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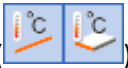


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






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1 GENERAL DESCRIPTION

1.1 INSTALLING AND RUNNING THE SOFTWARE

Please ensure that the following software and hardware requirements are met to run the Consteel program. Otherwise, it may not run at the expected speed or may not run at all.

Minimum hardware requirements:

- ▶ Processor: Intel Core i5 or equivalent
- ▶ Memory: 4 GB
- ▶ HDD: 300 MB
- ▶ Video-card: 512 MB non-integrated
- ▶ Operating-system: 64-bit MS Windows 7, 8, or 10

Recommended hardware:

- ▶ Processor: Intel Core i7 or equivalent
- ▶ Memory: 32 GB
- ▶ Video-card: 2 GB MB non-integrated

Installation needs administrative or power user rights. Without that, the hard lock driver and those .dll files, which are indispensable for the system is cannot be installed.

Downloading the install package

The *Consteel* install package can be downloaded from the *Downloads/Install packages* section of the *Consteel* website (<https://consteelsoftware.com/downloads/>) for registered users only.

Registration process

To create a new user account, click the **LOG IN** button in the upper right corner of the Consteel website (<https://consteelsoftware.com>), then click REGISTER at the bottom of the pop-up window.

In the **Create Account** window, you must enter the user's email address, name, and a chosen password. It is important to enter a real email address, because you will then need to confirm your email address with an automatically sent email. At the bottom of the window it is possible to subscribe to Consteel's professional newsletter and to accept the terms of use and privacy policy. You can then click on the **Register** button



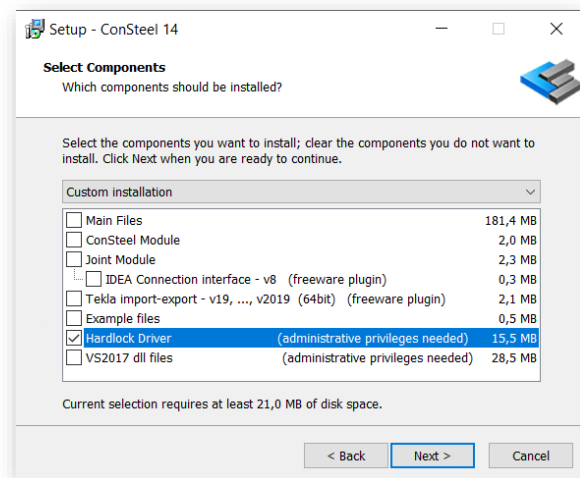
to proceed, and another window will inform you that the registration confirmation e-mail has been sent to the specified e-mail address and the registration must be completed using the link in the email. If you don't receive the email in a long time, you may need to check your spam and promotional folders in your email system. If the email is not found there either, you can request to send the confirmation email again if you try to login with your email address and password, then clicking on the *Send confirmation email again* text. After confirming the registration, you can log in to your user account.

Installing Consteel

To install, start the downloaded Consteel installation file (<https://consteelsoftware.com/en/downloads/>) and follow the instructions. As a first step the language of the setup must be set. The *Consteel* will use this language for the first time you start it, but you may switch to another language later. The installing program will copy the elements of the software into the directory you have specified (default directory: C:\Program Files\Consteel 14), then it will position the Menu of the program onto the selected place of the „START“-menu. Finally, the install shield will place the starting-icon onto the desktop. The last step of the setup is the hard lock driver installation. This has no progress signal, so you have to wait until it finishes.

Network operation

If you have purchased a network enabled hardware key, it can be connected to any computer on the internal network with a free USB port on which the hardware key driver has been pre-installed. This driver is also part of the Consteel installation package, which is installed on the computer by default with Consteel (see previous point), but it is also possible to install it independently if you want to connect the hardware key to a server computer. To do this, start the Consteel installation package as described above, then in the *Select Components* window all you have to do is select the Hardware Key driver item, leave the rest blank and click *Next* to complete the installation.





Starting the program

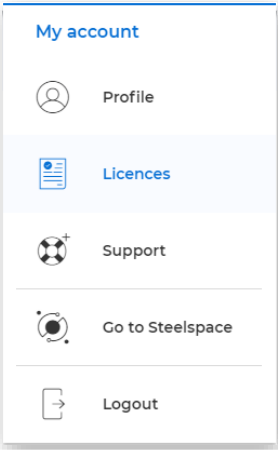
Consteel can be started with hardware key protection for a purchased copy or using an online license. The online license is currently only available for student, teacher, or trial versions for free through a registered Consteel user account. See the link below for details on how to apply for a license: <https://consteelsoftware.com/en/how-licensing-works>

Before starting the program, you must plug the dongle into an empty USB port on your computer, or in the case of a network key, the key must be available on a computer on the local network. If, after start-up, Consteel cannot find the correct hardware key connected to the computer (or over the network), a login window will appear to launch the program using the online license assigned to the Consteel user account. To do this, you must enter the username (email address) and password registered on the website.

A screenshot of the Consteel Login window. The window has a title bar with 'Login' and a close button. Inside, there's the Consteel logo and the text 'Log in with your Consteel account!'. Below this are two input fields: 'User name' and 'Password'. There's a checkbox labeled 'Remember my credentials' which is checked. At the bottom, there are two buttons: 'Login' and 'Sign in to online account'.

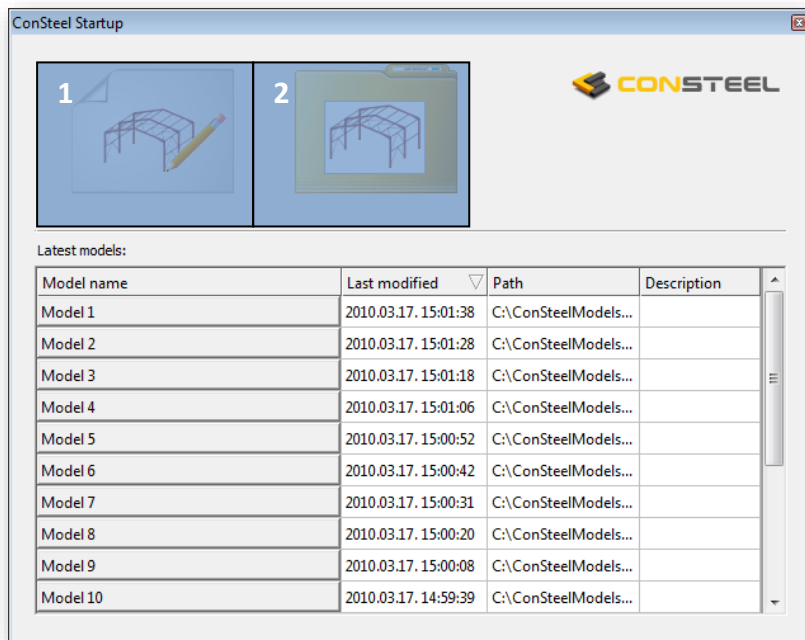
If the user does not have an online license, pressing the “Sign in to online account” button will open the default internet browser application and load the Consteel website. Here you can apply for a new license by clicking on the "Login" button in the upper right corner of the page and then entering the "Licenses" menu.

Products ▼ References ▼ Downloads Knowledge base About ▼ Contact ▼ [Log in](#)

A screenshot of the 'My account' dropdown menu. It has a title 'My account' in blue. Below the title are five items, each with an icon and text: 'Profile' (person icon), 'Licences' (document icon, highlighted in blue), 'Support' (globe icon), 'Go to Steelspace' (circular arrow icon), and 'Logout' (door icon).



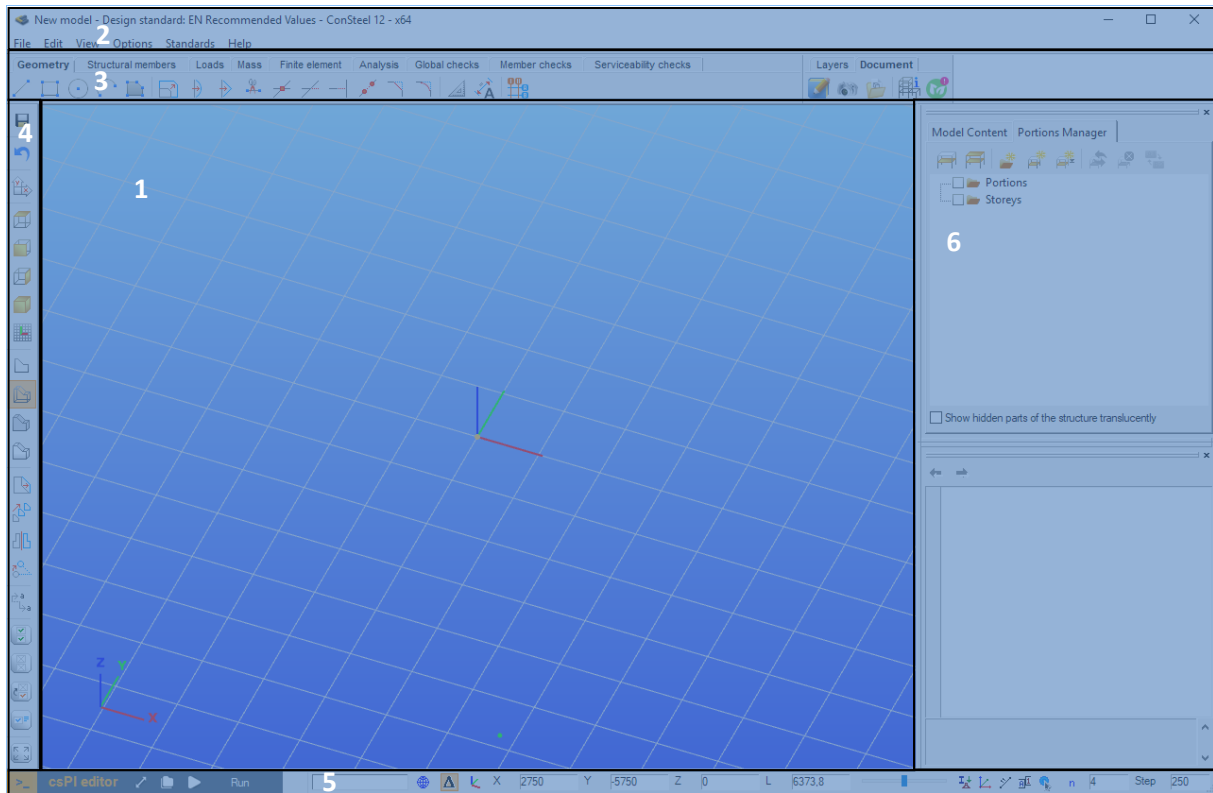
The starting of *Consteel* opens a startup dialog window which allows to create and open models easily. The latest models can be opened without browsing folders. They are sorted by the last modification date as a default setting, but it can also be sorted by name or by model path.



The first big button (#1) is for creating a new model, the second (#2) is for opening model from the folder.



1.2 THE MAIN WINDOW



The main window consists of six separate parts containing different functionalities. The graphical window is the area for the 3D structural modelling (#1); the menu on the top contains some important commands (#2); the tabs from left to right lead the user through the steps of structural design (#3); the side bar on the left contains functions for grids, views, most commonly used transformations and selections (#4); the status bar on the bottom makes the drawing phases easier (#5) and the object and parameter tables at the right gives always sophisticated information about the model, making fast modifications possible (#6).

1.2.1 THE GRAPHICAL WINDOW

The structural model appears always in the graphical window. There are no other window opening options; however, there are lots of viewing possibilities in this single window. The graphical window supports the modelling by the global coordinate system (GCS) and a moveable, rotatable and size adjustable grid. The coordinate system at the left bottom corner always denotes the unchangeable GCS; the origin of the user coordinate system (UCS) takes place at the middle point of the grid which is always the plane “XY” of the UCS. The following moving possibilities and quick view settings can be used during the structural model manipulation:



► **Move:**

push and hold down the middle mouse button or use the four arrow buttons on the keyboard to move the model on the screen

► **Rotate:**

hold down the **ALT** key and the left mouse button. The center of rotation is always adapting the actual model view

► **Scaling:**

spin the middle mouse button forth and back or use the **+** and **-** buttons on the keyboard or hold down the **ALT** key and the right mouse button

► **Zoom window:**

window drawing by the left mouse button, while pressing **SHIFT+ALT** keys

► **Hotkeys for vie:**

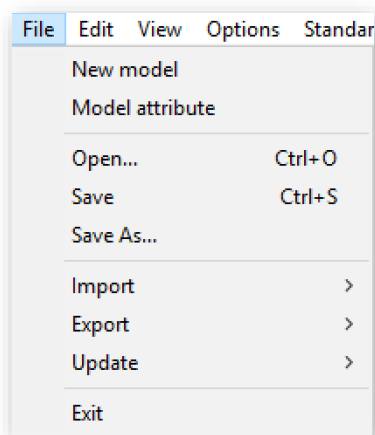
- **Ctrl+1:** Switch to **top view**
- **Ctrl+2:** Switch to **front view**
- **Ctrl+3:** Switch to **side view**
- **Ctrl+4:** Switch to **axonometric view**
- **Ctrl+5:** Perpendicular to actual raster plane
- **Ctrl+0:** Quick **zoom all**

1.2.2 THE MENU

The *Consteel* menu does not contain many commands since the main functionality is placed to the structured tabs and side bars and the applicability and modelling efficiency does not really need to duplicate the functions. However, six important function groups appear here: the **FILE** handling, some **EDIT** options (undo-redo), **VIEW** and diagnostics, **OPTIONS** for settings (for saving, updating, selecting language, and for model diagnostics), **STANDARDS** for reviewing and defining standard parameters for design and **HELP**.



FILE menu:

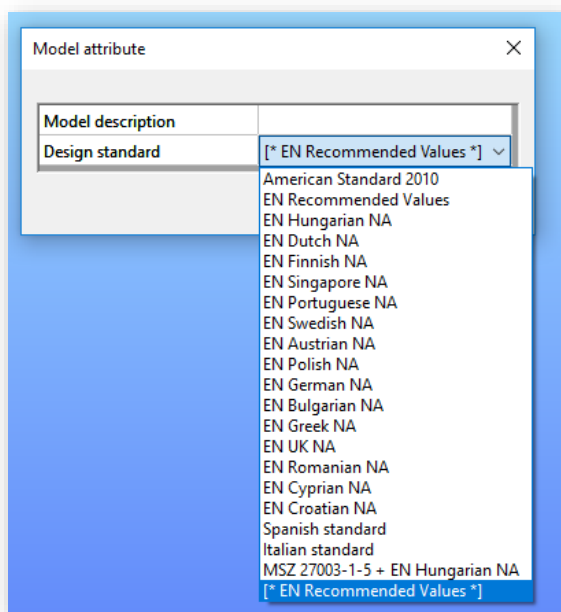


New model

A new structural model can be created.

Model attribute

The model description and the EN National Annex, or design standard can be changed.
(These parameters can be set at first by creating a new model.)



