ST14 - Welded Beam-to-Column Connection

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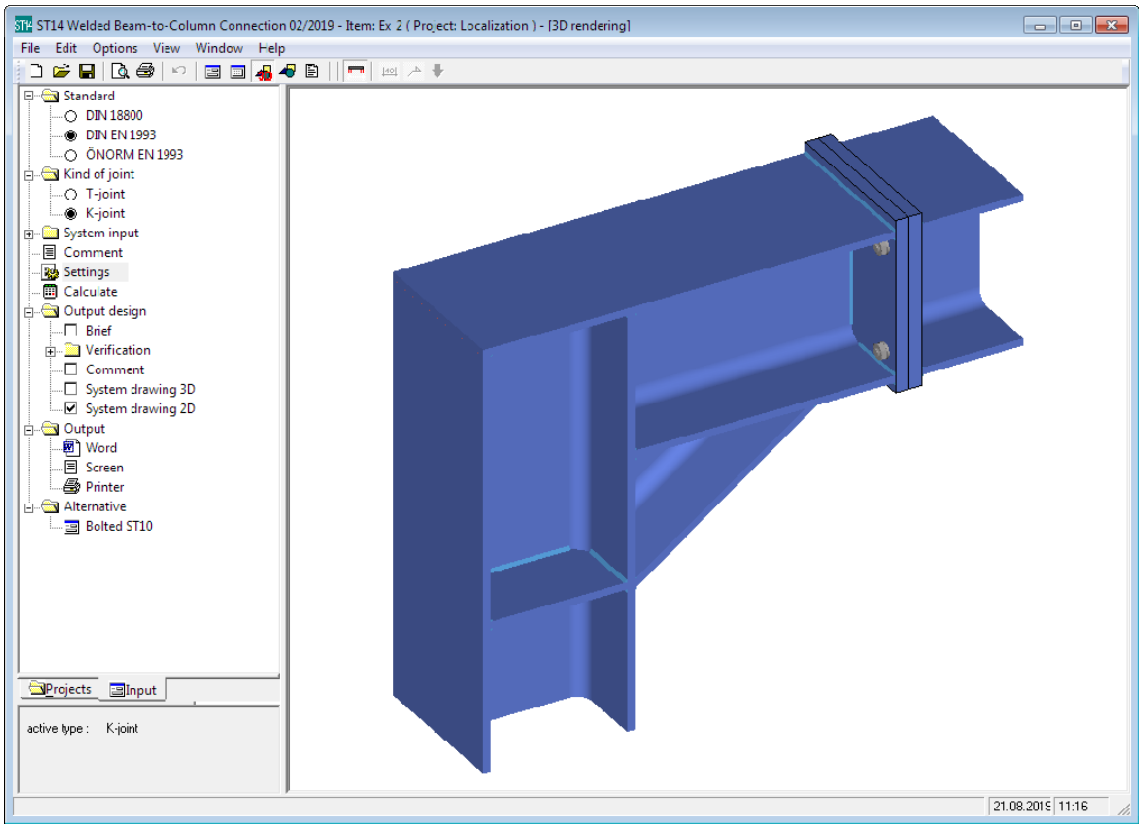

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Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com ▸ Support ▸ Articles/Information ▸ Basic operating instructions.

Application options

ST14 is an application program for the calculation of welded rigid steel frame joints in accordance with DIN 18800, DIN EN 1993 and ÖNORM EN 1993.

Structural system

You can verify typical variants of T-joints and knee joints of double-T profiles:

- T-joint with haunch on one or both sides (joint bracing) and inclined beam
- Knee joint with haunch on one side (joint bracing) and inclined beam
- Knee joint with welded tension plate in addition
- Knee joint with a bolted field joint as rigid end plate connection in flush or protruding version

In all variants, you can increase the bearing capacity of the shear field by applying transverse stiffeners or a web plate on one side of the web. In addition, you can fit web ribs inside the column.

Loading (actions)

You have to enter the design values of the internal forces N, My and Vz. The internal forces must result for the biggest part from dead loads.

Alternating moments can be included.

You can enter multiple combinations of actions via dedicated tables.

Calculation

Subject to verification are the weld seams, the shear fields as well as the transverse stiffeners or the load application points and the field joint, if applicable.

The software proposes the required weld seam thickness values, if you activate the corresponding option.

Output

You can document the results in a well-structured, abbreviated or extensive output with the help of a customizable output profile. Optionally, you can generate a three- or two-dimensional graphic representation of the structural system and include additional text notes in the output.

Limitations

The software assumes a braced connection with stiffeners in the column.

The field joint is proofed only under a load that generates tension in one chord and pressure in the opposite chord.

If calculated according to DIN 18800, further restrictions arise for the field joint. According to the old DSTV ring binder only S235 and bolts HV 10.9 are allowed. According to the new ring binder (2000), S355 and bolts HV 8.8 are also permitted, but the vertical rows of bolts are limited to two.

The proof of the welds follows the simplified procedure. The permissible threshold weld stresses are used as the basis.

Data entry

Definition of the structural system

First, select the appropriate joint among T-joint and knee joint in the Main menu or the corresponding item in the Edit menu.

Note: *A subsequent change of the connection involves the risk of data loss. The software takes over all suitable parameter settings, but when changing from T to knee, for instance, the upper joint bracing will be lost.*

After this, define the geometry of the frame joint, its material and the internal forces. If you want to calculate multiple combinations of internal forces in order to compare them, you can enter and handle them via the list of internal forces (accessible via the Actions >> General dialog or the toolbar).

