D10+ Glued Laminated Girder

Contents

Application options

The D10+ program is suitable for the design and optimization of the following girder types:

- Parallel chord straight/curved
- Single-pitch roof
- Saddle roof UK straight/round
- Fishbelly circular/parabolic
- Ridge options
  - without saddle
  - sway saddle with raised dry joint
  - fixed saddle

The plies can optionally run in parallel to the girder top edge if the geometry allow this.

The structural systems that can be calculated in this program comprise single-span girders with one or two cantilevers.

Available standards

- DIN EN 1995
- ÖNORM EN 1995
- BS EN 1995
- NTC EN 1995
- PN EN 1995
- EN 1995

Loads

In addition to the typical standard loads of dead load, snow and live loads over the entire beam length, other load types (single and trapezoidal loads) can be calculated. In addition, an exceptional snow load can be taken into account with any factor.
Wind and snow loads are automatically generated as "Standard load cases" in accordance with the applicable standards and can be modified via the "Additional load cases" tab.
During the calculation, entered loads are automatically superimposed with consideration of all combination coefficients.
Internal pressure or suction can be applied via the coi(+) and cpi(-) fields.

Verifications - Calculation

Verifications are carried out for cut grains and shear stresses, the increased longitudinal edge stresses, transverse tension and the interaction between transverse tension and shear at ridge points as well as normal force.

In addition, the stability against tilting and the resistance to bearing stress and deformation are verified. A camber can be specified separately for the span and the cantilever to verify the serviceability.

The lateral girder load is determined and the rise of the initial imperfection can be specified.

Calculation options

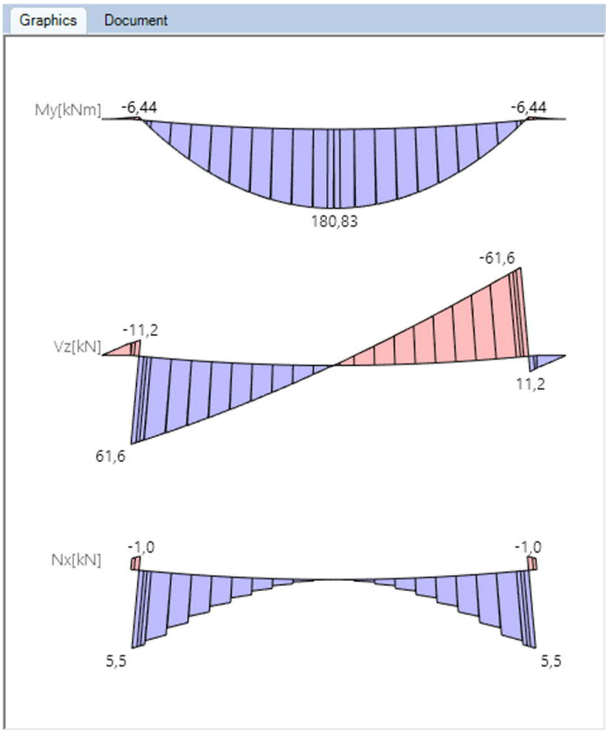
- Depending on the relevant NA, options are offered for reducing the design shear force, such as the reduction of concentrated loads close to the supports.
- Optionally, torsion in the area of the supports due to pre-deformation can be taken into account in the shear resistance analysis including the calculation of the fork support moments.

- Transverse tensile reinforcements: automatic laying of transverse tensile reinforcements with glued-in threaded rods and fully threaded screws including dimensioning of the holes to be produced along the edges of the girder.
- By specifying a distance to the lower girder edge, the user can control the spacing in the transverse tension zones and how the spacing dimensions are rounded. The weakening of the cross section is taken into consideration in the other verifications.
- Fire protection: Verification of the fire resistance period.

Output

The scope of the output can be reasonably limited by options.

You can optionally include e. g. a parts list of the transverse reinforcements in the output.



Graphical display of results

The following graphics can be displayed for combinations and load cases

- Internal forces M, V
- Support reactions Az
- Deflection wz
- Maximum utilizations

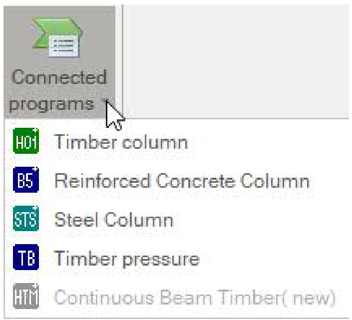
Construction

- Timber volume and surface area to be coated

Load transfer

The bearing loads can be transferred to the program Timber Column HO1+, Reinforced Concrete Column B5+, Single-span Steel Column STS+ and the Toolbox module TB-HHP Timber Pressure.

For the straight parallel chord the interface to the Continuous Timber Beam HTM+ is activated too.



Basis of calculation

All internal forces, superpositions and verifications are calculated with consideration to the special requirements of the selected design standard and its National Annexes.

The verifications of the bending load resistance with consideration of cut grains, the shear load resistance, the stability (against tilting, with different effective lengths for the cold and hot design, if applicable) and the serviceability (deflection) are performed.

In the area of the ridge and/or the curvatures, additional verifications to check increased strain on the longitudinal edge, transverse tension and the interaction of transverse tension and shear force can be performed.

Normal forces are taken into account in the verifications.

The design of transverse tensile reinforcements follows the rules of the selected standard. If it does not specify any rules for transverse tensile reinforcements, the calculation is based on the National Annex for Germany, which is considered as a generally acknowledged rule of engineering in this case.

