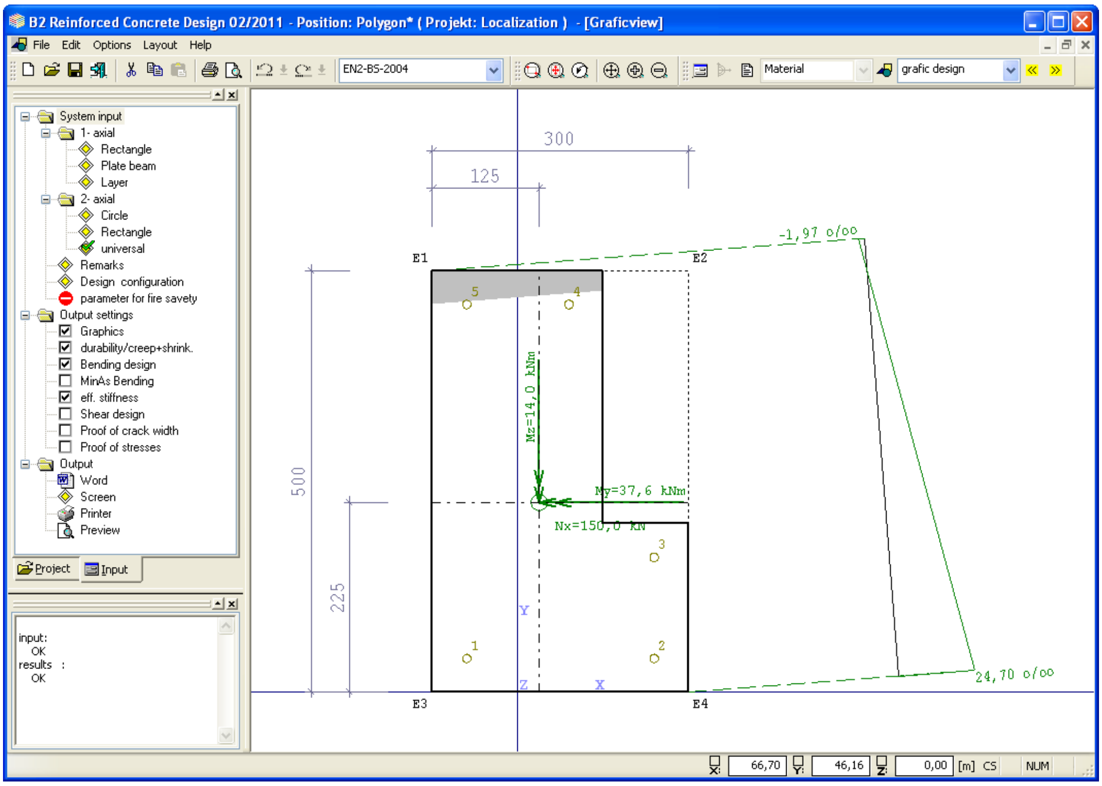
Reinforced Concrete Design B2

User manual for Frilo design calculation applications



Frilo on the web

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B2 Manual, revision 1/2011

Frilo application: B2 - Reinforced concrete design

This manual deals with the basic features of the *B2* application.

Contents

Further information and descriptions are available in the relevant documentations:

Analyses on Reinforced Concrete Cross Sections.pdf

Durability - Creep Coefficient and Shrinkage Strain.pdf

Application options

The application B2 is intended for the design and structural analysis of steel concrete cross sections in accordance with the following standards:

- DIN 1045 7/88, DIN 1045-1 (2001), DIN 1045-1 (2008)
- ÖNORM B 4700 (2001-06-01)
- Eurocode 2 (NAD Italy 02/1996)
- British Standard BS 8110 (1997) and BS 8500-1 (2001)
- DIN EN 1992 1-1 (Draft 2008) *)
- BS EN 1992 1-1 (NA 2004) *)
- ÖNORM EN 1992 1-1 (B 1992 1-1 (2007)) *)
- EN 1992 1-1 (2004) *)
- UNI EN 1992-1-1/NTC:2008 *)
- NEN EN 1992-1-1:2005/NB:2007 *)
- NBN EN 1992-1-1 ANB 1e uitg., 2010 *)
- CSN EN 1992-1-1/NA: Cervenec 2007 *)

*) *One National Appendix is included in the programmprice, additional NA´s are available (see pricelist).*

You can select the desired standard as a start option via the function "Standard" in the dialog "Design configuration".

The following table gives an overview of the optional scope of calculation for each type of cross section:

Cross section	Effect of actions	ULS bending + longitud. force	ULS/SLS effective rigidity	ULS shear force + torsion	Stress analysis reinf./concrete	Crack width proof	Comments
T-beams	Uniaxial	X	X	X	X	(1)	Cast-in-place concrete joint/with lattice girders (2)
Rectangle 1	Uniaxial	X	X	X	X		Cast-in-place concrete joint/with lattice girders (2) n/m diagrams
Rectangle 2/ box	Uniaxial and biaxial	X	X	(2)	X	_	
Circle/ annulus	Uniaxial and biaxial	X	X	(1)	X	(1)	n/m diagrams
layers cross section	Uniaxial	X	X	X	X	X	Cast-in-place concrete joint/with lattice girders (2)
General cross section	Uniaxial and biaxial	X	X	-	-	-	**(Additional module!)** Rigidity for the design situation "fire": (3)

(1) except BS 8110
(2) only DIN 1045-1
(3) Rectangle and circle cross sections with general reinforcement, only DIN 1045-1

Standards and terms

DIN 1045-1

If DIN 1045-1 (2008) is not explicitly mentioned, the term "DIN 1045-1" refers to to the version 2001 as well as the version 2008 of DIN 1045-1.

EN 1992 1-1

If the national annexes are not mentioned explicitly, the statements apply to all national annexes in the same way.

NDP

The abbreviation refers to definable parameters in the national annex. The corresponding national annex should be taken into consideration.

The following shortcuts are used for the individual national annexes:

EN:	recommended values EN 1992 1-1
NA_D:	Germany
NA_A:	Austria
NA_GB:	UK
NA_I	Italy
NA_NL	Netherlands
NA_B	Belgium
NA_CZ	Czech Republic

Information concerning the standards

DIN 1045-1 — The amendment 2008 is included in the List of Technical Construction Regulations 02/2008 and will be introduced in the Federal States in the beginning of 2009.

EN 1992 1-1:

NA_D: E DIN 1992 1-1/NA

Please note that the current version has the status of a draft. The introduction of the standard is expected in the course of 2010.

NA_A: ÖNORM B 1992 1-1 (2007)

The Austrian Institute of Standardization will withdraw the currently applicable standard B4700 on 1 June 2009. Therefore, EN 1992 1-1 is the only state-of-the art standard at present (http://www.eurocode.at/)

NA_GB: NA to BS EN 1992 1-1 (2004)

In June 2008, the British Standard Institute adopted EN 1992 1-1, the standard BS 8110 applicable until then is no longer supported. (http://www.eurocodes.co.uk)

NA_I: UNI EN 1992-1-1/NTC:2008

Even though the final version of this National Annex is not available yet, you can use the Eurocode in combination with the document "Norme tecniche per le costruzioni" (/56/) published on 4 February 2008 and the supplementary circular "Circolare finissima 2.2.2009" (/57/).

