Rafter Purlins - D7+

Contents

Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com in the Campus-download-section.

Application options

Rafter purlins combine the functions of rafters and purlins. They are supported by trusses and run in parallel to the eaves.

Available standards

▪ DIN EN 1995:2010/2013

▪ ÖNORM EN 1995:2009/2010/2015/2019

▪ NTC EN 1995:2008/2018

▪ BS EN 2012/2019

▪ PN EN 1995:2010

▪ EN 1995:2008/2014

The software designs

▪ single-span purlins,

▪ tie purlins and

▪ articulated purlins

for roofs with an inclination of up to 45°, which are loaded by self-weight, snow and wind.

The loads can be selected in accordance with EN 1991 (+NA).

The design is performed in accordance with EN 1995 (+NA) and the respective superposition regulation is considered.

The snow and wind loads as per EN 1991 (+NA) can be defined by selecting a climatic zone specific to the respective country or by selecting a municipality in Germany, for instance. The loads are automatically assigned to action groups.

In the output, the actions, the combinations of actions and the results are presented in detail for each load case and each load case combination.

The decisive verifications of the load-bearing capacity and the serviceability complete the output documentation.

The verifications of the fasteners are performed in accordance with EN 1995 (+NA) and are also included in the output.

Tie purlin

Currently, systems with equal span lengths exposed to uniformly distributed loads can be calculated.

Available fasteners for the design of the tie points:

- Nails (round wire nails and plain-shank nails as well as special nails with profiled shanks)

- Special dowels

Articulated purlin

For articulated purlins, you can choose between structural systems with equal support distances and systems with smaller end spans. The latter option offers the benefit of identical cross sections, hinge forces and hinge spacing. The first hinge can be in the first interior span or in the end span. For reasons of stability after the failure of a span, hinged spans and hingeless spans (Gerber girder) should alternate in the selected structural system.

The following fasteners are available for the design of the hinges:

- Bolts
- Special dowels

Depending on the design of the hinge additional verifications might be required.

The following applies to all systems

All load case combinations are examined and the internal forces decisive for the design are determined.

Cross-breaking strength analyses are performed in accordance with EN 1995.

The stiffness of the fasteners in the connections is not considered in the determination of the stiffness and of the internal forces.

The deflection of articulated purlins is calculated as for a continuous beam. The stiffness of the double cross sections above the supports in not considered. According to the reference literature, this method balances out the disregard of the stiffness of the fasteners.

The purlins must be secured against tilting and uplift at the supports. A separate verification of the uplift resistance is required in the area of the intersecting building edges.

In connection with large span widths, bends could occur at the hinges and must be considered in the constructive layout of the roof skin.
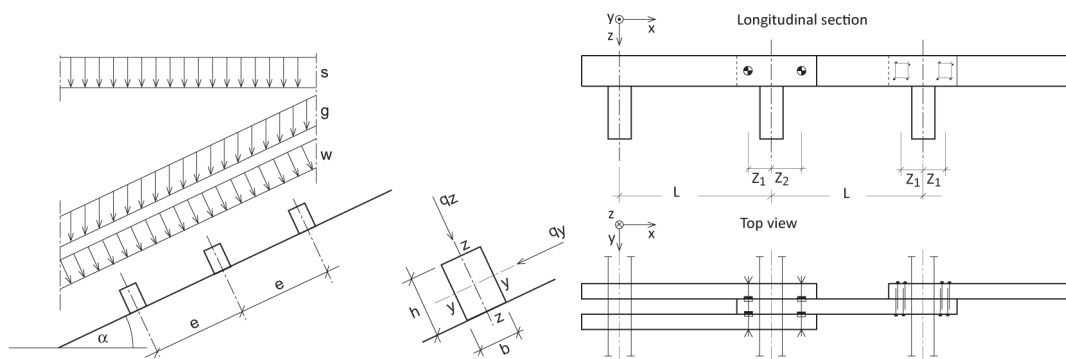
Basis of calculation

The basis for the calculation of single-span, tie and articulated purlins is EN 1995 with its national loading regulations for EN 1990 and EN 1991.