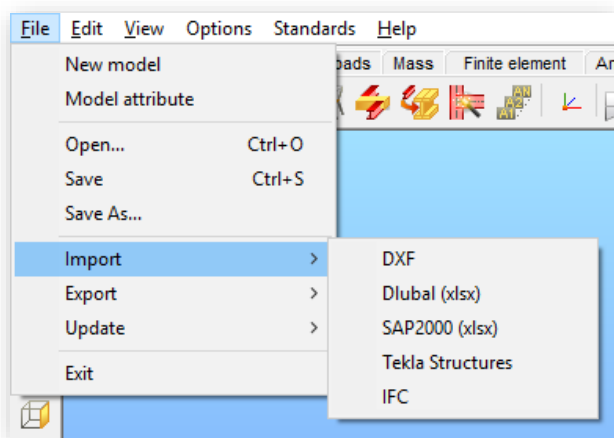
Open, Save, Save As

The functions are according to their names.

Import



Import menu contains a wide range of import possibilities from the very basic DXF wireframe import to the widespread IFC, furthermore the complex Dlubal and SAP2000 model import including the loadings as well.



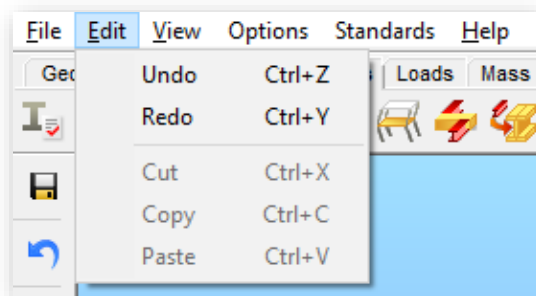
Export

The selected part of the model can be exported to *TEKLA Structures* or to IFC. In case of slab reinforcement result, the colored result view can be exported to DXF format as well.

Update

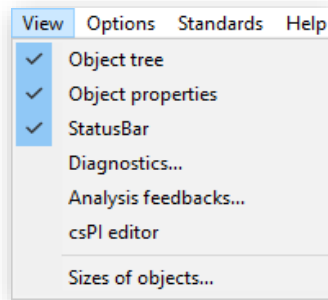
In case of connected Tekla model (previously Tekla import or export is needed), connected Tekla model can be updated and modified acc. to the actual Consteel model.

In the **EDIT** menu the common functions can be found:

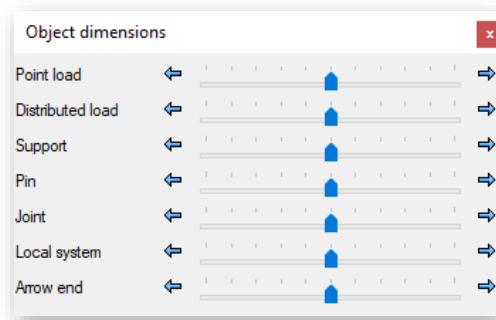




VIEW menu:



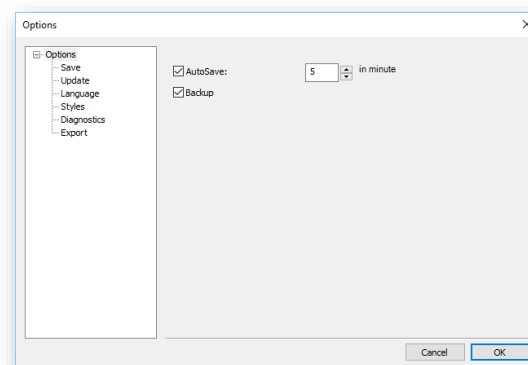
With the first four functions the visibility of the dockable windows on the right side of the main screen, can be switched on/off. With the **SIZES OF OBJECTS...** function, the size of the objects can be changed.



OPTIONS menu:

The following settings can be found: **SAVE**, **UPDATE**, **LANGUAGE**, **STYLES**, **DIAGNOSTICS**, and **EXPORT**.

Save



If **Autosave** is clicked, the program automatically performs a save periodically in accordance with the adjusted number of minutes. If **Backup** is clicked, *Consteel* creates a



backup file *after a manual save is performed*. The backup model file can be used as a normal model by removing the **.bak** extension.

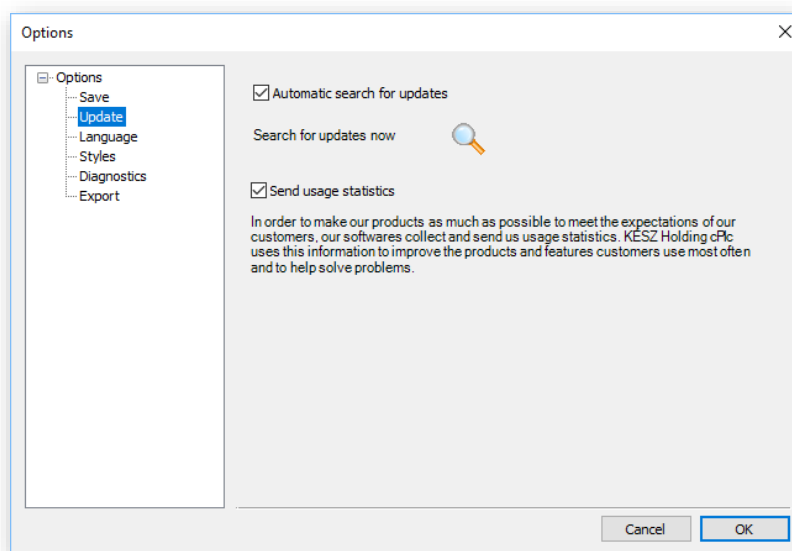
Convert previous models to Consteel 14

When the backup feature is active, the first time you save a model from an earlier version in Consteel 14, a backup is automatically made in the format of the original version. The file name of this copy is created according to the following scheme: model_filename - Consteel XX.bak (where XX = the version number).

Update

Consteel looks for an available new version on the web at every startup. It can be turned off. The check for a new version can be performed manually by clicking on the **Search for**

updates now () button.



Customer experience improvement

To make our products as much as possible to meet the expectations of our customers, our software collects and send us usage statistics. KÉSZ Holding Plc uses this information to improve the products and features customers use most often and to help solve problems.

Our products collect and sends the following information: software version, used functionalities, running time, location

Sent information does not contain any personal information (such as your name, address, or phone number) and is not used to identify you.

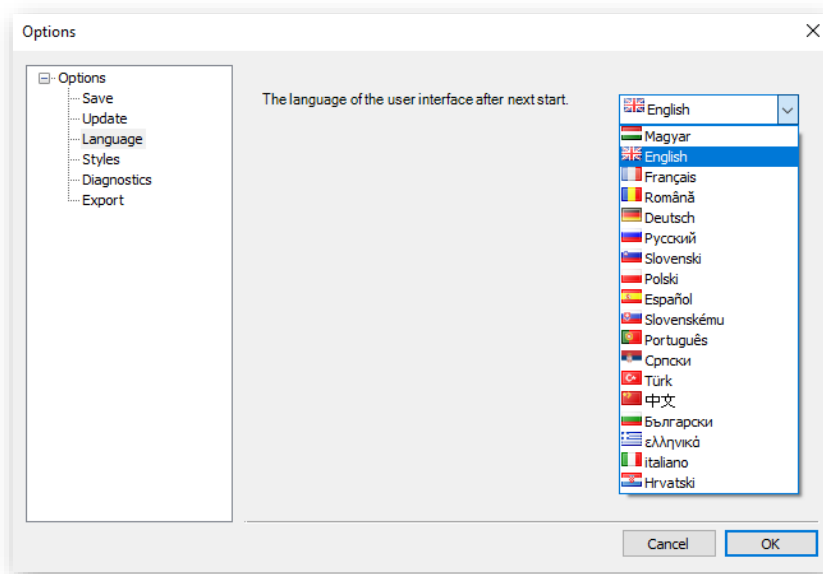


In case of commercial license, collection of usage statistics can be turn off by clicking off the checkbox. In case of trial and educational licenses, collection of usage statistics is continuous.

Language

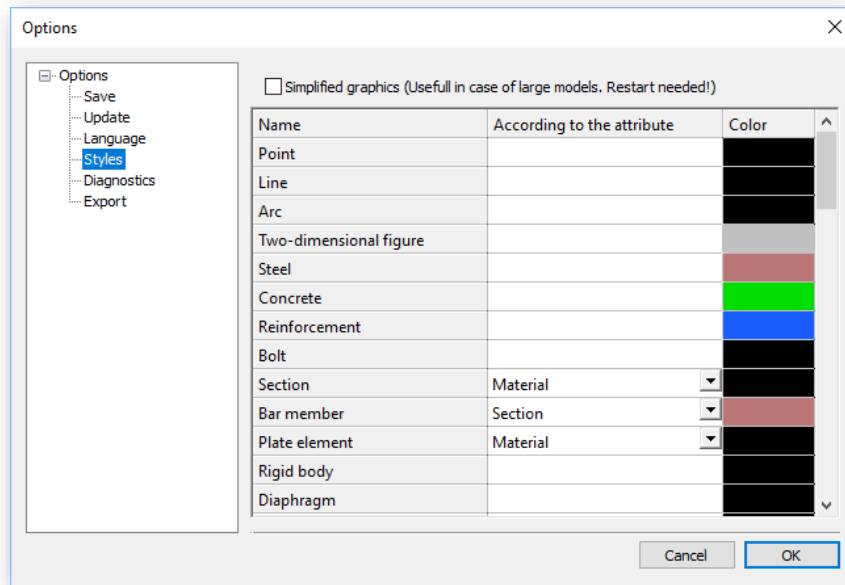
The language of the user interface can be set here from the following languages: English, German, Spanish, Italian, Greek, Portuguese, Russian, Chinese, Turkish, Hungarian, Polish, Slovak, Slovenian, Rumanian, Bulgarian, and Serbian.

Consteel must be restarted after a change.

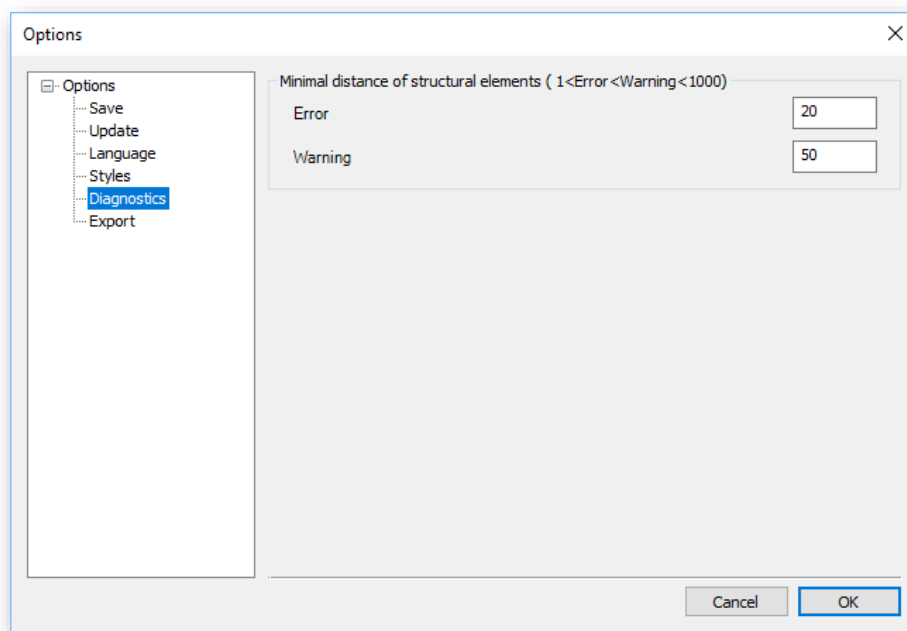


Styles

Color of the objects can be changed.



Diagnostics



Before the analysis the program checks possible modelling mistakes.

There are two different levels of warn the user for possible modelling mistakes:

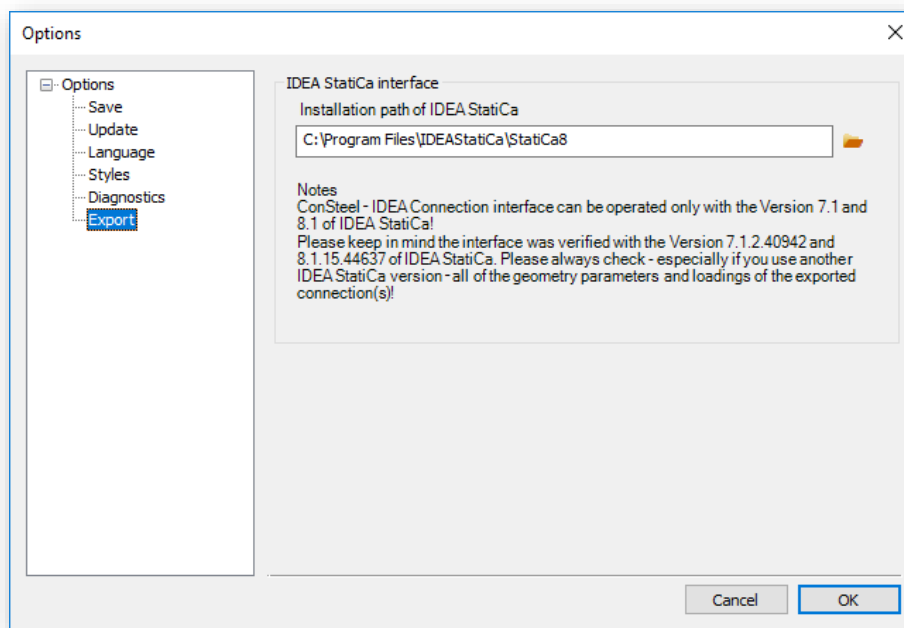
- **Error:** if the distance between the endpoints of two members is more than 0 but less than the adjusted value, the program sends an error message and shows with red sign the relevant members in the diagnostics window and does not perform the analysis.



- **Warning:** if the distance between the endpoints of two members is more than the defined error level distance, but less than the adjusted value here, the program sends a warning message, and shows with yellow sign the relevant members in the diagnostics window.