NA_NL: NEN EN 01/01/1992/NB

The Eurocode for the construction of buildings is applicable in the Netherlands. The coexistence period will last for one year after the introduction of the final version. (/53/)

NA_CZ: After publication of the National Annexes, the old national standards were withdrawn on 31 May 2010.

Basis of calculation

The topics

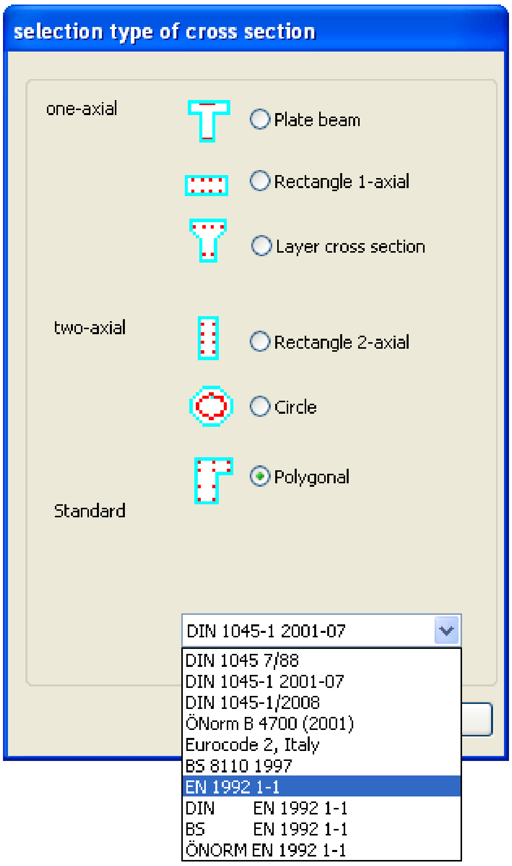
- Design for bending and longitudinal force
- Calculation of the effective rigidity
- Shear design
- Proofs of serviceability
- Accidental design situation

are dealt with in the document "Analyses on Reinforced Concrete Cross Sections.pdf".

System input

The items of the main tree reveal the input options of the application.

When you set up a new item, a window for the selection of the type of cross section and the standard is displayed.



Type of cross section:

Uniaxial

Rectangle

T-beam

Layers

Biaxial

Circle

Rectangle

Polygon

Note: The processing of polygonal cross sections requires the additional module B2-Poly.

Standard selection

- DIN 1045 7/88
- DIN 1045-1/2001
- DIN 1945-1/2008
- ÖNORM B 4700/2008
- Eurocode 2 (NAD Italy 02/1996)
- British Standard BS 8110 (1997) and BS 8500-1 (2001)
- DIN EN 1992 1-1 (Draft 2008)
- BS EN 1992 1-1 (NA 2005)
- ÖNORM EN 1992 1-1 (B 1992 1-1 (2007))
- EN 1992 1-1 (2004)

Change the type of cross section

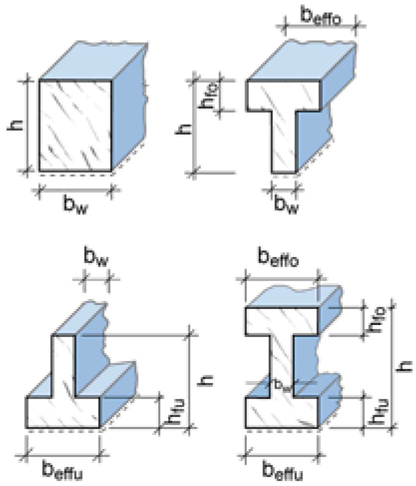
In order to change the type of cross section in an existing item, double-click on the desired cross section in the main tree. A confirmation dialog is displayed and allows you to confirm or cancel the overwriting of the data.

T-beam / rectangle uniaxial

Material → See Material input

Options → See design options DIN 1045, DIN 1045-1, ÖNORM B4700, EC2 Italy, BS 8110, EN 1992 1-1

Cross section See illustration



Cast-in-place compl.: DIN 1045-1; EN 1992 1-1
(See dialog Cast-in-place complement)

Environmental conditions / requirement classes

→ See Environmental conditions / requirement classes

Reinforcement

dob distance of the upper layer (from the top edge or the cast-in-place complement, if applicable)

dun distance of the lower layer (from the bottom edge)

You must specify the distance of the center of gravity for multilayer reinforcements.

DIN 1045-1, EN 1992 1-1:

The reinforcement distance should comply with requirements due to durability. In case of noncompliance, a corresponding note is displayed in the information window.

Reinforcement distribution:

- → See Design according to the Kh (Kd) method
- → See Design for a given reinforcement relation
  Asu/Aso= 1, 3, 5, 7

Effect of actions → See Input of action-effects

Design Display of the design results
→ See Design - Results.

Cast-in-place complement

You can enter cast-in-place complements for the cross section types rectangle uniaxial, T-beam uniaxial and layers cross section uniaxial.

Cross section

Height: height of the cast-in-place complement

hE <= hfo - 5 cm, if hfo = 0, then HErg <= h - 5 cm

Joint finishing

DIN 1045-1 (2001):

In accordance with the definition in DAfStb Booklet 525 S.84

DIN 1045-1 (2008), EN 1992 1-1:

Very smooth Cast against steel or smooth timber formwork.

Smooth Screed surface or finished with slide or extruder process or untreated.

Rough Exposure of aggregate skeleton >= 3 mm (40 mm distance approx.)

NA_D: or sand surface method, average peak-to-valley depth > 1.5 mm

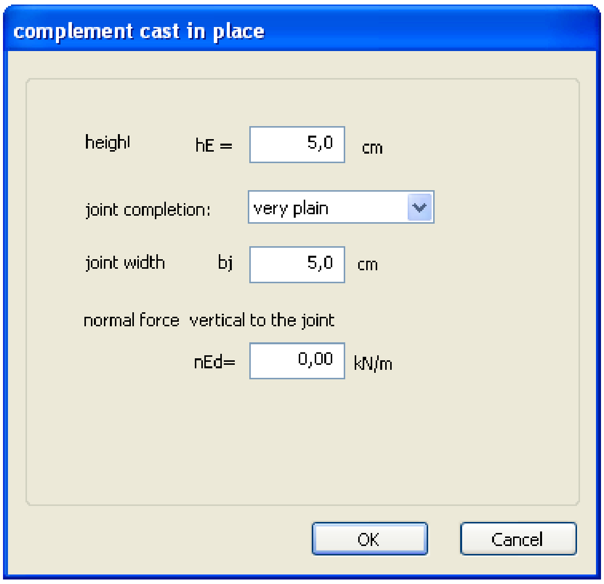
Interlocked Interlocking according to figure 6.9

NA_D: or when dg>=16 mm and exposure of aggregate skeleton > 6 mm or sand surface process average peak-to-valley depth > 3 mm

bj Accountable joint width, reduced in regard to the total width due to prefabricated formwork, if applicable.

BFug <= beffo

nEd Lower design value of the normal force perpendicular to the joint per length unit, negative pressure.



Layers cross section input

Material → See Material input

Options → See design options DIN 1045, DIN 1045-1, ÖNORM B4700, EC2 Italy, BS 8110, EN 1992 1-1

Cross section You can enter any simple symmetrical cross sections. Each layer has a distance from the top and a width. The distance of the first layer is equal to 0.