Material

Select the structural steel grade or define a material via the "Free definition" option.

To expand the list, click on or enter user-defined values (free selection).

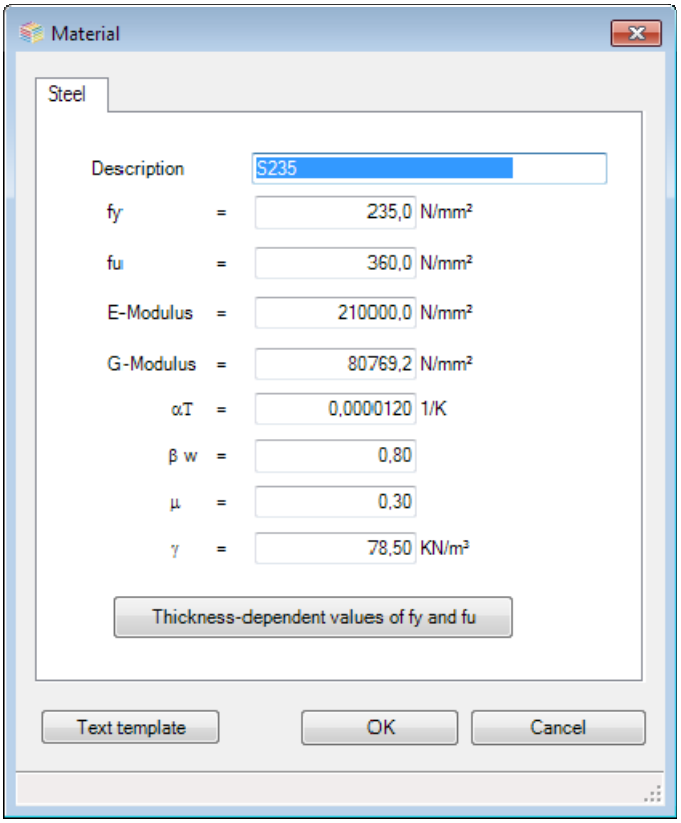
γ_M the default value of the partial safety factor of the resisting side γ_M is 1.1. You can set it to 1.0 if γ_M is included in the internal forces.

α_W the α_W factor of the permissible limit weld seam stress as per DIN 18800 P. 1 is set to 0.95 for S235 and to 0.8 for S355. For other steel grades, you must specify it manually.

Free selection

Select the "Free selection" option in the list of steel grades and click subsequently on the ... button.

Enter a designation for the material and the characteristic values for the modulus of elasticity and the yield strength $f_{yk.}$



Actions

The design values of the actions (subscript d) in the in the beam are entered in this section.

Knee joint the internal forces can optionally be applied to the column in the variant "beam above column".

Depending on the pre-condition, internal forces can be assigned to different reference points in the frame joint.

Sign definition: see the chapter Actions - General.

Nd axial force transmitted in the direction of the defined centre line (depends on the reference point), positive if it produces tension.

Vzd shear force perpendicular to the defined centre line (depends on the reference point).

Myd moment transmitted about the y-axis; positive, if it produces tension on the bottom side of the section.

T-joint to verify the shear field, you must enter the internal forces acting in the column in addition → see Actions - General.

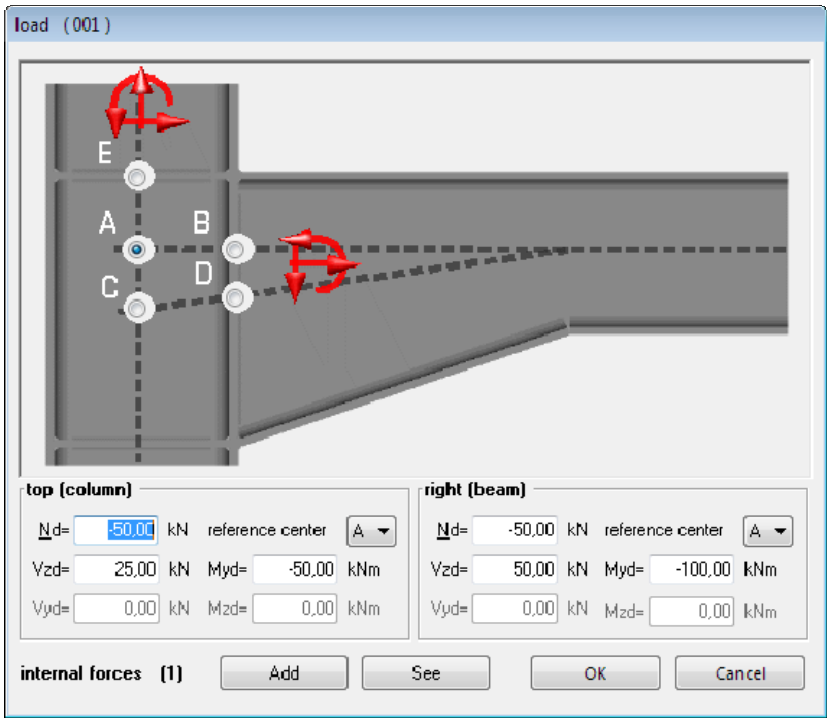
Knee joint to verify a bolted connection as per DSTV, if such a connection was defined, you must enter the associated internal forces in the "Actions - General" dialog.