Export

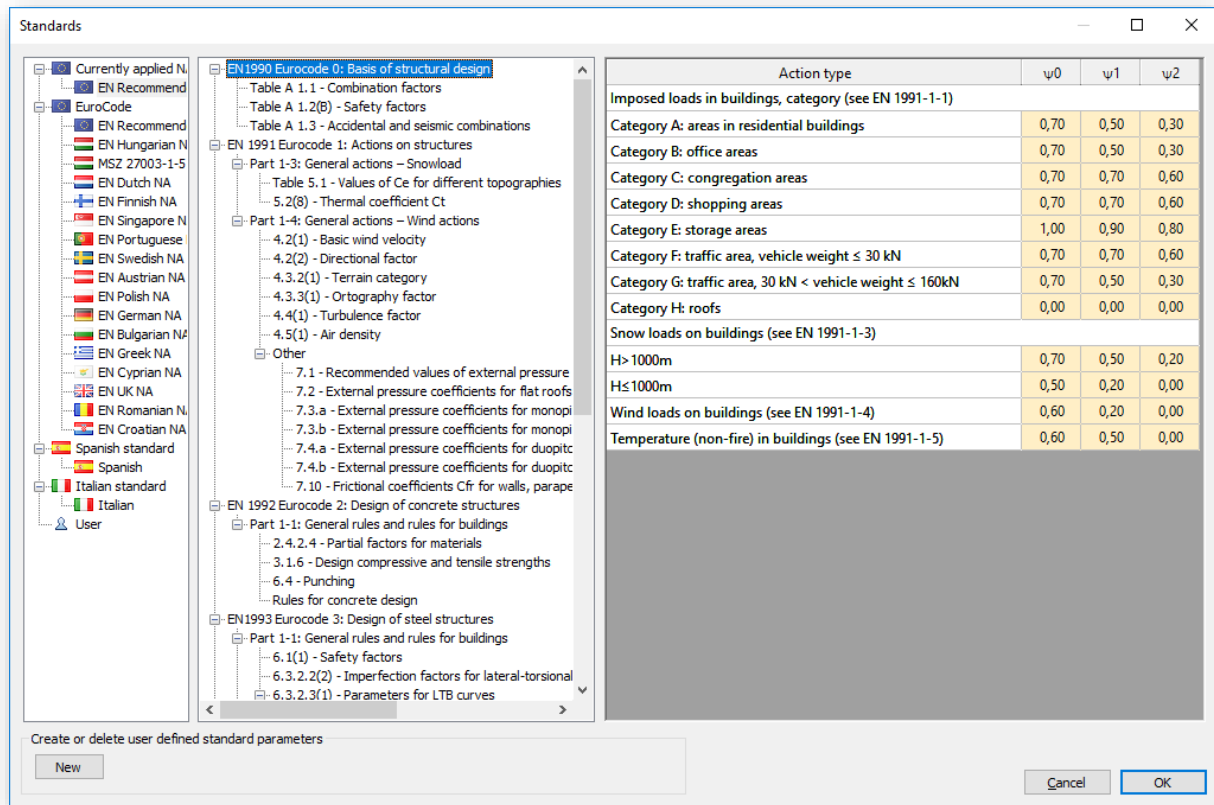
There is some third parties' program which required direct (such as IDEA StatiCA) connection for Export.



On this menu, all the necessary settings can be made.

STANDARDS menu:

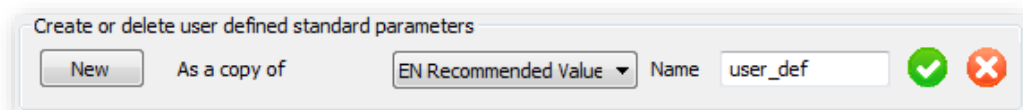
The menu provides a great opportunity to view existing and to create new standard parameters in an easy way. The used standard can be set in the **FILE** menu.



The first row of the Standard tree shows the applied standard which is stored in the model.

For creating a new, user defined standard:

- press **NEW** button
- select one of the existing standards from the list

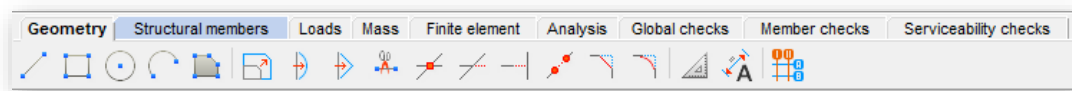


- name the new defined standard
- parameters for the new defined standard can be changed in the chapters

User defined National Annex saved to the following file:
 \Documents\Consteel\UserStandard.xml



1.2.3 TABS



The tabs contain the systematically collected functions of modelling, analysis, and design, leading the engineers through the logical steps of the structural design.

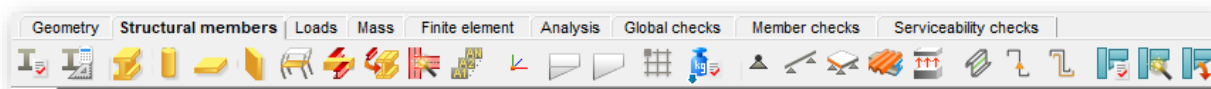
By approaching any of the icons with the cursor, the short name of the icon will be appeared.

GEOMETRY TAB



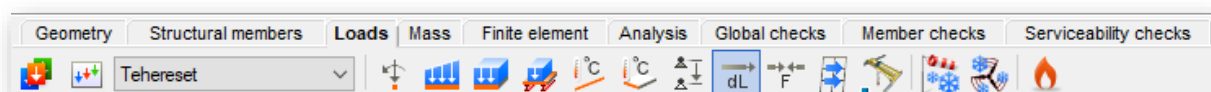
It contains all the important CAD drawing and modification functions as well as dimensioning and measuring tools.

STRUCTURAL MEMBERS TAB



The functions related to cross-sections; structural columns, beams, slabs and walls, frame corner wizard, diaphragm and rigid body, supports and connections are collected on this tab. The automatic members to plate conversion function can be also found on this tab.

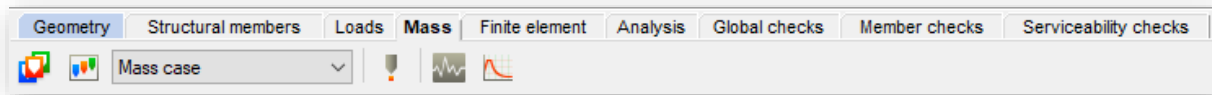
LOADS TAB



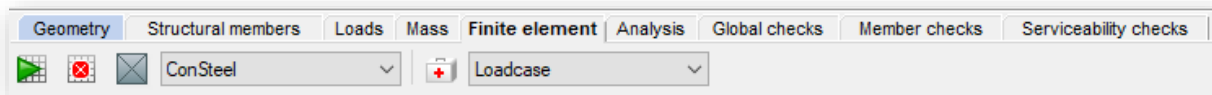
All types of loading including load cases, load groups, load combinations and unique loads placed on the structure can be created with the **LOADS** tab. The functions of meteorological load generation, crane and train load, and fire effect and protection can be found also here.

MASS TAB

Mass cases, mass groups, point masses, response spectrums and seismic effects can be created on the **MASS TAB**.

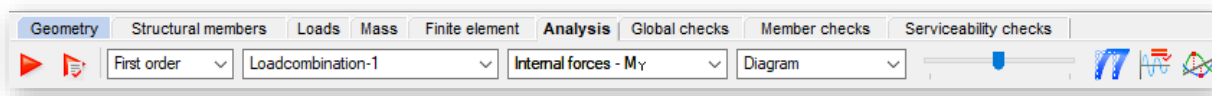


FINITE ELEMENT TAB



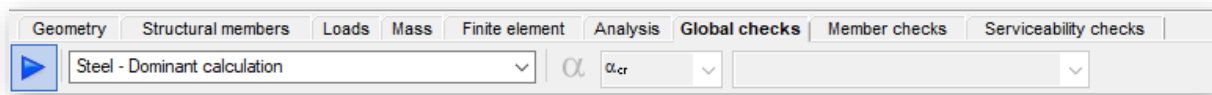
It contains functions connected with the finite element mesh generation and modification and a model check option indicating possible modelling mistakes.

ANALYSIS TAB



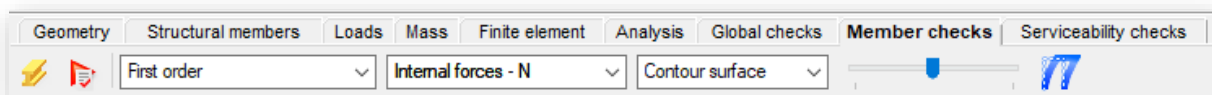
The types of the structural analysis can be set and executed, the results can be viewed and labelled in various forms.

GLOBAL CHECKS TAB



The **GLOBAL CHECKS** tab contains the options and results of possible cross sections checks as well as the global buckling standard checks.

MEMBER CHECKS TAB



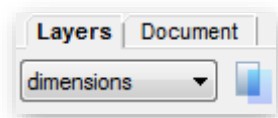
Steel member design related checks functions (buckling, lateral-torsional buckling, and interaction stability) and the composite beam design related functions can be found on the **MEMBER DESIGN** tab.

SERVICEABILITY CHECKS TAB



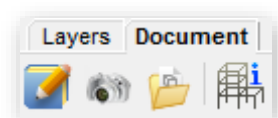
All serviceability related functions (horizontal and vertical deflection checks) can be found on the **SERVICEABILITY CHECKS** tab.

LAYERS TAB



It provides functions for adjusting the layer properties.

DOCUMENT TAB

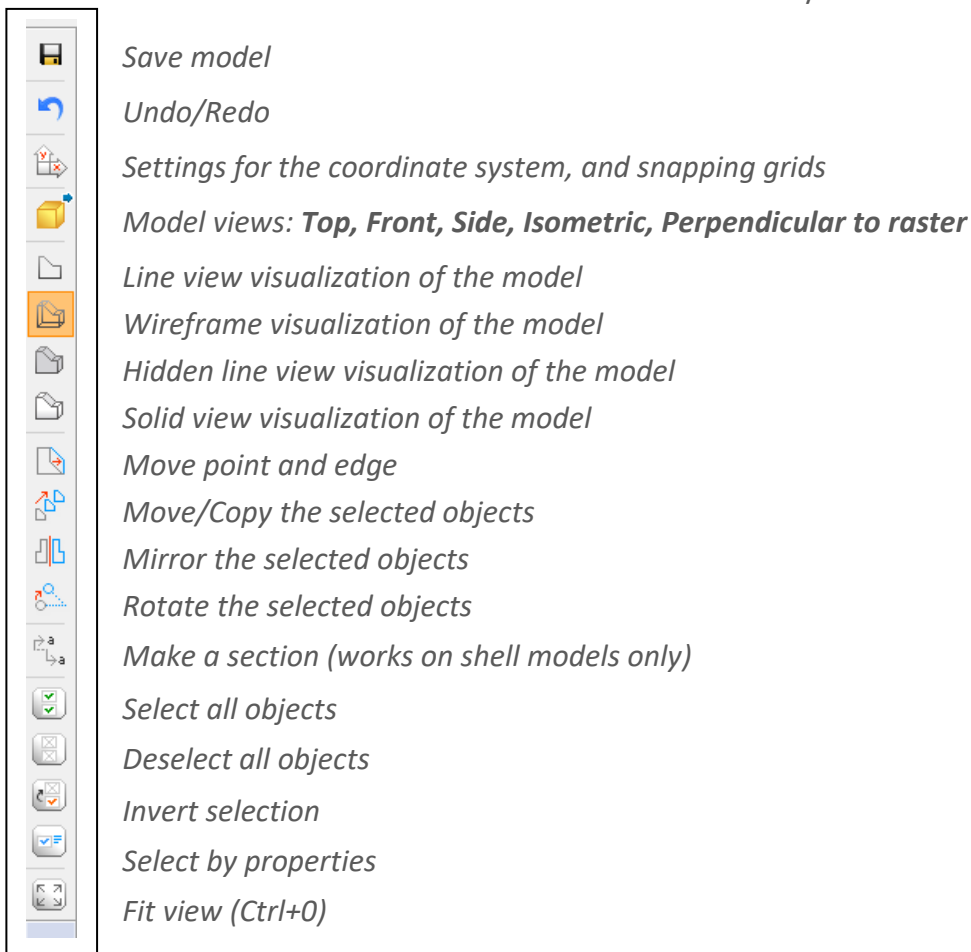


The functions of the **DOCUMENT** tab allow the flexible creation of a detailed statical documentation and contain a model information tool.



1.2.4 THE SIDE BAR

The side bar at the left of the main screen contains the mostly used functions for modelling.

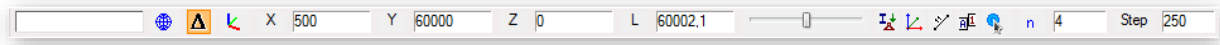


1.2.5 CSPI PANEL




At the bottom left of the screen, the csPI control panel can be found. csPI is a programming interface made specially for Consteel, with which parametric models can be built. All the objects which can be found in Consteel can be created through csPI, and all the parameters of these objects are available to set from csPI. Please see **CHAPTER 15 CSPI-CONSTEEL PROGRAMMING INTERFACE** to know more!

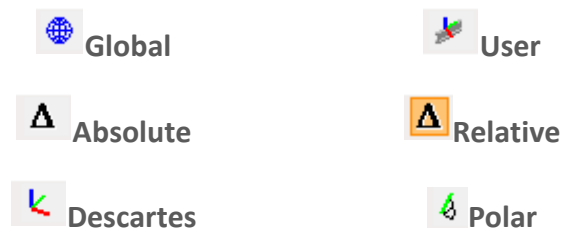


1.2.6 THE STATUS BAR










The first field is a progress bar showing the progress of actions.

The next 3 icons on the status bar (  ) specify the meaning of the coordinates during drawing/modelling actions, while values are entered manually after pressing the appropriate letter ("X, Y, Z, L" for the coordinate axis or a length into a direction, or "a, b, L" for polar coordinates). The user can change the interpretation of the manually entered values with the following settings:




Even if you are in Descartes coordinate system, you have already picked the first point of a new structural beam, while approaching another point with your cursor in the model space, after typing "L" (lowercase), you can enter the length of your beam manually into the L field. By pressing the Enter key the beam is added to the model with the length "L" and the direction defined by the two points.

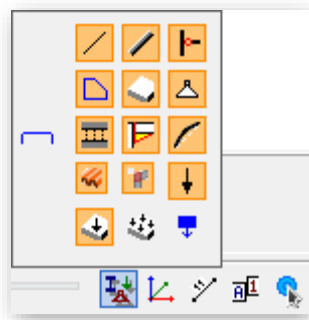
By moving or clicking the slider () with the right mouse button, the size-representation of the objects can be changed. The next four icons (   ) allow the sophisticated visibility adjustment. By approaching any of these icons with the cursor a group of graphic symbols will appear ordered into a matrix shape.















Clicking the first icon on each of these four visibility setting matrix the scope of the settings will be changed between global () (valid for all tabs), or valid only for the current tab ()).

By setting this option on any of the 4 visibility matrixes, the selected scope will change on all the other three accordingly.


Changing this scope will also change the visibility between the previously adjusted global and the current tab visibility settings.

Visibility options of graphic symbols ()



-  Visibility of lines, created with line, circle and arc function of **GEOMETRY** tab
-  Visibility of structural members created with the beam or column function in the **STRUCTURAL MEMBERS** tab; switching these members to non-visible their centerlines might still be visible accordingly to the status of line visibility settings ()
-  Visibility of pins (end releases)
-  Visibility of the two-dimensional shapes; switching these two-dimensional shapes to non-visible their surrounding lines might still be visible accordingly to the status of line visibility settings ()
-  Visibility of the 3 D objects (plates, slabs and walls); switching these 3D objects to non-visible the surrounding lines and 2 D shape components might still be visible accordingly to the status of line visibility settings of lines () and 2d shapes ()
-  Visibility of supports
-  Visibility of link elements
-  Visibility of placed joints symbols
-  Visibility of initial bow imperfection
-  Visibility of point, line, and surface loads




Visibility of load transfer surfaces; switching these load transfer surfaces to non-visible their surrounding lines might still be visible accordingly to the setting of visibility of the lines ()

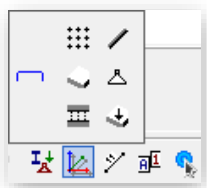


Visibility of distributed surface loads



Visibility of masses

Visibility options of the grid and the local coordinate system ()



Visibility of the grid



Visibility of the local coordinate systems of structural members (beams and columns)



Visibility of the local coordinate systems of three-dimensional objects (plates, slabs, and walls)



Visibility of the local coordinate systems of supports




Visibility of the local coordinate systems of link elements













Visibility of the local coordinate systems of the load transfer surfaces

When the visibility of an object is off, the local coordinate system of the object also will not be visible!