Cast-in-place compl.: → See dialog Cast-in-place complement only with DIN 1045-1

Thickness hE <= thickness of the first layer

Joint width bj <= width of the first layer,

additional BFug <= width of second layer, when HErg = thickness of first layer

Environmental conditions / requirement classes

→ See Environmental conditions / requirement classes

Reinforcement

dob distance of the upper layer (from the top level or the cast-in-place complement, if applicable)

dun distance of the lower layer (from the bottom edge)

You must specify the distance of the center of gravity for multilayer reinforcements.

DIN 1045-1, EN 1992 1-1:

The reinforcement distance should comply with requirements due to durability. In case of noncompliance, a corresponding note is displayed in the information window.

Reinforcement distribution:

- → See Design according to the Kh (Kd) method
- → See Design for a given reinforcement proportion Asu/Aso= 1, 3, 5, 7

Effect of actions → See Input of action-effects

Design Display of the design results
→ See Design - Results.

Rectangle biaxial

Material → See Material input

Options → See design options DIN 1045, DIN 1045-1, ÖNORM B4700, EC2 Italy, BS 8110, EN 1992 1-1

Cross section

bw width > 0

h height > 0

bi box width (full cross section = 0, otherwise > 0)

di box thickness (full cross section = 0, otherwise > 0)

Environmental conditions / requirement classes

→ See Environmental conditions / requirement classes

Reinforcement

b1 distance of the upper layer (from the top edge)

d1 distance of the lower layer (from the bottom edge)

You must specify the distance of the center of gravity for multilayer reinforcements.

DIN 1045-1, EN 1992 1-1:

The reinforcement distance should comply with requirements due to durability. In case of noncompliance, a corresponding note is displayed in the information window.

Reinforcement distribution:

- Distributed over the corners: 4 · 1/4, 3 · 1/6+3/6, 3 · 1/8+ 5/8, 3 · 1/10+ 7/10
- Distributed over the sides: Asli= Asre, Asu= Aso
- Distributed over the circumference

Effect of actions → See Input of action-effects

Design Display of the design results
→ See Design - Results.

Circle / annulus

Material → See Material input

Options → See design options DIN 1045, DIN 1045-1, ÖNORM B4700, EC2 Italy, BS 8110, EN 1992 1-1

Cross section

da outer diameter > 0

di inner diameter (full circle: Di=O, otherwise > 0)

Environmental conditions / requirement classes

→ See Environmental conditions / requirement classes

Reinforcement

d1 distance from the circumference > 0

DIN 1045-1, EN 1992 1-1:

The reinforcement distance should comply with requirements due to durability. In case of noncompliance, a corresponding note is displayed in the information window (in case of multilayer reinforcements, higher distances are required for the resulting layer).

The reinforcement is distributed over the circumference.

Effect of actions → See Input of action-effects

Design

Display of the design results
→ See Design - Results.

General cross section biaxial

Material → See Material input

Options → See design options DIN 1045, DIN 1045-1, ÖNORM B4700, EC2 Italy, BS 8110, EN 1992 1-1

Polygonal cross section

Outline: The input of the polygon is done by entering polygon points in a x/y system of coordinates into a table.

You can enter up to 100 polygon points.

Block-out: The polygon is entered via a table in the same way. This table can be accessed via the >> button on top of the table for the outline.

Note: Standard cross sections of B2 (rectangle, T-beam, layers cross section) can most efficiently be entered in the sections of the corresponding cross section types and converted into a polygonal cross section subsequently.

Note concerning the input in the table: All entered coordinates are shown in the graphic window. The recalculation is only performed after you exit the table. You can terminate the input of data and exit the table by specifying zero in the column "current no."

Environmental conditions / requirement classes

→ See Environmental conditions / requirement classes

General point reinforcement

The reinforcement can comprise up to 100 reinforcement points. The x/y coordinates are entered via a table.

You can optionally define a reinforcement point as a constant point, i. e. the area assigned to it once is not changed during the iteration.

The definition of constant points is done via an enhanced table that is accessible by clicking on the button >>. In this section, you also define the selected reinforcement that is required for the calculation of the effective rigidity.

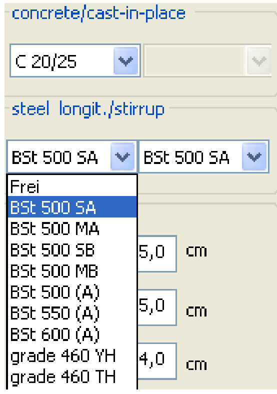
Effect of actions → See Input of action-effects

Design → See Results of polygonal cross sections

The following cross section types are available for the fire protection proofs:

- rectangle and general point reinforcement
- circle and general point reinforcement

Material input



The materials concrete/reinforcing steel are entered via standard-specific selection lists. Alternatively, you can freely define the material values via the menu item "Free" with DIN 1045-1 and EN 1992 1-1.

You can select different materials for the longitudinal reinforcement and the stirrups.

Material input DIN 1045 7/88

B15... B55	acc. to table 11
B65... B115	acc. to DafStb* directive for high-strength concretes
BSt 1, 3, 4	different materials for the longitudinal and the stirrup reinforcement, if applicable

Material input DIN 1045-1

C12/15....C100/115	standard and high-strength concrete acc. to table 9
LC12/13...LC60/66	lightweight concrete acc. to table 10 additional input for cast-in-place complement, if applicable

If high-strength concrete (> C50/60) is used, the design option "Ac net" (net concrete surface) should be selected (cf. /14/ p.161).

When entering a cast-in-place complement, you can select the material of the cast-in-place concrete in the top right selection list.

The selected concrete class should comply with requirements due to durability. When you select a lower concrete class, a corresponding note is displayed in the information window.

BSt 420 SB	bar steel acc. to DIN 488 old, standard ductility
BSt 500 SA	bar steel with standard ductility acc. to table 11
BSt 500 MA	fabric steel with standard ductility acc. to table 11
BSt 500 SB	bar steel with high ductility acc. to table 11
BSt 500 MB	fabric steel with high ductility acc. to table 11
BSt 450 SE	earthquake-resistant steel acc. to /5/ p.176 tab. 2.4

Material input EC2/Italy

C12/15... C50/60	concrete classes acc. to table 3.1
Fe B22 k...Fe B44 k	reinforcing steel acc. to NAD Italy /19/ p.17, table1-I and 2-I

Material factors acc. to EC2 (Italy), table 1

	Fundamental combination	Accidental combination
Concrete	1.6	1.3
Steel	1.15	1.00

Cf. /19/p. 68 for reinforced concrete and partially prestressed components.

Material input ÖNORM B4700

B15...B60	old concrete classes (B4200-10) acc. to table 4
C12/15… C50/60	new concrete classes (Eurocode) acc. to table 4

Reinforcing steel acc. to table 5, different materials for the longitudinal and the stirrup reinforcement, if applicable.

Material input BS 8110

C12/15... C50/60	concrete classes acc. to BS 8500-1 table 20, presently without high-strength and lightweight concrete
Grade 250 RH...	reinforcing steel according to BS 8110-1 table 3.1 and /20/table 1.3
Grade 485 WH	different materials for the longitudinal and the stirrup reinforcement, if applicable

Material input EN 1992 1-1

C12/15....C100/115	standard concrete acc. to 3.1.3 and NA
LC12/13...LC60/66	lightweight concrete acc. to 11.3.1 and NA, additional input of cast-in-place complement, if applicable

If high-strength concrete (> C50/60) is used, the design option "Ac net" (net concrete surface) should be selected (cf. /14/ p.161).

