Crane Runway Girder S9+

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

The S9+ application is suitable for the calculation of crane runways in accordance with EN 1993-1-1 and EN 1993-6.

Crane system

One or *two*

- top-mounted cranes (overhead travelling cranes - CFF, IFF, CFM, IFM system)
- underslung cranes (below the runway beams)
- monorail hoist blocks

Available standards

- DIN EN 1993
- ÖNORM EN 1993
- BS EN 1993
- PN EN 1993
- EN 1993

Verifications

- Verification of the stability against lateral torsional buckling in a second-order analysis
- Stress analyses for the cross section and the weld seams
- Analysis of the local wheel load transfer at the top or bottom flange
- Verifications in the fatigue limit state for the cross section and the weld seams
- Verifications in the fatigue limit state for the local wheel load transfer on the upper and lower flange
- Verification of the stability against buckling in accordance with the method of effective cross sections
- Serviceability verifications

Definition of the structural system

After having selected the crane system, you must define discrete supporting conditions, pinned joints and buckling stiffeners along the craneway girder. The total length of the girder must be specified. Any type of support can be defined with consideration of horizontal stiffening bracings.

- Material: S235, S275, S355...
- Constant cross section: rolled-shaped sections: I, IPE, HE-A, -B, -M, user-defined I-sections with or without reinforcing top flange angles on both sides.
- Crane rail: A-type, F-type or block rail (w/h) with structural effect, if applicable
- Elastic base of top-mounted crane rails
- Bumpers can optionally be fitted outside of the crane runway.

Loading

You can define one or two cranes that are operated independently of each other and optionally assign

- one of the lifting classes H1 to H4 and
- one of the duty groups S0 to S9 as per EN 1991-3

to them.

S9+ allows the calculation of lateral horizontal loads as per EN 1991-3.

Automatic generation of loads for special cases:

The following actions on the crane runway are automatically derived from the specified crane parameters:

- Self-weight
- Vertical wheel loads
- Horizontal lateral loads

In special cases, you can edit these actions. By defining other variable loads, for instance, you can work around a limitation to particular crane systems.

The S9+ application is distinguished by an easy and simple definition of standard cases on the one hand and a maximum of flexibility in special cases on the other hand.

In addition, wind and earthquake loads can be taken into account.

S9+ determines and puts out the bumper forces.

The combinations of actions are generated automatically. You can also directly influence this process.

Imperfection is taken into account in accordance with the horizontal supporting conditions right from the beginning.

Output / interfaces

- Additional output sections showing particular calculation results
- Variable output profile optionally structured according to the system, the loads, the general structural safety verifications or special verifications of the crane runway
- 3-dimensional graphical representation of the results of each superposition for the structural safety, the serviceability and the service strength
- Graphical representation of the limit line of the internal forces Qz, My, Qy, Mz, Mt and Mw
- Graphical representation of axial, shear and comparison stresses in each relevant point of the cross section over the entire crane runway girder, selectable per mouse click
- Graphical representation of the fatigue strength verifications of the entire crane runway girder.
- If the PLII+ and/or BTII+ applications are installed, you can transfer the system and the loading for the web buckling and/or stability analyses. Loads can be transfered to STS+ Single-span Steel Column, B5+ Reinforced Concrete Column and HO1+ Timber Column.

Limitations

- Constant cross section
- No hollow boxes
- Forces produced by start-up and braking operations of the crane bridge are not considered in the present software version.

You might be required to adjust subsequently the imperfection produced by the decisive action.

Basis of calculation

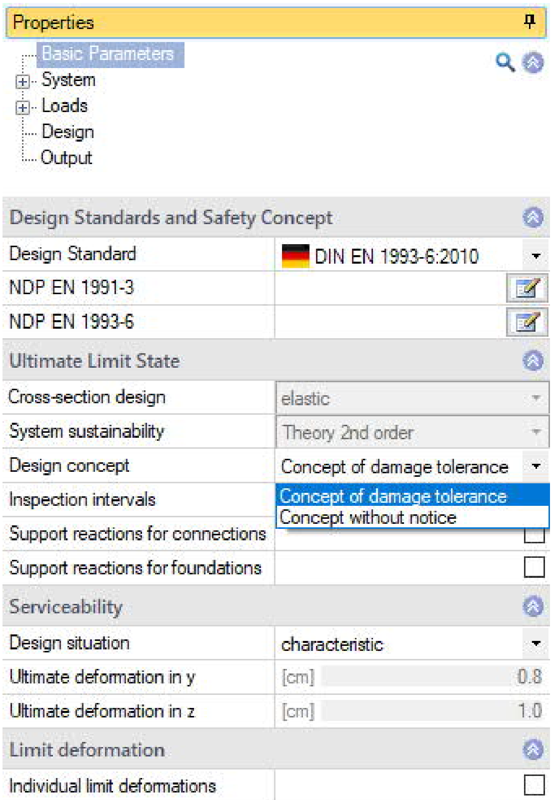
The theoretical fundamentals of the calculation of crane runway girders are described in detail in the reference literature mentioned in the software manuals.