Actions - General

The design values of the actions (subscript d) must be entered. They can be referenced to the points shown in the illustration below.

T-joint internal forces in the column top apply in point A or E, internal forces in the beam act in one of the points A to D.

Knee joint internal forces applying to the frame joint act in one of the points A to D.



The reference points are defined as follows:

A intersection of the column centre line with the beam centre line - without haunch

B intersection of the beam contact face to the column with the beam centre line – without haunch

C intersection of the column centre line with the beam centre line - with haunch

D intersection of the beam contact face to the column with the beam centre line – with haunch

E intersection of the column centre line with the contact face of the shear field on top

Note: *"Beam centre line incl. haunch" refers to the angle bisector of the haunch outline.*

Knee joint in the "Beam above column" variant, the role of the beam and the column are reversed. The haunch refers to the column in this case. Optionally, the internal forces can refer either to the column or the beam.

Nd axial force transmitted in the direction of the defined centre line (depends on the reference point), positive if it produces tension.

Vzd shear force perpendicular to the defined centre line (depends on the reference point).

Myd moment transmitted about y.

Sign convention: see the illustration in the "Actions - General" dialog showing the symbols of the positive internal forces.

List of internal forces

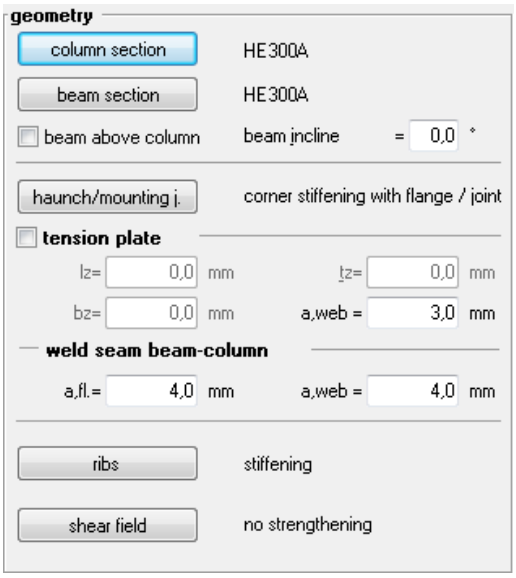
In the lower area of the dialog, the current number of the given combinations of internal forces is indicated in brackets.

Click on the "Add" button to insert the currently defined internal force immediately into the list.

To perform any kind of operations referring to internal forces (calculate, search maximum value, delete), you can access the list via the "View" button.

Geometry

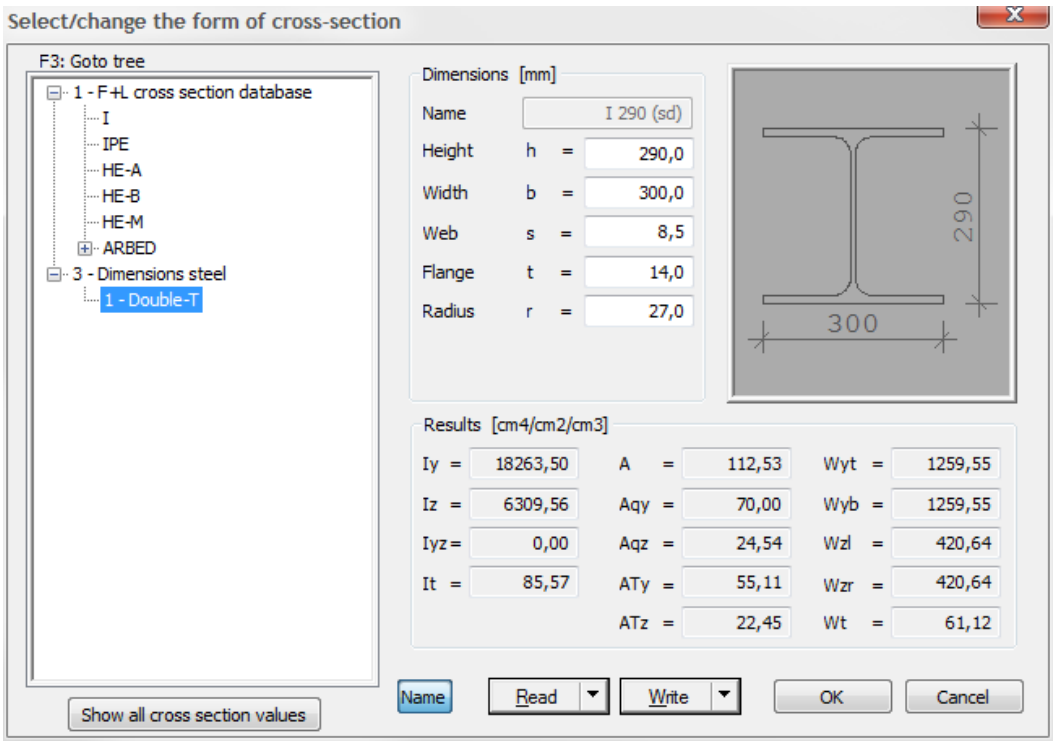
The buttons "Column section" and "Beam section" allow you to access the dialog for the selection or definition of the corresponding cross section.



Selecting/editing a cross section

You can define cross sections by specifying their dimensions or by selecting them from a list of standard steel shapes.
Available are double-T sections as per DIN and a series of special double-T sections make ARBED.

