V3 – Composite Beam

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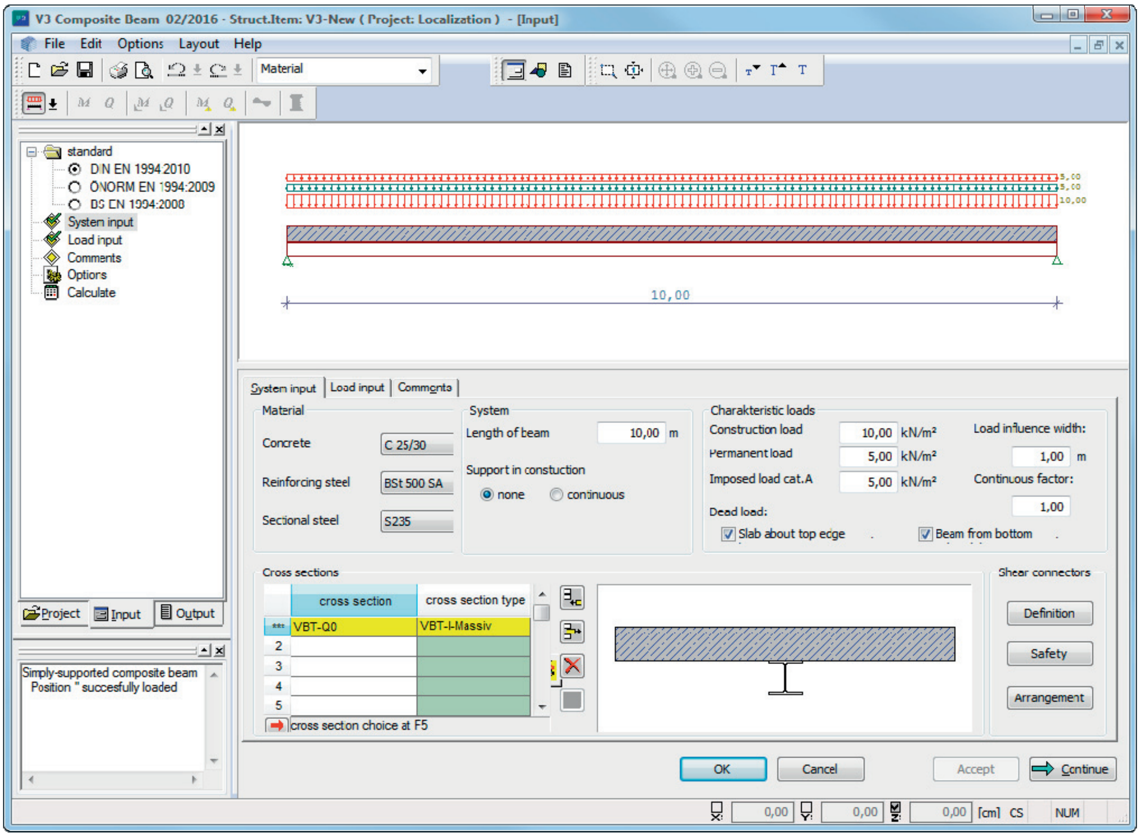


V3 – Composite Beam

Contents

Application options

The V3 application allows the calculation of single-span beam systems in accordance with DIN EN 1994-1-1, ÖNORM EN 1994-1-1 and BS EN 1994-1-1.

The composite cross sections are generated from standard rolled or welded steel sections in combination with any type of slab structure (solid slab, filigree floor with cast-in-place concrete, sectional sheet with cast-in-place concrete). The user can define distributed, uniform linear, concentrated and block loads.

The verification of the ultimate limit state is performed automatically in all critical points. The interaction of bending and shear force is taken into account. The calculation of the required number of shear connectors (bond protection) is performed for full and partial bond. The shear force connectors can be arranged along the shear force application line or distributed at equal spacing between two critical sections.

In the serviceability limit state, creep and shrinkage is taken into account in the calculation of the deformations. The beam cambers are calculated from the individual deformations according to the criteria preset by the user.

In addition, the hot design (R 30, R 60, R 90, R 120 and R 180) for encased steel beams is performed in accordance with EN 1994-1-2.

Basis of calculation

Calculation of cross-sectional properties

The calculation of the composite cross section is based on Bernoulli's hypothesis about cross sections remaining plane and Hooke's law. The composite cross section assembled from different materials is transformed into a cross section with uniform elastic properties for the calculation.

Concrete, reinforced concrete and structural steel have different moduli of elasticity. The reference value for the calculation is the modulus of elasticity of structural steel. Therefore, reduction factors must be introduced for the parts of the cross section made of concrete or reinforced concrete.

The elastic cross-sectional properties are obtained with the help of the total cross section method (in accordance with /11/) and calculated as follows:

$n_0 = \frac{E_a}{E_s}$ Relation of the moduli of elasticity of steel and concrete

$A_{c.0} = \frac{A_c}{n_0}$ Reduced concrete cross-sectional area

$I_{c.0} = \frac{I_c}{n_0}$ Reduced area moment of inertia of the concrete cross section

$A_{i.0} = A_{st} + A_{c.0}$ Ideal area of the total cross section assembled from the reduced concrete cross section and the total steel cross section.

$z_{i.0} = \frac{A_{st} \cdot z_{st}}{A_{i.0}}$ Ideal lever arm of the internal forces

$S_{i.0} = \frac{A_{st} \cdot A_{c.0} \cdot z_{st}}{A_{i.0}}$ Static moment of the ideal cross section

$I_{i.0} = I_{st} + I_{c.0} + S_{i.0} \cdot z_{st}$ Ideal moment of inertia of the composite cross section

The cross-sectional properties for long-term loading depend on creep inside the concrete.

$\alpha_T = \frac{A_{St} \cdot I_{St}}{A_{i.0} \cdot (I_{i.0} - I_{c.0})}$ Cross section parameter

$\alpha_I = \frac{I_{St}}{I_{c.0} + I_{St}}$ Cross section parameter

$\psi_{F.B} = \frac{1}{1 - 0{,}5 \cdot \alpha_T \cdot \varphi_t + 0{,}08 \cdot (\alpha_T \cdot \varphi_t)^2}$ Auxiliary creep factor ($\varphi_t \rightarrow$ creep coefficient)

$\psi_{I.B} = \frac{1}{1 - 0{,}5 \cdot \alpha_I \cdot \varphi_t + 0{,}08 \cdot (\alpha_I \cdot \varphi_t)^2}$ Auxiliary creep factor ($\varphi_t \rightarrow$ creep coefficient)

$n_{F.B} = n_0 \cdot (1 + \psi_{F.B} \cdot \varphi_t)$ Reduction coefficient

$n_{I.B} = n_0 \cdot (1 + \psi_{I.B} \cdot \varphi_t)$ Reduction coefficient

$A_{c.B} = \frac{A_c}{n_{F.B}}$ Reduced concrete cross-section area for loading constant over time

$I_{c.B} = \frac{I_c}{n_{I.B}}$ Reduced area moment of inertia of the concrete cross section for loading constant over time

$A_{i.B} = A_{st} + A_{c.B}$ Ideal area of the total cross section under loading constant over time, assembled from the reduced concrete cross section and the total steel cross section.