With curved plies, the ratio of radius to ply thickness (R/t) is checked and, in case of an excessive curvature, a warning message is displayed!

The verifications in the area of the cantilevers are limited to bending stress and shear stress analyses. We like to point out, however, that due to the complex geometry in the area of the supports, stress states similar to those in the ridge area might occur under particular conditions. The required verifications cannot be performed in this program.

The girder is divided into subsections according to the changes in its geometry. Internal forces and deformations are determined in a strut-and-tie calculation.

Restrictions

According to Eurocode, there are no restrictions regarding geometry and cut grains. Reference is made to the limitation of the cross grain cutting angle to 24° in the NAD.

D10+ allows the calculation of any defined geometry, in order to provide designers with a tool for the evaluation of their construction even in exotic cases. However, further verifications may be required.

Notches and cross-sectional jumps in the area of the support or the cantilever are not verified.

A verification of the stability against displacement is not performed.

Data entry

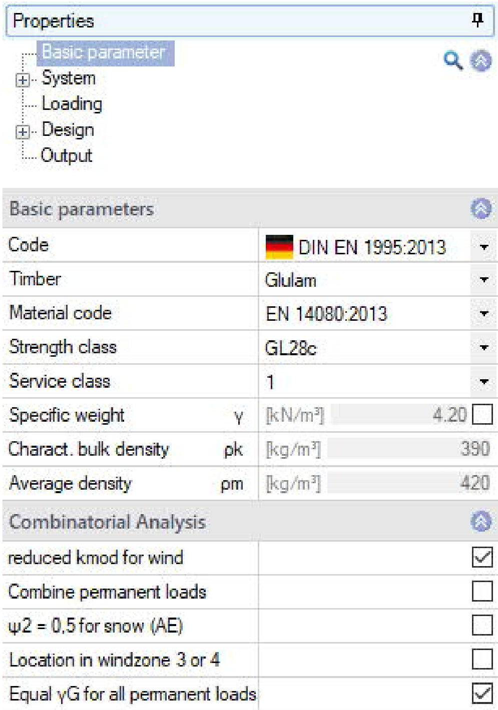
General notes concerning the data-entry fields

This program allows the calculation in accordance with various standards and National Annexes. Some of these standards differ considerably in regard to the load application, the combination rules, the determination of the decisive internal forces and the verification process.

Therefore, the data-entry fields and options can differ from those described below depending on the selected standard.

Basic parameters

Selection of the standards and the materials. Moreover, you can define the strength class and the service class as well as the specific weight in this section.



Strength class:
You can adjust the strengths and stiffnesses. To do this, click in the data-entry field and press the F5 key. In the pop-up menu "User-defined material" you can enter/edit/save/load new materials.

Combinatorial analysis

The available selection options and data-entry fields depend on the selected standard

kmod — check this option to use the modification coefficient ‘kmod’ under wind action as an average value for the load duration classes ‘short’ and ‘very short’.

Comine permanent loads — Specifies the combination rule für permanent loads / loadcases. If checked permanent loads / loadcases will be combined with their inferior and superior factors of safety in order to capture favourable effects appropriately. Otherwise only the superior factor of safety will be assumed.

ψ2=0.5 for snow (AE) — check this option to increase the value of the combination coefficient ψ2 to 0.5 for snow action in the seismic design situation (AE). (See introductory decrees of the German federal states, e. g. Baden-Württemberg).

Wind zone 3 or 4 — check this option if the building is situated in wind zone 3 or 4. In this case, you need not consider snow as an accompanying action to wind, which is the leading action.

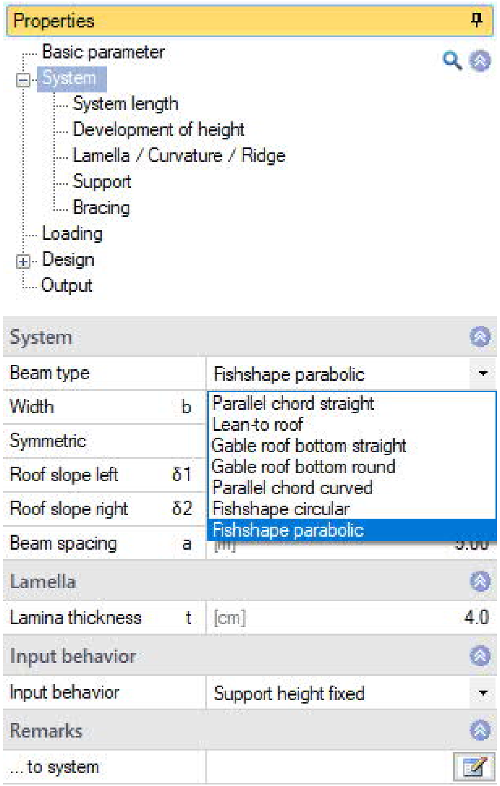
Equal γG for all permanent loads — If this option is selected, all permanent loads or load cases are applied together with the same partial safety factor (γG,sup or γG,inf). Otherwise, all permanent loads or load cases are combined with γG,sup and γG,inf.

Consequence class — select the consequence class to determine the partial safety factors.

Combination equation — select the equation from EN 1990 that should be used for the load combination in the permanent/transient design situation (6.10 and 6.10 a/b).