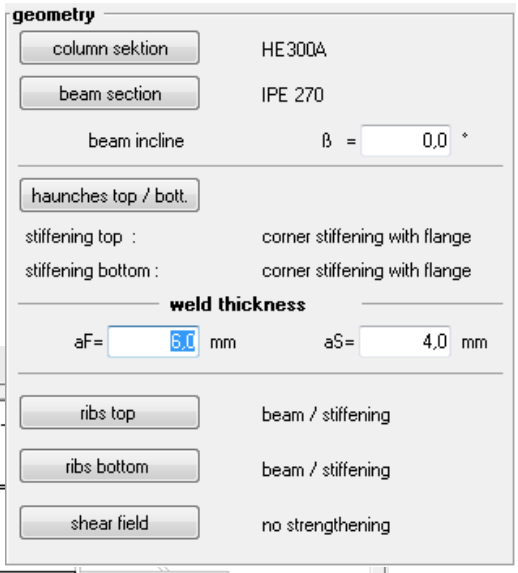
See also the document Selecting/Defining Cross Sections

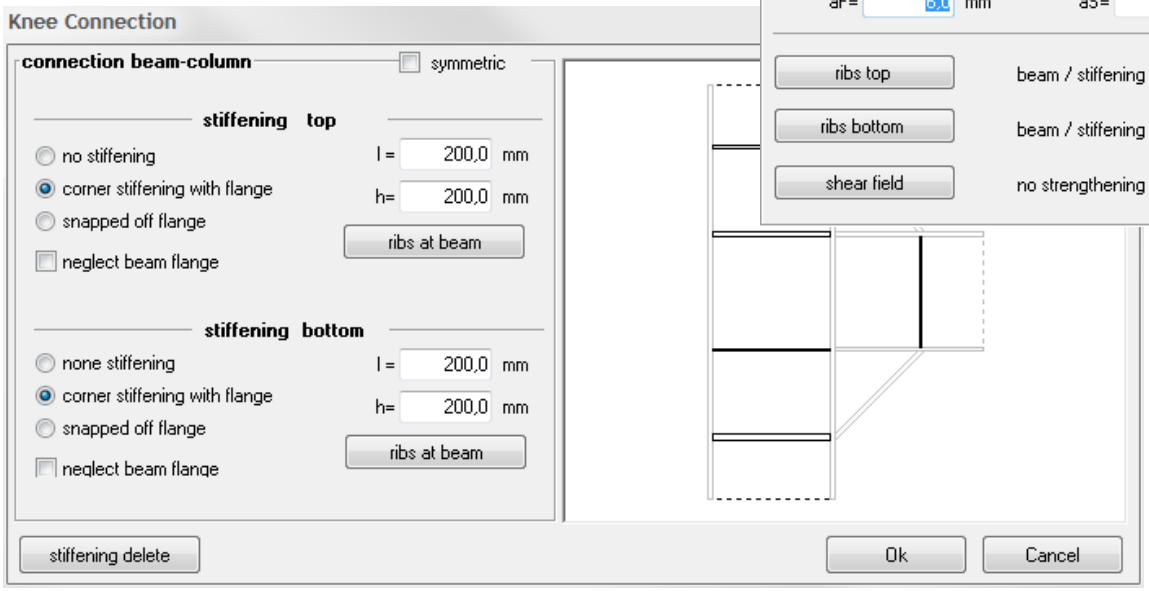


Geometry - T-joint

Beam inclination β angle between the centre line of the beam section and the horizontal line in degrees.

Haunches top/bottom accesses the dialog for the definition of haunches or joint braces. A haunch can be defined with a cranked chord or, in addition, with a continuous chord in the beam in the sense of a joint bracing. You can define additional stiffeners in the beam member at the chord end to ensure resistance against deflection forces.





For "symmetrical" versions, the data entry fields for the bottom haunch are disabled.

Weld seam thickness specifications

aF thickness of the weld seam at the chords of the beam

aS thickness of the weld seam in the web area of the beam

Note: *Depending on your settings, the data entry fields for aF and aS could be disabled – for automatic design, the weld seam thickness values are set by the software.*

Stiffeners on top column bracing by rib stiffeners at the upper beam flange
→ see the chapter Stiffeners.

Stiffeners on top column bracing by rib stiffeners at the lower beam flange
→ see the chapter Stiffeners.

Note: A braced connection is assumed.

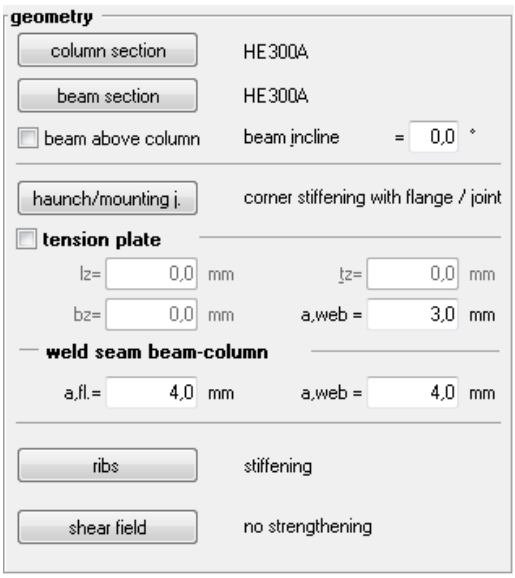
Shear field bracing of the shear field → see the chapter Shear field.