$z_{i.B} = \frac{A_{st} \cdot z_{st}}{A_{i.B}}$ Ideal lever arm of the internal forces (loading constant over time)

$S_{i.B} = \frac{A_{st} \cdot A_{c.B} \cdot z_{st}}{A_{i.B}}$ Static moment of the ideal cross section for loading constant over time

$I_{i.B} = I_{st} + I_{c.B} + S_{i.B} \cdot z_{st}$ Ideal area moment of inertia of the composite cross section for loading constant over time

The cross-sectional properties for shrinkage:

$\psi_{F.S} = 0{,}5 + 0{,}08 \cdot \alpha_T \cdot \varphi_t$ Auxiliary creep factor ($\varphi_t \rightarrow$ creep coefficient)

$\psi_{I.S} = 0{,}5 + 0{,}08 \cdot \alpha_I \cdot \varphi_t$ Auxiliary creep factor ($\varphi_t \rightarrow$ creep coefficient)

$n_{F.S} = n_0 \cdot (1 + \psi_{F.S} \cdot \varphi_t)$ Reduction coefficient

$n_{I.S} = n_0 \cdot (1 + \psi_{I.S} \cdot \varphi_t)$ Reduction coefficient

$A_{c.S} = \frac{A_c}{n_{F.S}}$ Reduced concrete cross section area for shrinkage

$I_{c.S} = \frac{I_c}{n_{I.S}}$ Reduced area moment of inertia of the concrete cross section for shrinkage

$A_{i.S} = A_{st} + A_{c.S}$ Ideal cross-sectional area of the total cross section affected by shrinkage, assembled from the reduced concrete cross section and the total steel cross section.

$z_{i.S} = \frac{A_{st} \cdot z_{st}}{A_{i.S}}$ Ideal lever arm of the internal forces (shrinkage)

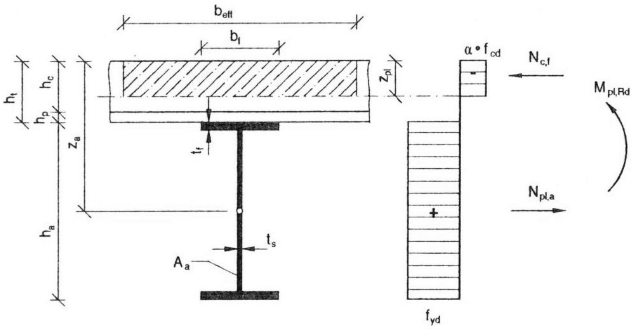
$S_{i.S} = \frac{A_{st} \cdot A_{c.S} \cdot z_{st}}{A_{i.S}}$ Static moment of the ideal cross section for shrinkage

$I_{i.S} = I_{st} + I_{c.S} + S_{i.S} \cdot z_{st}$ Ideal moment of inertia of the composite cross section for shrinkage

Calculation of the cross-sectional resistances

The calculation of the fully plastic moment resistance depends on the location of the neutral axis.

If the neutral axis runs inside the concrete chord, the following applies:



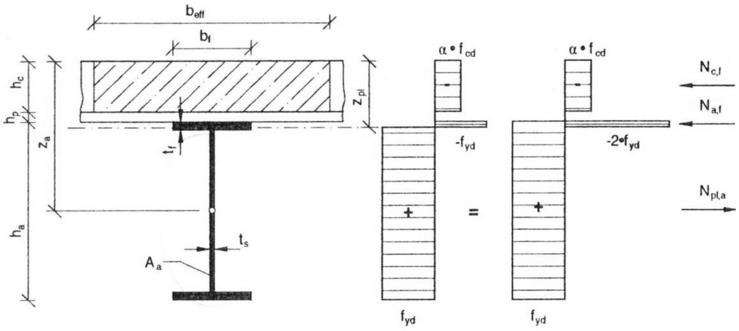
$$N_{pl,a} = A_a \cdot f_{yd}$$

$$z_{pl} = \frac{N_{pl,a}}{b_{eff} \cdot \alpha \cdot f_{cd}}$$

$$N_{c,f} = z_{pl} \cdot b_{eff} \cdot \alpha \cdot f_{cd}$$

$$M_{pl,Rd} = N_{pl,a} \cdot (z_a - \frac{z_{pl}}{2})$$

If the neutral axis runs in the flange of the steel beam, the following applies:



$$N_{pl,a} = A_a \cdot f_{yd}$$

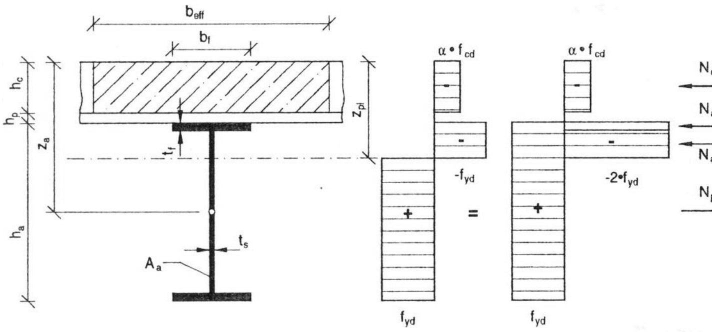
$$N_{c,f} = h_c \cdot b_{eff} \cdot \alpha \cdot f_{cd}$$

$$z_{pl} = h_c + h_p + \frac{N_{pl,a} - N_{c,f}}{2 \cdot b_f \cdot f_{yd}}$$

$$N_{a,f} = 2 \cdot (z_{pl} - h_c - h_p) \cdot b_f \cdot f_{yd}$$

$$M_{pl,Rd} = N_{pl,a} \cdot (z_a - \frac{h_c}{2}) - N_{a,f} \cdot \frac{z_{pl} +}{2}$$

If the neutral axis runs in the web of the steel beam, the following applies:



$$N_{pl,a} = A_a \cdot f_{yd}$$

$$N_{c,f} = h_c \cdot b_{eff} \cdot \alpha \cdot f_{cd}$$

$$N_{a,f} = 2 \cdot t_f \cdot b_f \cdot f_{yd}$$

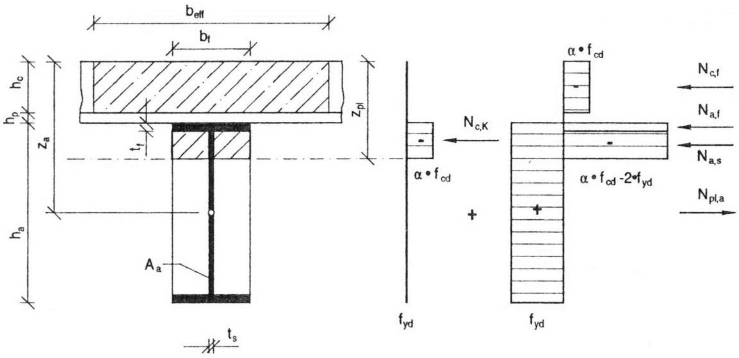
$$z_{pl} = h_c + h_p + t_f + \frac{N_{pl,a} - N_{c,f} - N_{a,f}}{2 \cdot t_s \cdot f_{yd}}$$

$$N_{a,s} = 2 \cdot (z_{pl} - h_c - h_p - t_f) \cdot t_s \cdot f_{yd}$$

$$M_{pl,Rd} = N_{pl,a} \cdot (z_a - \frac{h_c}{2})$$

$$-N_{a,f} \cdot (\frac{h_c + 2 \cdot h_p + t_f}{2}) - N_{a,s} \cdot (\frac{z_{pl} + h_p}{2}$$

If the neutral axis runs inside the web encasement, the following applies:



$$N_{a,f} = t_f \cdot b_f \cdot f_{yd}$$

$$z_{pl} = h_c + h_p + t_f + \frac{N_{pl,a} - N_{c,f} - N_a}{(b_f + t_s) \cdot f_{yd}}$$

$$N_{a,s} = (z_{pl} - h_c - h_p - t_f) \cdot t_s \cdot f_{yd}$$

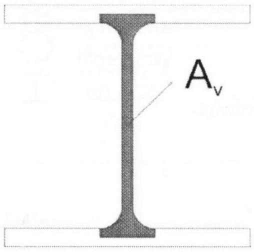
$$N_{c,K} = (z_{pl} - h_c - h_p) \cdot b_f \cdot f_{cd}$$

$$M_{pl,Rd} = N_{pl,a} \cdot (z_a - \frac{h_c}{2})$$

$$-N_{a,f} \cdot (\frac{h_c + 2 \cdot h_p + t_f}{2})$$

$$-N_{a,s} \cdot (\frac{z_{pl} + h_p + t_f}{2}) - N_{c,K} \cdot \frac{z_{pl} + h}{2}$$

The calculation of the shear resistance is performed on the web of the steel beam. The shear area A_v is determined on the "bone model".