When entering a cast-in-place complement, you can select the material of the cast-in-place concrete in the top right selection list.

The selected concrete class should comply with requirements due to durability. When you select a lower concrete class, a corresponding note is displayed in the information window.

Steel in accordance with Annex C and national regulations

NA_D:	BSt 500 SA ...Bst 500 MB
NA_GB:	B 500 A, B 500 B, B 500 C
NA_A:	Bst 500 (A), Bst 550 (A), Bst 600 (A), Bst 550 (B)
NA_I:	B450(A), B450(C)

Ductility class:	A (standard), B (high), C (very high)

Concrete - user-defined (DIN 1045-1, EN 1992 1-1)

Input of lightweight concrete

- Tick the option "Lightweight concrete"
- Enter the concrete density (> minimum density acc. to /5/ p.176 table 2.3)
- Tick the option "Lightweight sand" if applicable

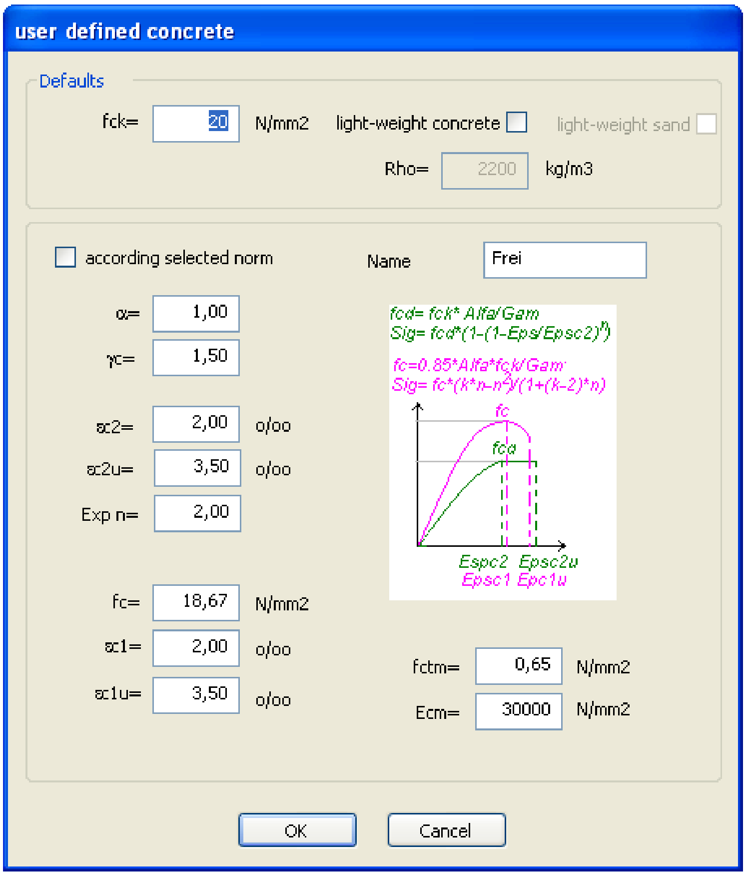
Free input

You can only enter the following values manually if the option "According to selected standard" is unticked. Otherwise, these values are set by default.

α	factor for long-term effect
γ	partial safety coefficient

Parabolic rectangular stress-strain diagram

$\varepsilon c2$	strain when attaining full strength
$\varepsilon c2u$	strain under maximum load
Exp n	exponent
fctm	average tensile strength
Ecm	average module of elasticity



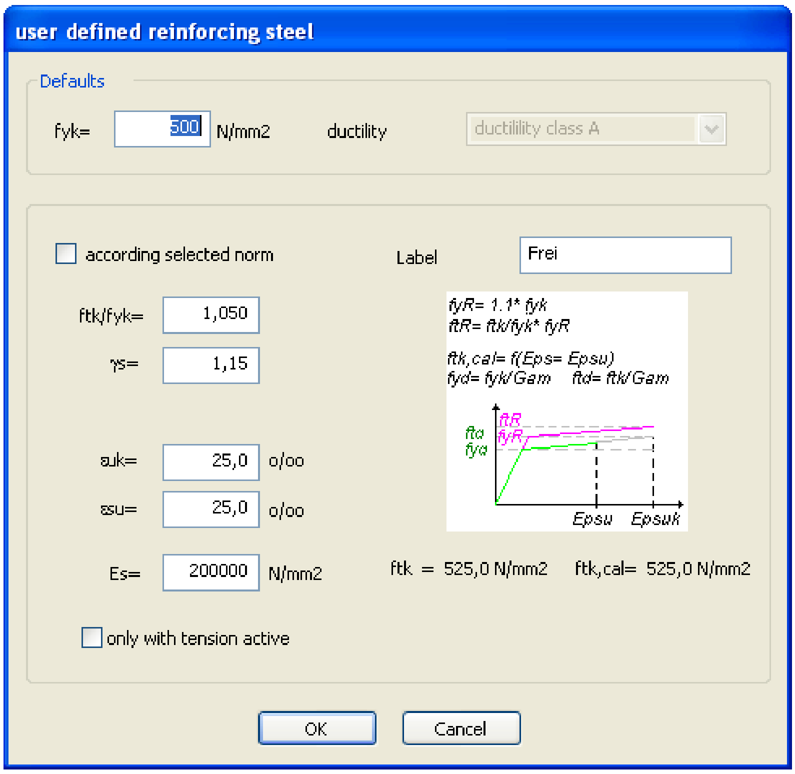
Reinforcing steel - user-defined (DIN 1045-1, EN 1992 1-1)

fyk	yield point
Ductility	ductility classes

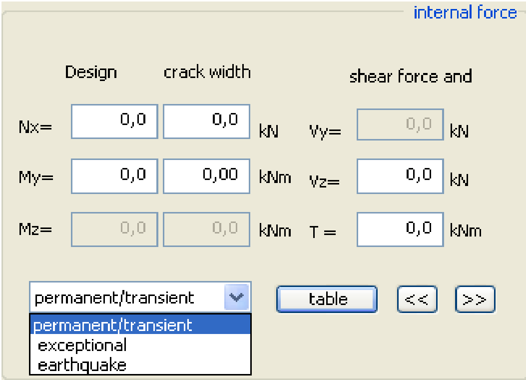
Free input

You can only enter the following values manually if the option "According to selected standard" is unticked. Otherwise, the steel properties are set by default.

ftk/fyk	standard ductility: 1.05, high ductility: 1.08, earthquake-resistant steel: 1.15 (see also /5/ p.176)
γs	corresponding partial safety factor
εuk	strain under maximum load
εsu	limit strain during design



Input of action-effects



Depending on the scope of calculation of the individual cross-section types (→ see Application options) particular action-effect options are enabled or disabled.

Alternatively, you can enter multiple action-effects also via the → action-effect table.

If several action-effects occur you can toggle between these combinations via the buttons << >>.