Utilization

When you activate the 'Calculate' option in the Main menu or the Edit menu, the various utilizations η are calculated for the structural system in the current state. This might be required after changes of the defined system or the definition of a new system.

Areas where η > 1 are colour marked in the system graph.

Geometry - knee joint



Beam inclination angle between the centre line of the beam section and the horizontal line in degrees.

Beam over column select this option if the beam should run above the column. In this case, the relation between the haunch and the member is inverted. The changed reference points of the internal forces shall be considered as well. The latters can optionally apply either to the beam or to the column.

Haunch/field joint accesses the dialog for the definition of a haunch or a field joint as a screwed connection as per DSTV (German Steel Construction Association). In the current software version, the field joint option is not available for the "Beam-over-column" connection.

Tension plate activate this option to provide a connection with a bolted or welded tension plate. The required data-entry fields are enabled, when you activate this option. Otherwise, the top chord runs over the connected section and is welded to the web of the latter (a,web).

lz length of the welded-on tension plate

bz width of the welded-on tension plate (max. width it that of the section)

tz thickness of the welded-on tension plate

a,web thickness of the weld seam on the web of the connected steel section

a,chord thickness of the weld seam on the chord along the steel section with the welded-on tension plate.

Beam-to-column connection

a,chords thickness of the weld seams at the chords of the beam

a,web thickness of the weld seam in the web area of the beam

Note: *In the beam-over-column variant, the weld seams refer to the chords and the web of the column.*

Note: *Depending on your settings, the data-entry fields for a,chords and a,web could be disabled. In automatic design, the weld seam thicknesses are set be the software.*

Stiffeners this button accesses the dialog for the definition of column braces by rib stiffeners at the lower beam flange.

Note: a braced connection is assumed.

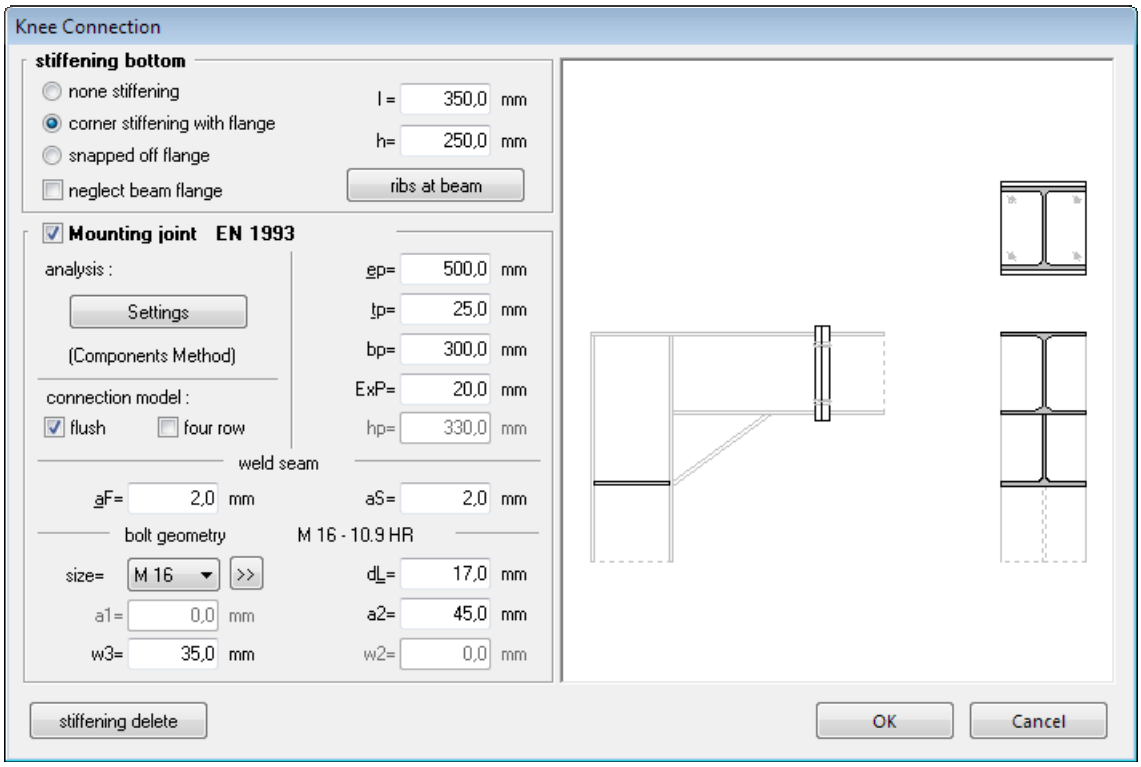
In the beam-over-column variant, a beam bracing at the right column flange is assumed in this case.

Shear field bracing of the shear field

Haunch / field joint

A haunch can be defined with a cranked chord or, in addition, with a continuous chord in the sense of a joint bracing.

You can define additional stiffeners at the chord end to ensure resistance against deflection forces. If a field joint is immediately at the chord end, no stiffeners are defined there. The deflection forces are borne by the end plate in this case. You should observe the constructive minimum distance of such a stiffener from the field joint. Otherwise, it may happen, that the software deletes the stiffener automatically after checking the geometry!



Field joint as per EN 1993 or DSTV (DIN 18800)

Activate this option to define a knee joint variant with a screwed field joint.