Input

Help texts and information on each individual input value are an integral part of the program interface. As soon as you click in an input field, a corresponding explanation of the input value is displayed in the information area (below). A general description of the program interface can be found in the document:
▸ Basic Operating Instructions.

Tip: Use the interactive input options directly in the graphic for changes - e.g. double-click on a graphic element or right-click for the context menu.

Basic Parameters



Design Standards and Safety Concept

Definition of the design standard and its National Annex.

NDP EN

Displays the nationally defined parameters of EN 1991-3 or EN 1993-6.

Ultimate Limit State

Design concept: design principles to prevent fatigue failure.
- Concept of damage tolerance
- Concept without notice

The selection of the design concept has an influence on the partial safety factor γMF .

Inspection intervals: number (1-4) of required inspections during the service life of the crane runway.

Support reactions for connections: calculation of the support reactions for connected structures with reduced dynamic coefficients. This option must also be selected if combinations of the support forces are to be passed on to a column program for calculation.

Support reactions for foundations: calculation of the support reactions for foundations with reduced dynamic coefficients.

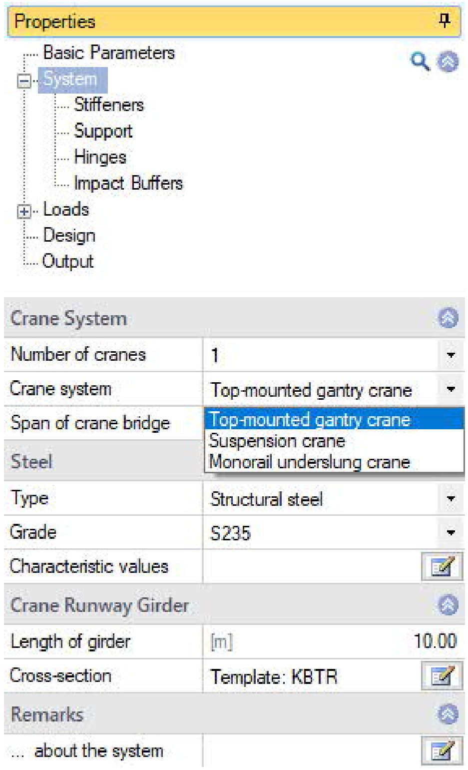
Serviceability Limit State

Design situation: defines the design situation for the serviceability verifications:
- characteristic
- frequent
- quasi-permanent

Ultimate deformation in y/z: The ultimate permissible limit deformations are calculated by the software but can also be entered if the option "Individual limit deformations" is checked.

Structural system

Crane system



Number of cranes	1 or 2 canes
Crane system	- Top-mounted gantry crane - Suspension crane - Monorail underslung crane *Note: The availability of menu items depends on the previous settings.*
Span of crane bridge	distance of system axes of the undeformed crane runways.

Steel

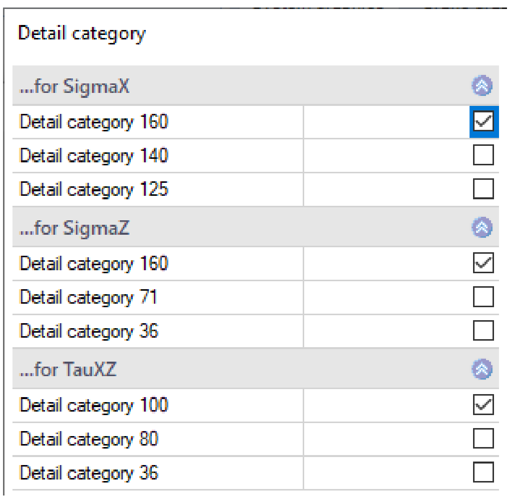
Selection of the steel type and grade; you can set the parameters also manually (user defined type).

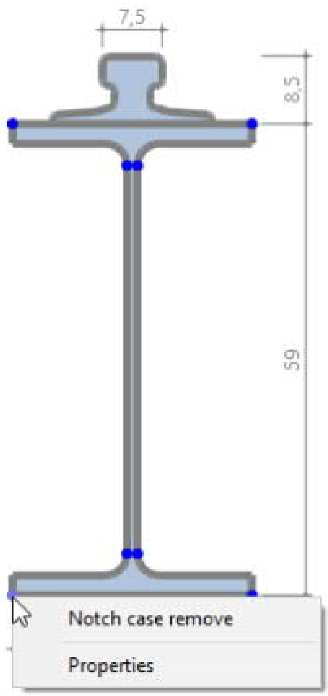
Crane Runway Girder

Length of girder	total length of the crane runway. The length corresponds to the dimension in the x-direction.
Cross section	name of the selected cross section. Press to access a dialog for editing the cross section.