Visibility options of object names ()

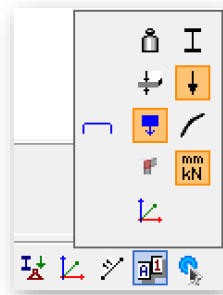










-  Visibility of the number of finite elements (visible only on the **FINITE ELEMENT** and **ANALYSES** tabs)
-  Visibility of names of bar elements
-  Visibility of names of three-dimensional objects (plates, slabs, and walls)
-  Visibility of names of supports
-  Visibility of names of pins (end releases)
-  Visibility of names of link elements
-  Visibility of the name of placed joints symbols
-  Visibility of the name of the load transfer surfaces
-  Visibility of the name of the shear fields
-  Visibility of the name of the reinforcement objects

When the visibility of an object is off, the name of it also will not be visible!

Visibility options of labels ()



-  Show material grades
-  Show shape names
-  Show the thickness of plates in mm
-  Show the load intensity
-  Show initial bow imperfections
-  Show the units of quantities



Show labels of the local coordinate axes



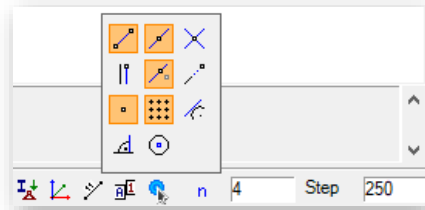
Show labels of frame corner zones



Show labels of masses

Action point sets ()

The **Action point sets** offer a wide range of setting the point snapping functions:









Snapping the end points of graphical (lines, arcs) and structural (beams, columns) objects



Switch divide function ON / OFF









► ON:

When the Divide snap mode is turned ON, a new field will appear on the status bar. There are 3 options for the divide snap point specification. The user can switch them by clicking on the icon before the numeric field:

-  , by clicking the  icon, the percentage icon appears. The percentage of the length of the approached element will be calculated, and from its approached end this length will be measured by the snapping points. Usually there is a rest distance at the end of the element
-  , by clicking to the  icon, a distance can be specified. This length will be measured by the snapping points from the approached end of the object. Usually there is a rest distance at the end of the element
-  , clicking to the  icon, the number of divisions can be specified. The created snapping points are the intersection points of subdivided lengths. There is no rest distance at the end of the element

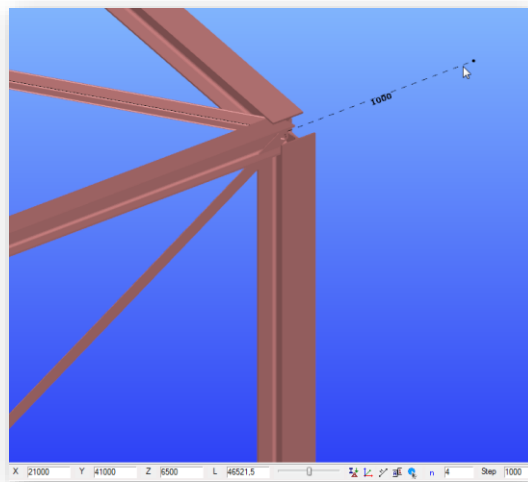
- OFF: The field of division will disappear from the bottom status bar



-  Snapping the intersection points of graphical (lines, circles, arcs) and structural (beams, columns) objects
-  Snapping the parallel point to a linear object
-  Snapping the nearest element point of an object
-  Snapping the lengthened point of a linear object. The system is showing the actual distance of the snapping point in [mm] from the endpoint of a linear element.
-  Switches ON/OFF the snap points of the raster.
-  Snapping point to create a tangent of an Arc / Circle from one point
-  Snapping point to create a perpendicular from one point to an object (Line or Arc/Circle)
-  Snapping the Center point of Arc / Circle.

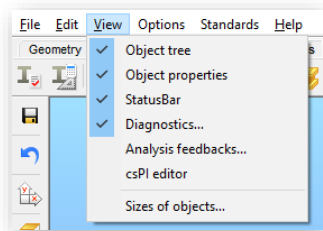
For snapping the center of linear elements, you must use the appropriate settings of snap divided points, see above!

The last field of the Status bar is the STEP field. Here the given number in mm is the snapping distance towards the length direction of line and bar elements, when the lengthening snapping point is ON.



1.2.7 THE WINDOWS OF OBJECT TREE, DIAGNOSTICS RESULTS AND OBJECT PROPERTIES

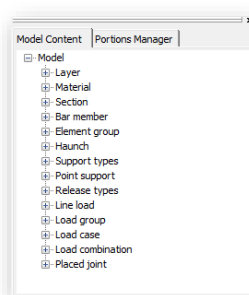
The visibility of the windows of the main screen can be switched ON / OFF in the **VIEW** menu.



Object tree window

The Object window has two tabs:

MODEL CONTENT tab

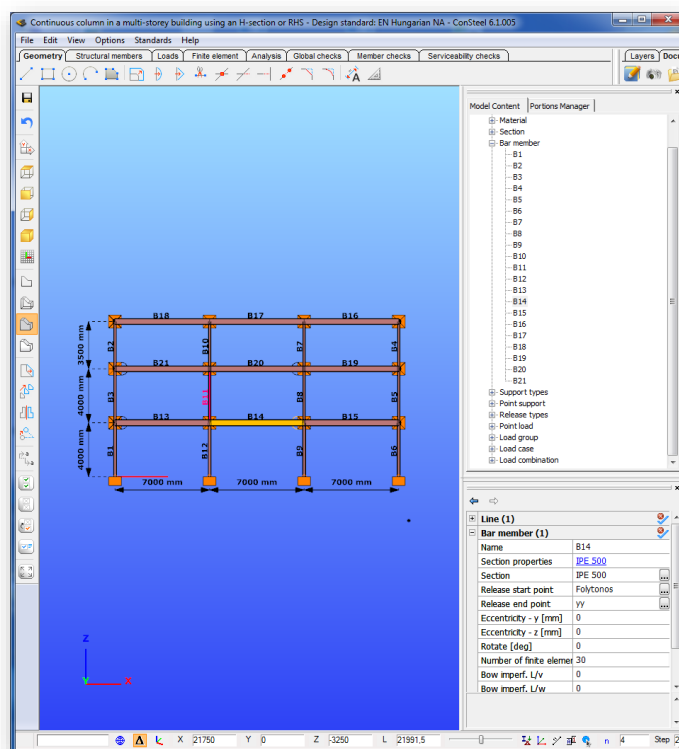


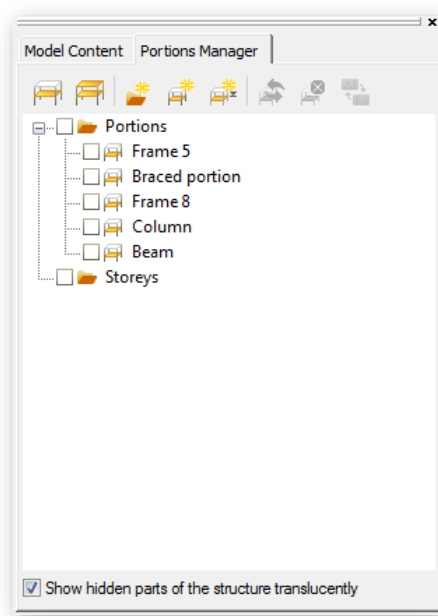
By default, the **MODEL CONTENT** tab contains all the predefined basic object types which can be used to build up a structural model.

While modelling, each new object (materials, sections, loads, members, supports etc.) will appear in the tree object structure in the appropriate group.

Selecting any of the objects, it will be highlighted (selected) in the model graphic. Multiple selections of objects are possible in this tree.

PORTIONS MANAGER tab

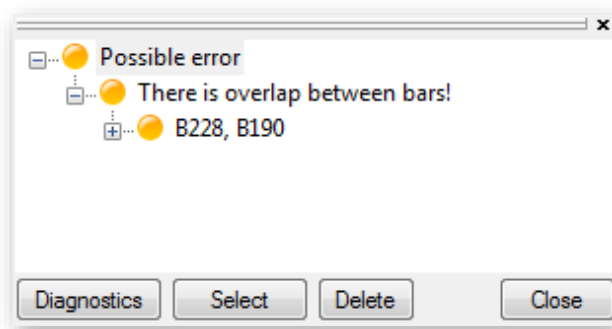




Please find the description of the **PORTIONS MANAGER** tab in **3.2 MODEL VIEWS**, and in **3.4 PORTIONS MANAGER** chapters below!

Diagnostic window

In case of geometrical or modelling mistakes (like overlapping two or more object, missing supports, etc..) are detected, the Diagnostic windows visibility will switch ON automatically showing the name of problematic objects in a tree structure.



The first type of diagnostic results are the error messages appearing in red color.

The second type of the diagnostic result are possible errors in yellow color.

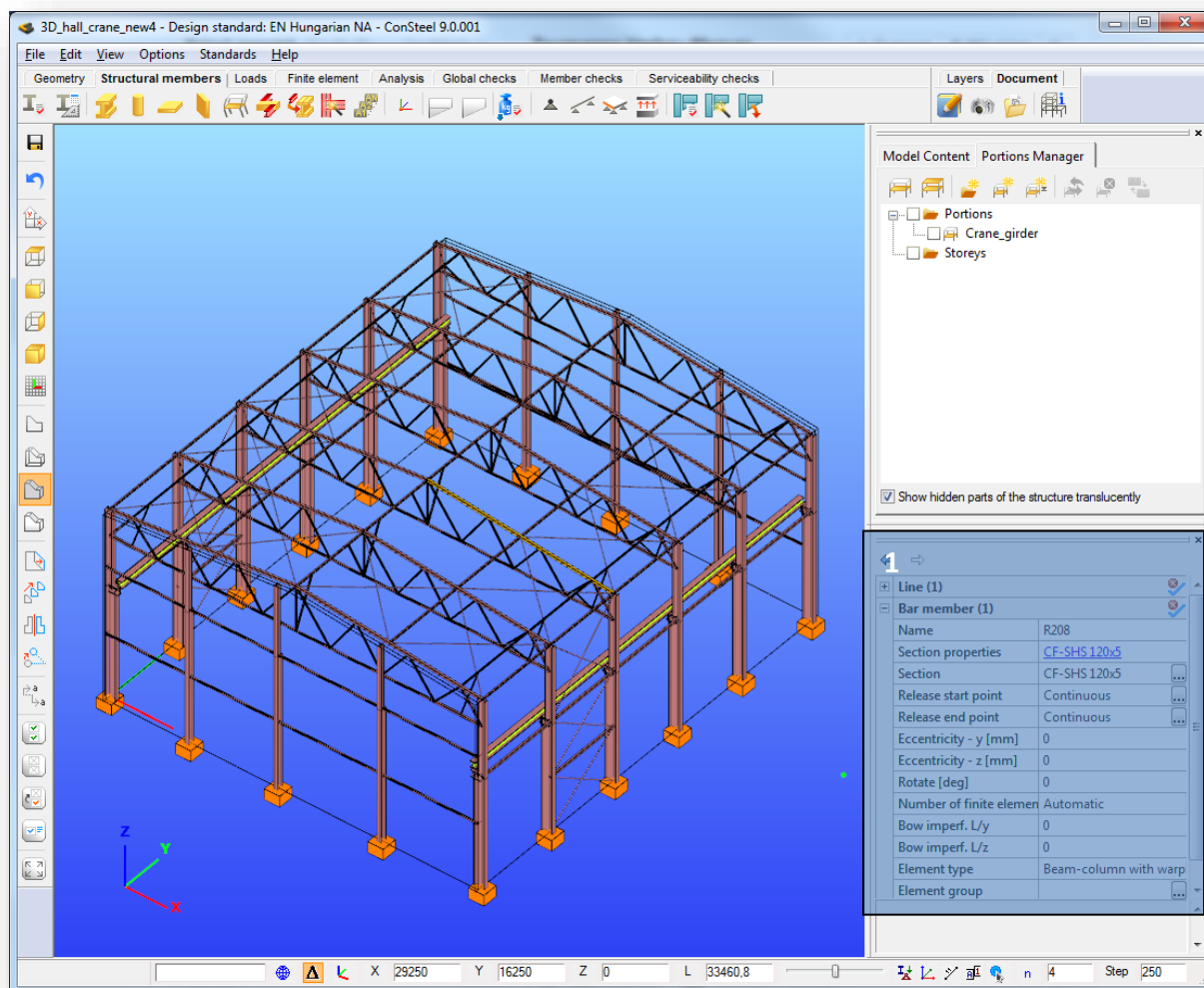
By clicking on any of the object name in tree structure, and pressing the **SELECT** button, the selected object will be highlighted in the model graphic. You can select more objects at the same time clicking their name while pressing the **SHIFT** or **CTRL** key.

The selected object can be erased by pressing **DELETE** button at the bottom of the Diagnostic window or using the **DELETE** key on the keyboard.




Object properties window

By selecting one object in the model space all the relevant properties of it will appear in this window (#1). The values of the parameters can be overviewed and in most cases these parameters can be changed.



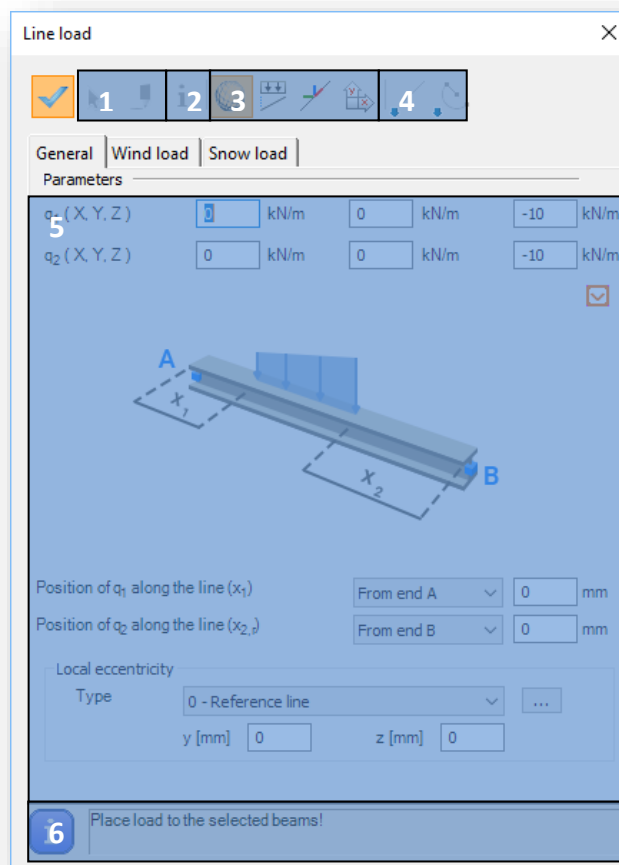
All selected objects (and sub-object) appear in the table. By expanding one object all its parameters can be seen and modified if possible. In the case of a multiple object selection only the identical parameters of all objects appear, however the different ones can also be changed to identical.






With the unselect button () previously selected object type can be removed from the selection.