It is assumed that the purlins are installed under the roof and are adequately secured at the supports to prevent buckling and lifting.

Internal forces and deflections are determined mathematically.

The coupling forces are determined mathematically from internal forces and overcoupling lengths. This may result in minor deviations from the tables.

Axial forces, e.g. compressive forces from bracing, can be specified span by span or over the entire length of the purlin. They are taken into account in the verification of load-bearing capacity with and without stability. This also applies to the verification of the fasteners.

Bearing stress can be verified with the toolbox module TB-HHP - Timber Compression.

Man load verifications are neglected during the design. If necessary, these must be taken into account additionally.

Articulated purlins

Since Gerber articulated purlins are statically determined systems, both the position of the joint points and the associated internal forces can be determined directly.

Compensation from left to right

$$V_{d,SL} = -p_d \cdot l + \sqrt{2 \cdot (p_d \cdot l)^2 - 4 \cdot p_d \cdot M_{d,SL}}$$ Shear force column to the left of the span

$$x_{G,1/2} = \frac{V_{d,SL}}{p_d} \pm \sqrt{\left(\frac{V_{d,SL}}{p_d}\right)^2 + \frac{2 \cdot M_{d,SL}}{p_d}}$$ Location of the hinge

$$M_{d,F} = M_d(x_0) = \frac{V_{d,SL}^2}{2 \cdot p_d} + M_{d,SL}$$ Span moment

Compensation from right to left

$$V_{d,SR} = p_d \cdot l - \sqrt{2 \cdot (p_d \cdot l)^2 - 4 \cdot p_d \cdot M_{d,SR}}$$ Shear force column to the right of the span

$$\overline{x}_{G,1/2} = -\frac{V_{d,SR}}{p_d} \pm \sqrt{\left(\frac{V_{d,SR}}{p_d}\right)^2 + \frac{2 \cdot M_{d,SR}}{p_d}}$$ Location of the hinge

$$x_{G,1/2} = l - \overline{x}_{G,1/2}$$

$$M_{d,F} = M_d(x_0) = \frac{V_{d,SL}^2}{2 \cdot p_d} + M_{d,SL}$$ Span moment

Remaining span

For the remaining span for which no moment distribution could be carried out, the missing parameters can also be determined based on the two known support moments:

$$V_{d,SL} = \frac{M_{d,SR} - M_{d,SL} + \dfrac{p_d \cdot l^2}{2}}{l}$$

Shear force column to the left of the span

$$x_{G,1/2} = \frac{V_{d,SL}}{p_d} \pm \sqrt{\left(\frac{V_{d,SL}}{p_d}\right)^2 + \frac{2 \cdot M_{d,SL}}{p_d}}$$

Location of the hinge

Calculation of deflection

Using the moment equation, after integration and determination of the integration constants at the serviceability level, we get:

$$w(x) = -\frac{1}{EI}\left[\frac{p_k}{24}\cdot\left(l^3 x - x^4\right) - \frac{V_{k,L}}{6}\cdot\left(l^2 x - x^3\right) - \frac{M_{k,SL}}{2}\cdot\left(lx - x^2\right)\right]$$

Tie purlins

Determination of the location of the coupling points

The coupling point must be implemented where the magnitude of the (negative) moment in the area of the column corresponds to the span moment that is to be used for the design.

