad \text{as per Schlaich/Schäfer, or}$$

$$\sigma_{ld} = \frac{F_{ed}}{l_p \cdot b_p} \leq \sigma_{rd} = k_2 \cdot v' \cdot f_{cd} \quad \text{as per EN 1992-1-1, 6.5.4 (4)}$$

- Germany:  $k_2 = 0.75, v' = 1.1 - f_{ck} / 500 \leq 1.0$

- Austria:  $k_2 = 0.9, v' = 1.0 - f_{ck} / 250$

and in node 1:

$$a1(1) = 2 \cdot d_1 \quad a1 \text{ at node 1}$$

$$a2(1) = \left( a1(1) \cdot \left( \frac{c\_hrz}{z\_vrt} \right) + l_p \right) \cdot \sin(\Phi_1) \quad a2 \text{ at node 1}$$

$$\sigma_{cd} = \frac{F_c}{a2(1) \cdot b_p} \leq \sigma_{rd} = 0,85 \cdot f_{cd} \quad \text{as per Schlaich/Schäfer or}$$

$$\sigma_{cd} = \frac{F_c}{a2(1) \cdot b_p} \leq \sigma_{rd} = k_2 \cdot v' \cdot f_{cd} \quad \text{as per EN 1992-1-1, 6.5.4 (4), } k_2 \text{ and } v' \text{ as described above}$$

$F_c$  compression strut force

### Verification of the anchorage

You can realise the tie beam reinforcement by means of tension stirrups, tension loops or longitudinal stirrups. The following verifications of the anchorage are performed, depending on the prerequisites:

- Verification as a straight bar end, loop or stirrup as per EN 1992-1-1 8.4.3 for tension and longitudinal stirrups in the area of the column and for tension stirrups, tension loops and longitudinal stirrups at the free corbel end.
- Verification of the lapping as per EN 1992-1-1 8.7.3 for tension loops and longitudinal stirrups in the column.

### Verification as a straight bar end or stirrup as per EN 1992-1-1 8.4.3

$$l_b = \frac{d_s}{4} \cdot \frac{f_{yd}}{f_{bd}}$$

Note: In the case of EN-Standards the influence of the lateral compression  $p$  is determined according to Table 8. by the factor  $\alpha_5 = 1 - 0.04 \cdot p$  mit  $0.7 \leq \alpha_5 \leq 1.0$ .

$$l_{b,min} = 0,3 \cdot \alpha_A \cdot l_b \geq 10 \cdot d_s$$

$$l_{b,net} = \alpha_A \cdot l_b \cdot \frac{A_{S,erf}}{A_{S,vorh}} > l_{b,min}$$

### Verification of the lapping as per EN 1992-1-1, 3

$$l_{s,min} = 0,3 \cdot \alpha_A \cdot \alpha_1 \cdot l_b \geq 15 \cdot d_s \geq 200\text{mm}$$

$$l_s = l_{b,net} \cdot \alpha_1 > l_{s,min}$$

### Anchorage verifications of the different stirrup types

#### Left to the load (in the column)

Tension stirrups and longitudinal stirrups are verified as straight bar ends. The existing anchorage length is measured from the front edge of the column.

Tension loops and longitudinal stirrups if installed, lap with the column reinforcement and are dimensioned in these zones in accordance with the required lap length.

#### Right of load (at the free corbel end)

Tension stirrups and loops are verified as stirrups in accordance with EN 1992-1-1. For eventually existing longitudinal stirrups, the verification is performed on a straight bar end.

The existing anchorage length is measured from the rear edge of the load plate, i.e. the entire load plate length is considered.

Depending on the type of stirrup, different bending roll diameters are available for selection. As a rule, the required anchorage length increases with smaller bending roll diameters.