Calculation method

EN 1993

In accordance with the component method with two or four vertical bolt rows. Various calculation options are available in the "Settings" menu.
→ See also Steel connections – Component method.pdf

DSTV

- In accordance with the former DSTV Guidelines (1984) with S253, bolts HV 10.9 and two or four vertical bolt rows

- In accordance with the more recent DSTV Guidelines (2000) with S235 or S355, bolts HV 8.8 or 10.9 and two vertical bolt rows exclusively. The calculation is based on the simplified method without consideration of the bracing effect of the beam web in the verification of the end plate in bending (EPB).

Flush — end plate flush to the surface or projecting on top.

Four rows — Selection between two or four vertical bolt rows.

ep distance of the end plate (outer edge of beam to beam splice in length direction).

ep cannot be smaller than the (bracing) haunch length.

tp thickness of the end plate.

bp width of the end plate.

pp projection of the end plate on bottom, in combination with the "flush" connection type also on top. pp can also be negative, max. negative value is equal to the thickness of the chord.

hp height of the end plate; only enabled, if the "projecting" variant was selected.

aF weld seam thickness at the flanges.

aS weld seam thickness in the web area.

Note: *Depending on your settings, the data-entry fields for "a,chords" and "a,web" may be disabled. In automatic design, the weld seam thickness values are set by the software.*

Bolts

Size select the desired bolt size from the list. After you have made your selection, the software proposes a new bolt pattern. In addition, an end plate thickness appropriate for the bolt diameter is proposed, if the calculation is done in accordance with the old DSTV Guidelines.

accesses the definition dialog for the bolt details.

dL hole diameter, depends on the selected bolt type and size.

Bolt spacing in the direction of the beam web

a1 distance of the bolt in the projection to the outer edge of the beam, only enabled if a projecting end plate was defined.

a2 distance of the inner bolt to the outer edge of the beam.

Bolt spacing in the direction of the beam chords

w2 distance of the bolts to the edges.

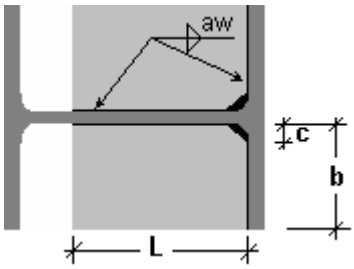
w3 inner spacing of the bolts on an end plate with four rows.

Each value that you enter is checked for plausibility in regard to the following conditions:

- The permissible minimum bolt spacing must be complied with.
- The total of all bolt distances must be equal to the corresponding plate dimension.
- When defining dL, an internal hole clearance of 0.3 to 2.0 mm for raw bolts and of 0.0 to 0.3 mm for fit bolts should be considered.

Stiffeners

The illustration shows the stiffener dimensions as they are used in the software, t = stiffener thickness. A short description of each data-entry fields is displayed in the status line (on bottom left).



Continuous stiffener — when you check this option, a three-sided stiffener connection is generated, i. e. the stiffener length *h* is equal to the clear distance of the flanges.

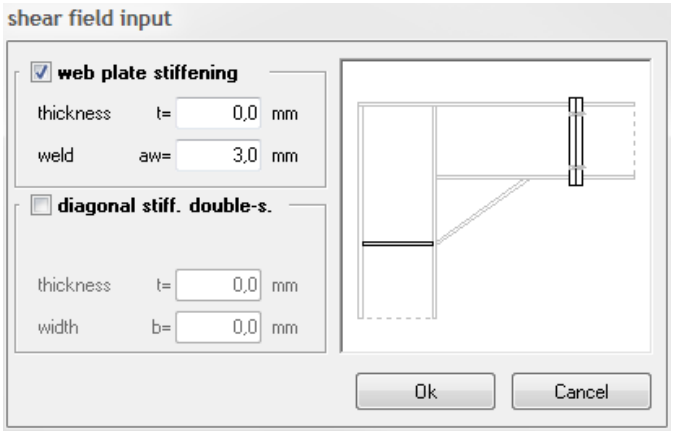
Take over flange thickness — check this option if the stiffener thickness *t* should be matched to the flange thickness of the connected section.

Stiffener width b — must not exceed the width of the corresponding flange of the section.

Delete stiffener — deletes the dimensions of the current stiffener. Attention: depending on the prerequisites of the verification, the software adds stiffener parameters automatically!

Shear field

Select the corresponding option to reinforce the shear field either with a web plate on one side or diagonal stiffeners on both sides.



Web reinforcing plate

Thickness t — thickness of the web plate

Weld seam aw — thickness of weld seam at the web plate

Diagonal bracing on both sides

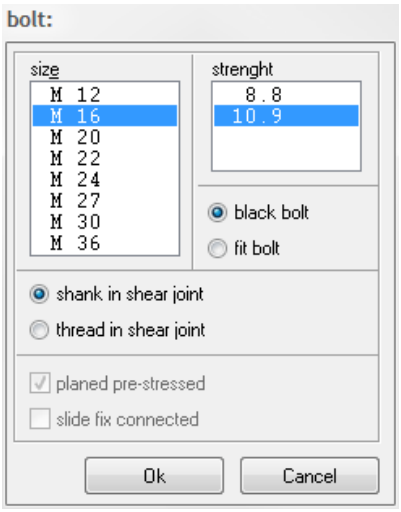
Thickness t — thickness of the stiffener

Width b — width of a diagonal stiffener (analogous to the rib stiffener)

To delete a bracing, just untick the corresponding checkbox.