Structural system

Recommendation: Enter the structural system and the girder shape directly via the context-sensitive menu on the graphic screen!



Selection of the beam type.

Straight TC/BC — parallel chord girder or single-pitch roof girder

Gable roof — double-pitch roof girder with straight bottom edge

General — girder with curved bottom edge, with or without fixed saddle and arch beam

- Parallel chord straight/curved
- Single-pitch roof
- Saddle roof bottom edge straight/round
- Fishshape circular/parabolic

To simplify the input, the option "Symmetrical" can be clicked.

Roof pitch — roof pitch on the upper chord left and right.

Girder spacing — the girder spacing is assumed to be the load influence width when generating standard load cases.

Input behaviour

Note: You can toggle during editing without changing the structural system!

DN and ridge fixed — the roof pitch (DN) and the position of the ridge in the span are retained when entering data. The bottom edge and the elevation of the supports are adjusted.

Support heightfixed — the elevation of the supports is retained when entering data. Top edge, ridge point and roof pitch are adjusted if necessary. If a roof pitch is changed, the ridge is shifted, the elevation of the ridge and the construction height remain the same.
Construction height Hm: Distance of the intersection of the upper edges to the line connecting the ends of the support areas a1/a2 on the span sides.

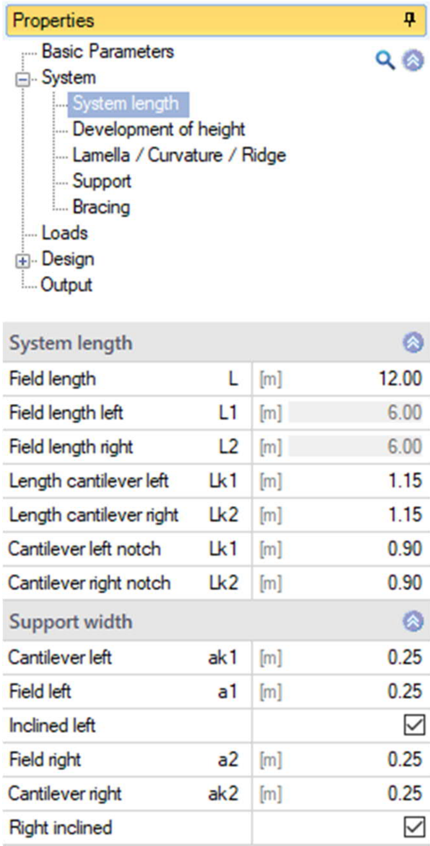
Note: Both modes develop their individual strengths in asymmetrical systems.

Remarks

You can use the remarks editor to enter your own texts/graphics/tables on the system and the results, which optionally appear in the output.

System lengths

In this section, you can enter the horizontal dimensions of the girder. The system lengths L1 and L2 refer to the ridge point.



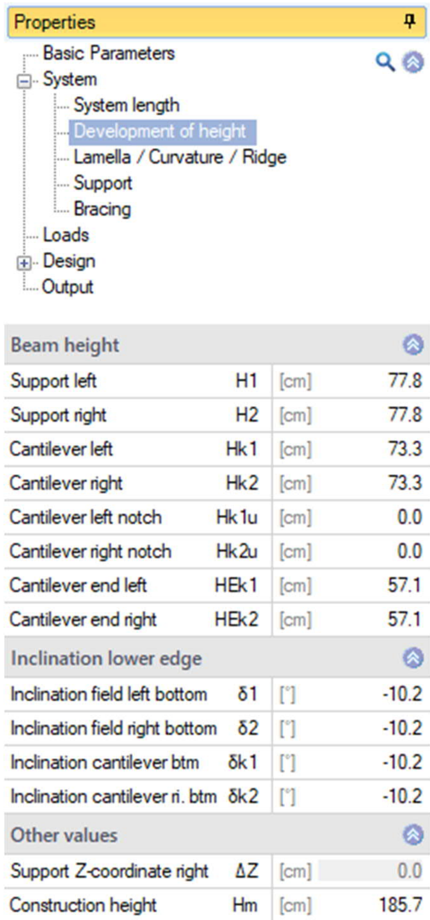
Cantilever notch: the bottom edge of the cantilever can be above or below the bearing surface, unlike in the previous version of D10. This allows the realization of constructive roof overhangs with a smaller cross-section or birdsmouth joints.

Support width

See chapter Supports.

Elevation development

Enter the vertical cross-section heights and the pitches of the bottom edges in this section.



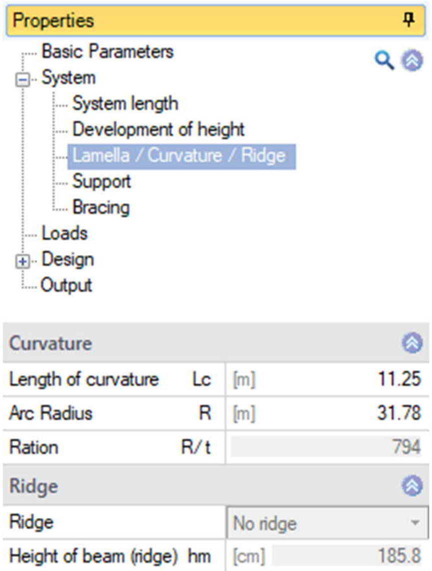
Right z-coordinate of support

Relative elevation of the support on the right, in relation to the support on the left.