## Bond conditions

Depending on the selected option, the software calculates the bond areas specified by the user. If the option "As cast-in-place concrete" was selected which means cast in upright position, the software uses the following associated values:

Bond area	In column	At the corbel end
Tension stirrup	I	II/I IAW distance
Tension loop	I	II/I IAW distance
Longitudinal stirrup	I	I

For tension stirrup or a tension loop at the corbel end, the bond area is calculated in accordance with the distance of the stirrup from the top edge or bottom edge of the corbel.

The following conditions apply:

Distance top = 30 cm

Distance bottom = 30 cm (with EN 1992-1-1)

If the distance of the upper tension stirrup or the upper tension loop from the top edge of the corbel is larger than the value specified for "Distance top", good bond condition can be assumed.

Analogously, good bond condition (VB I) is assumed, if the distance of the top tension stirrup or the top tension loop to the bottom edge of the corbel is not greater than the value specified for "Distance bottom".

## Bending roll diameter and minimum distances of the reinforcement

The size of the bending roll diameter can optionally be specified in the detail dialogs of the reinforcement.

The following applies with  $cR$  = minimum value of the concrete cover perpendicular to the bending plane:

for EN 1992-1-1 and  $d_{br} \geq 10 \cdot d_s$  applies:

$d_{br} = 10 \cdot d_s$     with  $cR > 100 \text{ mm}$     and  $cR > 7 \cdot d_s$

$d_{br} = 15 \cdot d_s$     with  $cR > 50 \text{ mm}$     and  $cR > 3 \cdot d_s$

$d_{br} = 20 \cdot d_s$     others

In all other cases, the following applies:

$d_{br} = 7 \cdot d_s$     with  $d_s < 20 \text{ mm}$

$d_{br} = 4 \cdot d_s$     others

The minimum reinforcement distances  $a_{min}$  are calculated by the software on the conditions  $a_{min} \geq d_s$  and  $a_{min} \geq 20 \text{ mm}$ .

## Automatic dimensioning of the corbel and reinforcement proposal

If the corresponding option is activated in the "Settings" dialog, the software automatically dimensions the corbel.

This is done as follows:

### Corbel dimensions

Length =  $1.5 \cdot \text{load distance}(a) + \text{concrete cover}$

Width = column width

Height =  $\text{load distance}(a) \cdot F$  (empirical value, depends on the corbel relation)

$F = 3$  at a load distance(a)  $\leq 9$

$F = 2$  at a load distance(a)  $\geq 36$

$F = (10/3 - \text{load distance}(a)/27)$  for values in-between

### Plate dimensions

Length =  $\text{Min}(\text{load distance}(a) - 2, \text{corbel length} - \text{load distance}(a) - \text{concrete cover}) \cdot 2$

Length  $\geq \text{corbel length}/4$

Width =  $\text{corbel width} - 2 \cdot \text{concrete cover} \geq 0.6 \cdot \text{corbel width}$

Reinforcement

Tensile reinforcement:

- strive for two layers maximum
- prefer several loops in a plane
- use large bending roll diameters first
- apply longitudinal stirrup in a non-structural manner
- use tension loops
- start with a diameter of 6 or use the default diameter
- two non-structural longitudinal stirrups with a diameter of 8 or 6

Web reinforcement:

- horizontal web stirrups in up to five layers, if necessary to prevent tensile splitting
- if non-structural, use two stirrups with a diameter of 8 or 6
  
- vertical stirrup with diameter of 6 if necessary to prevent tensile splitting
- if non-structural, use three stirrups with a diameter of 6

## Definition of the structural system

Select first the applicable [standard](#) in the main menu.

To ensure best possible calculation results, check also the [software settings](#).

Note: In the settings dialog, you can decide whether the software should propose the dimensions of the corbel and the reinforcement automatically or not.

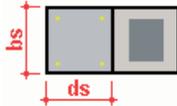
If the option for the proposal of the dimension is activated, the software sets the outer dimensions of the corbel automatically when you set the focus on the bk input field after having defined the material, the column dimensions and the loading - any previous specifications are lost in this case!