Detail category

In the cross-section dialog click with the right mouse button on one of the cross-section points shown as points. The functions "Detail category remove" and "Properties" are displayed. Click "Properties" to open the dialog for the Detail category and tick the desired options.



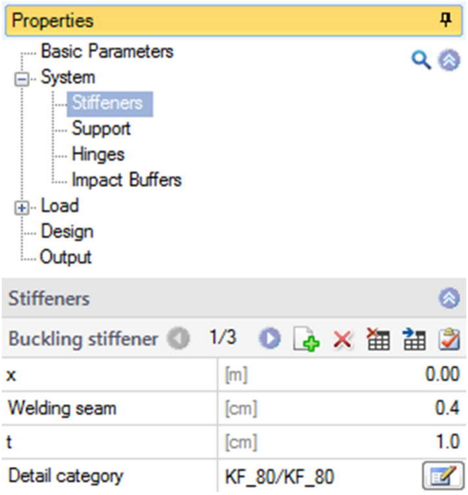


Note: *when moving the mouse over the cross-section points, the properties and the point number are displayed.*

Remarks

Allows you to enter comments about the defined system.

Stiffeners

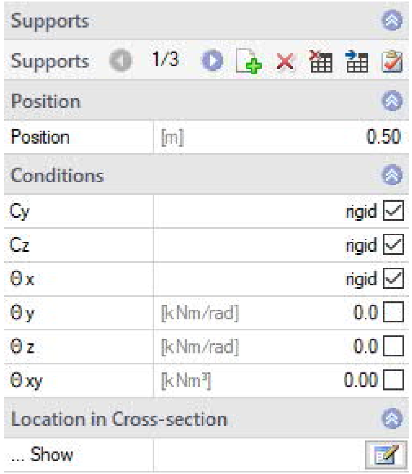


The definition of multiple buckling stiffeners is described in the chapter [Data entry via tables](#) (Basic operating instructions-PLUS)

Alternatively, you can edit stiffeners in a well structured table that is accessible via the "Stiffeners" tab (below the graphic screen).

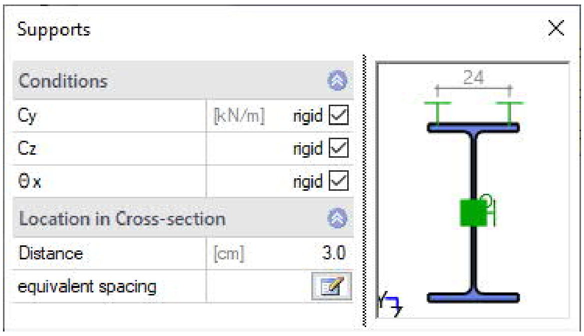
x	distance of the stiffener (central axis) to the left girder edge.
Welding seam	thickness of the weld seam of the buckling stiffener.
t	thickness of the buckling stiffener.
Detail category	activate the Edit button to access the selection dialog “Detail category”.

Supports

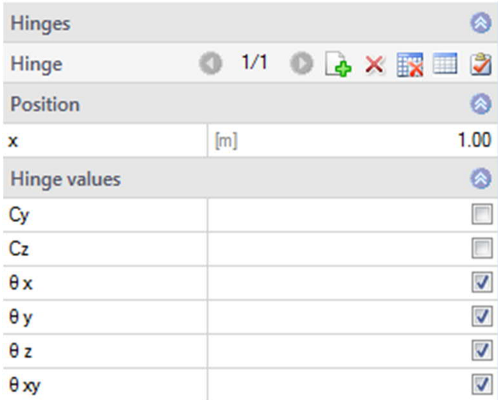


To define multiple supports, see the chapter [Data-entry via tables](#) (Basic Operating Instructions)

Position	distance of the discrete supportconditions to the left girder edge
Conditions	definition of discrete support conditions for translation, rotation and warping.
Location at cross section	displays the dialog for the definition of the support position in relation to the cross section (for Suspension crane / Monorail underslung crane).



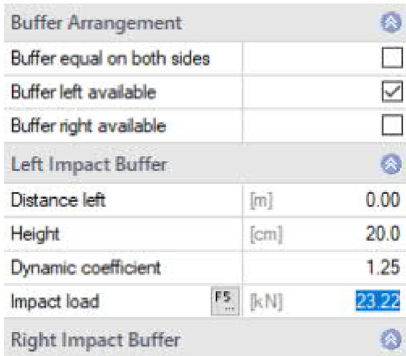
Hinges



x	distance of the joint to the left girder edge
Cy/Cz	shear force joint in the y-/z-direction.
θ	moment joint around the axis (x, y, z, xy = warping joint).