The design value of the plastic shear resistance is determined by the expression: $V_{pl,Rd} = \frac{A_v \cdot (f_y / \sqrt{3})}{\gamma_{M0}}$

The interaction between shear force and moment resistance is calculated automatically in accordance with EN 1994-1-1, 6.3.4.

Actions as per DIN EN 1990

The software application calculates automatically the load case combinations from the defined loads in accordance with the selected standard. Available standards are DIN EN 1990, ÖNORM B 1990 or BS EN 1990.

The design situations available in the V3 application are the permanent and transient situations.

Each combination of actions for the permanent and transient design situations must include the following actions:

– All permanent actions

– A dominant action with unfavourable effect as the leading action

– Variable actions with unfavourable effect as accompanying action

The combination of actions is usually mapped with the expression:

$$E_d = \sum_{j\geq1} \gamma_{G,j} \cdot G_{k,j} \oplus \gamma_{Q,1} \cdot Q_{k,1} \oplus \sum_{i>1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i}$$ Eq. (6.10), EN 1990

The selection of the action group in the load input section, the corresponding factors are set automatically.

For the verification in the ultimate limit state, the decisive combinations is taken into account and evaluated in the output.

The partial safety factors of the actions are as follows:

Permanent actions: $\gamma_{sup} = 1.35$

Variable actions: $\gamma_{sup} = 1.5$

The combination rule for the quasi-permanent design situation for the calculation of the deflections is mapped by the following expression:

$$E_d = \sum_{j\geq1} G_{k,j} \oplus \sum_{i=1} \psi_{2,i} \cdot Q_{k,i}$$ Eq. (6.16b), EN 1990

The combination coefficients of the actions are as follows:

	Actions	Combination coefficients		
		ψ_0	ψ_1	ψ_2
	Imposed loads in building construction as per EN 1991-1-1			
1	Category A: residential buildings	0.7	0.5	0.3
2	Category B: office buildings	0.7	0.5	0.3
3	Category C: places of assembly	0.7	0.7	0.6
4	Category D: selling areas	0.7	0.7	0.6
5	Category E: storage areas	1.0	0.9	0.8
6	Category F: vehicles $\leq$ 30 kN	0.7	0.7	0.6
7	Category G: vehicles 30 kN < F $\leq$ 160 kN	0.7	0.5	0.3
8	Category H: Roofs	0.0	0.0	0.0
	Snow loads in building construction as per EN 1991-1-3a			
9	Snow loads above 1,000 m above MSL	0.7	0.5	0.2
10	Snow loads below 1,000 m above MSL	0.5	0.2	0.0
11	Wind loads in building construction as per EN 1991-1-4	0.6	0.2	0.0
12	Temperature loads in building construction as	0.6	0.5	0.0

	per EN 1991-1-5			
a)	For countries not mentioned explicitly, the relevant local conditions should be taken into account.			

Source: EN 1990, table A.1.1

Additional specifications in DIN EN 1990 NA:

	Action	Combination coefficients		
		ψ_0	ψ_1	ψ_2
	Imposed loads in building construction as per EN 1991-1-1			
13	Soil settlements	1.0	1.0	1.0
14	Other actions	0.8	0.7	0.5

Source: DIN EN 1990/NA-1, table NA.1.1

Additional specifications in NA to BS EN 1990:

	Action	Combination coefficients		
		ψ_0	ψ_1	ψ_2
8	Category H: Roofs a)	0.7	0.0	0.0
11	Wind loads in building construction as per EN 1991-1-4	0.5	0.2	0.0
a)	See EN 1990, Para. 3.3.2, additional regulations for high-rising structures			

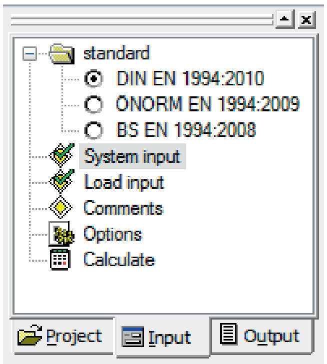
Source: NA to BS EN 1990, table NA.A.1.1

Hot design

The hot design is based on DIN V ENV 1994-1-2, Annex E.1.

The cross-sectional area of the composite cross section incl. web encasement is reduced with the help of the formula specified in the selected standard. The reduction depends on the fire resistance class (see chapter Options).

Selection of the standard



The calculation is based on the European standard EN 1994-1-1.

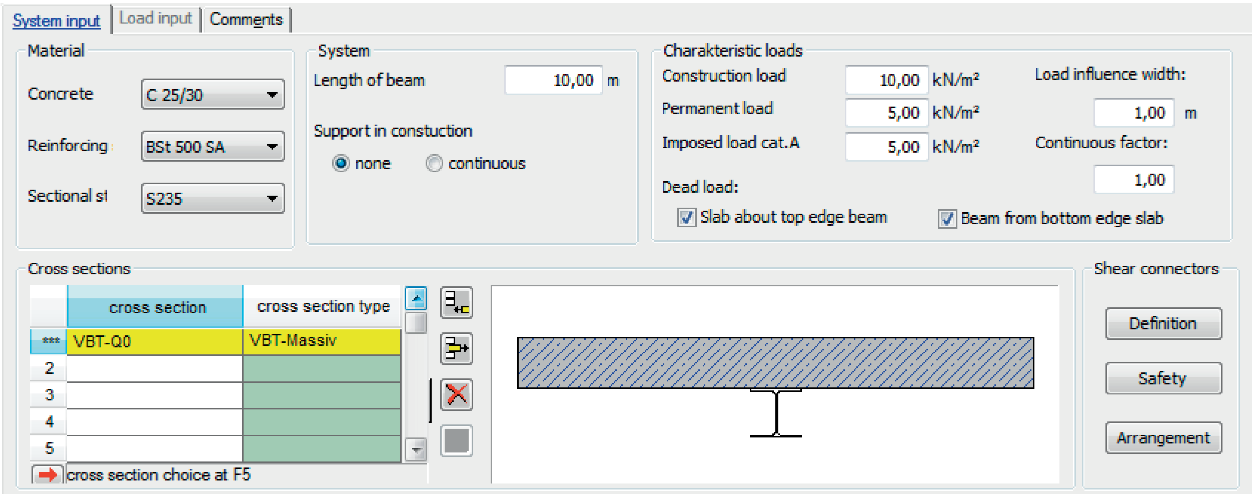
The user selects the applicable standard and the National Annex in the main tree, if several NAs are available; *see the note below.*

The selection includes all standards to which reference is made and their National Annexes.

If no National Annex is available for the selected standard, the basic standard without annexes is used.

Note: *The list price for the software application includes* <u>*one*</u> *National Annex - normally, that of the country where the buyer has its head office.*
National Annexes of other countries are optionally available in addition (see price list).

Definition of the system



Material

The material of the concrete slab, the reinforcing steel and the sectional steel is defined in the window for the input of the system.

The available items in the selection boxes depend on the material standards selected in the Options section.

When selecting a particular material, the material parameters, such as the modulus of elasticity and the compressive strength are set as defined in the selected standard.