Construction height Hm

Distance of the intersection of the upper edges to the line connecting the ends of the support areas a1/a2 on the span sides.

Lamella / Curvature / Ridge



Note: The menu is adjusted according to the selected girder type.

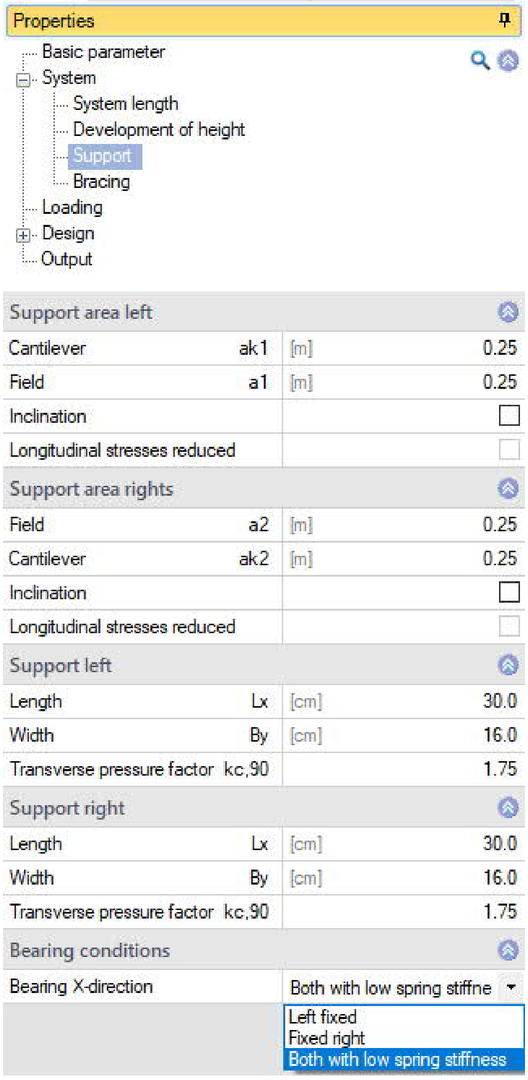
In this section, you can define the length of the curvature, the radius of curvature, the thickness of the plies as well as the orientation of the plies.

The informative field 'R/t' indicates the ratio of the radius to the ply thickness. A value of 300 or more is considered a good value for production.

Ridge (saddle)

In connection with the options 'No ridge' or 'Sliding ridge' you can specify the height 'hm' in the ridge or the position of the dry joint.

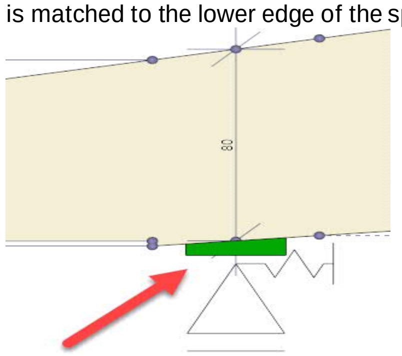
Supports



In this section, you can enter the lengths of the support areas and the dimensions of the supports.
The dimensions of the supports are limited by the length of the support areas ak1,a1, a2, ak2 and the girder width.

Support area

ak1/ak2	the dimension from the support axis to the end of the support area on the cantilever.
a1/a2	the dimension from the support axis to the end of the support area in the span.
Left/Right inclined	each support area can be inclined - the inclination is matched to the lower edge of the span.



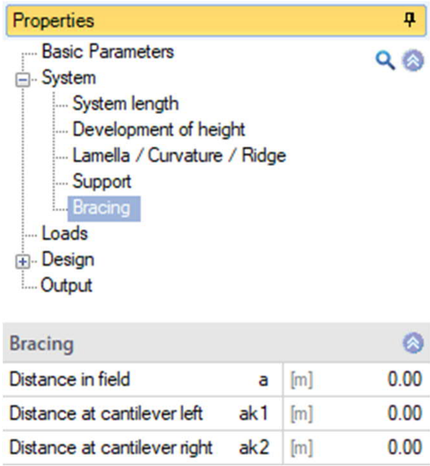
Lx	length of the support area in girder direction. It is at most as large as the support area.
By	width of the support area across the girder.
kc,90	transversal pressure coefficient for the bearing pressure analysis.

In the section 'Bearing conditions', you can define whether the support is fixed:
Support x-direction fixed/soft for left and right

Alternatively, the simulation of two very soft supports (spring approx. 1 kN/m) is available to simulate a girder on two cantilever columns for instance.

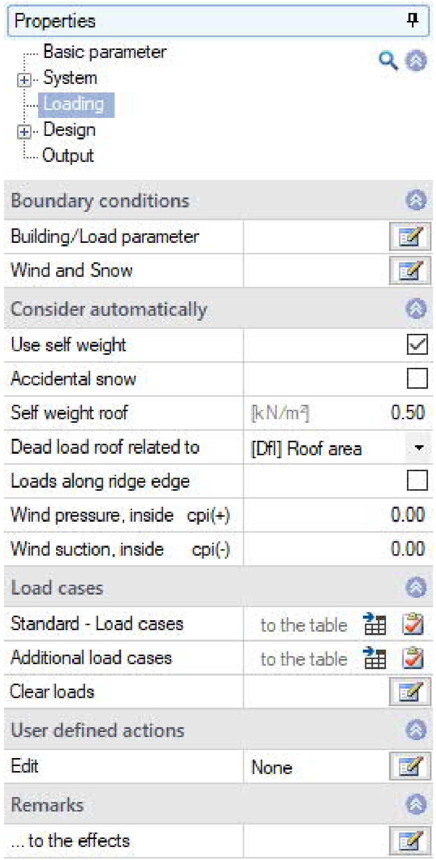
Bracing

a	distance of the lateral restraints in the span, 0 = continuous
ak1/ak2	distance of the lateral restraints on the cantilever arm, 0 = continuous