Analogously, the dimensions of the load plate are filled in automatically when you set the focus on the bp input field and the reinforcement is proposed when you change to the "Number of tension stirrups" field.

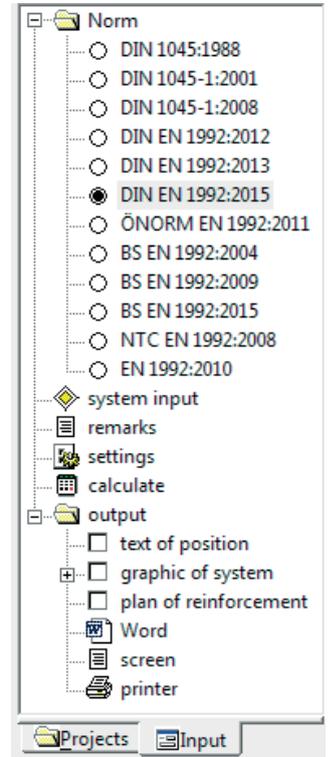
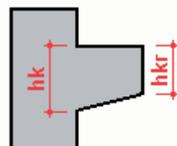
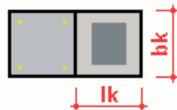
After the proposed values have been set, automatic setting is disabled and you can adjust the system values as required.

Material selection      the available materials depend on the selected standard.  
 Concrete cover          specification of nom c. If the concrete cover should vary on the different sides, you can make detailed specifications (c1 – c5) in the advanced dialog (access via the  button).  
*Note: If the concrete cover should be larger than the specified value, because you have defined large stirrup diameters, the software adjusts the value automatically.*

Column                    specification of the column dimensions (column width, column thickness ds)



Corbel                    specification of the corbel dimensions.  
 bk = width in z-direction  
 lk = length of the corbel  
 hk = total height of the corbel at the column side  
 hkr = height of the corbel on the right (face side)

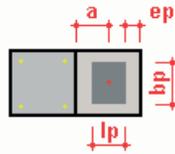


Load introduction plate specification of the load plate dimensions

**bp** plate width

**lp** plate length

**ep** distance of the plate to outer edge of the corbel



If you change to the "bp" input field, the software centres the load plate in regard to the load application point by adjusting the "ep" value. Analogously, the software adjusts the "ep" value automatically when you exit the "lp" input field.

Access the enhanced dialog () to enter a value for "ep" manually.

## Loading

This section allows you to define the loading on the corbel. The available options and fields depend on the selected standard.

loads			
vertical	F <sub>ed</sub> =	<input type="text" value="91,50"/> kN	a = <input type="text" value="8,0"/> cm
horizontal	H <sub>ed</sub> =	<input type="text" value="20,00"/> kN	h <sub>s</sub> = <input type="text" value="2,0"/> cm

- F<sub>ed</sub>** total vertical load (positive)  
**a** distance of F<sub>ed</sub> from the outer edge of the column  
**H<sub>ed</sub>** horizontal load (positive, if acting away from the column)  
**h<sub>s</sub>** distance of H<sub>ed</sub> to the top edge of the column

According to Booklet 600 DAfStb, H<sub>ed</sub> should be at least  $0.2 \cdot F_{ed}$  (ÖNorm B 1992-1-1 at least  $0.1 \cdot F_{ed}$ )!

This regulation was taken over by the Euro standards and has been implemented in the software application accordingly.

*Note: The corbel condition  $a/h \leq 1.0$  must be satisfied.  
The software handles corbels up to a relation of  $a/h \geq 0.3$ .*

## Reinforcement

Select the number and diameter of the stirrup types that should be used as tensile reinforcement (main) and tensile splitting reinforcement (web).

reinforcement					edge of console	
	number	Dm	Ac (cm <sup>2</sup> )	V	Vzd=	Myd=
tensile stirrups	<input type="text" value="1"/>	10	1,57		91,50 kN	11,71 kNm
tensile loops	<input type="text" value="1"/>	8	1,01			
longitud. stirrups	<input type="text" value="3"/>	8	1,51			
web stirrups	<input type="text" value="3"/>	6	1,70			
vert. stirrups	<input type="text" value="4"/>	6	2,26			

Ac tension	sel.	4,09	req.	1,86 cm <sup>2</sup>
Ac splitting	sel.	1,70	req.	0,93 cm <sup>2</sup>
<b>by web stirrups</b>				

distance of column longit. reinf. dr =  cm

dimensions and reinforcement propose  always calc.