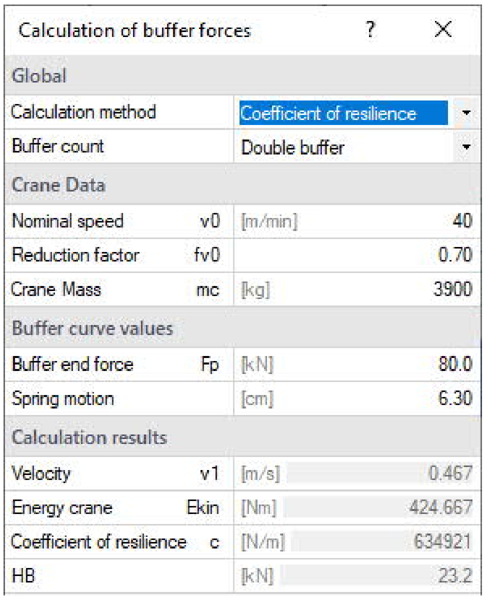
Impact buffers

Bumpers can be defined on the left and/or on the right or on both sides.



equal on both sides	the parameter setting of the left bumper is automatically transferred to the right bumper.
Distance left/right	distance of the buffer to the left/right girder edge. If the value is negative, the bumper is fitted outside the girder.
Height	distance between the bumper's line of action and the top edge of the rail.
Dynamic coefficient	dynamic factor for the impact on the bumper.
Impact load	characteristic value of the bumper end force without dynamic coefficient. Press the F5 key to access a dialog for the calculation of the bumper end force.

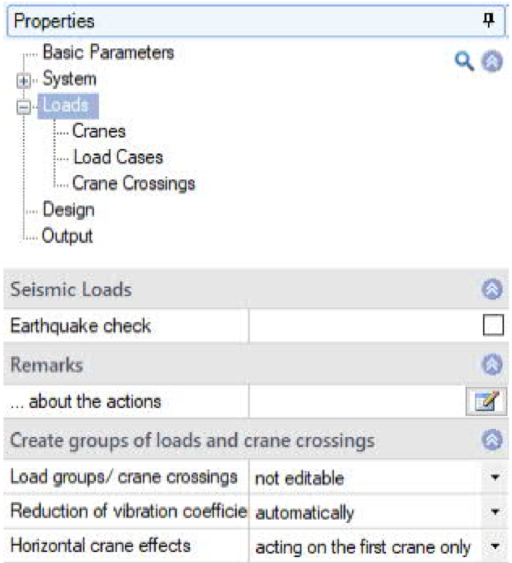
Dialog "Calculation of the buffer end forces" (F5-key)



Calculation method	two methods are available for the calculation of the bumper end forces: - calculation via a preset spring constant (coefficient of resilience) or - via the line of action of the bumper (buffer curve)
Buffer count	single and double bumpers are available for selection.
v0	rated crane speed.
fv0	factor for the reduction of the rated crane speed for the bumping situation (normally 70 %).
mc	crane mass that acts immediately on the bumper.
Ep	(select calculation method “buffer curve”): energy capacity of the bumper, which is part of the bumper end force.
Fp	bumper end force; it is the maximum force the bumper can bear in its elastic area.
Spring motion	maximum spring deflection on the bumper, which is part of the bumper end force.

The calculation results are displayed in the lower section of the dialog.

Load



Seismic Loads

Earthquake proof — when you tick this option, earthquake loads are taken into account in the generation of the load cases and the superpositions. The dialog "Basic values for the determination of the ground acceleration response spectrum" is displayed. Additional information: see Eartquake-chapter in the Building-programm GEO.

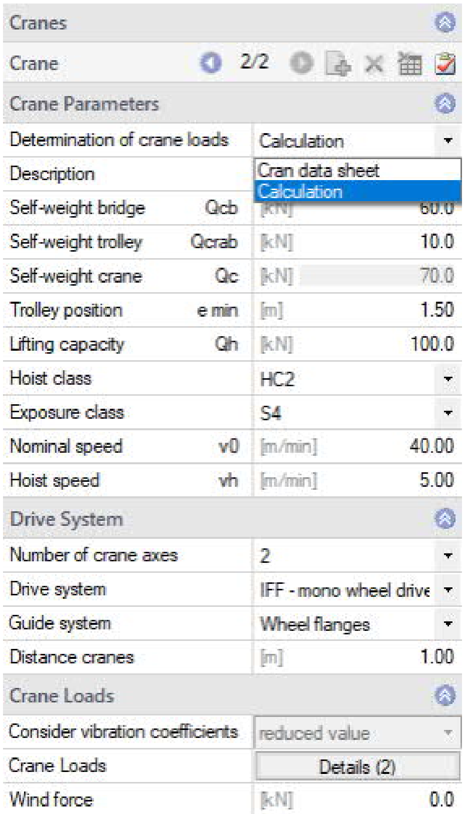
Remarks

Allows you to enter comments on the actions.