Loads

Boundary conditions



Building/Load Parameters

A dialog for entering the values for the building geometry and the position of the girder in the building is displayed:

- Elevation of the left support above the ground
- Number of girders including gable walls/gable girders
- Distance between girders, corresponds to the load influence width
- Length of the building
- Continuity factor: the load influence width (girder spacing) is multiplied by this factor
- Area with increased wind suction: the girder is exposed to increased wind suction in the edge/corner area at the gable
- Distance facade from the support axis left/right

Wind and snow

A dialog for entering the values to determine the snow and wind loads is displayed:

- Selection of a municipality/altitude above sea level.
- Selection of wind and snow zones.
- View of building with snow and wind loads

Consider automatically

Self-weight	the self-weight of the girder and its distribution over the girder length is automatically included. The type of saddle is taken into account. You can optionally switch off the automatic consideration.
Accidental snow	you can apply snow as an accidental load.
Factor for acc. snow	factor for the accidental snow load, typically 2.3 in the Northern Lowlands of Germany
Self weight roof	permanent loads of the roof construction consisting of purlins, bracings, roof covering etc.
Dead load roof related to	the dead load can be related either to the roof area or the floor area.
Loads along ridge edge	Loads with orientation to the roof pitch are applied along the cut edge for trusses without a ridge. The effective length of line loads (vertical, transverse) is reduced in this area. Loads (transverse) act perpendicular to the cut edge. Snow: The coefficient *mue* is calculated with the roof pitches left/right - up to 30° roof pitch this has no influence.
Wind pressure/suction inside cpi	coefficients for wind pressure/suction inside the building. They depend on openings in the outer skin and open sides of the building. Suction = positive value; pressure = negative value. Internal suction and internal pressure are added to the respective load cases of imposed roof loads acting in the same direction. This means either suction on the roof and internal pressure or pressure on the roof and internal suction.
Clear loads	Various cleanup options are available in a dialog (remove inactive load cases, etc.)
User defined actions	See Dokument actions user-defined.

Load cases

Via the icon "to table" or via the tabs below the graphic screen, you can access the input tables for the standard load cases and the additional load cases.

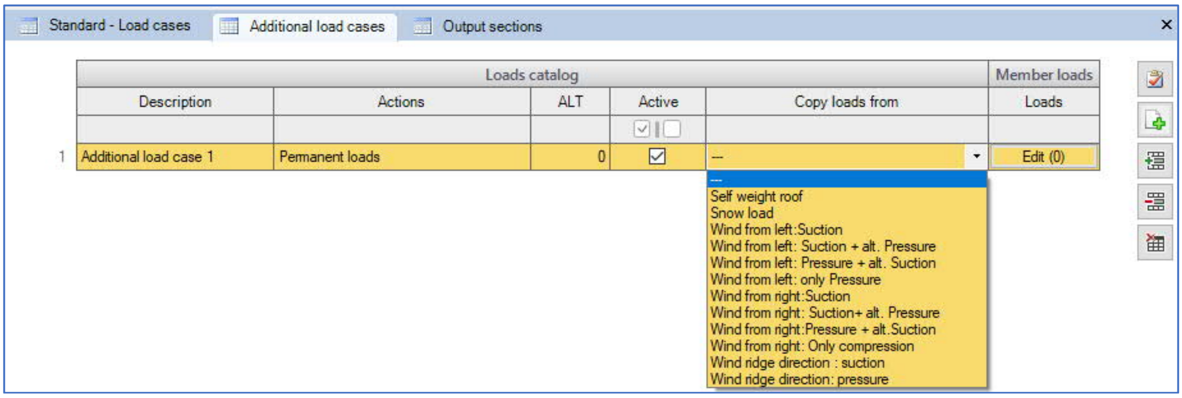
Standard load cases

Wind and snow loads are automatically generated as "standard load cases" according to the relevant standards. These load cases can be switched on and off individually or as a whole in the "Active" column but cannot be edited. Internal pressure or suction can be enabled via the fields cpi(+) and cpi(-).
"Standard load cases" can be copied to "Additional load cases" and edited there (column: "Copy loads from").
In addition, accidental snow load, e. g. in the North German lowlands, can be taken into account with a freely selectable factor.

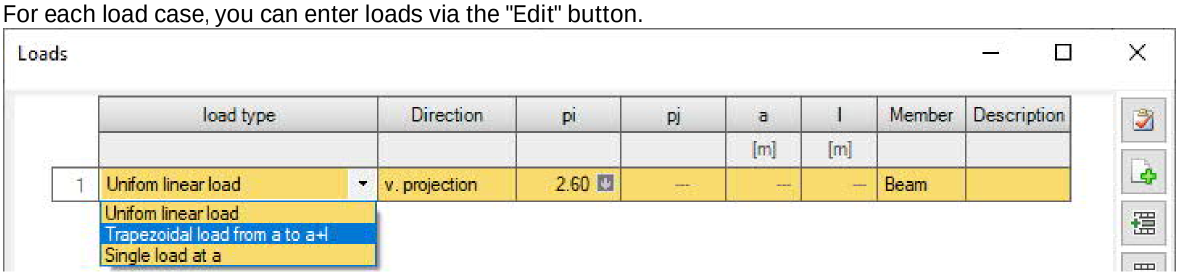
Additional load cases

In this section, you can define your own load cases or copy "standard load cases" to supplement or modify them.