**system calculated.**

The definition is done by entering the values in tables.

"As" specifies the totalised area of the reinforcement cross sections of the respective stirrup type – longitudinal stirrups are considered as single-shear all other types as double-shear.

"V" refers to the anchorage. An exclamation mark is displayed when the corresponding stirrup type is part of the main tensile reinforcement (applied structurally) and the anchorage verification that is required in this case was unsuccessful.

Activate the  button to specify further details on the respective stirrup type.

- See the chapter [tension stirrups](#)
- See the chapter [tension loops](#)
- See the chapter [longitudinal stirrups](#)
- See the chapter [web stirrups](#)
- See the chapter [vertical stirrups](#)

The total of the cross-sectional areas of the defined reinforcement and a comparison to the required As values is shown in the overview of the results:

**detail of reinforcement**

tensile stirrups

number=  Dm= 10 Ac= 1,57 cm<sup>2</sup>

**geometry**

2 stirrups per layer

side by side

inter

sideways displaced

Offset cy=  cm

closed stirrup

**bending root diameter**

dbr >= 4 ds

dbr >= 10 ds

At the same time, the internal forces at the face of the corbel are put out.

*Note:* You should also pay attention to the messages displayed in the information window below the main menu. Information about non-compliance with verification conditions or conflicts in the reinforcement layout is displayed there.

## Tension stirrups

Tension stirrups are used to bear tensile forces in addition to or instead of tension loops or longitudinal stirrups.

You must specify the number, diameter and bending roll radius.

The stirrups are distributed evenly above the tension loops with the minimum spacing. The centre of gravity of the reinforcement is displaced further down through this.

The bending roll diameter has an effect on the arrangement and dimensions of the longitudinal and vertical stirrups as well as the anchorage verification.

If the corbel is sufficiently wide, you can arrange two tension stirrups in a single layer. This has a favourable effect on the centre of gravity of the tensile reinforcement and, consequently, on the results of the verification.

Installation of two staggered stirrups means that they do not lie next to each other in the same layer but one immediately on top of the other with a lateral offset. The assumed lateral offset is determined on the basis of the minimum spacing of the tension stirrups in line with the available corbel width.

The tension stirrups are anchored inside the column, which may produce conflicts of geometry with the existing longitudinal reinforcement in the column. In particular, when the column width is identical to that of the corbel you can solve this conflict by moving the stirrups further inwards. You can do this by defining a corresponding offset via "cy". "cy" specifies the distance of the tension stirrups to the lateral corbel edge in addition to the concrete cover.

## Tension loops

Tension loops are also used to bear tensile forces.

You must specify the number, diameter and bending roll radius.

If you have already defined tension stirrups, the tension loops are arranged below the tension stirrups with a regular minimum spacing.

For further information about the geometry and the bending roll diameter, refer to the chapter [tension stirrups](#).

## Longitudinal stirrup

Longitudinal stirrups serve typically non-structural purposes, but you can use them to bear tensile force as well.

You must specify the number, diameter and bending roll radius.

They are evenly distributed over an area that is enclosed by the tension loops, tensions stirrups and web stirrups, if installed.

When you define longitudinal stirrups as the main tensile reinforcement, you should note that those stirrups which bend downwards at the free corbel end may only be used in accordance with reference /11/, if the load plate does not project over the beginning curvature and no important horizontal loading applies.

## Web stirrups

The horizontal web stirrups are used to counteract tensile splitting in the lower corbel web.