Create groups of loads and crane crossings

You can optionally select whether the generated load groups and crane crossings should be editable and how the dynamic factors shall be taken into account with two cranes. Horizontal crane effects indicates for which cranes these actions are applied. See also DIN EN 1991-3, Corrigendum 1: 2013-08.

Cranes



The number of cranes (1 or 2) is defined in the Structural system section.

The right/left arrows allow you to move the cursor to the next/previous data-entry field: 

Crane Parameters

Determination of the crane loads:

Calculation	the crane loads are calculated by the software on the basis of the parameters listed below and in accordance with EN 1991-3.
Crane datasheet	you must enter the crane loads (as specified on the datasheet). The definition menu is adjusted accordingly.
Qcb	self-weight of the crane bridge or the trolley.
Qcrab	self-weight of the trolley without hoisting devices.
Qcrab	self-weight of the crane without hoisting devices.
emin	minimum distance between the centroid axes of the wheels and the centre of gravity of the trolley at its outermost limit position.
Qh	rated hoisting capacity of the crane. The hoisting capacity includes the masses of imposed loads and the hoisting devices as well as a part of the mass of the ropes and chains of the hoisting device.
Hoisting class	hoisting class of the crane as per EN 1991-3, Annex B.
Exposure class	Exposure class as per EN 1991-3, Annex B.
v0	rated crane speed.
vh	hoisting speed of the crane.

Runway system

Number of crane axles — 2 or 4

Drive system — selection of the crane drive (central drive, individual wheel drives) and of the type of axles (fixed/fixed or fixed/free).

Track guidance system — wheel flange,
outer or inner guide rolls.

Distance cranes — distance of the guiding devices to the front/rear axle.

Crane Loads

Vibration coefficients — when you set the option for the reduction of the dynamic coefficients to "Manually", you can optionally decide whether the dynamic factors should be included with their full values or with reduced ones.

Crane Loads — click on the “Details” button to display the dialog for the definition of the wheel loads.

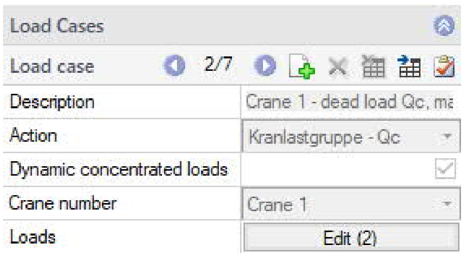
a	e	Qr,1j,min	Qr,2j,min	Qc,1j,max	Qh,1j,max	Qr,1j,max	Qc,2j,max	Qh,2j,max	Qr,2j,max	HT,1j	HT,2j	HS,1j	HS,2j
[m]	[m]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]
0,00	0,00	19,5	15,5	15,5	5,0	20,5	19,5	45,0	64,5	2,3	7,3	0,0	12,1
2,50	2,50	19,5	15,5	15,5	5,0	20,5	19,5	45,0	64,5	-2,3	-7,3	0,0	0,0

The table is only editable when you take over the crane loads from the crane datasheet or set the editable option for the load groups and crane crossings.
Explications on the different columns are displayed when you click into a table cell.

Wind force — characteristic value of the total wind power as per EN 1991-1-4, para. 5.3. Press the F5 key to launch a wizard (definition dialog) for the calculation of the wind power.

Load cases

The load cases are generated automatically by default. Tables are only editable when the corresponding option ("Editable") is activated, see Loading / Definition of load groups and crane crossings.



To define multiple load cases with the help of the load case toolbar see the chapter Data entry via tables (basic operating instructions).

Alternatively, you can edit load cases in the well structured load case table that is accessible via the Load Cases tab (below the graphic screen).

Action — selection of actions in accordance with EN 1990.

Dynamic concentrated loads — when you tick this option, the concentrated loads of the load case are considered as mobile loads, otherwise as static loads.