Bolt details

Haunch/field joint ▸ Bolt geometry >>



The bolt sizes M12 to M36 are available for selection in the strength classes 4.6 to 10.9. You can distinguish between raw bolts and fit bolts.

An internal hole clearance of 0.3 to 2.0 mm for raw bolts and of 0.0 to 0.3 mm for fit bolts can be defined.

You can select whether the joints of a connection shall all be assumed in the bolt shafts or the bolt threads.

In the joint as per DSTV, only pre-loaded bolts are used. The older DSTV Guidelines (1984) only permit HV 10.9 whereas the more recent DSTV Guidelines (2000) allow HV 8.8 in addition.

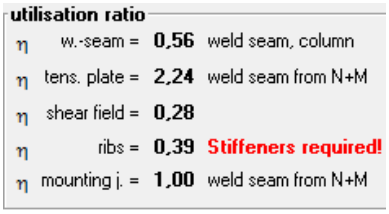
After having entered the bolt type, the hole diameter is set to the regular hole diameter of the corresponding bolt size. It can be edited and adjusted within the permitted range in the dialog associated to the bolt pattern.

The regular hole diameter of M16, for instance, is 17 mm for raw bolts (internal hole clearance of 1.0 mm) and 17 mm for fit bolts (internal hole clearance of 0.0 mm).

Friction-grip joints are not available.

Calculate / utilization

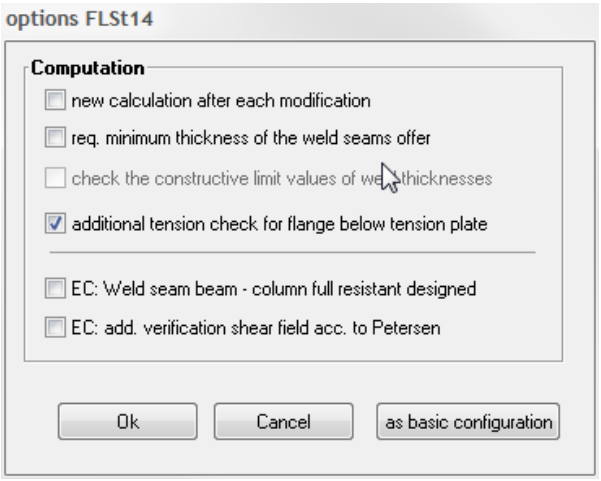
When you activate the 'Calculate' option in the Main menu or the Edit menu, the various utilizations η are calculated for structural system in the current state. This might be required after changes of the defined system or the definition of a new system. Areas where η > 1 are colour marked in the system graph.



Verification options - settings

To adjust the verification parameters, click on the "Settings" item in the Main menu.

Any changes to the settings in this dialog have an immediate effect on the defined frame joint. When you set up a new item, the software goes back to the default settings, however. In order to set user-defined values as defaults, activate the button "As default".



Propose req. minimum thickness of weld seams

Set this option if the software shall propose the thickness of all weld seams automatically. In this case, all data-entry fields referring to the thickness of weld seams are disabled and filled automatically with the appropriate values after each calculation run. The lower limit for the weld seam thickness is 2 mm.

Check the constructive limits of the weld seam thickness

Only available in combination with the previous option. When you tick this option, the software checks the proposed weld seam thickness values against the constructive weld seam limits and the thickness of the connected components.

Additional tension check for the flange below the tension plate

Specifies whether in the K-joint system with welded-on tension plate an additional simplified verification of the support flange below the tension plate is performed as a tension bar.

EN: Weld seam between beam and column full resistant designed

Only for calculation according to EN 1993: Determines whether the weld between the beam and the column is proofed in such a way that it can absorb the limit load capacity of the connected beam.

add. verification shear field The shear field is additionally and independently of the modeled transmission parameter β proofed by the Petersen method.

EN: optional proof shear field according to Petersen

Only for calculation according to EN 1993: determines whether the shear field is additionally proofed by the method according to Petersen.

List of internal forces

The list of internal forces allows you to handle any number of combinations of internal forces for the defined structural system in a table.

Click on the icon  associated to the list of internal forces or the "Display" button in the Actions - General dialog.

Sort

By clicking on the column title, you can sort each column in ascending or descending order.

Apply criteria to the listing

The options below the table allow you to set filters for the rows to be displayed.

The following options are available to filter the entries shown in the list:

- all combinations of internal forces
- all combinations of internal forces with a utilization of more than 100 %
- all combinations of internal forces with a maximum utilization between user-defined limits (in per cent). Maximum utilization in this context means the maximum loading rate from all verifications. To display all sections with a utilization rate greater than the specified lower limit, enter 0.0 for the upper limit.

Delete

Clicking on the "Delete" button deletes the currently selected combinations of internal forces.

Pressing the Shift or Ctrl key while selecting rows allows you to select several combinations of internal forces at a time.

Output

Click on the "Output" button to display the results of the selected combinations of internal forces on the screen. You can use the multi-selection feature to group the sections to be put out.

If you make no further selections, the combination of internal forces in the currently active (high-lighted) row is put out - not to be confused with the combination of internal forces entered in system definition section!

The number(s) of the combination(s) of internal forces is/are added to the output.