Depending on the selected calculation model and/or the relevant corbel condition, you can also arrange them in a non-structural manner (see also [Basis of calculation](#))

You must specify the number, diameter and bending roll radius.

Web stirrups are arranged in such a way that they enclose the vertical stirrups, if the column and the corbel have the same width. If the corbel is smaller than the column, the web stirrups lie always inside the vertical stirrups, see also the reinforcement examples in reference [/10/](#).

Vertically, they are distributed evenly below the tensile reinforcement.

If vertical stirrups have been defined and their number is greater than 1, a web stirrup is positioned at the lower end of the vertical stirrup, if possible.

Please take note of the special case that is produced when defining exactly two stirrups:

This case can produce situations where the effect of the web stirrups in the area of applying tensile splitting forces is affected by the non-structural arrangement. You should increase the number of stirrups in this case.

Only with outer web stirrups (column and corbel have the same width), it may become necessary to position a stirrup with an identical geometry above the vertical stirrup in the tension area of the corbel. To do this, activate the option "Position web stirrup in tension area". Optionally, you can add this stirrup to the (main) tensile reinforcement in the calculation.

## Vertical stirrups

Vertical stirrups are mainly used for non-structural purposes. Depending on the selected calculation model and/or the corbel condition, they can also bear tensile splitting forces in the lower corbel web (see also the [Basis of calculation](#)).

You must specify the number, diameter and bending roll radius.

The stirrups are evenly distributed over a particular section of the corbel length. The distance to the free corbel face is also determined by the tension and/or web stirrups and their bending roll diameter, if those stirrups have been defined.

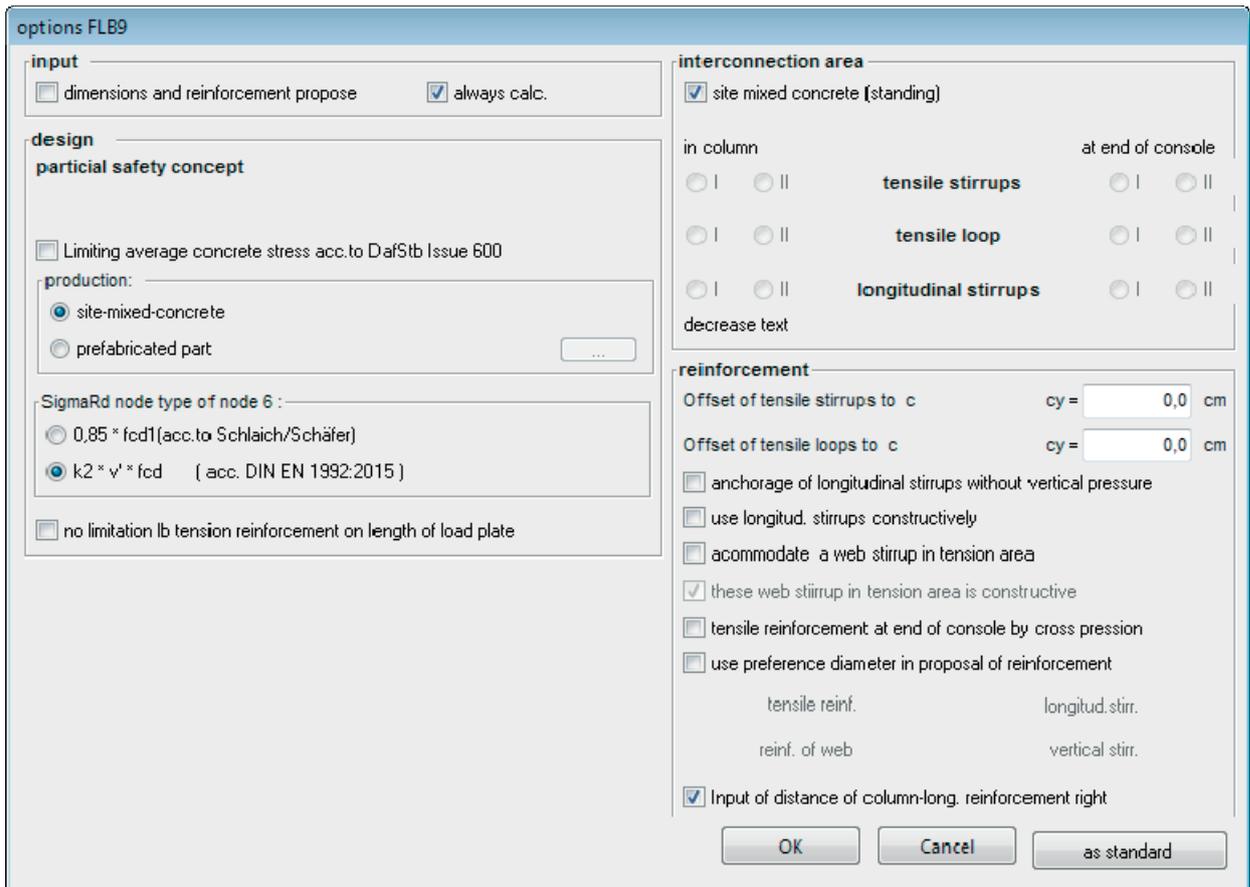
The detail dialog for the vertical stirrups is only enabled if a standard with partial safety concept was selected. In this dialog, you can specify the number and the diameter of the stirrups and their resisting shear force coverage.