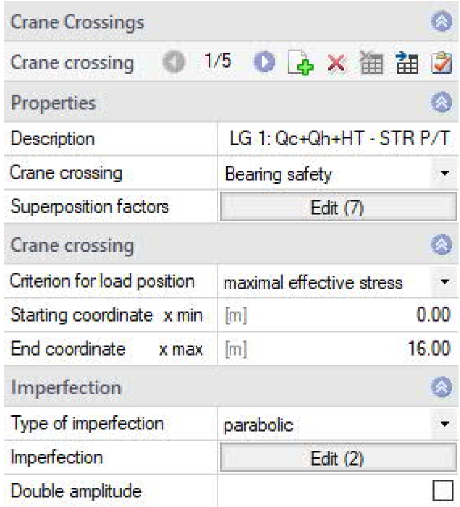
Crane number — number of the crane whose wheel loads are included in the load case.

Loads — click on the „Edit” button to display the dialog for the definition of the loads of the selected load case. Explications on the different columns are displayed when you click into a table cell.

	Load type	Direction	Value left	Distance	Value right	Load extension	Impact	Description
				[m]		[m]		
1	Single load in a	in z	19.5	6.00	---	---		Qc,2,1,max,nc
2	Single load in a	in z	19.5	3.50	---	---		Qc,2,2,max,nc

Crane crossings

The crane crossings are generated automatically by default. Tables are only editable when the corresponding option ("Editable") is activated, see Loading / Definition of load groups and crane crossings.

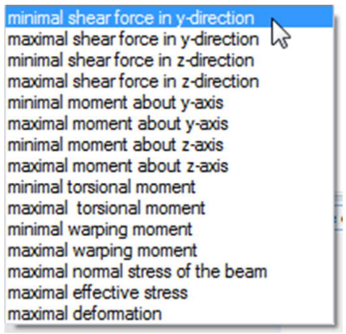


Properties

Crane crossing — selection of the crane passage in view of the verifications to be performed:
- Structural safety
- Serviceability
- Support forces
- Fatigue

Superposition factors — activate the "Edit" button to display the dialog for the definition of the superposition factors (dynamic coefficient φi, partial safety factor φF, combination coefficient ψi - the superposition factor is the product of these three values).

Crane Crossing



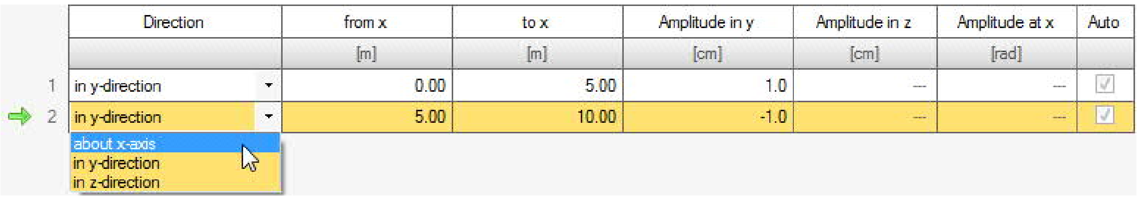
Criterion for load position — selection of the target function for the decisive load position of a crane passage (minimum/maximum shear force ... maximum deformation).

xmin / xmax — coordinates of the beginning and the end of the first wheel of the first (front) crane in the x-direction

Imperfection

Type of imperfection — select whether the imperfection half waves shall be sine-shaped or parabola-shaped.

Imperfection — click on the “Edit” button to display the dialog for the definition of the imperfections for the current crane passage.



Invert amplitudes of the imperfection half waves.
Note: A imperfection direction is assigned to the current crane passages. Alternatively, the opposite deflection direction must also be examined.

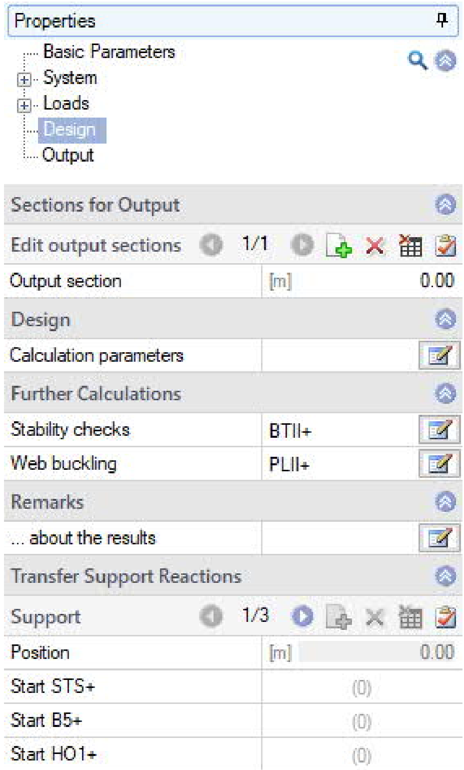
Double amplitude — according to DIN EN 1993, the amplitudes of the initial bow imperfections are to be doubled if 0.7 < lambdaLT < 1.3.