Nx longitudinal force, point of application in accordance with the Configuration, positive tension, negative compression

My bending moment in y-direction, positive in accordance with the configuration

Mz bending moment in z-direction, positive in accordance with the configuration

Vy design shear force in y-direction, positive in accordance with the configuration

Vz design shear force in z-direction, positive in accordance with the configuration

T torsional moment

Flexural design / shear force and torsion

DIN 1045 7/88	service loads
Otherwise	ultimate limit state according to the selected design situation

Crack width proof

DIN 1045 7/88	frequent combination
DIN 1045-1	quasi-permanent combination, special cases acc. to table 18
EC2 Italy	quasi-permanent combination
ÖNORM B4700	quasi-permanent combination
BS 8110	currently not available
EN 1992 1-1	quasi-permanent combination, special cases acc. to table 7.1 (NDP)

Stress calculation (only via table)

Nx longitudinal force, point of application in accordance with the configuration, positive tension, negative compression

My bending moment, positive according to the configuration

Mz bending moment, only with the cross section types rectangle biaxial and circle, positive according to the configuration

DIN 1045-1/EC2 Italy/B4700, EN 1992 1-1:

infrequent and quasi-permanent load combination

Define the design situation

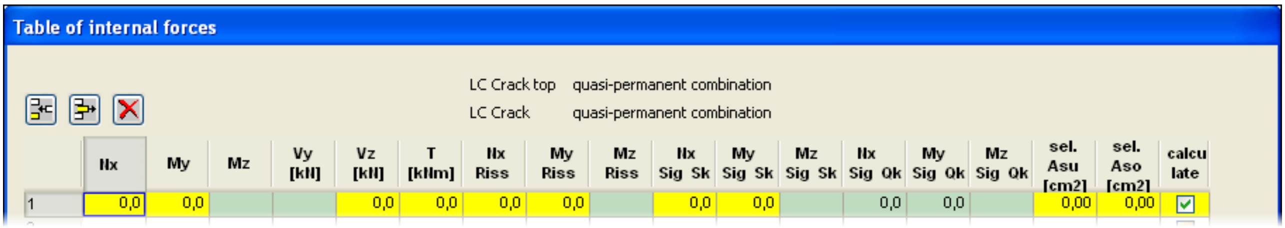
DIN 1045-1 / ÖNORM B4700 / EC2-Italy / EN 1992 1-1:

- permanent/transient
- accidental
- earthquake

After having selected the situation(s) from this list, the entered action-effects of the ultimate limit state are assigned to the corresponding design situation(s).

Action-effect table

If a cross section should be designed for more than one action-effect combination, you can use the action-effect table, which is available with all cross section types. Each action-effect combination holds a separate line in the table and you can enable it for subsequent calculation.



Depending on the scope of calculation of the individual cross-section types (→ see Application options), particular action-effect options are enabled or disabled.

You can also enter the actions-effects required for the stress analysis in this section.

If the load combination for the crack width proof corresponds to the quasi-permanent load combination (standard with reinforced concrete), the values in the corresponding columns are set automatically.

In addition, you can enter the reinforcement selected for the rigidity calculation, the crack width proof and the stress analysis. If the value of the selected reinforcement is equal to zero, the result from the bending design is assumed.

Environmental conditions / requirement classes

With the exception of DIN 1045 7/88 (direct access) you can access the dialogs for the durability and the calculation of the creep coefficient and the shrinkage strain via the buttons durability/creep/shrinkage.

(→ See also the document Durability, creep coefficient and shrinkage strain)

The button >> allows you to access the dialog for the control of the crack width proof.

Environmental conditions DIN 1045 7/88

Selection of the environmental conditions according to table 10. The relevant crack width is internally assigned to the requirement class selected in line 1 ... line 4.

Environmental conditions / creep coefficient and shrinkage strain EC2 (Italy)

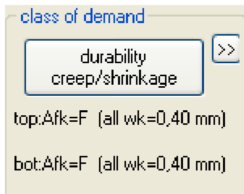
Uwk 1 ..Uwk5C Selection of the exposure classes according to table 4.1 (control of the permissible concrete stress).

perm.wk. Selection of the permissible crack width for reinforced concrete components 0.3 mm, prestressed concrete components 0.2 mm and special requirements 0.15 mm.

Environmental conditions / creep coefficient and shrinkage strain ÖNORM B4700

For reinforced concrete components: perm.wk = 0.3 mm
For special requirements: perm.wk = 0.15 mm

Durability / environmental conditions / creep coefficient and shrinkage strain (DIN 1045-1, EN 1992 1-1)

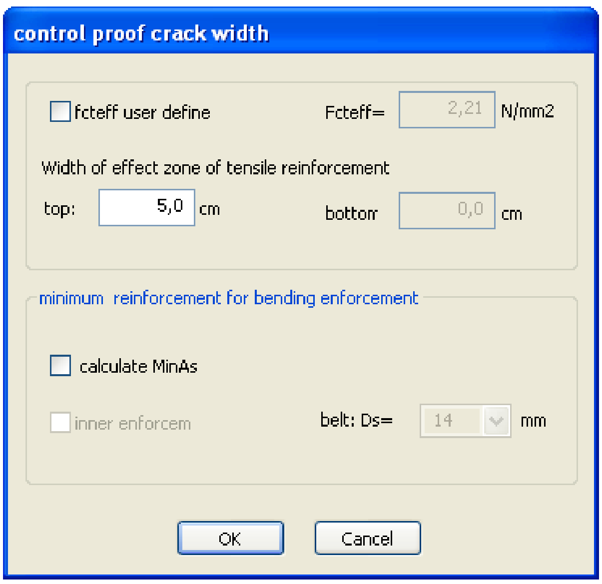


When you exit the dialog by clicking OK, the entered values are matched to the durability requirements if they do not comply with them.

Control of the crack width proof

The button >> in the requirement classes (DIN 1045-1) or environmental conditions (EC2 Italy, ÖNORM B4700, EN 1992 1-1) section allows you to access this dialog.

fcteff



The option allows to modify the concrete tensile strength. Full strength after 28 days is set by default.

Width of the effective zone of the tensile reinforcement

Correspondingly, the width of the effective zone of the tensile reinforcement decisive for the crack width proof is limited in the slabs of T-beams according to /13/ p.145:
beff(ZII) = 0,5 · beff(ZI) + 2 · cl with cl = nomc,l).

Minimum reinforcement

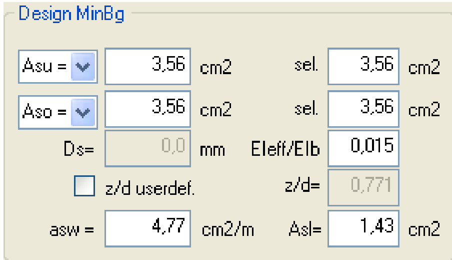
Option for the calculation of the minimum reinforcement for imposed bending. In case of internal imposed bending, a reduction (k<1.0) can be taken into consideration.

You can specify a different bar diameter for the flange.

→See also the Crack width proof.

Control of the design

Design - results



In the design section of the application interface, the decisive design results are displayed. The available input fields depend on the selected cross section.