The resisting shear force coverage can optionally be selected. If you activate the option, you must specify a stirrup spacing that is smaller than the structurally required minimum spacing (see [Basis of calculation](#)). The number of vertical stirrups depends on the specified spacing and is set automatically.

## Verification options - settings

► Main menu ► Settings.

Any changes of the settings in this dialog have an immediate effect on the defined corbel and the values set in the system definition section. If you set up a new item, however, the software goes back to the default settings. Activate the button "As default" to save the user-defined settings as a standard.



### Definition options

Propose dimensions and reinforcement:

If this option is active, the software will propose values as soon as you perform defined operations such as accessing or exiting particular input fields - previous specifications are overwritten by the proposed values!

The defined operations are the following:

- Accessing the "bk" input field launches the proposal of the corbel geometry and the deletion of the defined reinforcement automatically.
- Accessing the "bp" input field launches the proposal of the load plate geometry automatically.
- Accessing the "Number of tension stirrup" field launches the proposal of the reinforcement automatically.

After the proposed values have been set, automatic setting is disabled and you can adjust the system values as required.

Always calculate: a calculation is performed each time you edit and change any value. If this option is not checked, you can launch the calculation manually by activating the "Calculate" button.

**Design**

**Partial safety concept**

**Limitation of the mean concrete stress as per DAfStb, Booklet 600**

Optional limitation of the mean reinforced concrete stress for the calculation of  $V_{Rd,max}$  can be carried out as per Booklet 600 page 186 of the German Committee for Reinforced Concrete DAfStb or EN 1992-1-1, eq. (6.9)

**Manufacturing**

available options are "Cast-in-place concrete" or "Pre-cast component". The selected option has an effect on the determination of the material coefficients  $\gamma_c$  and  $\gamma_s$ .

**SigmaRd node type 6**

limit stress for the design of the compression strut underneath the load plate in node type 6 as per EN 1992-1-1 or in accordance with Schlaich/Schäfer, as specified in "Betonkalender 2001" P2 p. 311 et seq.

**No limitation  $l_b$  of tensile reinforcement to load plate length**

activate this option if the distance  $e_1$  of the support to the outer corbel edge is low and requires a reduced width of the compression strut and consequently, the consideration of the required  $l_b$  without lateral pressure.

**Bond area**

**Cast-in-place concrete** activate this option if the corbel is cast in place i.e. upright. The software assigns the stirrup automatically to the applicable bond area:

Bond area	In column	At the corbel end
Tension stirrup	I	II/I IAW distance
Tension loop	I	II/I IAW distance
Longitudinal stirrup	I	I

Otherwise, define the decisive bond areas manually. They are registered in the software without verification.