System

In the system input section, the total length and the construction history of the composite beam are defined.

Beam length

The total length of the single-span beam. The supporting conditions are generated internally by the software.

Support during construction

The construction method of the beam has an influence on the deformation behaviour under service loads and the steel stresses in the steel beam before the curing of the concrete.

Continuous support during construction (dead-load bond)

Composite beams with dead-load bond are supported during concreting. If the beam was supported continuously, no stresses are generated in the composite beam. If only individual auxiliary supports are used, the steel stresses during construction are lower than if concreting is done without auxiliary supports due to the reduction of the span width. After removal of the supports, the concreting loads (self-weight loads) act on the composite beam in addition to the finishing and live loads. The bearing reactions of the supports in the construction state result from the concreting loads (without portions from the erection loads). They are calculated automatically and taken into account for the loading on the composite cross section.

No support during construction (live-load bond)

If the beam is not supported during the concreting work, the self-weight loads act only on the steel beam. Only the finishing loads and live loads act on the composite cross section. This type of bond is referred to as live-load bond.

Characteristic actions

The user can define standard loading in the system input section that is sufficiently dimensioned for most systems. Additional line and point loads are defined in the Load input section.

All loads are characteristic actions. Therefore, they are entered without a safety factor γ.

A line load q is calculated from the defined affected width (total value of left plus right) and the continuity factor β of the floor above:

$$q = \bar{q} \cdot b \cdot \beta$$

$\bar{q}$: Area load in kN/m^2

b: Affected width

β: Continuity factor: A continuity effect due to the slab above can be taken into account via the continuity factor, if applicable.
Examples:

β = 1.25 double-span slab

β = 1.10 multi-span slab

β = 1.00 single-span beam (default)

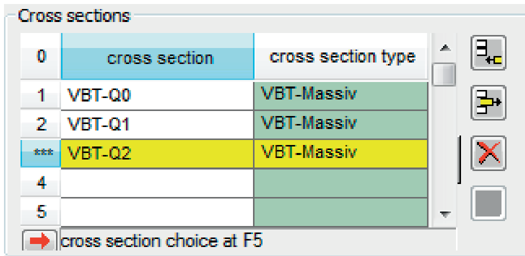
Erection loads are live loads that apply only during construction. They act only on the beam in the way defined in the System input section, independently of whether support was provided during construction or not.

Finishing loads and live loads act on the composite beam. They apply only after the curing of the concrete. Finishing loads (e. g. suspended ceilings, flooring etc.) are permanently acting loads.

The dead loads are the loading due to the weight of the concrete slab and the steel beam including the encasing concrete, if applicable. The software calculates them automatically from the geometric dimensions of the cross section and the material densities. The calculation can include or exclude the concrete slab. If the concrete slab is not included in the calculation, the line loads from the steel beam self-weight and the encasing concrete, if applicable, are assumed as dead loading. The weight of the concrete slab is not considered.

Cross sections

The cross section list in the system input window allows the user to add, edit and delete cross sections.

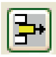


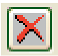
Defining a new cross section:

- Either click to the Add button  and confirm your selection by pressing the F5-key or
- double click inside the next empty cell of the "Section type" column

Editing an existing cross section:

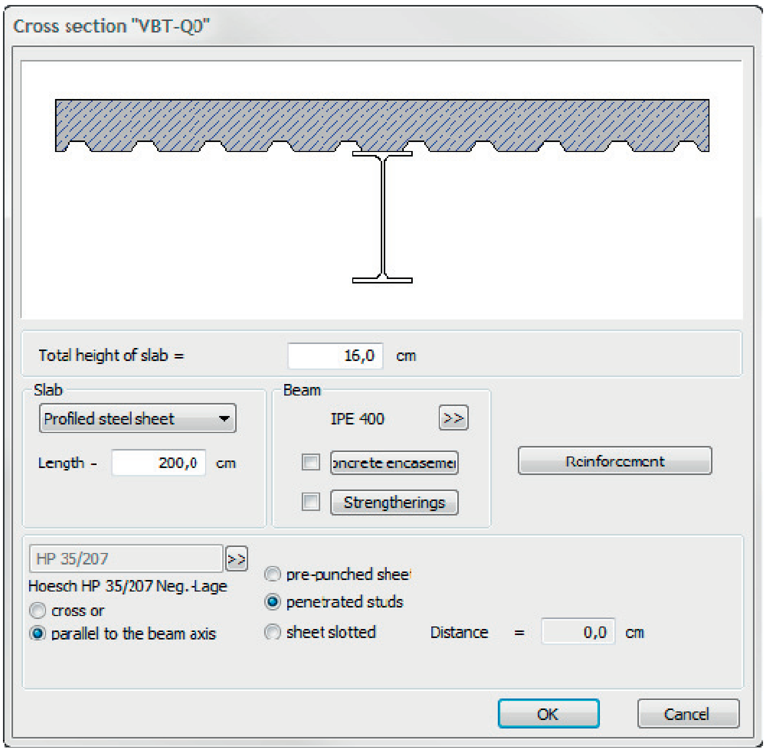
- Either by pressing the F5-key or
- clicking to the arrow button 

Activating the button  deletes the currently selected cross section

Activating the button  deletes all cross sections.

Cross section input dialog

The composite cross section consisting of the concrete slab and the steel shape can be defined with all required input parameters.

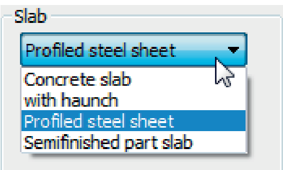


Slab

The concrete slab that bears the area loads can have different designs depending on the requirements.

V3 allows the calculation of the following concrete floor structures.

- Solid slab
- Haunched solid slab
- Pre-cast concrete slabs with cast-on concrete (e.g. pre-cast filigree slabs)
- Cast-in place slab on sectional sheet



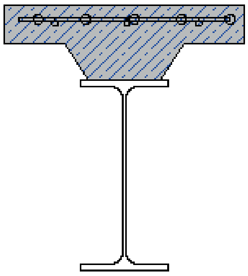
The concrete quality of the slab is defined in the Material section of the system input window.

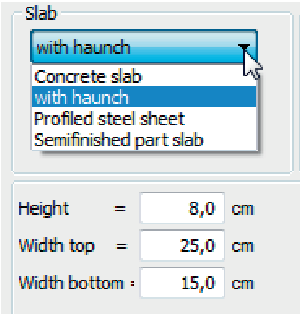
Independently of the design, always the total height of the concrete floor should be entered, i.e. if a filigree floor is used, the total height includes the filigree slab and the cast-on addition and if a haunched cross section is used, the height of the haunch is to be included.

The length specifies the distance from the left to the right slab edge.

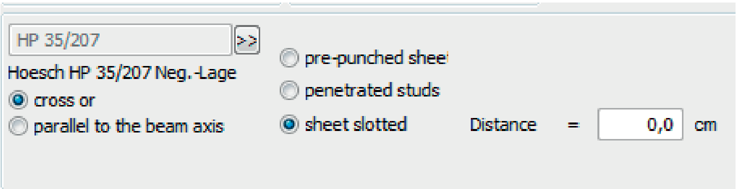
Haunched concrete slab

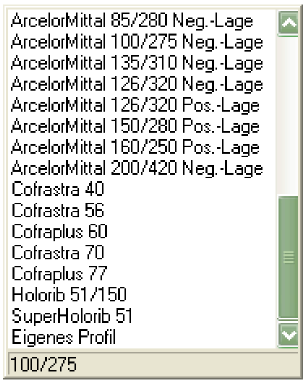
The dimensions of the haunch are defined by specifying the haunch height, the width on top and the width on bottom.