In case of erroneous inputs or calculation errors, a corresponding message is displayed. If all inputs are valid, the following design results are displayed:

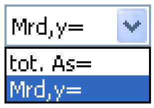
You can subsequently modify the result by editing the default values:

- Selected Asu / Aso and/or As (shear design, eff. rigidity, crack width):
  The results of the bending design are set by default.
- kz and/or z/d user-defined (relative lever arm for the shear design):
  The direct result of the bending design is set by default,
  if no bending design was performed, 0.9 · d
  DIN 1045-1, DIN EN 1992 1-1: limitation z < max(d-2 · nomc, d-3-nomc)

Uniaxial rectangle, T-beam, layers cross section

- Asu, Aso — required flexural reinforcement (→ Design for bending with longitudinal force)
- Mrd — resisting moment, Nxd and reinforcement are given (please expand the list)
- Eleff/Elb — effective rigidity referenced to state I for the selected reinforcement and the considered effect of actions (→ Calculation of the effective rigidity)
- Ds — limit diameter for the selected reinforcement (→ Crack width proof)
- asw, Asl — required stirrup reinforcement and torsion additions (→ Shear design)

Circle/annulus



- tot. As — required flexural reinforcement (→ Design for bending with longitudinal force)
- MRdy — resisting moment in y-direction, Mzd, Nxd and tot.As are given
- Eleff/EI — effective rigidity referenced to state I for the selected reinforcement and the considered effect of actions (→ Calculation of the effective rigidity)
- Ds — limit diameter (→ Crack width proof), only with DIN 1045-1
- asbü — required stirrup reinforcement, only with DIN 1045-1

Biaxial rectangle

- tot. As — required flexural reinforcement (→ Design for bending with longitudinal force)
- MRdy — resisting moment in y-direction, Mzd, Nxd and tot.As are given
- MRdz — resisting moment in y-direction, Mxd, Nxd and tot.As are given
- Eleff/EI,y — effective rigidity referenced to state I for the selected reinforcement and the considered effect of actions
  (→ Calculation of the effective rigidity)
- Eleff/EI,z — effective rigidity referenced to state I for the selected reinforcement and the considered effect of actions
  (→ Calculation of the effective rigidity)
- asbü — required stirrup reinforcement, only with DIN 1045-1

General cross section biaxial

tot. As — Required flexural reinforcement,
→ see Design for polygonal cross sections.

Note: *Whether the iteration is successful or not depends on the reasonable definition of the reinforcement points, preferably for each polygon corner.*

Please note that all reinforcement points with the same weighting i.e. the same area are considered in the first place for the design result. By defining reinforcement points exposed to less effect of actions (e.g. in the compression zone) as points with constant areas, you can optimize the result.

Areas known as difficult in iteration are the transitions from pure longitudinal action to bending with longitudinal force (e.g. white areas in the design diagrams).

For this reason, moments under a related limit moment m < 0.0023 are not considered (my = My/(Ac · fcd · Dz) mz = Mz/Ac · fcd · Dy); Dy and Dz are the dimensions of the rectangle enclosing the polygon). Because Dy and Dz do not vary with the compactness of the polygon, you should prefer a design with increased moments.

- MRdy — resisting moment in y-direction, Mzd, Nxd and tot.As are given
- MRdz — resisting moment in y-direction, Mxd, Nxd and tot.As are given
- EIeff/EI,y — effective rigidity referenced to state I in y-direction
- EIeff/EI,z — effective rigidity referenced to state I in z-direction

Note: *You can select a reinforcement for each cross section. If the reinforcement area is the same for each reinforcement point, you only need to define selected As (default). You can define different reinforcement areas via the enhanced reinforcement table (button >> on top of the reinforcement table)*

With general cross sections, uniaxial effect of actions can also produce curvatures in the direction where the moment is equal to zero.

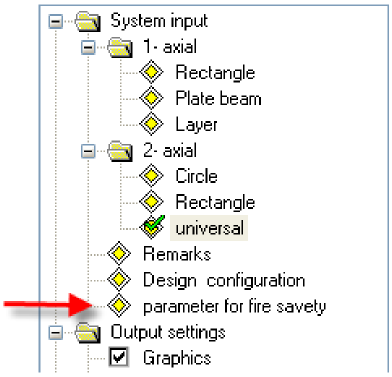
Therefore, you should consider the curvatures instead of the effective rigidities in the deformation calculation approach.

Fire protection parameters

This dialog is only enabled for DIN 1045-1 and the relevant cross section types

- general cross section rectangle + general point reinforcement,

- circle and general point reinforcement.



In this section, you can define the parameters required for the hot design and the rigidity calculation in the accidental design situation fire

Fire resistance: Select a fire-resistance class among R30, R60, R90, R120, R180 according to the target fire-resistance period.

For fire-resistance class R180, no temperature profiles are specified in /42/Annex A. In case of rectangular cross sections, temperature profiles according to CEB Bulletin 145 (/45/) implying temperatures on the safe side are used.

Temperature profiles for circular cross sections with R180 are not dealt with in any literature known to us. The profiles we use are based on our own FEM calculations

Concrete aggregate: has an effect on the thermal strains /42/ fig. 3.1 and the stress-strain curve of the concrete /42/ fig. 3.5.

Quarzitic aggregates are set by default,
if less typical calcerous aggregates should be considered, the user must select them explicitly.

Steel production: has an effect on the stress-strain curve of the steel /42/ fig. 3.3.

Cold-worked steel is set by default.

The more favourable hot-rolled steel must be selected explicitly by the user.

Temperature addition: In order to minimize errors occurring when the temperature profiles calculated on cross sections with h = 30 cm are transferred to greater or smaller cross sections, a positive (h < 30 cm) or negative (h > 30 cm) temperature addition should be entered.

Design for polygonal cross sections

In the design, the state of strain in the ultimate limit state, in which the internal action-effects on the concrete and the reinforcing steel and the external action effects are in a balance, is calculated for the cross section failure (DIN 1045-1: fig. 30) with the given forces N, My, Mz.

The result are three non-linear equations. Their iterative solution with the help of the Newton method delivers the unknown border strain, the zero-line inclination and the required reinforcement.

The internal action-effects on the concrete are calculated by splitting the concrete compression zone into thin strips.

The internal action-effects on the steel include portions for the reinforcement points with constant areas as well as for the points with areas varying during iteration that result subsequently from the balance conditions.

Note: *Whether the iteration is successful or not depends on the reasonable definition of the reinforcement points, preferably for each polygon corner.*

Please note that all reinforcement points with the same weighting i.e. the same area are considered in the first place for the design result. By defining reinforcement points exposed to less effect of actions (e.g. in the compression zone) as points with constant areas, you can optimize the result.

Areas known as difficult in iteration are the transitions from pure longitudinal action to bending with longitudinal force (e.g. white areas in the design diagrams).

Therefore, moments under a relative limit moment m < 0.0023 are not considered
my = My / (Ac · fcd · Dz) mz = Mz / (Ac · fcd · Dy).

Dy and Dz are the dimensions of the rectangle enclosing the polygon.

Because Dy and Dz do not vary with the compactness of the polygon, you should prefer a design with increased moments.