## Reinforcement

<b>Offset of tension stirrups/loops</b>	offset of the tensile reinforcement due to the column reinforcement ( $c_y$ = distance to outer corbel edge minus lateral concrete cover).
<b>Longitudinal stirrups non-structural</b>	check this option if the defined longitudinal stirrups should not be assigned to the (main) tensile reinforcement but used non-structurally for constructive purposes. If they are assigned to the tensile reinforcement, the software performs the corresponding anchorage verification.
<b>Web stirrups in tension area</b>	if the column and the corbel have the same width and vertical stirrups have been defined, it can be useful to position a stirrup with the same geometry as the web stirrups at the upper end of the vertical stirrups in the tension area to create a reinforcement cage.
<b>Web stirrup non-structural</b>	if the previous option (web stirrup in tension area) has been activated, this option allows you to decide whether the current stirrup should be assigned to the (main) tensile reinforcement or not. A separate verification of the anchorage is performed if the stirrup fulfils a structural function.
<b>Lateral compression</b>	activate this option if the tensile reinforcement at the free corbel end should generally be under lateral compression in the anchorage verification. In this case, factor $\alpha_2$ is set to 2/3 at least.
<b>Preferred diameter</b>	if the option for the automatic proposal of the reinforcement is active, the software tries to find a reasonable stirrup layout on the basis of the smallest bar diameter in each case. You can influence the proposed values by activating the preferred diameter option and defining a minimum diameter for each stirrup type that should be used. The software will propose a stirrup layout with the user-defined diameters in this case.

## Output

Output of the system data, results and graphical representations on the screen or printer.  
The Output item in the main menu allows you to start the output on a printer or the screen.

Screen	displays the values in a text window on the screen
<a href="#">Printer</a>	starts the output on the printer
Word	output to MS-Word, if this software is installed on the computer

### Output profile

The output profile allows you to define the scope of the output.

Item comments	output of your comments to the item.
System graph	output of the structural system of the corbel
Reinforcement drawing	output of the reinforcement drawing on an additional page

## Application-specific icons

In addition to the standard icons, each software application offers application-specific functions via additional icons and tool bars.



The buttons allow you to select the output on the screen

- system graph
- main stresses in state I (symbolically)
- side view of the corbel with reinforcement
- reinforcement drawing
- realistic three-dimensional view (GL)

## Reference literature

- /1/ DIN 1045 7/88
- /2/ DIN 1045 - 1
- /3/ Booklet 220 of the German Committee for Reinforced Concrete DAfStb
- /4/ Booklet 399 of the German Committee for Reinforced Concrete DAfStb
- /5/ Booklet 400 of the German Committee for Reinforced Concrete DAfStb
- /6/ Booklet 600 of the German Committee for Reinforced Concrete DAfStb
- /7/ Betonkalender 1997 Part 1, Bemessung Stahlbetonteile (GRASSER)
- /8/ WALRAVEN, LEHWALTER (Beton und Stahlbetonbau 1989 S.81 ff)
- /9/ Bemessungsbeispiele zur DIN 1045, Deutscher Beton- Verein e.V., Wiesbaden, Berlin, Bauverlag 1991, (p.143 et seq.)
- / 10 / Beispiele zur Bemessung nach DIN 1045-1, Volume 1 Hochbau  
Deutscher Betonverein, Ernst & Sohn
- /11/ LEONHARDT, Vorlesungen über den Massivbau Part 3, p. 187 et seq.
- /12/ Betonkalender 2001, Part 2, Konstruieren im Stahlbetonbau (SCHLAICH, SCHÄFER)
- /13/ Betonkalender 2002, Part 1, Grundlagen der Bemessung nach DIN 1045-1 in Beispielen (LITZNER)
- /14/ EN 1992-1-1:2010
- /15/ DIN EN 1992-1-1/NA correction 1