1.3 GENERAL STRUCTURE OF DIALOGUE WINDOWS



Several dialogue windows – especially the most important ones on the **STRUCTURAL MEMBERS** and **LOADS** tabs – show the same structure to make the orientation in the labyrinth of tools and functions easy. The usual parts of these dialogues are described below:



- #1 -  the method of placement (assign to an element or draw from one point to another)
- #2 -  extract data from a previously placed object. All the parameters are copied from the selected object
- #3 -  coordinate system in which the directions are considered
- #4 -  additional drawing functions if the placement is chosen by drawing ()



The main parameters of an object (#5) are placed in the middle part of the dialog.

General | Wind load | Snow load |

Parameters

$q_1(X, Y, Z)$ 0 kN/m 0 kN/m -10 kN/m

$q_2(X, Y, Z)$ 0 kN/m 0 kN/m -10 kN/m

☒

Position of q_1 along the line (x_1) From end A 0 mm

Position of q_2 along the line ($x_{2,r}$) From end B 0 mm

Local eccentricity

Type 0 - Reference line ...

y [mm] 0 z [mm] 0

The information field (#6) always gives information about the next required step of the placement.



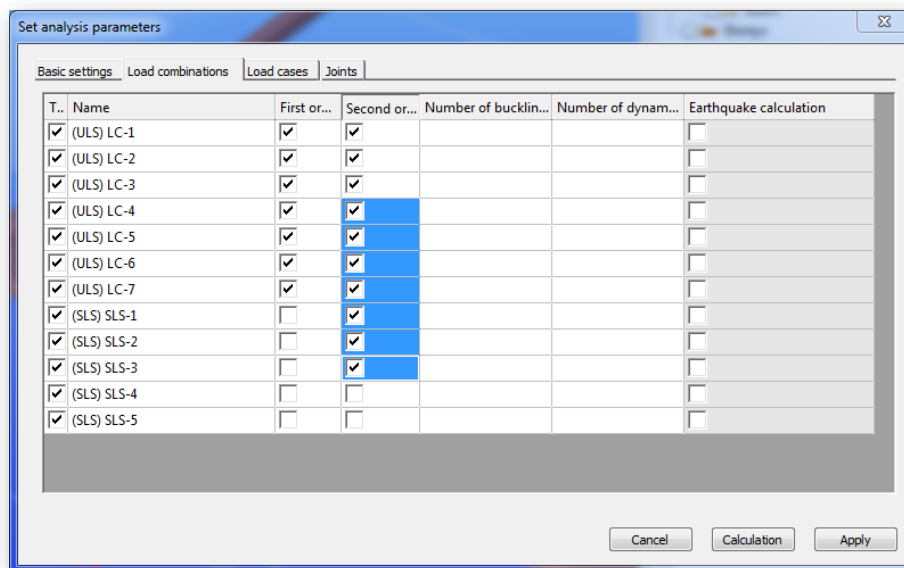
Every icon on these dialogues has a tooltip with the name of the function. The text will appear when the mouse approaches the icon.

1.4 GENERAL FUNCTIONS FOR TABLES

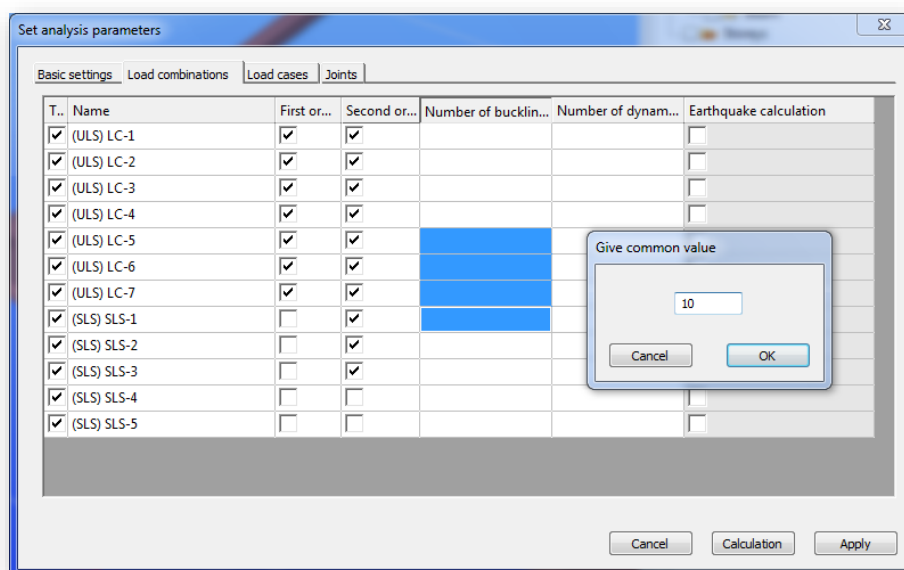
Basically, there are two types of tables in *Consteel*: the input tables and the output tables. Since tables are usually for working with large amount of data, both table types have special features making the data managing more comfortable.

Input tables (used in the **LOAD COMBINATIONS** and **ANALYSIS PARAMETERS** dialogues) have the following common features:

- ▶ clicking on the heading cells the whole column below will be selected
- ▶ if there is a checking option in the table the multiple checking is possible for the selected cells clicking on the right mouse button



- ▶ if there is a value entry option in the table cells, multiple value entry is possible for the selected cells clicking on the right mouse button and defining the common value



- ▶ In case of editable tables, cell contents can be copied by pressing **CTRL+C** and pasted by pressing **CTRL+V** in the table or to MS Excel or to other spreadsheet applications

Output tables (used on the **ANALYSIS** and **STANDARD RESISTANCE** tabs and in the **DOMINANT VALUES** and **MODEL INFORMATION** dialogues) have the following common features:

- ▶ the rows of the table can be ordered according to a column (increasing, decreasing or ABC order) clicking to its heading cell
- ▶ the actual table can be saved to file for Excel



- ▶ the actual table can be saved for the own documentation which can be inserted into the final report in the documentation module (see **CHAPTER 13 DOCUMENTATION**)

1.5 HOT KEYS

The hot keys can significantly speed up the modelling work. *Consteel* provides the following hot keys:

- ▶ **CTRL+N:** new model
- ▶ **CTRL+O:** open model
- ▶ **CTRL+S:** save model
- ▶ **CTRL+Z:** undo last action
- ▶ **CTRL+Y:** redo
- ▶ **CTRL+A:** select all
- ▶ **CTRL+I:** inverse selection
- ▶ **CTRL+1:** switch to XY view
- ▶ **CTRL+2:** switch to XZ view
- ▶ **CTRL+3:** switch to YZ view
- ▶ **CTRL+4:** switch to XYZ view
- ▶ **CTRL+5** switches the view perpendicular to the raster
- ▶ **CTRL+C:** copy the selected cell contents from the editable tables
- ▶ **CTRL+V:** past the copied cell contents
- ▶ **ESC:** unselect all or terminate (or abort) the last action
- ▶ **Delete:** delete selected objects
- ▶ **F1:** open Help system
- ▶ **F3:** runs analysis with the actual settings
- ▶ **X:** manual definition of X coordinate value
- ▶ **Y:** manual definition of Y coordinate value



- ▶ **Z:** manual definition of Z coordinate value
- ▶ **a:** manual definition of alpha polar coordinate value
- ▶ **b:** manual definition of beta polar coordinate value
- ▶ **L:** manual definition of a length from the previous point in a defined direction
- ▶ **R:** switch between the global and last defined user coordinate system
- ▶ **Middle mouse button:** move model
- ▶ **ALT+left mouse button:** rotate model
- ▶ **ALT+right mouse button:** zooming model
- ▶ **↑:** move model up
- ▶ **↓:** move model down
- ▶ **→:** move model right
- ▶ **←:** move model left
- ▶ **middle mouse button:** scale model
- ▶ **+:** scale up model
- ▶ **-:** scale down model
- ▶ **SHIFT+left mouse button:** unselect
- ▶ **SHIFT+ALT+left mouse button:** window scale



2 FILE HANDLING

2.1 BASICS

The file handling of *Consteel* follows the same usual and simple way of the MS Windows standard. The saved files contain all information about the model, it can be relocated to another folder and opened. By default, the **.csm** file extension is associated with *Consteel* and these files can be opened by double click.

2.2 FILE TYPES

The following file types are handled by *Consteel*:

.csm: the Consteel model file, native binary file type. It can be opened with or without results. The result file is saved to a separate file with **.csr** (Consteel result) extension, but this file cannot be opened solely. For open and save.

.csm~: the Consteel model file created by the autosave functionality. AutoSave settings can be edited in the **OPTIONS** menu.

.csm.bak: the Consteel model backup file. Backup save settings can be edited in the **OPTIONS** menu. The Backup file is created at every manual save and stores the previous saved version of the model. If necessary, the .bak extension can be deleted and backup model used as a normal model.

.anf: *StruCad* text file type. Only for open.

.csf: old *Consteel* version binary file type (Consteel 2.x, 3.x). Only for open.

.asc: *Tekla Structures* ASCII file. Only for open.

.dxf: *AutoCad* text file type. For open and save.

.sc1: *BoCad* text file type. For open and save. (optional module is needed for Bocad!)

.snf: *StruCad* text file type. For open and save.



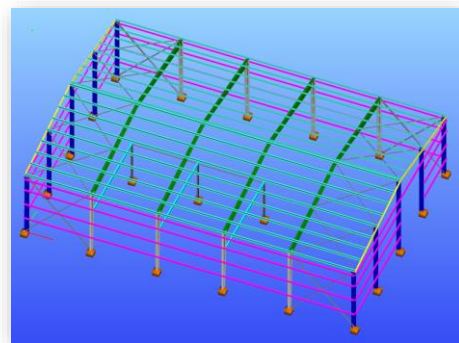
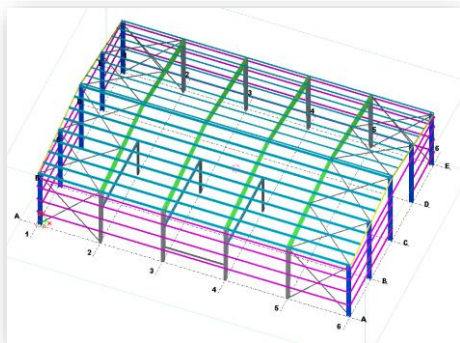
2.3 TEKLA STRUCTURES MODEL IMPORT, EXPORT AND UPDATE

The smooth and quick transition from the structural model to the detailing model can save significant time and cost. Therefore, *Consteel* has a high-level interface module to *Tekla Structures 64-bit*. Besides the export of the global structural model (i.e. beams, columns, slabs, walls) all the joint models of *Consteel* have the corresponding *Tekla* component. The designed structural model with the placed joint models can be converted into one detailed model without additional modelling efforts for the joints. This unique interface can save significant detailing time and therefore reduce appreciably the project costs.

Consteel uses *Tekla Open API* (Application Programming Interface), also known as the .NET API. This provides an interface for third party applications to interact with the model in *Tekla Structures*. Therefore, both applications need to have to be installed to export model from *Consteel* to *Tekla Structures*.

2.3.1 IMPORT STRUCTURAL MODEL FROM TEKLA STRUCTURES

During the process, we have the possibility to import the structural members defined in Tekla Structures to Consteel. From the structural parts of Tekla Structures, bar members can be imported (beams, columns, arched bars).

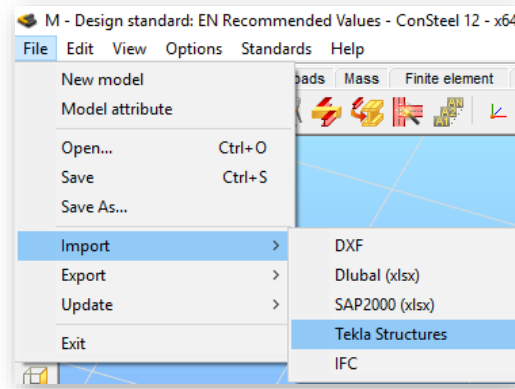


Import function is compatible with the following versions of Tekla Structures:

- ▶ 19.0, 19.1 64 bit
- ▶ 20.0, 20.1 64 bit
- ▶ 21.0, 21.1 64 bit
- ▶ 2016, 2016i 64 bit
- ▶ 2017, 2017i
- ▶ 2019, 2019i
- ▶ 2020



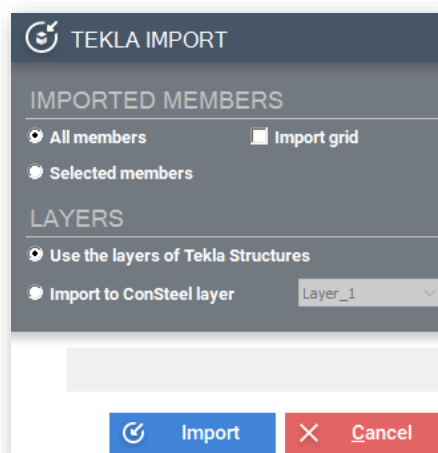
For the import process from Tekla Structures, it is indispensable to run Tekla, and Consteel in parallel. In Tekla Structure the model what is desired to be exported must be opened, alongside with an empty model opened in Consteel. For the proper importation process, it is recommended to use the Default environment of Tekla Structures. To start the import procedure, open **FILE** menu, select the **IMPORT** tools and click on **TEKLA STRUCTURES**.



On the opened import dialogue, we have the possibility to choose if the whole model, or just the selected parts of the model is desired to be imported to Consteel from the parallely running Tekla Structures model. If only the selected model parts are desired to be imported, these parts already must be selected in Tekla Structures.

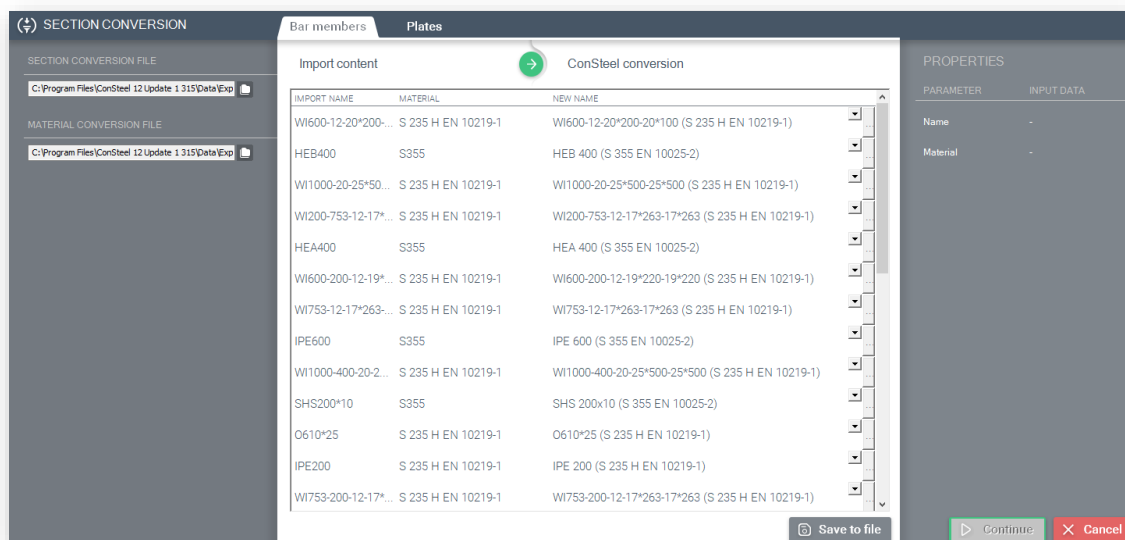
Furthermore, the layer handling must be selected. By default, the imported model will use Consteel layers, but optionally it is possible to use the layers defined by the classes in Tekla Structures. In this case, members of a Tekla Structure class can be imported to a new layer in Consteel, what will use the colors of that class.

