S9+ Crane Runway Girder

FRILÔ Software GmbH
www.frilo.com
info@frilo.com
As of 13/10/2017
Frilo Application: S9+ Crane Runway Girder

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Further information and descriptions are available in the relevant documentations:

- **Basic Operating Instructions-PLUS**: General instructions for the manipulation of the user interface
- **FDC – Menu items**: General description of the typical menu items of Frilo software applications
- **FDC – Output and printing**: Output and printing
- **FDC - Import and export**: Interfaces to other applications (ASCII, RTF, DXF ...)
- **FCC**: Frilo.Control.Center - the easy-to-use administration module for projects and items
- **FDD**: Frilo.Document.Designer - document management based on PDF
- **Frilo.System.Next**: Installation, configuration, network, database
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
- 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

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 transferred to STS+ Single-span Steel 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.
**Basic parameters**

**Design Standards and Safety Concept**

**Design Standard**
Definition of the design standard and its National Annex

**equal** γ for all permanent loads

Option ticked: the same values of the partial safety factor (γG, sup or γG, inf) are assumed for all permanent loads/loadcases.

Option not ticked: the permanent loads/loadcases will be combined among each other with γG, sup and γG, inf.

**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.

**Bearing forces for connections**
calculation of the support reactions for connected structures with reduced dynamic coefficients.

**Bearing forces 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.
Structural system

Crane system

Number of cranes 1 or 2 canes
Crane system - Top-mounted crane
- Underslung crane
- Monorail hoist block

Note: The availability of menu items depends on the previous settings.

Span of crane bridge distance of system axes of the undeformed crane runways.

Material

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 a number of a numbered cross intersection. The functions "Detail category remove" and "Properties" are displayed. Click "Properties" to open the dialog for the Detail category and tick the desired options.

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 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 support conditions to the left girder edge.
- Check as suspension: The support is defined as a suspension for the underslung crane and the monorail hoist block. In the standard setting the verification of the local bearing load introduction at the top flange is performed. The verification is performed with two bearing points.
- Location at cross section: additional input: the distance(s) of the bearing points from the outer edge of the flange.
- You can deactivate this verification under Design - Calculation parameters.

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.

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 on the left  distance of the buffer to the left 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"

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 travel  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

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.

Remarks  you can 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.

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

Crane 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.

Guiding devices 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 button to display the dialog for the definition of the wheel loads.

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 tab (below the graphic screen).

Action selection of actions in accordance with EN 1990.

Dynamic single 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 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.
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 $\varphi_i$, partial safety factor $\varphi_F$, combination coefficient $\psi_i$ - 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 to display the dialog for the definition of the imperfections for the current crane passage.

<table>
<thead>
<tr>
<th>Direction</th>
<th>from x</th>
<th>to x</th>
<th>Amplitude in y</th>
<th>Amplitude in z</th>
<th>Amplitude at x</th>
<th>Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>in y direction</td>
<td>0.00</td>
<td>5.00</td>
<td>1.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>in y direction</td>
<td>5.00</td>
<td>10.00</td>
<td>-1.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
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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 $0.7 < \lambda_{LT} < 1.3$. 

**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**

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

Number of elements:
number of finite elements to be produced in the system discretisation ($1 \leq n \leq 5,000$).

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

Verification of local bearing load introduction:
See ▶ Supports.

**Further calculations / interfaces to BTII/PLII**

Stability verifications interface to BTII+ (Lateral Torsional Buckling Analysis). Activating the option launches the software and transfers the entire structural system to BTII+.

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

**Transfer Support Reactions**
The combinations of the bearing forces can be transferred to the STS+ program (Single-span Steel Column).
For this purpose, the option "Support reactions for connections" must be selected (Basic parameters).
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.
Output

A general description of the output options is available in the document:
- FDC - Output and printing_eng.pdf

View selection

The tabs "System Graphics", "Crane graphic" 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 edit 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