Minimum reinforcement

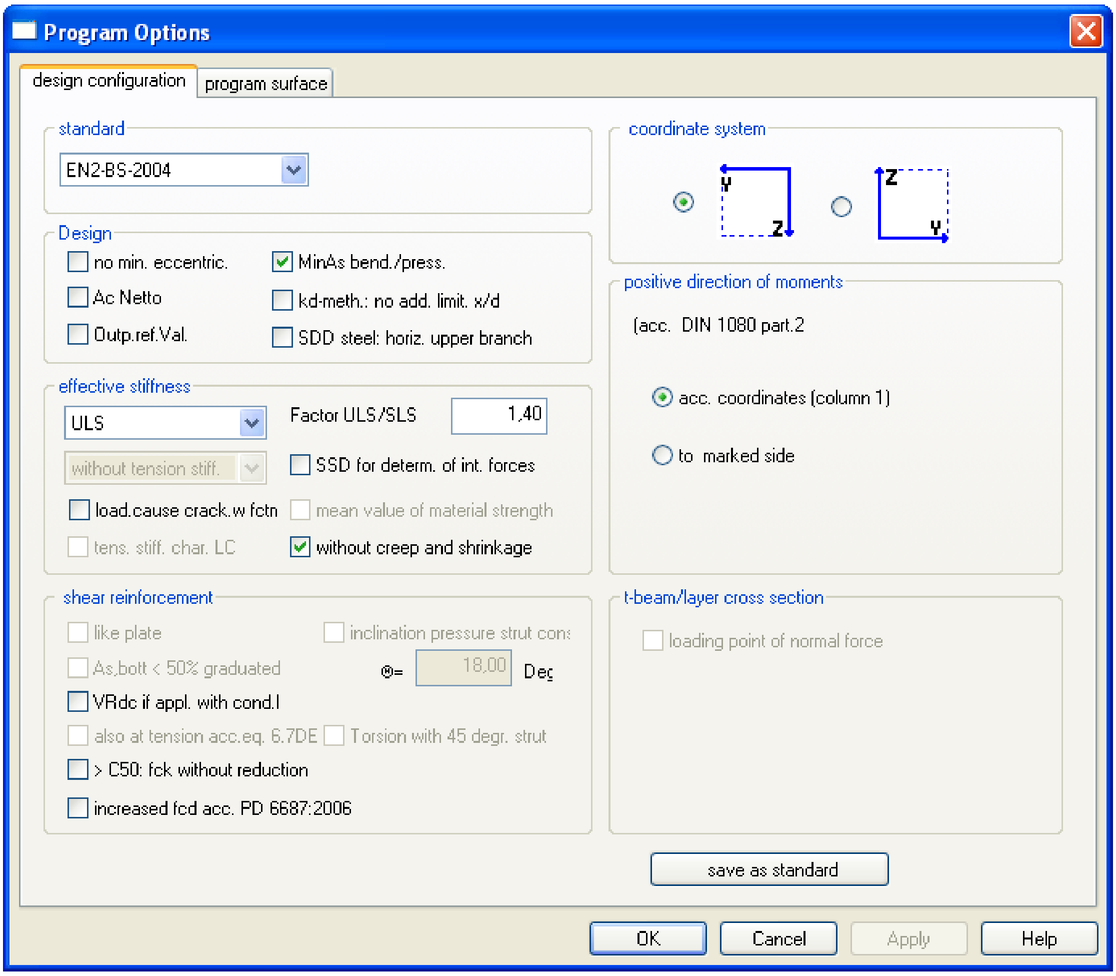
Where compression members (ed/h < 3.5) are concerned, the system checks automatically whether a design of the minimum reinforcement is decisive.

The required minimum reinforcement for components exposed to bending stress is currently not considered.

You can disable the consideration of the minimum reinforcement in the section
→ Design configuration.

Design configuration

Access via the menu item >> Design configuration in the main tree.



Standard

Standard selection → see also System input - standard selection.

When you edit the standard, the concrete and steel classes are matched to the new standard.

System of coordinates

Selection of a system of coordinates:

- My left, Mz bottom (DIN 1080 P. 1, standard)
- My right, Mz top (bar rotated by 180 degrees)

Positive direction of moments

Definition of the positive direction of moments:

- corresponding to the coordinate axes *(DIN 1080 P.2 tab. 1 col. 1)*
- tension sides in positive coordinate direction *(DIN 1080 P.2 tab. 1 col. 2)*

Design

ν **= 1.75 = const.** *(only with DIN 1045 7/88)*

A partial safety coefficient ν **(**Nue) of 1.75 is always used in the design independent of the strain state.

SDD steel with upper horizontal branch *(DIN 1045-1, EN 1992 1-1)*

The inclination of the upper horizontal branch of the stress-strain diagram of the reinforcing steel is neglected in order to obtain results comparable to design charts, for instance.

MinAs flex./comp. member
Enables the minimum reinforcement for flexural and/or compression members.

No additional limitation x/d: → See Design acc. to the KH-method
DIN 1045-1, EC2 Italy, BS 8110, EN 1992 1-1:

No default because limitation is also required without action-effect redistribution.

ÖNORM B4700:

Default because limitation is only required with action-effect redistribution.

Ac net
The concrete area displaced by the reinforcing steel is deducted in the calculation of the internal action-effects on the concrete (recommended when high-strength concrete is used).

Effective rigidity

DIN 1045 7/88

Effect of actions

With breaking loads:	design action-effects · 1.75
With service loads:	design action-effects

DIN 1045-1 / B4700 / EC2 / BS8100 / EN 1992 1-1:

Effect of actions

ULS	action-effects in the ultimate limit state
SLS=ULS/factor	action-effects in the serviceability limit state action-effect SLS = action effect ULS / factor
SLS=Ic q.-perm.	action-effects in the serviceability limit state quasi-permanent load combination
Factor ULS/SLS	factor for the conversion of the action-effects

Tension stiffening

Cross section Qc, Ic	method for the calculation of the tension stiffening on the current section either under quasi-permanent (Qc) or infrequent load combination (Ic).
Component Qc, Ic	method for the estimation of the average tension stiffening of a component at the section exposed to most action-effects either under quasi-permanent (Qc) or infrequent load combination (Ic).
Default	no tension stiffening → see Calculation of the effective rigidity.

W/o creep and shrinkage
If you enable this option, the influence of creep and shrinkage is not considered for the calculation of the effective rigidity.

Default	w/o creep and shrinkage

SDD (stress-strain diagram) for the calculation of action-effects

DIN 1045-1:	Border conditions in compliance with 8.6.1 (7). If the option "Mean values for material strength" is checked, border conditions shall be in compliance with 8.5.1.

EN 1992 1-1: Border conditions in compliance with 5.8.6,
if the option "Mean values for material strength" is checked,
border conditions shall be in compliance with 5.7.

→ See Calculation of the effective rigidity.

Shear design

Like plate
The shear design is based on the assumption that the cross section is a plate (plate strip) independent of the relation of width to height.

As,field < 50% staggered *(EC2-Italy or ÖNORM B4700)*
Scaling factor k = 1.6 -d >= 1 *(ÖNORM kc)* can be set to a favourable value for the determination of VRd1.[2]

VRdct / VRdc in state I, if appl. *(DIN 1045-1 / EN 1992 1-1)*
Calculation of the shear resistance of the concrete according to equation 72 or 6.4 when the border and main tensile stresses are smaller than fctk 0.05/1.8 and/or fctd.

Eq.73 / Eq. 6.7 aDE also with tension *(DIN 1045-1 / DIN EN 1992 1-1)*
You can optionally select a calculation of the strut inclination acc. to Equation 73 or 6.7aDE for cross sections under longitudinal tension. In most cases, the design results are more favourable as in a calculation with cot Θ = 1.00.