Design

Output sections

To define multiple output sections with the help of the table toolbar:

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

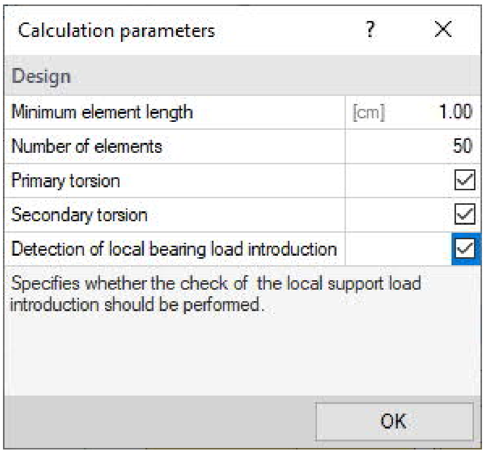


Output section	indicates the x-coordinate of the user-defined output section. The output sections allow you to obtain calculation results at particular points of the girder.

Calculation and design

Calculation parameters	accesses a dialog for the setting of the calculation parameters.

Dialog Calculation parameters



<u>Minimum element length:</u>
minimum length of a finite element in [cm]. A minimum length greater than one centimetre is recommended.

<u>Number of elements:</u>
number of finite elements to be produced in the system discretisation (1 ≤ n ≤ 5,000).

<u>Primary/secondary torsion:</u>
When you check this option, the shear stresses due to primary torsion are taken into account in the calculation of the comparison stresses.

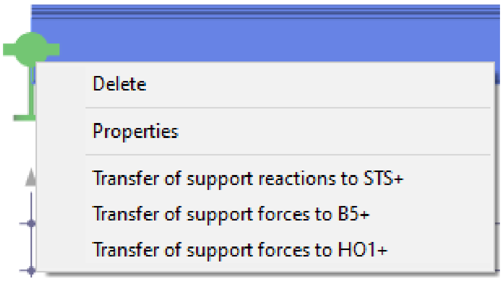
<u>Verification of local bearing load introduction:</u>
Specifies whether the verification of the local support load introduction should be performed (Suspension crane / Monorail underslung crane).

Interfaces to BTII+/PLII+ - further calculations

Stability verifications	interface to BTII+ (Lateral Torsional Buckling Analysis). Activating the option launches the software and transfers the entire structural system to BTII+.[1)]
Web buckling	interface to PLII+ (Plate Buckling). Activating the option launches the software and transfers a selected buckling field and its loading to PLII+.[1)]

[1)] If this software is installed on your computer and you hold a valid licence.

Transfer Support Reactions



The combinations of support forces can be transferred to

STS+ Single-span Steel Column,

B5+ Reinforced Concrete Column

HO1+ Timber Column

To do this, the "Support reactions for connections" option must be selected under Basic parameters.

Load transfer can also be called up via the context menu (right mouse button) on a support (Fig. above).

The desired combinations can be selected (marked) in a dialog, the load axes can optionally be rotated through 90°, and the combinations can be assigned to actiongroups.

In a further intermediate dialog, parameters such as column height, cross-section width/height, height of the load application point and eccentricity can be specified.

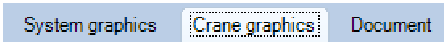
Output

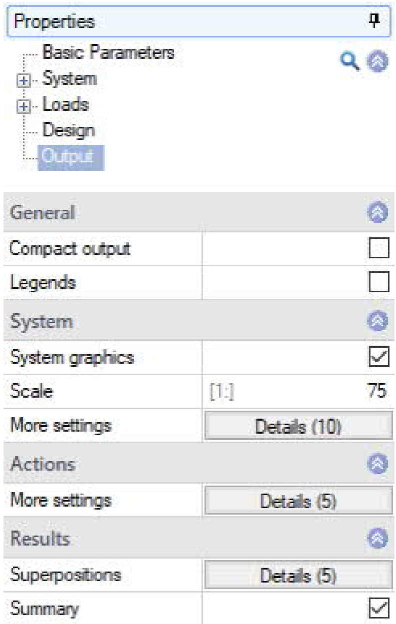
A general description of the output options is available in the document:

- [Output and printing]

View selection

The tabs "System graphics", "Crane graphics" and "Document" allow you to toggle between the GUI, the 3-d view of the structural system and the preview of text documents.