In simple terms, the distances to the column S in the program (as well as in the literature) are determined in proportion to the span length l as follows:

$x_{(2)L} = 0,10 \cdot l$; $x_{(2)R} = 0,17 \cdot l$;   Coupling point on the 2nd support for the initial/final beam

$x_{(n)L} = 0,10 \cdot l$ und $x_{(n)R} = 0,10 \cdot l$;   Other coupling points (n ≠ 2)

Determination of coupling forces

The individual purlin timbers can absorb a maximum of a support moment above the column, which corresponds to the span moment - the individual purlin timber is normally dimensioned for this. This support moment results from the coupling force multiplied by the distance of the coupling point from the support as the lever arm. Converted to the coupling force this means:

$$F_{v,(n)L} = \frac{\left|M_{F(n)}\right|}{x_{(n)L}} \text{ bzw. } F_{v,nR} = \frac{\left|M_{F(n-1)}\right|}{x_{(n)R}}$$

If you divide the overdesign on the column from the two span moments proportionally to the span moments, you get more precise values:

$$F_{v,(n)L} = \frac{M_{mod(n)}}{x_{(n)L}} = \frac{\left(\left|M_{F(n)}\right| - \left(\left|M_{F(n-1)}\right| + \left|M_{F(n)}\right| - \left|M_{S(n)}\right|\right) \cdot \dfrac{\left|M_{F(n)}\right|}{\left(\left|M_{F(n)}\right| + \left|M_{F(n-1)}\right|\right)}\right)}{x_{(n)L}}$$

$$F_{v,(n)R} = \frac{M_{mod(n-1)}}{x_{(n)L}} = \frac{\left(\left|M_{F(n-1)}\right| - \left(\left|M_{F(n-1)}\right| + \left|M_{F(n)}\right| - \left|M_{S(n)}\right|\right) \cdot \dfrac{\left|M_{F(n-1)}\right|}{\left(\left|M_{F(n)}\right| + \left|M_{F(n-1)}\right|\right)}\right)}{x_{(n)R}}$$

Example of the coupling force to the left of support 2 (n = 2):

$$F_{v,2L} = \frac{M_{mod(n)}}{x_{2L}} = \frac{\left(\left|M_{F2}\right| - \left(\left|M_{F1}\right| + \left|M_{F2}\right| - \left|M_{S2}\right|\right) \cdot \frac{\left|M_{F2}\right|}{\left(\left|M_{F2}\right| + \left|M_{F1}\right|\right)} \right)}{x_{2L}}$$

It should be noted that for the span moment, the largest value in the respective bar between the coupling points is used for the design. As a result, negative moments in the area of the coupling point can also become decisive.

Calculation of deflection

If the changes in stiffness of the coupling points (double cross-sections and fasteners) are neglected, the deformation can be determined analogously to the hinged girder.

Definition of the structural system

Assistant

The [assistant](#) is automatically launched when you start the software. It supports the user in defining the most important parameters for a new item. With the help of the assistant, you can quickly define a structural system and gain a first impression of the results. Subsequently, you can adjust secondary parameters in a second step.

Note: You can disable the automatic start of the assistant via the corresponding option on the bottom of the window.

Basic parameters

Select the desired [standard](#) and the material.

Species of timber: - Softwood

- Hardwood

- Glulam

Strength class - F5 key:

The strengths and stiffnesses can be adjusted for solid wood and glued laminated timber. To do this, click in the input field and press the F5 key. You can enter / edit / save / load new material in the "User-defined material" pop-up menu.

*Note: Glulam implemented according to EN 14080: 2013 for Germany and Italy. The "old (DIN)" glued laminated timbers are marked with a * (e.g. GL24c *).*

Service class	1: closed, heated:	AH<65%; BMC<15%
	2: roofed, open:	AH<85%; BMC<20%
	3: weathered:	AH>85%; BMC<24%

Combinatorial analysis

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

reduced 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'.

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

ψ2   check this option to increase the value of the combination coefficient ψ2 to 0.5 in the accidental design situation under snow load. (See introductory decree of the 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 with wind being the leading action.