With the **IMPORT** button, the process can be initiated.





In the next step, reference point must be clicked in Tekla Structures. It is important to note, that it is important to check the alignment of the coordinate system in Tekla Structures. After selecting the reference point in *Tekla*, the **SECTION IMPORT MANAGER** window appears. It is possible to change the conversion file for grades and for sections or edit the section name and grade manually.



The two main cases of the conversion:

► **Automatic conversion:**

- Standard section library-based conversion: Based on the conversion files, sections coming from Tekla structures can automatically assigned to a section from the Standard section library of Consteel
- Standard macro-based conversion: For those sections, which cannot be converted directly to a standard library section, Consteel will try to align a so called „Standard macro” section based on the parameters of the imported section.

- **Manual conversion:** If based on the conversion file, Consteel does not able to align any standard library section for the imported section, and the parameters does not fit to any of the standard library cross sections, section conversion has to be performed manually. This can be done by either selecting a previously loaded cross section from the dropdown menu, or by clicking on the (...) button and selecting a proper section from the library. These automatically unconvertible sections are represented with their shapes at the properties part of the **CONVERSION DIALOGUE**.

If manual changes have been made the list can be saved and can be used as a conversion file in future exports. After clicking **OK** button, the model will be exported.



2.3.1.1 LIMITATIONS OF THE IMPORT OF BAR MEMBERS

Bar members

- ▶ I and H profiles:
 - ▶ Hot rolled
 - ▶ Symmetric welded section with constant and variable height
 - ▶ Not-symmetric welded section with constant and variable height
- ▶ L profiles:
 - ▶ Hot rolled, with equal and unequal plates
 - ▶ Cold formed, with equal and unequal plates
- ▶ U profiles:
 - ▶ Hot rolled
- ▶ T profiles:
 - ▶ Hot rolled
- ▶ Box sections:
 - ▶ Symmetric welded section with constant height
 - ▶ Not-symmetric welded section with constant height (section will be defined with the thicker flange thickness)
 - ▶ WQ section cannot be imported
- ▶ Roundbars:
 - ▶ Constant height
 - ▶ Sections with different diameter in the main and sub axes is not possible
- ▶ Hollow sections:
 - ▶ Hot rolled square and rectangular , constant height
 - ▶ In case of tapered member, parameters must be set manually
- ▶ Tube sections:
 - ▶ Hot rolled sections with constant and variable height
 - ▶ Ellipse shaped section cannot be imported
- ▶ Z profiles
 - ▶ Cold formed, folded edges
 - ▶ Cold formed sections without folded edges cannot be imported
- ▶ C profiles
 - ▶ Cold formed, folded edges
 - ▶ Cold formed sections without folded edges cannot be imported
- ▶ Multi-line ,continuous beam cannot be imported

Plates

- ▶ Contour plates cannot be imported

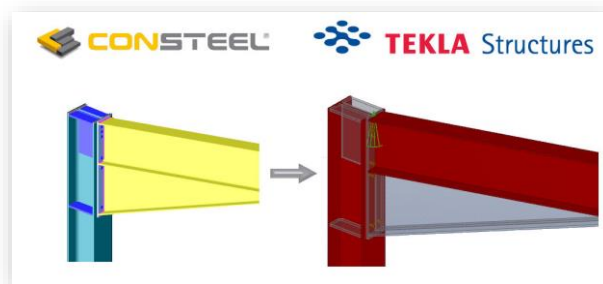


Connections

- Macros defined in Tekla Structures cannot be imported

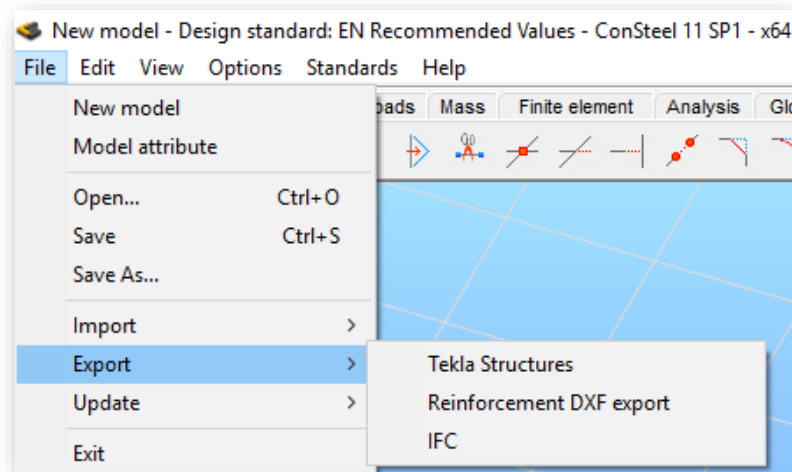
2.3.2 COMPLETE MODEL EXPORT INTO TEKLA STRUCTURES

Besides the export of the global structural model (i.e. beams, columns, slabs, walls) all the joint models of *Consteel* have the corresponding *Tekla* component. The designed structural model with the placed joint models can be converted into one detailed model without additional modelling efforts for the joints. This unique interface can save significant detailing time and therefore reduce appreciably the project costs.

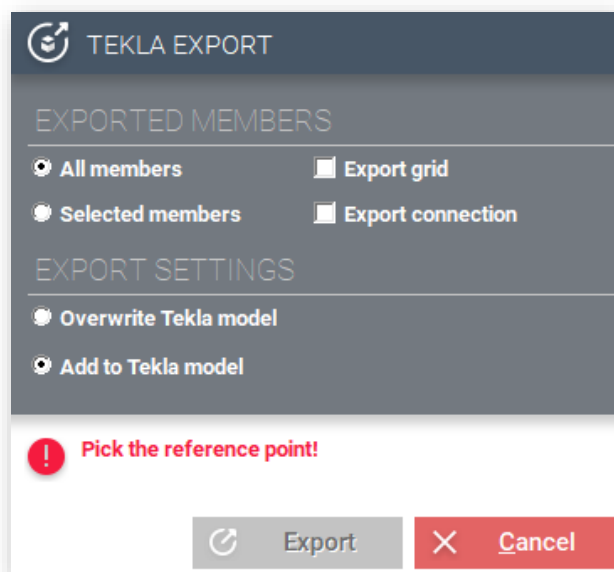


The *Consteel* export to *Tekla Structures* can be used from version 19 onward.

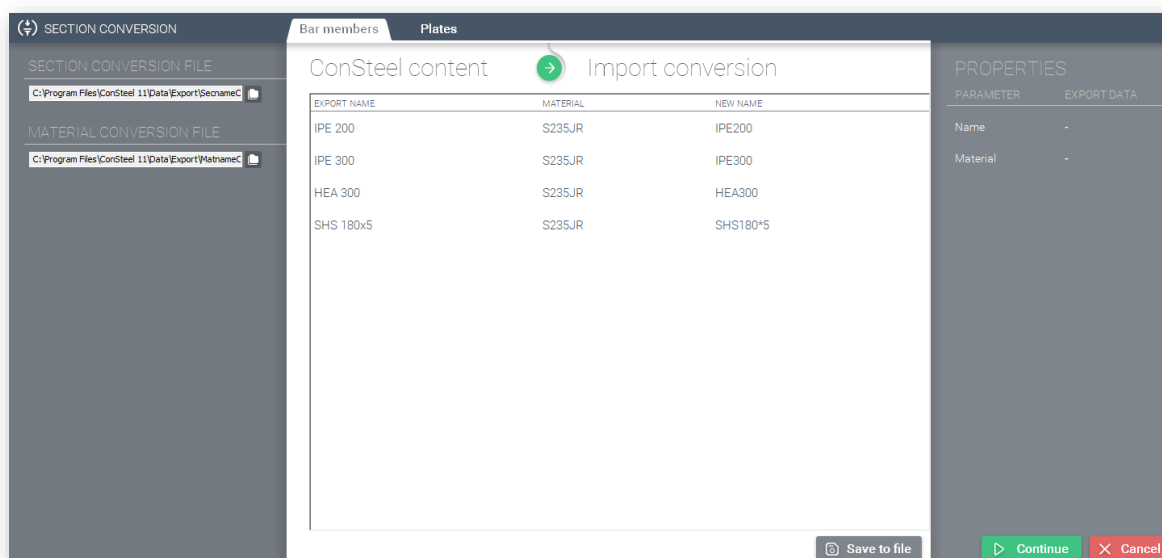
To export a model from Consteel it is important to run both programs at the same time and to have a model opened in *Tekla Structures*. Then click on the **FILE** menu and select **EXPORT** then select **TEKLA STRUCTURES**.




A dialog window opens asking for selecting model parts to be exported. Keep in mind that only those joints will be exported which are placed in the model and selected before exporting. Exportation of the model grid is also possible if the checkbox is checked. The next step is to select a reference point and to click on the **EXPORT** button.



After selecting the reference point in *Tekla*, the **SECTION CONVERSION** dialogue appears. It is possible to change the conversion file for grades and for sections or edit the section name and grade manually.



If manual changes have been made the list can be saved ( **Save to file**) and can be used as a conversion file in future exports. At the **PROPERTIES** part of the dialogue, the parameters of the selected member are shown. After clicking **OK** button, the model will be exported.

2.3.2.1 LIMITATIONS OF THE EXPORT OF JOINTS AND BAR MEMBERS

Bar members



- ▶ Arched members are not exported
- ▶ Compound sections

Semi rigid or pinned base plate → Base Plate (1042)

- ▶ No haunch can be exported
- ▶ Anchor rod type must be set manually in *Tekla* (*Consteel* settings has no effect on the export)
- ▶ Anchor rod properties which have effect on the export are the followings: diameter, grade
- ▶ Foundation will not be exported
- ▶ Upper and lower flange weld thickness would be the same in *Tekla* model (different *Consteel* settings has no effect on the export)

Beam to column, moment end plate with haunch → Haunch (40)

- ▶ Upper and lower haunch dimensions are the same (upper haunch dimensions come from the lower)
- ▶ No shear stiffeners are exported into *Tekla* only supplementary web plate
- ▶ Flange stiffeners are not exported into *Tekla*

Beam to column, simple end plate → Haunch (144)

- ▶ Column top height modification must be set manually

Beam to column, simple end plate → Haunch (146)

Beam splice connected with a pitch, simple or moment end plate without haunch → Haunch (40)

- ▶ Left and right sided macros are exported separately, explosion of components and redefinition of bolt parts are needed in *Tekla*

Beam splice connected in line, simple or moment end plate without haunch → Joining plates (14)

Beam splice, moment end plate with haunch → Apex haunch (106)

- ▶ No upper haunch

Beam splice plate → Splice connection (77)

Bolted circular flange plate → Round joining plates (124)

Stiffened end plate (27)

- ▶ There is no web stiffener plate in *Tekla*



Beam to beam, simple end plate → End plate (144)

Beam to beam, web fin plate → Fin plate (146)

Gusset plate for hollow and tube brace sections → Tube gusset (20)

Bolted gusset plate for angle brace → Bolted gusset (11)

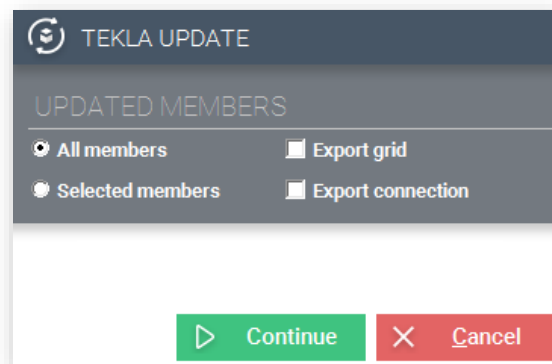
2.3.3 CHANGE MANAGEMENT BETWEEN TEKLA AND CONSTEEL: TEKLA UPDATE

Besides the import and export functions *Consteel* can check and update *Tekla Structures* models during the detailing. Update of *Tekla Structures* model is always based on *Consteel* model with the following attributes:

- ▶ Element name
- ▶ Material name
- ▶ Section name
- ▶ Section parameters
- ▶ Element geometry and position

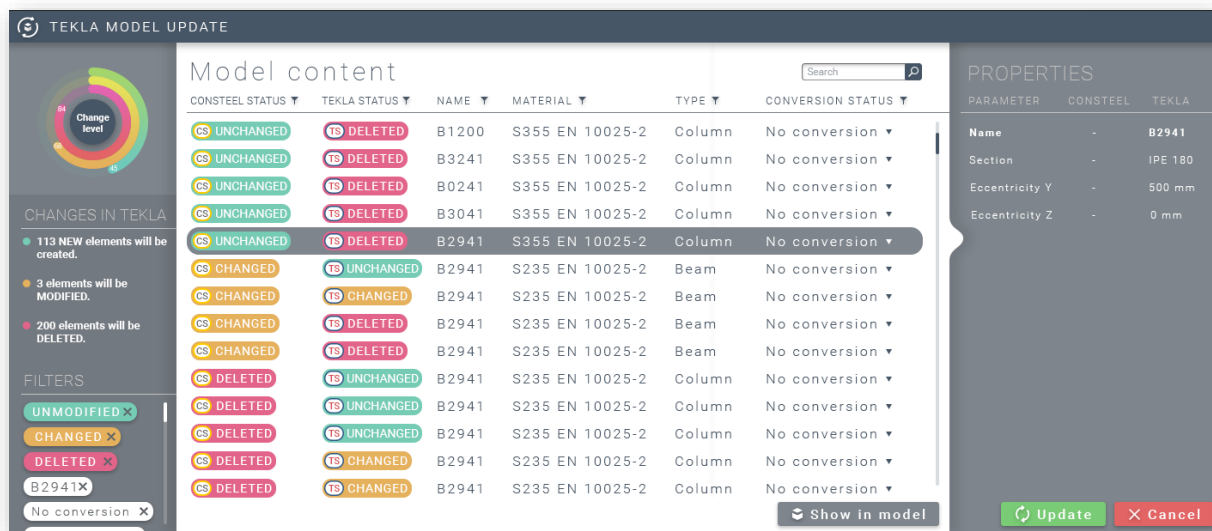
For doing model update a complete model import (or export) process is necessary before.

To update Tekla model, it is important to run both programs at the same time and to have a model opened in *Tekla Structures*. Then click on the **FILE** menu and select **EXPORT** then select **TEKLA STRUCTURES UPDATE**.



A dialog window opens, and we have the possibility to choose if the whole model, or only the selected parts of the model is desired to be exported. Then click on the **CONTINUE** button.

During the process *Tekla Structures* model and parts will be updated. In case of conflict the following dialog will be appeared, and users can make the decision and applied which model parts will be used.



Clicking on **UPDATE** button the whole process will be finished. New elements created in *Consteel* will be automatically exported to *Tekla Structures*. The next table consists the merge cases.

		UPDATE / MERGE
CS UNCHANGED	TS UNCHANGED	-
CS UNCHANGED	TS CHANGED	MERGE
CS UNCHANGED	TS DELETED	MERGE
CS CHANGED	TS UNCHANGED	UPDATE
CS CHANGED	TS CHANGED	MERGE
CS CHANGED	TS DELETED	MERGE
CS DELETED	TS UNCHANGED	MERGE
CS DELETED	TS CHANGED	MERGE
CS DELETED	TS DELETED	-

2.4 IFC IMPORT AND EXPORT



IFC is a global standard for data exchange in the building industries. IFC is both a common data model and an open file format. Building industry professionals can use IFC to share data regardless of what software application they use to get their job done.