Sectional sheet



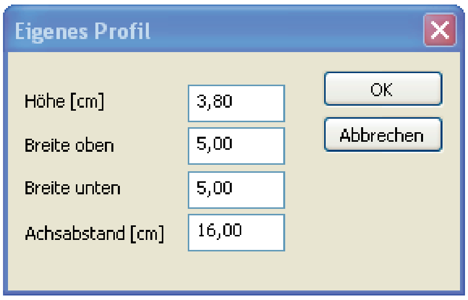


A comprehensive database is available to the user for the selection of the sectional sheets.

Activating the button >> displays all sectional sheets available for selection.

<u>User-defined shape:</u>

The last item in the list allows the user to define a sectional sheet manually. The dimensions of the previously selected sectional sheet are displayed in this dialog and the user can edit them as desired. The modified section can be used in the calculation like any standard sheet, it is not registered in the database, however.



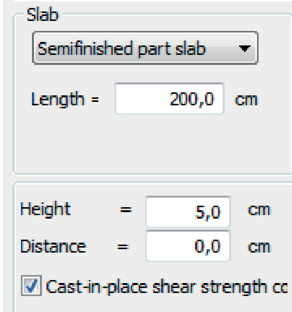
The run of the ribs depends on the span direction of the composite floor. If the ribs run cross to the longitudinal beam axis, the floor spans from beam to beam. If the ribs run in parallel, the floor spans in direction of the longitudinal beam axis.

If discontinuous sectional sheets are used, the user must specify the **distance** of the web axis of the steel beam to the front end of the sectional sheet.

If continuous sectional sheets are used, the user must specify whether the stud connectors are **welded** through the sheet metal or **pre-punched** trapezoidal sheet metal is used.

Depending on the dimensions of the sectional sheet metal and the distance, if discontinuous sheets are used, the software application calculates the exact component dimensions that form the basis of the calculation of the cross-sectional properties.

Filigree floor

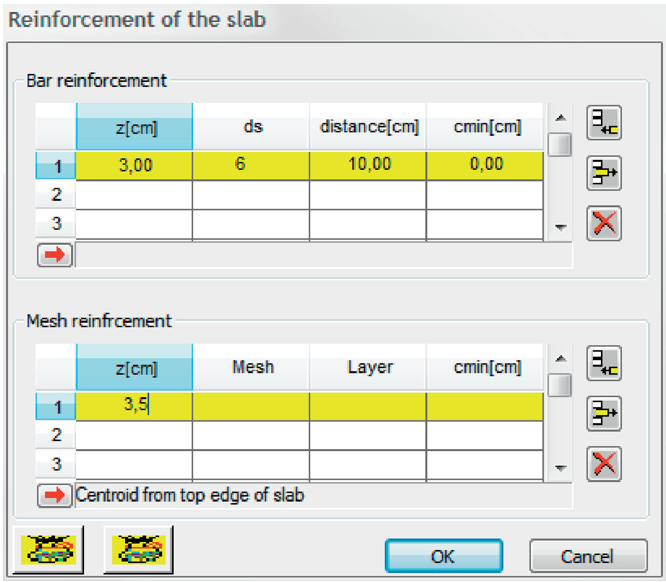


If filigree slabs are used the software prompts the user to specify the height (or thickness) of the slab and the clear spacing between the filigree slabs.

If there is a shear-proof bond between the filigree slab and the cast-on concrete slab, both slabs are considered in the calculation of the cross section. If there is no shear-proof bond, the filigree slab is considered as permanent shuttering, and only the cast-in-place concrete slab is included in the calculation of the cross section.

Slab reinforcement

Click on the button Reinforcement to access the reinforcement dialog.



Several reinforcement layers can be laid in each concrete slab. The location of the reinforcement in the cross section is defined by specifying the distance *z* to the upper component edge. The minimum concrete cover is defined via *cmin*.

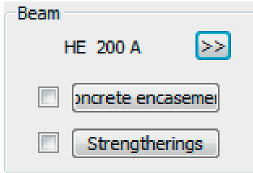
<u>Steel bar reinforcement</u>

If bar steel should be used, the reinforcement content in the concrete slab is determined by the selection of the diameter and the specification of the bar spacing. The diameter is freely selectable. The user can either select a diameter from a list with customary bar diameters or specify a user-defined diameter.

<u>Wire-mesh reinforcement</u>

If wire-mesh reinforcement should be used, the reinforcing fabric can be selected from a list of available types. The installation direction determines the reinforcement cross section, on which the calculation of the cross section is based.

Steel beam



The user can access the shape selection via the button >> in the beam section.

The user can select **I**-beams as rolled shapes from a shape database or specify user-defined dimensions manually.

See also the document [Selecting or defining cross sections.pdf]

Moreover, the user can add encasing concrete and/or stiffeners to the steel beam cross section.

Web encasement

In order to comply with fire protection requirements, for instance, the user can optionally define an overall concrete encasement for the steel beam. The low heat conductivity of the concrete delays the warming up of the composite cross section.

Concrete quality:

The concrete quality is defined via a selection list (see also [Material]).

Load-bearing capacity of the concrete encasement in the cold state:

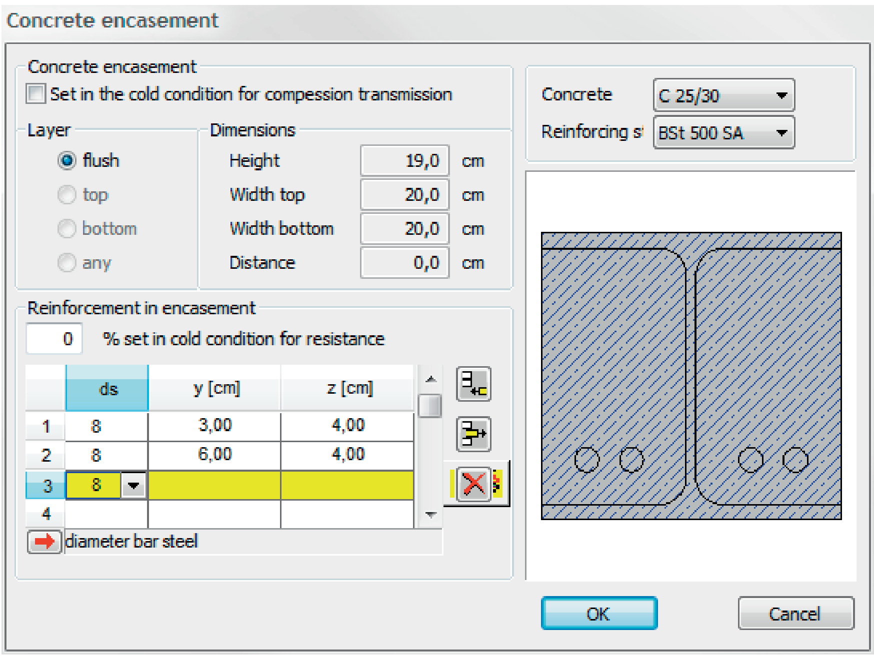
The user can optionally apply compression loads to the concrete encasement in the cold state. In this case, a sufficient number of stirrups or dowels should be provided for the encasement.

Location of the concrete encasement:

Currently, only encasement flush with the steel beam can be defined.