Equal γG ...   defines whether equal values of the partial safety factor ($\gamma_{G,sup}$ or $\gamma_{G,inf}$) should be assumed for all permanent loads/loadcases. Otherwise the permanent loads/loadcases will be combined among each other with $\gamma_{G,sup}$ and $\gamma_{G,inf}$.
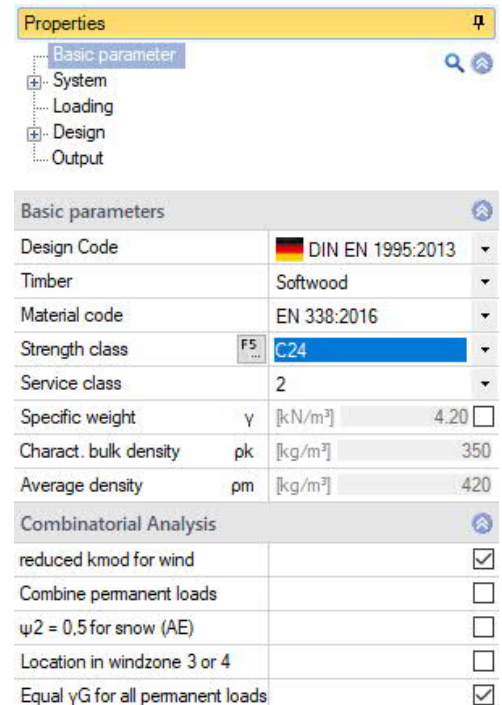
For some standards the following input fields are displayed:

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).

System

Roof pitch	roof pitch α
a	purlin spacing in the roof plane
Purlin type	- single-span purlin
	- tie purlin
	- articulated purlin
System type	- equal span lengths
	- smaller end spans
Hinge locations	
	- in interior span
	- in end span
Consider end span	check this option to take the end span into account in the determination of the tying/articulation points.

Spans

Number of spans	number of spans of the rafter purlin system (up to 10)
L	length of the spans
Cross section...	enter the dimensions of the cross section, width b and height h

Remarks
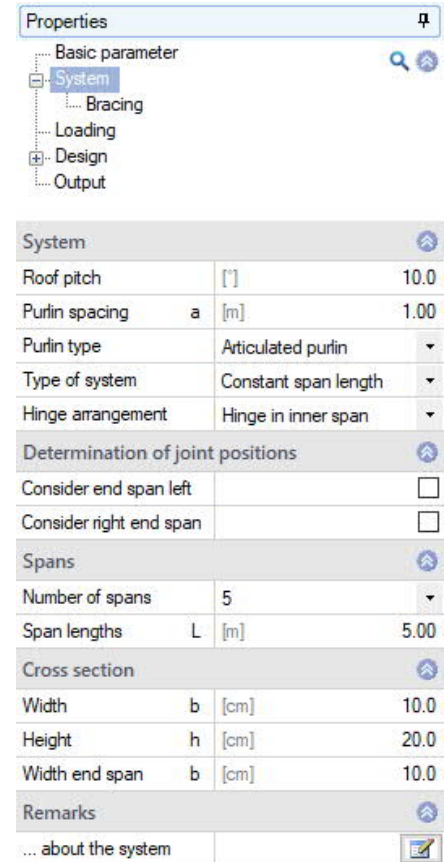
You can optionally enter comments to the system that are subsequently included in the output.
See also Remarks Editor.

Bracing

The lateral support influences the approach of the buckling and tilting length.

Selection:

- None

- Continuous

- Mid span

- Third points

- Quarter points

Loading

Self-weight	Disregard/Uniformly distributed load/Exact (frame)	
Municipality	Wind & Snowloadparameters. Displays a [dialog](#) allowing you to define the wind zone (by selecting a municipality in Germany) and the associated values as well as other wind and snow parameters. *The generated loads are added to the load list. They cannot be edited subsequently. You can delete entries from the list, however.*	
Wind zones	The greatest suction and pressure values are determined from all selected areas. Wind directions are taken into account as follows: H, I, J: always all wind directions F, G: all wind directions or F, G: only the wind directions across the ridge (eaves / purlin)	
Accidental snow	(only in comb. with DIN EN 1995): check this option to include snow as an accidental load (e.g. in the Northern Lowlands of Germany).	
Factor	(only in comb. with DIN EN 1995): factor for the accidental snow load; typically, 2.3 in the Northern Lowlands of Germany	
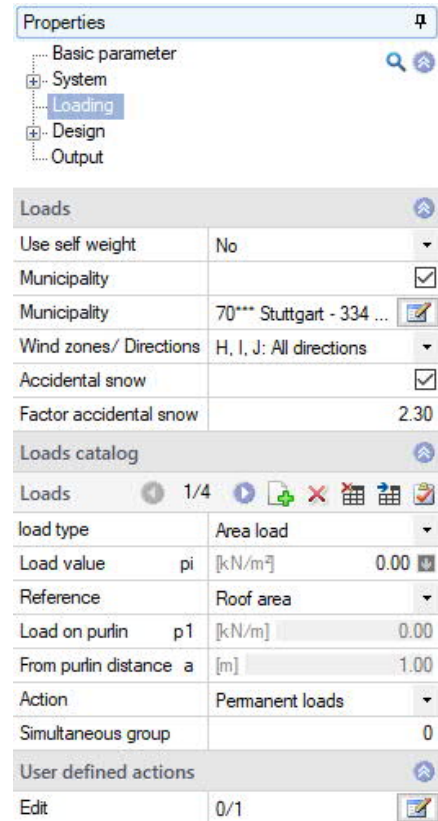
Loads

Enter the values for the first load directly in the corresponding data-entry mask.

Add additional loads with the help of the load toolbar:

- see [Data entry via tables](#) (Basic Operating Instructions)

To add loads, always set up a new entry first by activating the button (an empty data-entry mask is displayed each time).

Alternatively, you can enter additional loads also in a well-structured load table - click on the Loads tab (below the graphical representation) to access the table.

Load type	Uniform line load / area load / axial force	
Last value pi	Direct entry of the load value or call of the [load value combination](#) via the "arrow symbol" .	
Reference	base area/roof area	
Action	allows you to select an action that is assigned to this load: permanent, category H: roofs, wind loads, snow below/above 1,000 m altitude, permanent, removable (pv-Photovoltaics).	
Sim group	Loads can be assigned to a simultaneous group. Loads related to a group (i.e. with the same group number) are always applied together.	
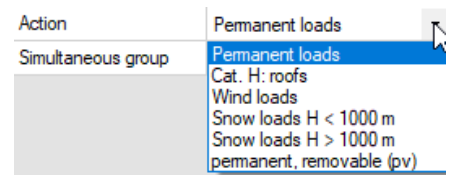
Alternative group   loads of an alternative group are mutually exclusive.

User defined actions   see separate [document](#)

Design

Fasteners

The fasteners available for selection depend on the selected [type of purlin](#).

Type   special dowels, nails, bolts (only in comb. with articulated purlins) / Bolts (only with coupled purlin)

If you need more information on a parameter or data-entry field,

click on the field/option to display a brief help text in the lower area of the window.

Special dowels:

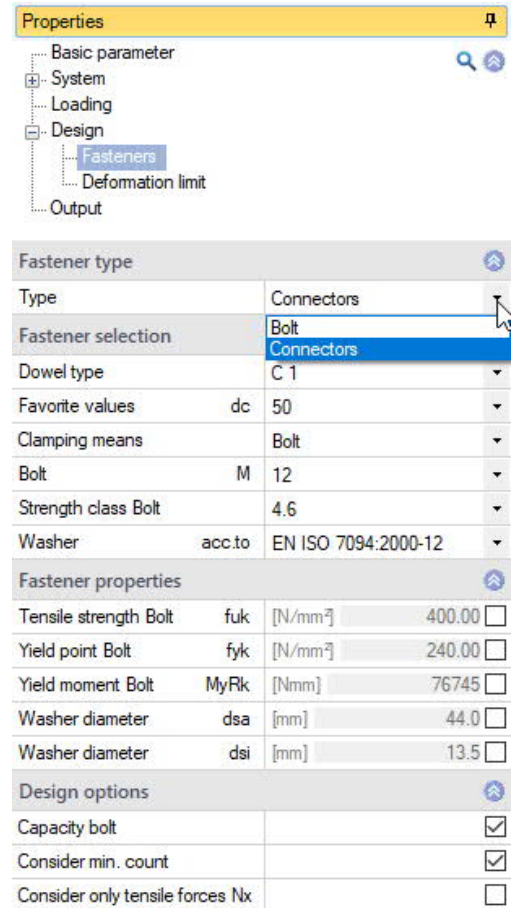Dowel type: A = joint ring
               C = toothed plate