Alt load cases of the same alternative group (> 0) do not apply simultaneously



For each load case, you can enter loads via the "Edit" button.



Note: To add a new table row, click on the "+" icon on the right.

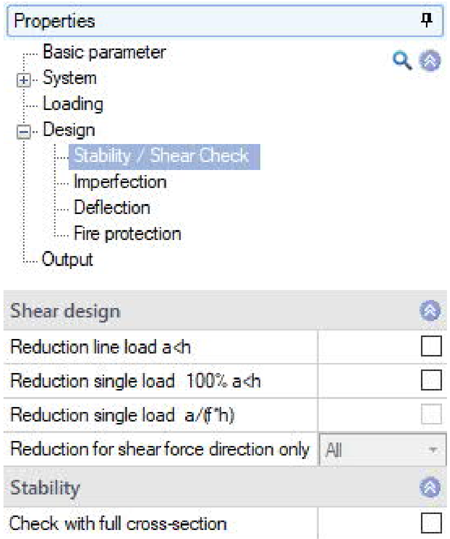
Load type	uniform linear load, trapezoidal load and concentrated load.
Direction	transverse, vertical, v. projection
pi, pj	load value at the beginning or end of the line load
	Via the arrow icon, a load value compilation can be called up - see description in the LAST+ program.
a	specifies the distance of the load to the front end of the component.
l	specifies the length of the line load.

During the calculation, all load cases (standard and additional load cases) that are set to active are automatically superimposed in accordance with the valid combination rules and with consideration of alternative groups.

Design

Shear design

Reduction of line loads



The share of distributed loads in the design shear force is determined at a distance a = 1 * h.

This option may be used for girders under bending stress with supports at the lower girder edge and load application at the upper girder edge. Accordingly, the essential loads should act opposite the support and press into the support.

Reduction of concentrated/single loads

The share of concentrated loads in the design shear force is not considered if the concentrated load applies at a distance of maximally a = 1 * h from the edge of the support.

This option may be used for girders under bending stress with supports at the lower girder edge and load application at the upper girder edge. Accordingly, the essential loads should act opposite the support and press into the support.

Optionally, you can reduce all loads or only loads acting in a particular direction.

Imperfection

Optional application of the German rule for torsion by horizontal deformation: "Md/80 rule"

Imperfection horizontal	horizontal imperfection in middle of the span related to the span length. L/400 pre-deformation L/500 deformation of the bond L/222 = total = entered value Exact values of a deformation calculation of the bond may also be used.
Elevation of bond	distance of the bond from the girder axis in relation to the cross-section height. Upper edge = 0.5; lower edge =-0.5. This takes the backing effect of the bond into account.
Parabolic shape	the parabolic shape corresponds to the derivation with the result: MT = Md/83.33
Always for...	Optionally, the torsional moment is always applied for the cross-section design in front of the support. The rule Lambda,ef < 225 to dispense with the torsional moment is disregarded.

Torsion in the support area

Torsion in the support area is caused by vertical loads in conjunction with a truss axis that is curved in plan. The curvature is made up of the pre-curvature (imperfection) and the bracing deflection due to horizontal loads.

According to German rules, the curvature must be taken into account when calculating the fork bearing moments and the cross-section design in the support area for shear and torsion.

EN 1995 and other National Annexes do not contain any rules on this.

A torsional moment of MT = Myd / 80 should be applied in the support area.

According to the technical literature, the torsional moment is derived for the single-span beam under uniform load with parabolic curvature of the beam axis. In this case, the torsional moment is MT = Myd / 83.33. In principle, this is the sum of the vertical loads multiplied by the lateral deflection of the girder axis in plan.

Using the formulas from the derivation gives the torsional moment to be absorbed by the fork bearing:

$M_{tor,d} = V_d \cdot 2 / 3 \cdot f_F = (p \cdot L / 2) \cdot (2 / 3 \cdot f_F)$

When designing the truss cross-section in the support area for shear and torsion, the effect of the bracing can be taken into account as follows:

$M_{tor,d} = V_d \cdot 2 / 3 \cdot f_F - q_d \cdot L / 2 \cdot e$

Whereas:

V_d	The shear force next to the support
e	Height position of the bracing, to be entered in the program as e/h due to variable cross-section heights h must be entered as e/h in the program. Positive e/h (bracing at the top) reduces the torsion with positive field moments and increases the torsion with negative moments. With e/h=0, the bracing has no influence on the torsion.
p	Uniform load
L	span
f_F	Stitch of the horizontal deformation = L / 400 (pre-deformation) + L / 500 (bracing deflection) = 9 / 2000 · L = 1 / 222 · L) After an exact deformation calculation of the bracing, smaller values may also be appropriate.
q_d	Truss side load (stabilization load) on the bracing, calculated with Myd,field and the tilting coefficient (kmy,Kcrit) of the unstiffened beam (without bracing).
2 / 3	is the fullness of a parabolic deformation figure

With the above standard values and e/h=0, this corresponds to MT = Myd / 83.33.