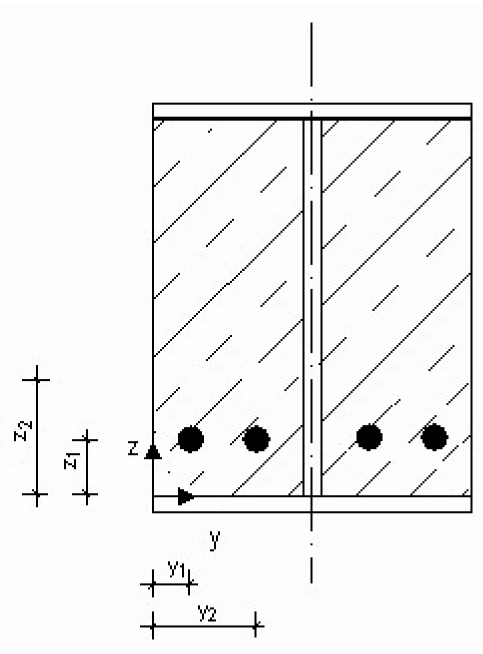
Encasement reinforcement:

In order to ensure a sufficient fire resistance period, encasement reinforcement could be laid in. It is required to compensate the loss of bearing capacity of the steel parts (bottom flange, part of the web), which lose their strength when heating up excessively under fire. The selection of a suitable layout of the encasement reinforcement can have a strong effect on the bearing capacity.
To define the encasement reinforcement, the user must specify the reinforcement steel grade, the bar diameter and the layout of the reinforcement (spacing y and z).



Location of the reinforcement:

The location of the reinforcement in the cross section is defined by specifying the distances y and z. The distances refer to the left bottom edge of the steel shape. The user defines the reinforcement bars only for half of the encasement, the software automatically arranges the bars in a double-symmetrical layout.



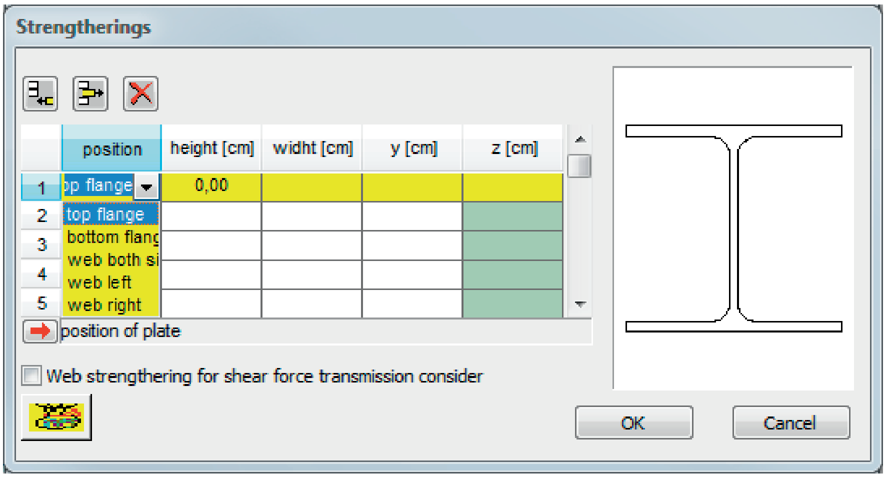
Stiffeners

The user can select additional stiffening sheets. In addition to the height (sheet thickness) and width, their position on the steel beam must be defined.

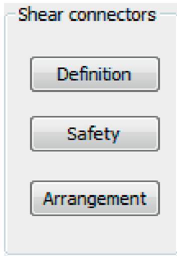
The exact position of the web stiffening sheets is defined by specifying the z and y coordinates and selecting the side of the web (right, left, on both sides).

The user must specify whether the web stiffeners should bear shear forces, i. e. should be considered in the calculation of the shear force resistance.

All sheets are always included in the calculation of the moments' resistance.



Shear connectors



Buttons in the right lower section of the system input window provide access to the options and dialogs for the definition, safeguarding and layout of the shear connectors.

Definition

Stud connectors are used as shear connectors, which are defined by the shank diameter and the total length. Selection boxes in the upper left window section display commercially available stud connectors for selection.

Alternatively, the user can specify user-defined values for the diameter and the length in the input fields on the right. The values in the selection boxes on the left are ignored in this case.

The tensile strength of the dowel is customizable, in case the local construction supervision authorities should impose other values than the default strength of 460 N/mm². The dowel material can have a strength of maximally 500 N/mm².

The load-bearing capacity of the dowel and its position are calculated by the software application.

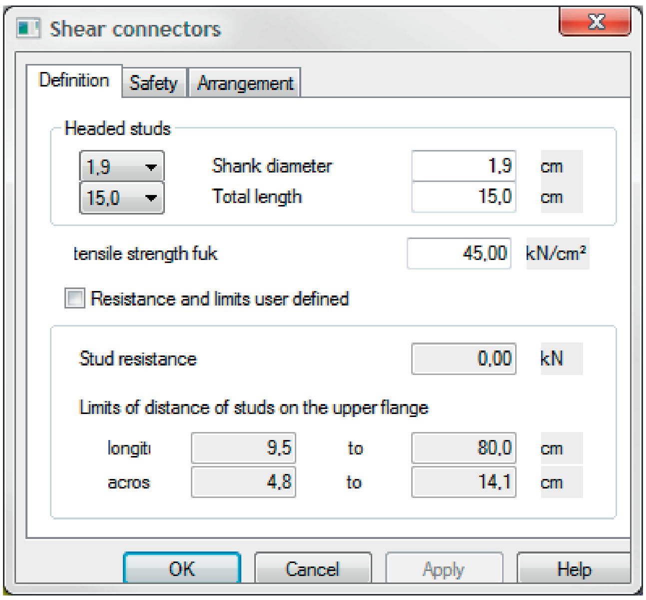
<u>Pre-setting of load-bearing capacities and limits</u>

The user can optionally pre-set the load-bearing capacity of the dowels and their arrangement (minimum and maximum spacing in longitudinal and transverse direction on the top flange).

According to EN 1994-1-1, 6.6.3.1 (1), the smaller of the two P_{Rd} values should be specified. If zero is specified, the dowel resistance is calculated.

If the user does not specify the spacing, it is calculated in accordance with the geometry and the minimum spacing.

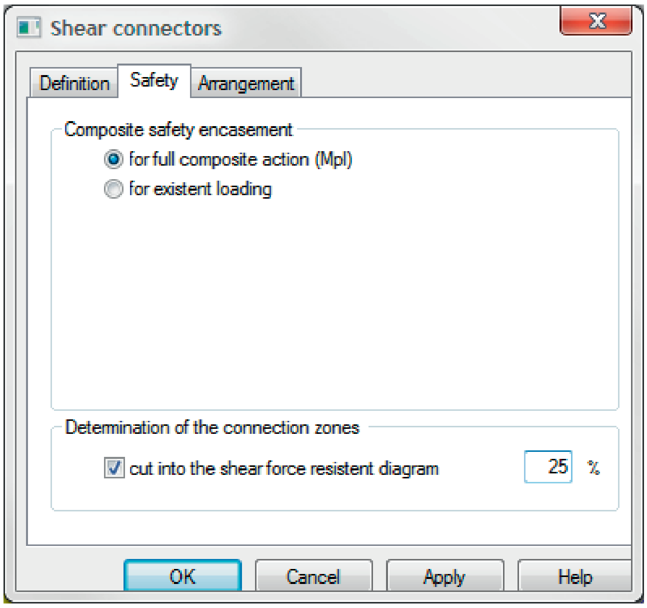
The user can define the complete dowel arrangement manually via the Arrangement tab.