Deformation limits

Permissible deflections

Perm. wInst   permissible initial deflection
                   wInst(standard) = L/300

Perm. wNetFin   permissible total deflection
                   wNetFin(standard) = L/300

Perm. wFin   permissible final deflection
                   wFin(standard) = L/200

Output & results

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

The different options allow you to define the scope of data to be put out.

Click on the 'Document' tab above the graphical window to display the output data in PDF format - see also Output and printing_eng.
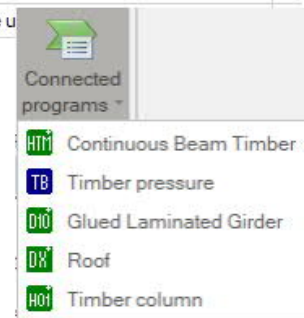
Result graphs

To display the result graphics, click on the button 'Results' in the upper toolbar:
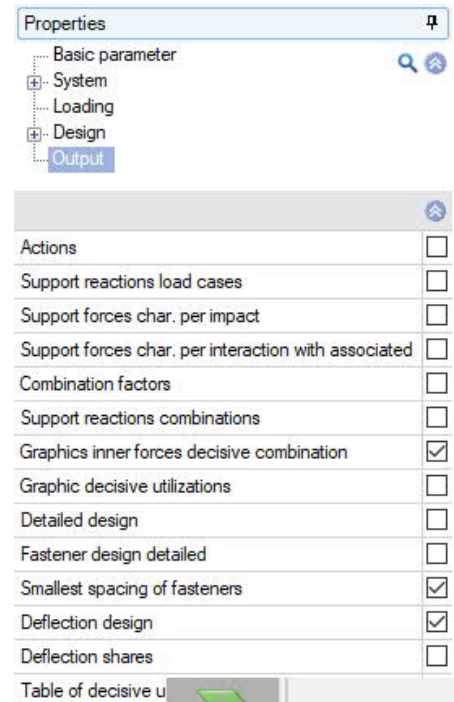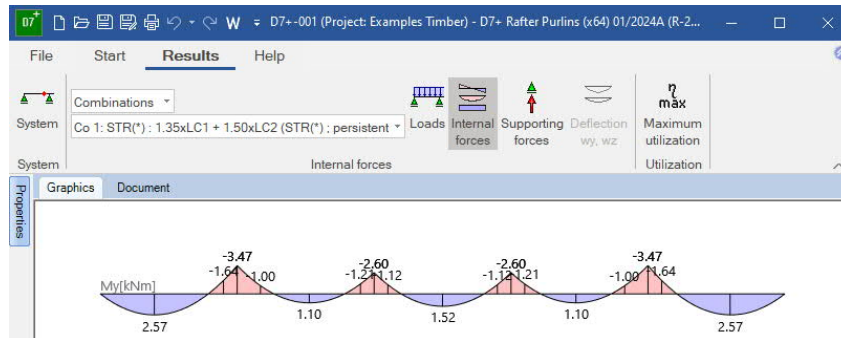
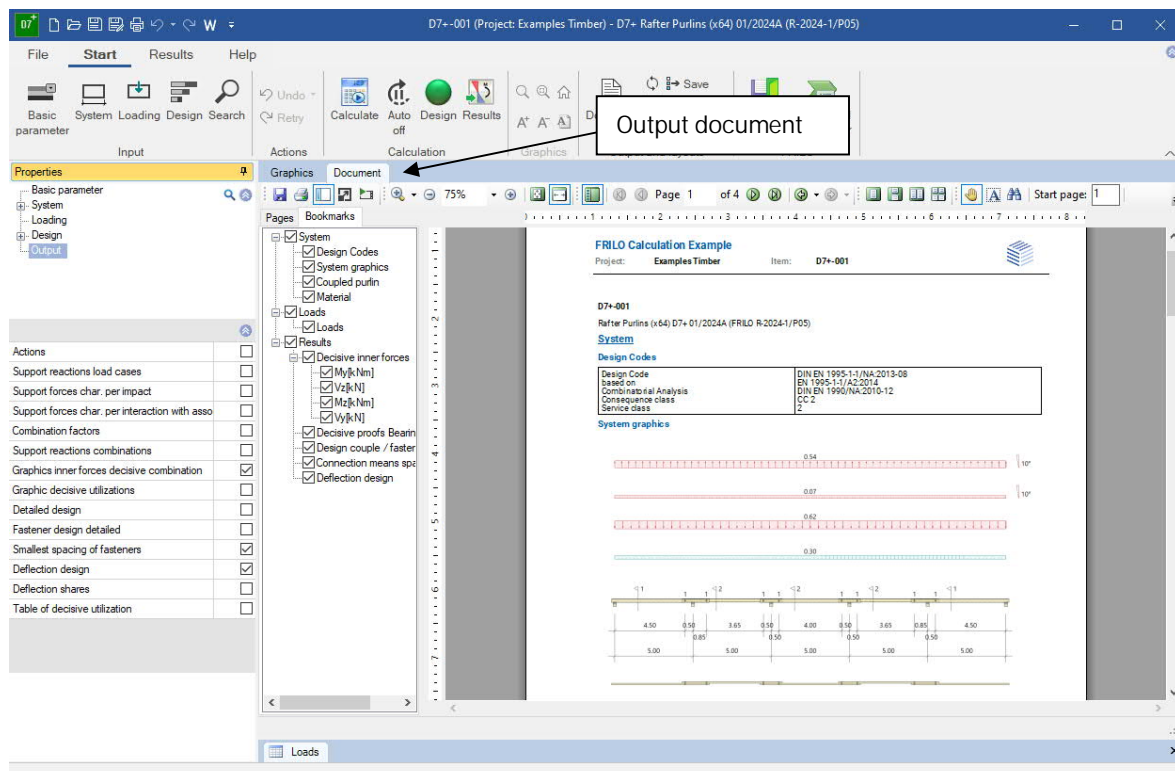## Interface to the Continuous Beam