Approximately, these formulas can be used for non-uniformly distributed loads and also for cantilevers. In the case of large and concentrated loads in the center of the span or at the tip of the cantilever, however, the parabolic filling approach (2/3 · fF) leads to an underestimation of the torsional stress. In this case, the eccentricity f_F should be increased appropriately.

The D10+ program uses these formulas with parabolic curvature as follows:

span: $M_{tor,d} = V_{d,Feld} \cdot (2/3 \cdot f_F) \cdot K - q_d \cdot L/2 \cdot e$

cantilever: $M_{tor,d} = V_{d,Krag} \cdot (1/3 \cdot f_k) \cdot K + q_d \cdot L_k \cdot e$

Whereas $f_k = 2 \cdot 1/222 \cdot L_k$

If you have selected "Parabolic shape", the

factor is set to K=1,

otherwise K=(83.33 / 80).

The effect of the bracing when calculating Mtor,d is only applied if the distance between the tilting brackets (= bracing posts) is less than or equal to half the span length. Otherwise, no effective bracing is assumed.

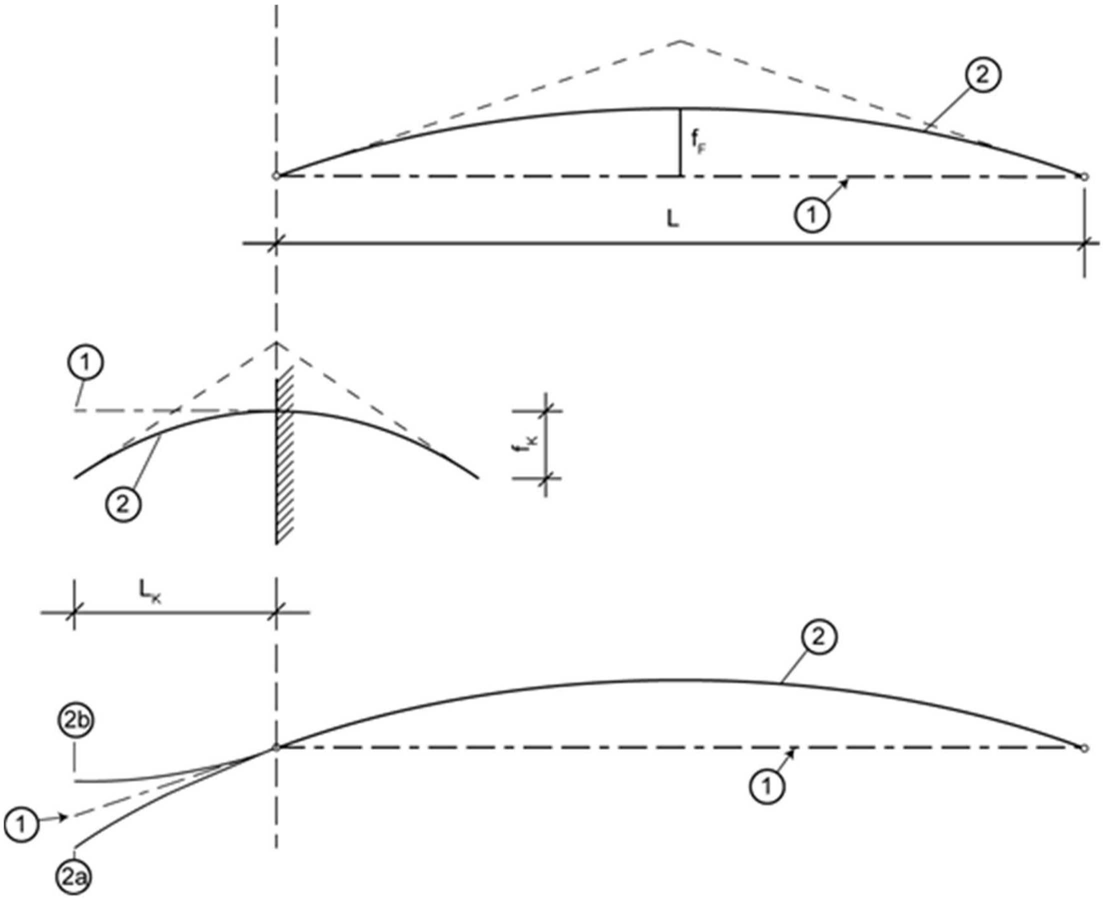
The lateral load q_d is always output, even if the distance between the tilting brackets is greater than or equal to the span length.

The following sketch illustrates the horizontal deformation approach.

Line 1: ideally straight beam axes

Line 2, 2a: horizontal deformation for torsion in the cross-section

Line 2a, 2b: Deformation variation for the maximum fork support moments



Transverse tension

You can select how the minimum force for transverse tensile reinforcements should be determined:

According to standard	the reinforcement is designed in accordance with the standard.
Constructive	constructive reinforcement for transverse tension caused by climate conditions.
Full reinforcement	the reinforcement is designed for the full transverse tensile force.

As a connection device type you can select:

- glued-in threaded rods
- fully threaded screws
- other means of connection

Deflection

Optionally, the calculation can be performed with or without shear deformation.

Serviceability

w,inst	Limit value of the elastic deflection
w,net,fin	Limit value of the sum of elastic deflection and creep deformation
w,fin	Limit value of the final deformation

Cambers

Span camber	upwards is positive
Cantilever camber left	upwards is positive
Cantilever camber right	upwards is positive

Deflection analyses

Here you can enable/disable the deflection analyses for spans and cantilevers.