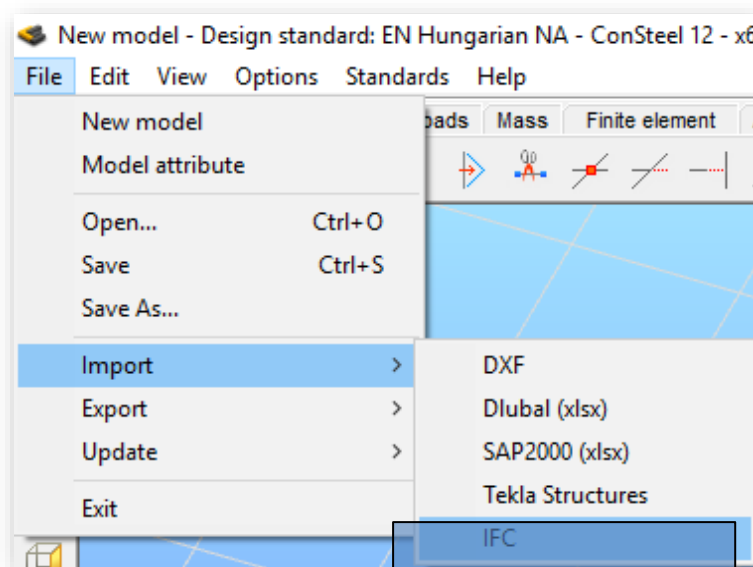
The IFC specification is developed and maintained by building SMART International as its "Data standard".

2.4.1 IMPORT OF IFC FILES

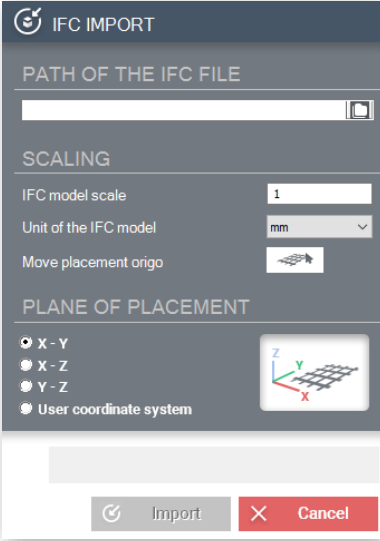
The IFC import function of Consteel supports the importation of those ifc files, which were exported with the following format scheme:

► IFC 2x3

The IFC import function can be initiated from the **IMPORT** submenu of **FILE** menu, with the **IFC** button:



After selecting the IFC function, the import dialogue will appear. The path of the ifc file which should be imported can be given directly, or it can be browsed with the folders button. At the scale options, scaling of the imported model can be adjusted. Origo of the placement can be defined if it is desired, but if it is not, Consteel will place the imported file into the global origo. For the plane of the placement the main planes, and user defined coordinate systems are also available to use.

IFC IMPORT

PATH OF THE IFC FILE

SCALING

IFC model scale: 1

Unit of the IFC model: mm

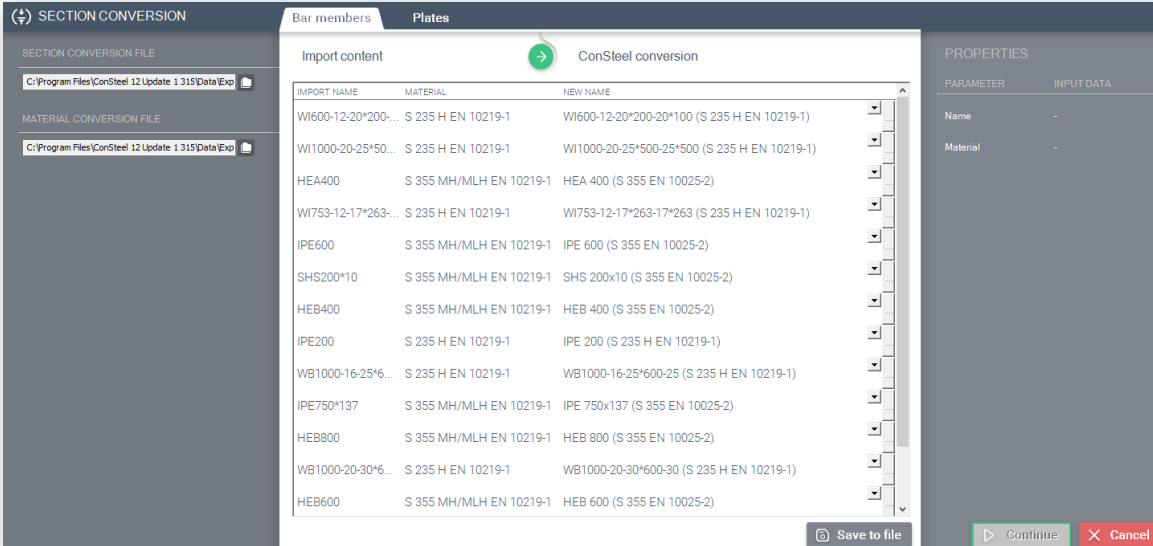
Move placement origo

PLANE OF PLACEMENT

☒ X - Y
☐ X - Z
☐ Y - Z
☐ User coordinate system

Import Cancel

After clicking on the **IMPORT** button, the **SECTION CONVERSION** dialogue will appear, where section and material data from the ifc file can be assigned to Consteel sections and materials. Consteel will automatically try to assign sections to all members, using the section and material conversion table (located in the installation folder of Consteel), but manual assignment is also possible. In the left column of the conversion table, section names from the ifc file can be seen, followed by the material names coming from the ifc file. The next column stands for the assigned Consteel sections and materials.



SECTION CONVERSION

Bar members Plates

SECTION CONVERSION FILE

C:\Program Files\ConSteel 12 Update 1 315\Data\Exp

MATERIAL CONVERSION FILE

C:\Program Files\ConSteel 12 Update 1 315\Data\Exp

Import content ConSteel conversion

IMPORT NAME	MATERIAL	NEW NAME
WI600-12-20*200...	S 235 H EN 10219-1	WI600-12-20*200*100 (S 235 H EN 10219-1)
WI1000-20-25*50...	S 235 H EN 10219-1	WI1000-20-25*500-25*500 (S 235 H EN 10219-1)
HEA400	S 355 MH/MLH EN 10219-1	HEA 400 (S 355 EN 10025-2)
WI753-12-17*263...	S 235 H EN 10219-1	WI753-12-17*263-17*263 (S 235 H EN 10219-1)
IPE600	S 355 MH/MLH EN 10219-1	IPE 600 (S 355 EN 10025-2)
SHS200*10	S 355 MH/MLH EN 10219-1	SHS 200x10 (S 355 EN 10025-2)
HEB400	S 355 MH/MLH EN 10219-1	HEB 400 (S 355 EN 10025-2)
IPE200	S 235 H EN 10219-1	IPE 200 (S 235 H EN 10219-1)
WB1000-16-25*6...	S 235 H EN 10219-1	WB1000-16-25*600-25 (S 235 H EN 10219-1)
IPE750*137	S 355 MH/MLH EN 10219-1	IPE 750x137 (S 355 EN 10025-2)
HEB800	S 355 MH/MLH EN 10219-1	HEB 800 (S 355 EN 10025-2)
WB1000-20-30*6...	S 235 H EN 10219-1	WB1000-20-30*600-30 (S 235 H EN 10219-1)
HEB600	S 355 MH/MLH EN 10219-1	HEB 600 (S 355 EN 10025-2)

Save to file Continue Cancel

PROPERTIES


PARAMETER	INPUT DATA
Name	-
Material	-

There is two possible for the assignment of sections:

- **Straightforward assignment:** In this case the sections in the ifc file can be found in the conversion tables, and Consteel will automatically assign the correct section
- **Partially straightforward assignment:**



- „Standard macro sections” case: If the section in the ifc file cannot be found in the section conversion table, but the parameters of it fit to a standard type of section (IPE for example), Consteel will create a so called „standard macro section”, and assign it to the section from the ifc file.
If Consteel is not able to assign any standard macro section to a section, using the (...) button, sections can be loaded from the section library at any time
- *Macro section assignment:* In case of sections, where the assignment cannot be performed, Consteel will draw the shape of the section at the **PROPERTIES** side of the dialogue, providing some guidance about the type of the section, so the correct macro section can be loaded from the section administrator, using the (...) button.

After the assignments of the sections are performed, the table can be saved into a user conversion file with the ( Save to file) button and can be used later at any time. By pressing the **CONTINUE** button, the import process will be performed.

2.4.1.1 AVAILABLE OBJECTS FOR THE IMPORT PROCESS

Steel members:

- ▶ I profiles:
 - ▶ Members in general positions, straight or curved, hot rolled sections with constant flange thickness symmetric I sections
 - ▶ Members in general positions, straight or curved, welded sections with constant flange thickness symmetric I sections
 - ▶ Members in general positions, straight or curved, welded sections with constant flange thickness asymmetric I sections
 - ▶ Members in general positions, straight or curved, hot rolled sections with sloped flange symmetric I sections
- ▶ H profiles:
 - ▶ Members in general positions, straight or curved, hot rolled sections with constant flange thickness H sections
 - ▶ Members in general positions, straight or curved, welded sections with constant flange thickness H sections
- ▶ T profiles:
 - ▶ Members in general positions, straight or curved hot rolled T sections
 - ▶ Members in general positions, straight or curved welded T sections
- ▶ U profiles:
 - ▶ Members in general positions, straight or curved hot rolled U sections
 - ▶ Members in general positions, straight or curved welded U sections



- ▶ Members in general positions, straight or curved hot rolled, sloped flange U sections
- ▶ Hot rolled hollow sections:
 - ▶ Members in general positions, straight or curved hot rolled hollow sections
- ▶ Cold formed hollow sections:
 - ▶ Members in general positions, straight or curved cold formed hollow sections
- ▶ Hot rolled tube sections:
 - ▶ Members in general positions, straight or curved hot rolled tube sections
- ▶ Cold formed tube sections:
 - ▶ Members in general positions, straight or curved cold formed tube sections
- ▶ Hot rolled L profiles:
 - ▶ Members in general positions, straight or curved hot rolled, equal or unequal flange length L sections
- ▶ Cold formed L profiles:
 - ▶ Members in general positions, straight or curved cold formed, equal or unequal flange length L sections
- ▶ Cold formed C profiles:
 - ▶ Members in general position, straight or curved cold formed C sections with edge
 - ▶ Members in general position, straight or curved cold formed C sections without edge
 - ▶ Members in general position, straight or curved cold formed C sections with edge and sloped flanges
- ▶ Lindab C profiles:
 - ▶ Members in general position, straight or curved cold formed asymmetric C sections with edge
- ▶ Welded C profiles:
 - ▶ Members in general position, straight or curved welded C sections without edge
- ▶ Cold formed J profiles:
 - ▶ Members in general position, straight or curved, cold formed J sections
- ▶ Cold formed U profiles:
 - ▶ Members in general position, straight or curved, cold formed U sections
- ▶ Cold formed Z profiles:
 - ▶ Members in general position, straight or curved cold formed Z sections with edge
 - ▶ Members in general position, straight or curved cold formed Z sections without edge
 - ▶ Members in general position, straight or curved cold formed Z sections with edge and sloped flanges
- ▶ Plate profiles:
 - ▶ Members in general position, straight or curved plate sections
- ▶ Box profiles:
 - ▶ Members in general position, straight or curved welded box sections
- ▶ Maltese/Half Maltese cross profiles:



- ▶ Members in general position, straight or curved welded Maltese/half Maltese cross sections
- ▶ WQ profiles:
 - ▶ Members on general position, straight or curved, welded WQ sections

Reinforced concrete members:

- ▶ Members in general position, straight, T shaped sections
- ▶ Members in general position, straight, circle shaped sections
- ▶ Members in general position, straight, hollow circle shaped sections
- ▶ Members in general position, straight, rectangle shaped sections
- ▶ Members in general position, straight, hollow rectangle shaped sections
- ▶ Members in general position, straight, trapezoid shaped sections
- ▶ Members in general position, straight, I shaped sections

Plates

- ▶ Horizontally positioned rectangle plates without holes, with or without chamfer or rounding
- ▶ Horizontally positioned polygonal shaped plates without holes, with or without chamfer or rounding
- ▶ Horizontally positioned circle shaped plates without holes, with or without chamfer or rounding
- ▶ Horizontally positioned rectangle plates with general (inside the plate) holes, with or without chamfer or rounding
- ▶ Horizontally positioned polygonal shaped plates with general (inside the plate) holes, with or without chamfer or rounding
- ▶ Horizontally positioned circle shaped plates with general (inside the plate) holes, with or without chamfer or rounding

Wall plates

- ▶ Vertically positioned plates without holes, with or without chamfer or rounding

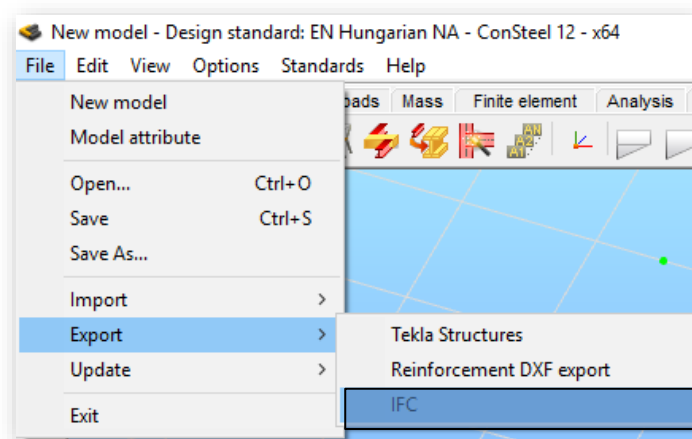
2.4.2 EXPORT OF IFC FILES

Members from Consteel can be exported from into ifc format, too. The export process uses the following file format:

- ▶ IFC 2x3

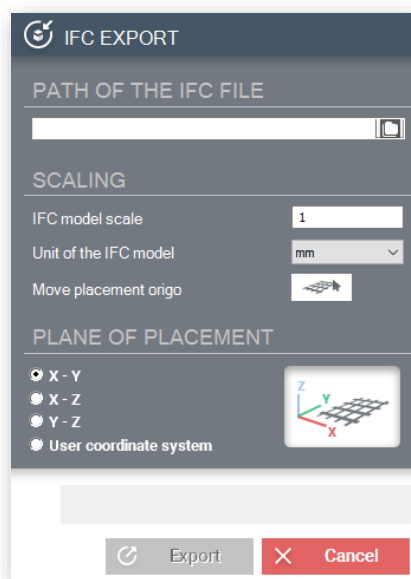


To export a model to **IFC** format, press the IFC button in the **EXPORT** submenu of **FILE** menu.



After pressing the **EXPORT** button, the **IFC EXPORT DIALOGUE** will appear, where the path of the saved file can be set, besides the scaling parameters and the planes of the exported model.

Pressing the **EXPORT** button again, will initiate the process, and the whole model will be exported.