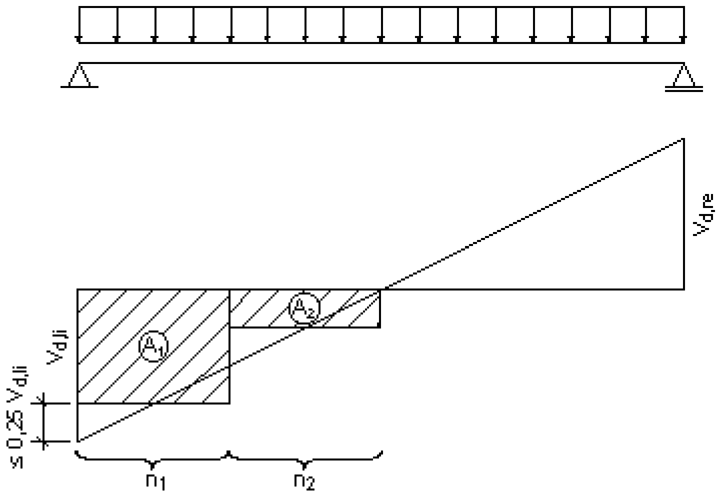


Safety

The verifications of the bond safety in building construction are based on the computed state of failure. The bond safety is verified either under full composite action (M_{pl}) or ($M_{pl,Rd}$) or under the existing loading M_{Sd}. The required number of dowels and the required transverse reinforcement are calculated in accordance with the linearised partial bond method.

The stud connectors are distributed according to the resisting tensile force diagram along the beam. If the cross section is constant, the distribution corresponds to the shear force diagram.





n = n1 + n2

$$n_1 = \frac{A_1}{A_1 + A_2} \cdot n \; ; \qquad n_2 = \frac{A_2}{A_1 + A_2} \cdot n$$

In building construction, a reduction of the peaks in the resisting tensile force diagram is allowed. It is achieved by specifying a percentage. Maximally, 25 % are allowed.

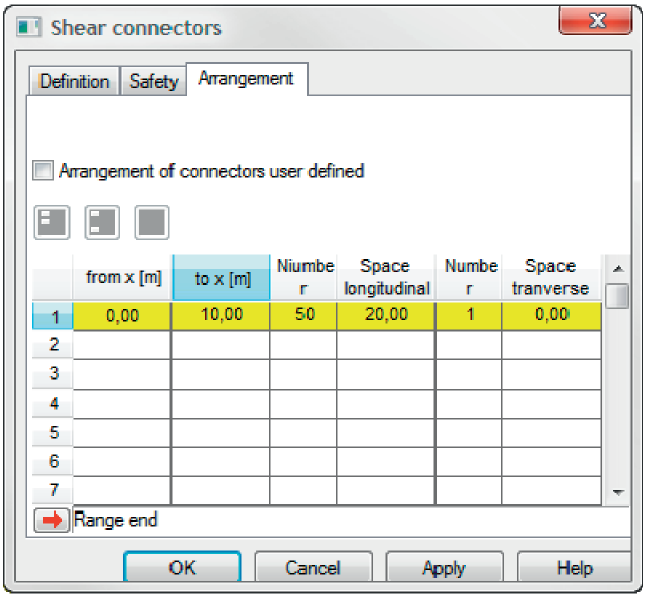
Pre-setting of the shear connector arrangement

By activating the option "Preset shear connector arrangement", the user can define his/her own arrangements.

The dowel arrangement is defined by specifying the global coordinates in longitudinal direction "from x" ... "to x" for each area. The number of stud connectors in a particular area is determined by specifying the number in longitudinal and transverse direction.

If the user edits and changes these values subsequently, all depending values are adjusted accordingly.

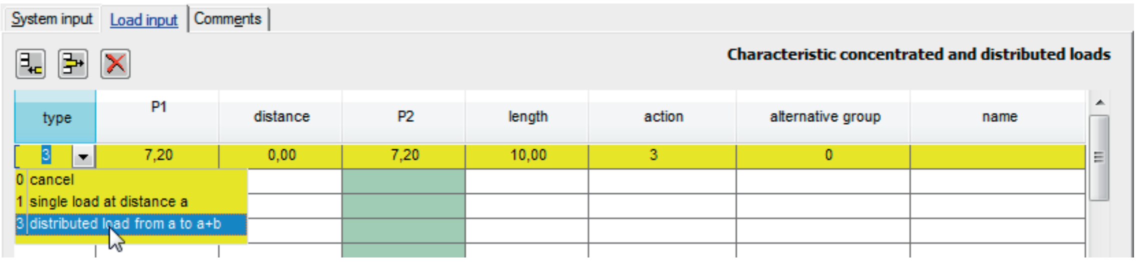
Attention: *When the user presets the shear connector arrangement for the calculation, it is unsure whether the verifications of the minimum dowelling and the moments' resistance produce positive results. The user must check the results after the calculation and define a closer spacing of the dowels, if required.*



Definition of the loads

In the load input section, the user can add other loads (line and point loads) to the standard actions defined in the system input section.

All loads are characteristic actions. Therefore, they are entered without the safety factor γ.



Type 1 = concentrated load

3 = uniformly distributed linear load

0 = finishes the load definition

P1 with concentrated loads = load value

with uniformly distributed loads = load ordinate

Distance distance of the load value or the left load ordinate to the front end of the beam

P2 right load ordinate with uniformly distributed loads

Length length of the uniformly distributed load

Action action group as per DIN EN 1990,
see also load combinations as per EN 1990

Alternative group alternative group of the load; loads of the same alternative group exclude each other

Item optional item reference

Options/Settings

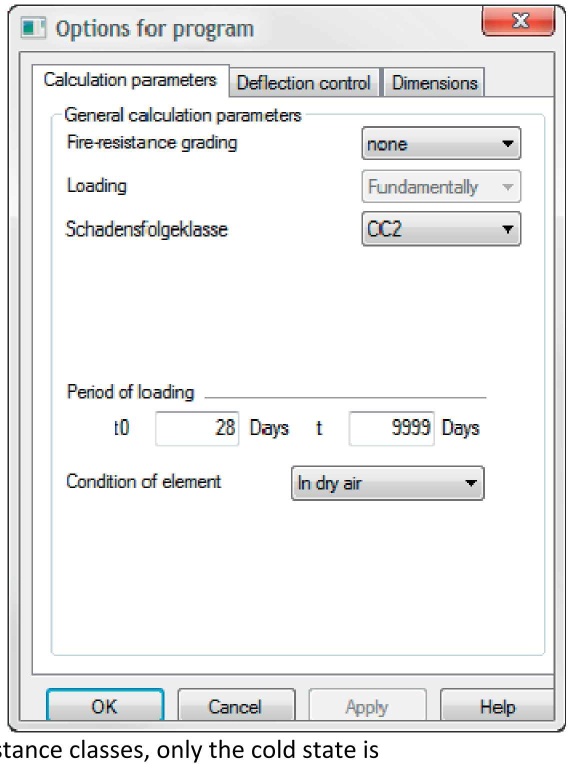
The Options window is accessible via

the menu item

Options >> Settings - composite single-span beam

or the

main tree >> Options



Calculation parameters

Fire-resistance class

Specification of fire resistance classes for the bearing strength verifications under fire exposure.

Available fire resistance classes for composite beams with concrete encasement are R 30, R 60, R 90 and R 180. A prerequisite for the verifications under fire exposure is the definition of a concrete encasement.

The verifications are based on DIN V ENV 1994-1-2.

If the option "none" is selected in the selection list of the fire-resistance classes, only the cold state is verified. If a fire resistance class is selected, the verifications are performed for the hot and the cold state.

See also: Hot design

Loading

The loads in the V3 application are assumed as being "essential". The partial safety factors for the Loads and the Material are set automatically.

See also: Load combinations as per EN 1990

Loading period

The effective concrete age is defined by

t0: concrete age when the load application starts

t: concrete age at the time of examination

These specifications are required for the calculation of the cross-sectional properties because the moments of inertia and the deflections change with time due to creep and shrinkage.