Const. strut inclination *(DIN 1045-1 / ÖNORM B4700 / EC2-Italy / EN 1992 1-1)*
The ticking of this option allows you to define a strut inclination independent of the state of the effect of actions for sections that shall be calculated with the inclination angle at the relevant section but are not decisive for the shear resistance analysis, for instance. You should ensure compliance with the limitation of the strut angle in the relevant standard → see Shear design.

Torsion with 45 degrees strut *(EN 1992 1-1)*
Torsion design with simplified methods

For concrete types > C50 characteristic compressive strength (fck) without reduction *(NA_GB))*

If the shear resistance of the concrete is verified via a test, you may take the characteristic compressive strength (fck) for concretes > C50/60 as per NA to BS EN 1992-1-1 also without deduction into account.

Increased design compressive strength of concrete (fcd) in accordance with PD 6687:2006 *(NA_GB)*
According to PD 6687:2006 you may take an increased design compressive strength of the concrete (fcd) calculated with αcc=1.0 into account in the verification of the shear resistance.

T-beam / layers cross section

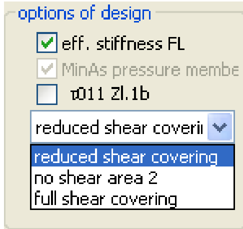
Point of application of the normal force in the centre of the cross section
You can optionally define a central application of loads with T-beams and layers cross sections (standard: load application in the centre of gravity).

Save as default

The button 

allows you to save configuration settings as default, i.e. when defining a new item these values are set automatically.

Design options DIN 1045 7/88



Effective rigidity

When you tick this option, the effective rigidity is calculated for breaking and/or service loads → see Design configuration.

Shear design

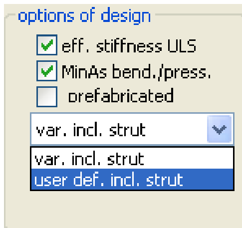
$\tau_{0\,11}$ acc. to line 1b:	The limit value for slabs with continuous reinforcement is determined according to table 13 line 1b.
Reduced shear cover:	The shear areas for beams and/or slabs are taken into consideration.
No shear area 2:	For precast components with cast-in-place concrete according to H. 400 p. 126, for instance.
Full shear cover:	For non-decisive sections when the decisive section is included in area 3, for instance.

MinAs compression member

The compliance with minimum reinforcement for compression members is checked.

Default: enabled with compression force.

Design options DIN 1045-1



Effective rigidity

When you enable this option, the effective rigidity is calculated for the action-effects in the ULS and/or SLS, → see Design configuration.

Shear resistance

Variable strut inclination:	assumption of an inclination according to the effect of actions on the cross section.
Default strut inclination:	an inclination of 45° is assumed if you have not made any other selection in the design configuration section.

Precast component

When you enable this option, reduced material factors are used in the design.

MinAs flexural/compression members

With longitudinal forces:	compliance with the minimum reinforcement for compression members is checked.
With bending stress:	compliance with the minimum reinforcement for flexural members is checked with the cross section types T-beam, rectangle or layers (uniaxial).

Design options ÖNORM B4700

Effective rigidity

See Design options DIN 1045-1.

Shear resistance

Variable strut inclination: assumption of the flattest possible inclination within the limits of Equation 23.

Default strut inclination: see design options DIN 1045-1 .

Variable strut inclination according to Sigsd:

assumption of the flattest possible inclination within the limits of equation 24.

Variable strut inclination with constant Asz:

equation 24 applies due to the constant flexural tension reinforcement between bearings.

MinAs flexural/compression members

With longitudinal compression forces: compliance with the minimum reinforcement for compression members is checked.

With bending stress: compliance with the minimum reinforcement for flexural members is checked with the cross section types T-beam, rectangle or layers (uniaxial).

Design options EC2 (Italy)

Effective rigidity

See Design options DIN 1045-1.

Shear resistance

Standard method: the strut inclination results from the relation VRd1/Vsd depending on the effect of actions.

Variable strut inclination: assumption of the flattest possible strut inclination, see → Shear design according to EC2 (Italy).

Default strut inclination: see design options DIN 1045-1.

MinAs flexural/compression members

With longitudinal compression forces: compliance with the minimum reinforcement for compression members is checked.

With bending stress: compliance with the minimum reinforcement for flexural members is checked with the cross section types T-beam, rectangle or layers (uniaxial).

Design options British Standard BS 8110

Effective rigidity

See Design options DIN 1045-1.

MinAs flexural/compression members

With longitudinal compression forces:	compliance with the minimum reinforcement for compression members is checked.
With bending stress:	compliance with the minimum reinforcement for flexural members is checked with the cross section types T-beam, rectangle or layers (uniaxial).

Design options EN 1992 1-1

Effective rigidity

See Design options DIN 1045-1.

Partial safety coefficients:

In accordance with Annex A, reduced partial safety coefficients (NDP) could be used for pre-cast components that are subject to special quality control.

Shear resistance

Variable strut inclination:	assumption of the flattest possible inclination.
	(NDP, with NA_A acc. to 4.6 (1))
Default strut inclination:	an inclination of 45° is assumed if you have not made any other selection in the Configuration design.

Variable strut inclination according to Sigsd (NA_A)

When σsd < fyd: flatter limit angle acc. to 4.6 (2)

Variable strut inclination with constant Asz (NA_A):

A flatter limit angle acc. to 4.6 (2) is assumed due to a constant flexural tension reinforcement between bearings.

MinAs flexural/compression members

With longitudinal compression forces:	compliance with the minimum reinforcement for compression members is checked.
With bending stress:	compliance with the minimum reinforcement for flexural members is checked with the cross section types T-beam, rectangle or layers (uniaxial).

Output

Output of the system data, results and graphical representations on the screen or the printer.

The item Output in the main tree allows you to start the output on a printer or the screen.

Output profile	allows you to define/limit the scope of data to be put out (output profile).
Screen	displays the values in a text window
Printer	starts the output on the printer
Word	allows the output in the form of an RTF file. The application MS Word is launched (if installed). You can format the output individually in Word.

Output profile

You can define the scope of data to be printed in this section. Select among the available output options:

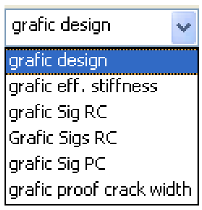
- Graphic
- Durability/creepage + shrinkage
- Bending design
- Minimum flexural reinforcement
- Effective rigidity
- Shear design
- Crack width proof
- Stress analysis

Text view

The input and result values are shown as text. The detailed output includes intermediate values. They are presented in form of a table, if several action-effect combinations have been selected.

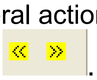
The menu item Output profile (in the main tree or the Edit menu) allows you to select the analyses that should be included in the output.

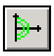
Graphic view



The cross section, reinforcement and strain condition of the selected analysis are shown in the form of a graphic including dimensions.

The total output of an analysis with one action-effect (print icon) covers half a standard page.

In case of several action-effect combinations, you can select the desired combination via the arrow keys .

The icon  in the toolbar allows you to put out general n/m diagrams for the uniaxial symmetric design of rectangle and circle cross sections.

Click again on the icon to return to the standard application mode.

Literature

See document "Analyses at the reinforced concrete section", chapter Literature.