Edit

Click on the "Edit" button to access the dialog of the table of internal forces. You can add new combinations of internal forces or edit the existing ones.

Calculation

Activating the "Calculate" option launches the recalculation for all cross sections.

Transfer to structural system

Double-click on a combination of internal forces in the table or activate the "Add to the system" button to take over the selected internal forces in the definition dialog.

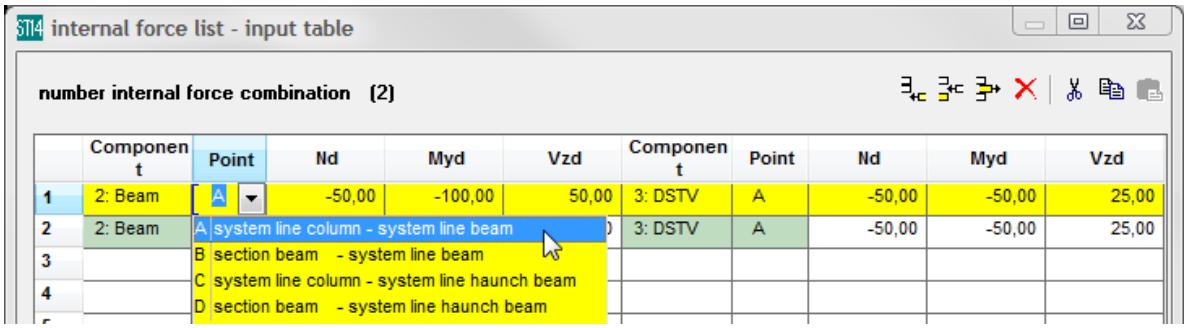
Table of internal forces

In this dialog, you can edit the defined combinations of internal forces in the table and add additional ones.

The available table columns (internal forces) depend on the defined structural system.

Explanations of the parameters to define are given in the "Actions - General" dialog of the T-joint and the knee joint.

Note: Some data entry fields offer selection lists. Click on to expand the corresponding list.



Output

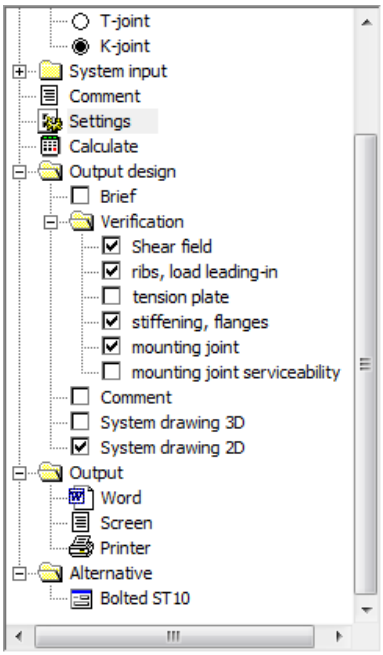
Output of the system data, results and graphical representations on the screen or the printer.

The Output item in the Main menu allows you to start the output on a printer or the screen.

Output profile	the dialog offers comprehensive options for the control of the output scope.
Word	the output data are transferred to the text editor MS Word provided that it is installed on the respective computer. You can edit and format the output data in MS Word.
Screen	displays the values in a text window on the screen
Printer	starts the output on the printer
Print Preview	File ▸ Print Preview shows the output as PDF. You can save this PDF as file – standard pdf-viewer functions are available.

Output profile

The output profile allows you to define the scope and contents of data to be put out. Only the activated options are considered in the output scope. Depending on the context of the currently active connection variant, particular options might be disabled.



Brief	option to include or exclude intermediate results from the output (uncheck the option to obtain intermediate results).

Verifications

Shear field	output of the shear field resistance verifications.
Stiffeners	output of the stiffener resistance verifications as well as the verifications concerning the load application.
Tension plate	output of the verifications in the tension plate, if applicable.
Bracing	output of the verifications in the (haunch) bracing area as well as of the verifications in the chords due to partial internal forces.
Field joint	output of the verification of the field joint, if applicable.
Serviceability	only in combination with a field joint as DSTV-connection in accordance with the older DSTV Guidelines (1984, DIN 18800).
Comment	Your comments on the system.
System 2D	two-dimensional representation of the frame joint with details (dimensions and/or legends).
System 3D	three-dimensional front view of the frame joint in isometric mode.

Direct transfer to ST10 – Bolted Beam-to-Column Connection

You can transfer the defined structural system to the ST10 application for further processing as a bolted connection. The internal forces combination of the system definition is transferred and converted to the reference point A, if required.

To do this, activate the corresponding menu item in the Main menu (sub-item of "Alternative") or the option "Bolted ST10" in the "Edit" menu.

Application-specific icons

In addition to the standard icons, each application program offers application-specific functions via additional icons and tool bars.

 List of internal forces

 Connection in 3-d

 Hide/display dimension lines

 Hide/display legends

 Hide/display internal forces

Reference literature

[1] DIN 18800, November 1990, Part 1.

[2] PETERSEN, CHR.: *Stahlbau*. 3rd Edition. Vieweg & Sohn, Braunschweig , Wiesbaden 1993.

[3] Typisierte Verbindungen im Stahlhochbau, 2nd Edition. Deutscher Stahlbau - Verband DSTV in Zusammenarbeit mit dem Deutschen Ausschuss für Stahlbau (DASt). Stahlbau-Verlagsgesellschaft mbH, Köln 1984.

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