Single-span and tie purlins can be transferred to the program Continuous Beam Timber HTM+ via the "Connected programs" button.

Other interfaces with system and / or load transfer:

Toolbox-HHP, Glued Laminated Girder D10+, Design of Roofs, Timber Column HO1+

Output document

Reference literature

/1/   Ehlbeck, J. und Siebert, W.: Tragverhalten von Nagelverbindungen bei gleichzeitiger Beanspruchung auf Abscheren und Herausziehen. Research report on behalf of the Federal Ministry for Regional Planning, Building and Urban Development, can be obtained from Informationszentrum Raum und Bau of the Fraunhofer-Gesellschaft, Nobelstr. 12, 7000 Stuttgart 80, Tel.: +49 (0)711/6868-500

/2/   Brüninghoff, H. und Probst, T.: Genagelte Koppelpfetten mit glattschaftigen Nägeln nach DIN 1151. Research report on behalf of the Entwicklungsgemeinschaft Holzbau. Holzwirtschaftlicher Verlag der Arbeitsgemeinschaft Holz e.V., Düsseldorf 1986

/3/   Holzbau-Statische Berechnungen Part 1, Holzwirtschaftlicher Verlag der Arbeitsgemeinschaft Holz e.V., Düsseldorf 1988

/4/   Werner, G.: Holzbau Teil2: Dach- und Hallentragwerke. Werner-Verlag, Düsseldorf, 1982

/5/   DIN 1052:2004/2008

/6/   EN 1995:2004/2008