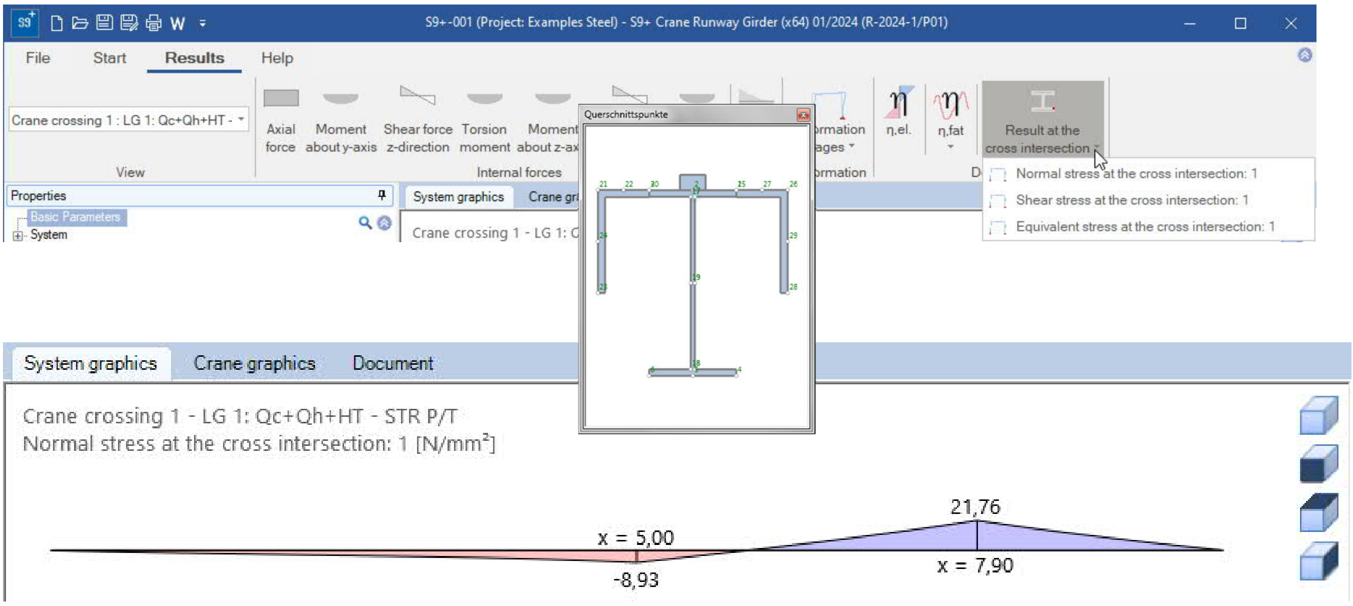


Output options

The different options and the corresponding “Details” buttons allow you to determine and limit the output scope.

Results

You can access the views of the different result graphs via this tab (select by clicking).



Reference literature

[1] EN 1990 2002-10: Eurocode: Bases of structural design

[2] DIN EN 1991-3:12-2010: Eurocode 1: Actions on structures – Part 3: Actions induced by cranes and machinery, German version of EN 1991-3:2006

[3] DIN EN 1991-3/NA:2012-12: National Annex to Eurocode 1 - Nationally Defined Parameters: Actions on structures – Part 3: Actions induced by cranes and machinery.

[4] ÖNORM B 1991-3 Eurocode 1:2007-06-01: Actions on structures – Part 3: Actions induced by cranes and machinery.

[5] NA to BS EN 1991-3:2006: UK National Annex to Eurocode 1: Actions on structures - Part 3: Actions induced by cranes and machinery.

[6] DIN EN 1993-6:2010-12: Eurocode 3: Design of steel structures - Part 6: Crane supporting structures

[7] DIN EN 1993-6/NA:2010-12: National Annex to Eurocode 3 - Nationally Defined Parameters: Design of steel structures - Part 6: Crane supporting structures

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[9] NA to BS EN 1993-6:2007 UK National Annex to Eurocode 3: Design of steel structures – Part 6: Crane supporting structures.

[10] Kindmann, Rolf, Prof. Dr.-Ing.: Tragfähigkeit von doppeltsymmetrischen I-Querschnitten auf Basis der DIN EN 1993-1-1, Tagungsband Dresdner Stahlfachtagung 2012, TU Dresden: 2012.

[11] Kuhlmann, Ulrike, Prof. Dr.-Ing.,Zizza, Antonio, Dipl.-Ing., Braun, Benjamin, Dr.-Ing.: Stahlbaunormen – DIN EN 1993-1-5: Bemessung und Konstruktion von Stahlbauten – Plattenförmige Bauteile, Stahlbaukalender 2012, Ernst & Sohn Verlag: 2012.

[12] Stahlbaukalender 2006

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[18] Schweda, Erwin, Prof. Dipl.-Ing., Krings, Wolfgang, Prof. Dr.-Ing: Baustatik Festigkeitslehre, 3. Auflage, Bauwerk-Verlag: Düsseldorf 2000.