Fire protection

If the option “Fire exposure” is checked you can specify the required fire resistance period (t_F) in minutes and select the exposed sides of the girder.

Based on these specifications, the program selects the charring rates, which depend on the material and the selected standard.

Always perform shear analysis

The shear analysis under fire exposure is not required by all standards. There is no verification defined in EN 1995, for instance. If laminated girders are used, which often have the smallest cross sections in the areas with the highest shear loading, the analysis should always be performed.

The option "Always perform shear analysis" ensures the required verifications also in combination with standards and NAs that do not explicitly require this analysis. Old German verifications are used, which have been converted into the modern form of verification (DIN 4102-4:1994 and DIN 4102-22:2004, cf. Holz-Brandschutz-Handbuch, Verlag Ernst & Sohn). According to these standards, the shear utilization under fire exposure is derived from the shear utilization at normal temperatures. It results from the formula:

$$\eta_{fi} = 0{,}5 \cdot \frac{\eta_{NT} \cdot b_{NT} \cdot h_{NT} \cdot k_{mod,NT}}{b_{fi} \cdot h_{fi} \cdot k_{fi}}$$

Always simplified

Most standards allow principally a more accurate and a simplified method. For some verifications, a particular method is stipulated.

Therefore, the application switches automatically to the suitable method in accordance with the selected standard, NA and the loading. The additional charring rates associated to each verification are automatically taken into account.

The "Always simplified" option makes sure that the simplified method is used in all verifications, even if it is not allowed by the selected standard. In most cases, the simplified method in on the safe side.

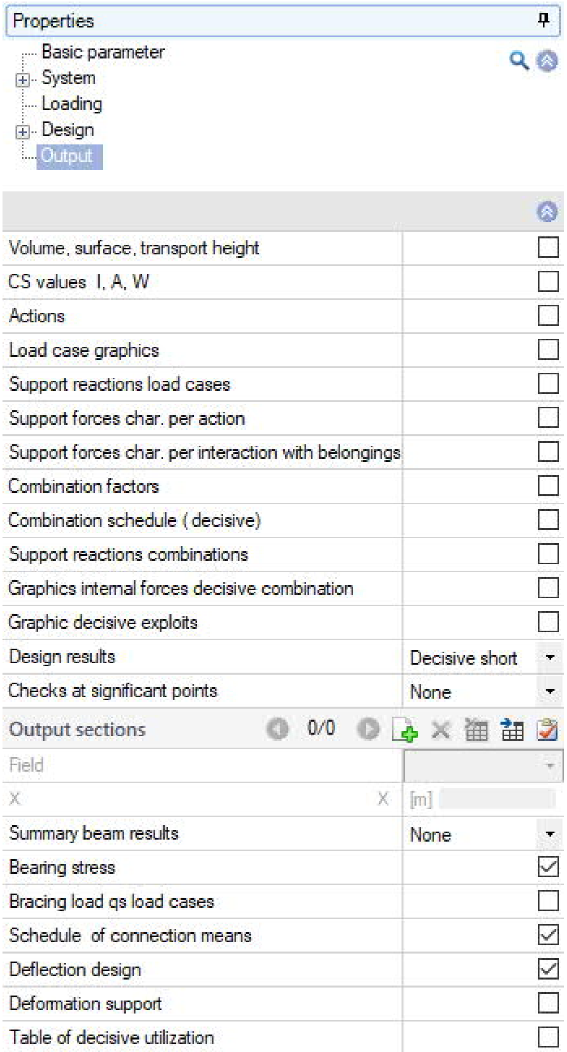
The applied method and the residual cross sections are indicated in the output.

Lateral restraints under fire

Check this option to enter other distances in the event of a fire, e. g. due to the failure of the bond or the roof panel. Bracing components (such as the roof bond, panel, ...) may have a lower fire resistance period than the girder.

See also → Fire protection verification of timber components.pdf

Output



Before starting the output, click on the calculation icon if the option "automatic calculation after each input" is switched off ("Auto off" icon).

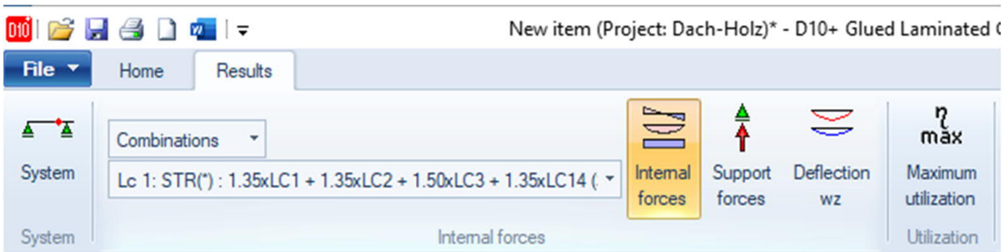
After the calculation, the utilization is displayed in the lower right section of the graphics window and provides a good overview of the efficiency of the structural system entered.

Output scope

By checking the desired options, you can determine the scope of data to be put out. You can also define output sections and/or have them put out by the "Verifications at significant sections" program.

Result options

Via the “Results” tab, you can display the different result graphs.



Output as a PDF document

Via the „Document“ tab, you can displays the document in PDF and print it.

See also [Output and printing.pdf]