See also: Calculation of cross-sectional properties

Location of the component

This specification is required for the calculation of the cross-sectional properties because the moments of inertia and the deflection changes with time due to creep and shrinkage.

See also: Calculation of cross-sectional properties

Deflection control

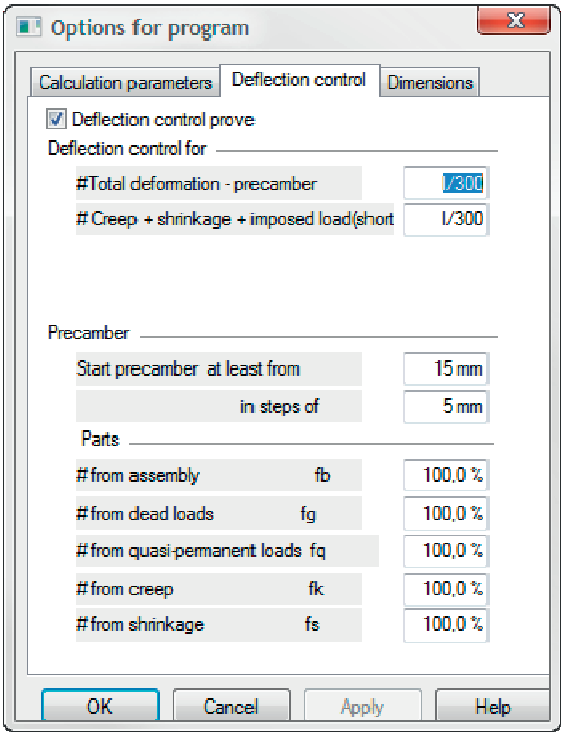
Verification of the deflection control

If the option Verify deflection control was activated, the following deformations are calculated:

- Deformation in the construction state, if the beam is not supported during construction (see System). Otherwise, deformation is set to zero.
- Deformation caused by the decisive quasi-permanent load combination
- Deformation caused by creep. The stiffness of the composite cross section at the times t = 0 and t = infinite are calculated. The decisive deflection is the difference to the deformation caused by the quasi-permanent load combination at the respective time.
- Deformation caused by shrinkage. The shrinkage of the concrete while the beam is fixed with dowels produces a shrinkage moment in the composite beam. The deformation is caused by the internal action.

The total deformation is the sum of all these deflections. Deformation by creep and shrinkage will occur in any case and cannot be influenced after the construction.

Compliance with the specified limiting values should always be made sure to avoid subsequent sagging of the beam.



See also: Calculation of the cross-sectional properties, Load combinations as per EN 1990

Cambers

The user should select cambers in such a manner that no sag occurs under quasi-permanent action after creep and shrinkage is finished.
A camber can only be installed if the beam exceeds a particular lengths. Therefore, the user must define reasonable limiting values for the installation of cambers during construction. In order to obtain reasonable numerical values for the specification of the required camber, the user can define a step width.

Portions

Allows the individual weighting of the deformations for the calculation of the total deformation.

Dimensions

This dialog allows the user to adjust the dimensions for the individual item.

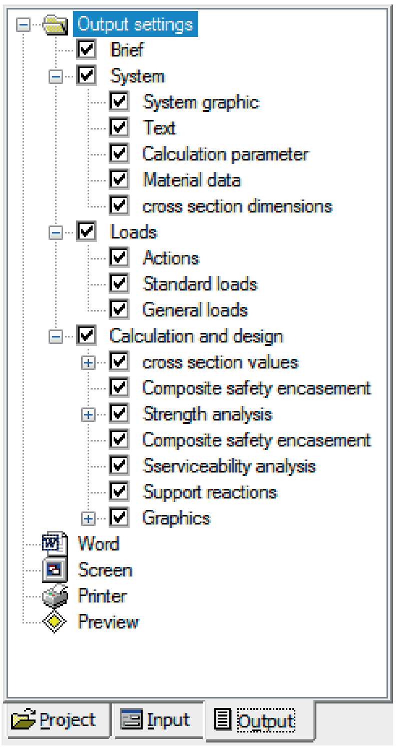
If the user saves the settings as basic settings, every new item is set up with these settings.

The Reset button allows the user to return to the default Frilo settings.

Output

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

The Output tab in the main tree allows you to access the output options (right ill.)



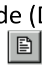
Output profile	allows you to adjust the scope of the output to your requirements by ticking or unticking of the corresponding options. The option Brief version provides for an automatic adjustment of the scope. Only the most important system data and results are put out. The existing settings are not overruled in this case.
Word	If installed on your computer, the text editor MS Word is launched and the output data are transferred. You can edit the data in Word as required.
Screen	Output of the system and result data in the form of tables on the screen (without graphics)
Printer	starts the output on the printer
Page view	displays a preview of the printed page (page layout) to check the output before printing.

 Activating this button in the upper toolbar displays the graphic output data on the screen.

 Activating this button in the upper toolbar displays the text output data on the screen.

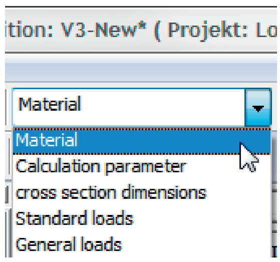
Note:

By clicking to the printer button  in the upper toolbar, the content of the currently active window (text or graphics) is printed.

Please note that results are only available if a calculation of the system was made (Double click on the menu item Calculated in the main tree or simple click on the text output button ).

Contents of the text output

In order to display a particular section of the output text on the screen, click to the corresponding heading in the selection list (see illustration). The associated text section is displayed.



Tool bar for the graphics view

Click first to the graphic button , to display the graphic window.

A tooltip for the individual button is displayed when the user points with the mouse cursor to the button for a short time.

The buttons for the graphics view have the following functions:

- System and load graphics with optional switching to other beam views from the left to the right
- View of the moments and shear force diagrams in the state of failure
- View of the moments and shear force diagrams in the hot state
- View of the moments and shear force diagrams in the construction state
- View of the bending behaviour in the serviceability limit state
- View of shear connector arrangement

The T button on top right allows the user to adjust the font size in the graphics view.

Reference literature

/ 1 / Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings; German version EN 1994-1-1:2004, edition July 2006

/ 2 / National Annex to Eurocode 4 - Nationally Defined Parameters: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings; DIN EN 1994-1-1/NA, draft, edition March 2009

/ 3 / Eurocode 4: Design of composite steel and concrete structures - Part 1-2: General rules - Structural fire design; German version EN 1994-1-2:1994, edition June 1997

/ 4 / Eurocode: Basis of structural design; German version EN 1990:2002, edition October 2002

/ 5 / Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings; German version EN 01/01/1992:2004, Edition October 2005

/ 6 / Concrete, reinforced and prestressed concrete structures – Part 1: Design and construction, DIN 1045-1, edition August 2008

/ 7 / Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings; German version EN 1993-1-1:2005, edition July 2005

/ 8 / Steel structures – Part 1: Design and construction, DIN 18800-1, edition November 2008

/ 9 / Steel structures – Part 5: Composite steel and concrete structures - design and construction, DIN 18800-5, edition March 2007

/ 10 / Schneider, K.-J. (Hrsg.), Bautabellen für Ingenieure: 13. Auflage, Werner Verlag, Düsseldorf 1998

/ 11 / Roik, Bergmann, Haensel, Hanswille: Betonkalender 1999 Teil II, Kapitel B, Verbundkonstruktionen, Bemessung auf der Grundlage des Eurocode 4 Teil 1: Ernst & Sohn Verlag, Berlin 1999

/ 12 / Kuhlmann, Fries, Günther: Stahlbau Kalender 1999, Kapitel 3, Beispiele aus dem Verbundhochbau: Ernst & Sohn Verlag, Berlin 1999