2.4.2.1 AVAILABLE OBJECTS FOR THE EXPORT PROCESS

Steel members:

- ▶ I profiles:
 - ▶ Members in general positions, straight or curved, hot rolled sections with constant flange thickness symmetric I sections



- ▶ Members in general positions, straight or curved, welded sections with constant flange thickness symmetric I sections
- ▶ Members in general positions, straight or curved, welded sections with constant flange thickness asymmetric I sections
- ▶ Members in general positions, straight or curved, hot rolled sections with sloped flange symmetric I sections
- ▶ H profiles:
 - ▶ Members in general positions, straight or curved, hot rolled sections with constant flange thickness H sections
 - ▶ Members in general positions, straight or curved, welded sections with constant flange thickness H sections
- ▶ T profiles:
 - ▶ Members in general positions, straight or curved hot rolled T sections
 - ▶ Members in general positions, straight or curved welded T sections
- ▶ U profiles:
 - ▶ Members in general positions, straight or curved hot rolled U sections
 - ▶ Members in general positions, straight or curved welded U sections
 - ▶ Members in general positions, straight or curved hot rolled, sloped flange U sections
- ▶ Hot rolled hollow sections:
 - ▶ Members in general positions, straight or curved hot rolled hollow sections
- ▶ Cold formed hollow sections:
 - ▶ Members in general positions, straight or curved cold formed hollow sections
- ▶ Hot rolled tube sections:
 - ▶ Members in general positions, straight or curved hot rolled tube sections
- ▶ Cold formed tube sections:
 - ▶ Members in general positions, straight or curved cold formed tube sections
- ▶ Hot rolled L profiles:
 - ▶ Members in general positions, straight or curved hot rolled, equal or unequal flange length L sections
- ▶ Cold formed L profiles:
 - ▶ Members in general positions, straight or curved cold formed, equal or unequal flange length L sections
- ▶ Cold formed C profiles:
 - ▶ Members in general position, straight or curved cold formed C sections with edge
 - ▶ Members in general position, straight or curved cold formed C sections without edge
 - ▶ Members in general position, straight or curved cold formed C sections with edge and sloped flanges
- ▶ Lindab C profiles:



- ▶ Members in general position, straight or curved cold formed asymmetric C sections with edge
- ▶ Welded C profiles:
 - ▶ Members in general position, straight or curved welded C sections without edge
- ▶ Cold formed J profiles:
 - ▶ Members in general position, straight or curved, cold formed J sections
- ▶ Cold formed U profiles:
 - ▶ Members in general position, straight or curved, cold formed U sections
- ▶ Cold formed Z profiles:
 - ▶ Members in general position, straight or curved cold formed Z sections with edge
 - ▶ Members in general position, straight or curved cold formed Z sections without edge
 - ▶ Members in general position, straight or curved cold formed Z sections with edge and sloped flanges
- ▶ Plate profiles:
 - ▶ Members in general position, straight or curved plate sections
- ▶ Box profiles:
 - ▶ Members in general position, straight or curved welded box sections
- ▶ Maltese/Half Maltese cross profiles:
 - ▶ Members in general position, straight or curved welded Maltese/half Maltese cross sections
- ▶ WQ profiles:
 - ▶ Members on general position, straight or curved, welded WQ sections

Reinforced concrete members:

- ▶ Members in general position, straight, T shaped sections
- ▶ Members in general position, straight, circle shaped sections
- ▶ Members in general position, straight, hollow circle shaped sections
- ▶ Members in general position, straight, rectangle shaped sections
- ▶ Members in general position, straight, hollow rectangle shaped sections
- ▶ Members in general position, straight, trapezoid shaped sections
- ▶ Members in general position, straight, I shaped sections

Plates

- ▶ Horizontally positioned rectangle plates without holes, with or without chamfer or rounding
- ▶ Horizontally positioned polygonal shaped plates without holes, with or without chamfer or rounding
- ▶ Horizontally positioned circle shaped plates without holes, with or without chamfer or rounding



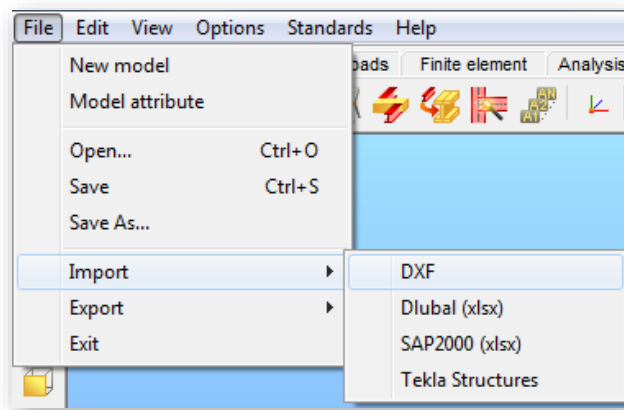
- ▶ Horizontally positioned rectangle plates with general (inside the plate) holes, with or without chamfer or rounding
- ▶ Horizontally positioned polygonal shaped plates with general (inside the plate) holes, with or without chamfer or rounding
- ▶ Horizontally positioned circle shaped plates with general (inside the plate) holes, with or without chamfer or rounding

Wall plates

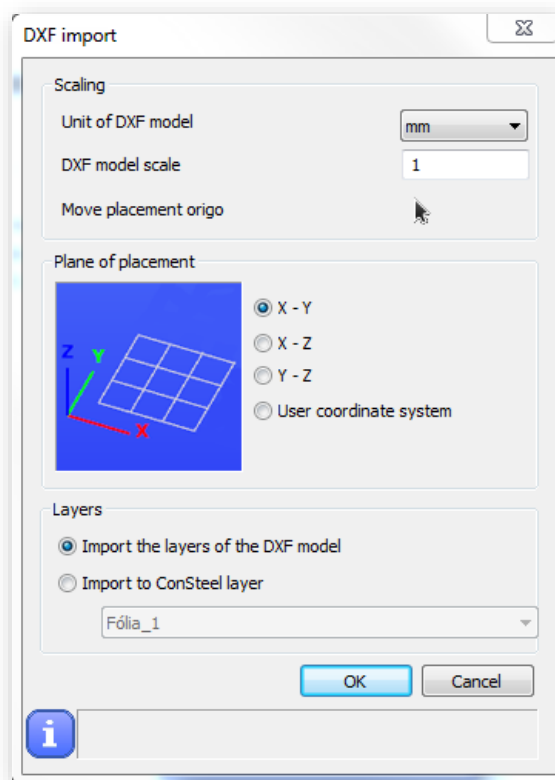
- ▶ Vertically positioned plates without holes, with or without chamfer or rounding

2.5 DXF IMPORT

To import a dxf drawing file, click on **FILE** menu, **IMPORT** tools. Choose **DXF** from the available import functions.



A windows file opening dialog will pop-up, where the dxf file must be selected on the computer. After clicking OK, the drawing file will appear in the modelling area of *Consteel*, and dxf import dialog will be opened automatically.



On the DXF import dialog the following modifications can be made:

- ▶ Unit of dxf model (mm/cm/m)
- ▶ DXF model scale with scale factor
- ▶ Move placement origo (origo of the dxf file)
- ▶ Plane of placement

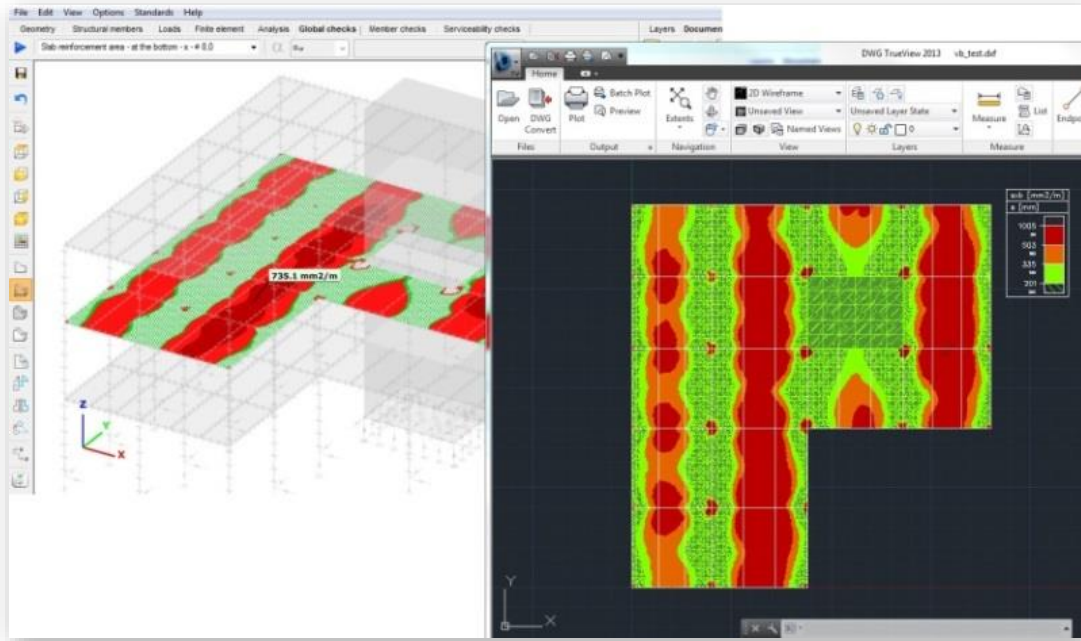
X-Y, X-Z, Y-Z of the global coordinate system, or User defined coordinate system)

- ▶ Layer handling

Layers of the dxf drawing can be imported to Consteel with its properties, or the whole dxf can be imported to an already existing Consteel layer

With the **OK** button, the modifications can be applied, and the dxf drawing will be placed in the modelling area.

2.6 EXPORT OF REINFORCEMENT INTO DXF



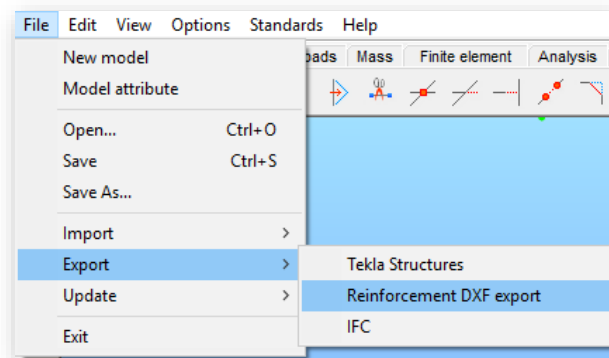
With the export function, contour surface of the required reinforcements with the corresponding color palette can easily be exported into dxf file format.

During the export, reinforcements contour surfaces for different directions (+x, -x, +y, -y) and their corresponding color palettes will be placed on different layers

Objects, which will be exported with the function:

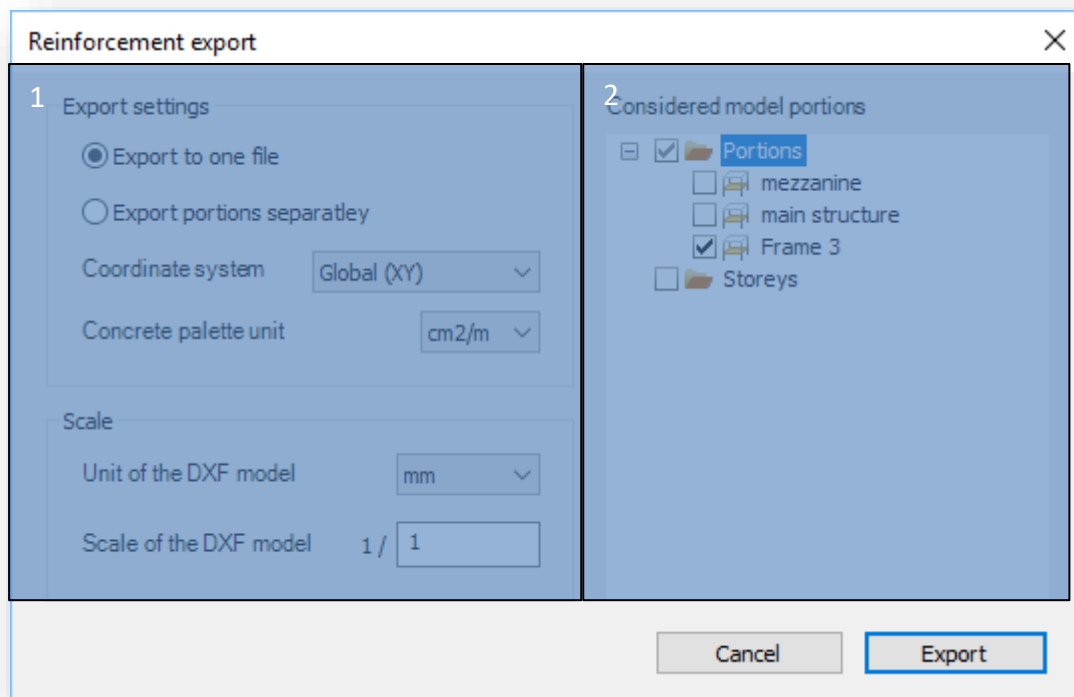
- ▶ Grid: Line, dashed line, or dotted line with the corresponding captions
- ▶ Plates with their contour lines
- ▶ FE division
- ▶ Labels such as name, plate thickness, material grade if the visibility is turned on
- ▶ Color palettes

The function can be initiated from the **FILE** menu's **EXPORT** functions:





After clicking on the **REINFORCEMENT DXF EXPORT** function, the Reinforcement export dialogue will pop-up:



On the right (#2) side of the dialogue, the model portions are shown, while on the left (#1) side, export related adjustable settings are listed, such as:

- ▶ Export settings:
 - Export to one file
 - Export portions separately, into individual dxf files
- ▶ Coordinate system:
 - Global coordinate system
 - User defined
- ▶ Unit setting for the dxf file [mm, cm, m]
- ▶ Unit of the reinforcement color palette [cm2/m, mm2/m]
- ▶ Scale of the dxf model by ratio

At the Considered model portions (#2) field, those portions can be selected which should be exported.

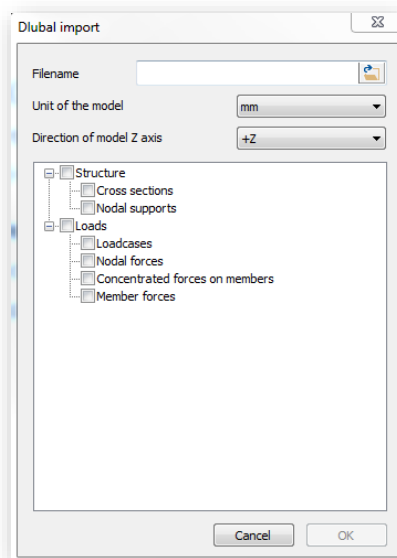
After clicking on the **EXPORT** button, the **SAVE** dialogue will appear, where path of the dxf file must be given.

2.7 DLUBAL RSTAB AND SAP2000 MODEL IMPORT(.XLSX)




Consteel is able to import model data, contained in an Excel (.xlsx) file, where different model data is stored on different worksheets. These table files can be exported from the software above.

To import the model data, click on **FILE** menu, **IMPORT** tools. Choose **DLUBAL(xlsx)** or **SAP2000(xlsx)** from the available import functions. Import settings for the two software works the same. After selecting the import function, the **IMPORT** dialog will appear:



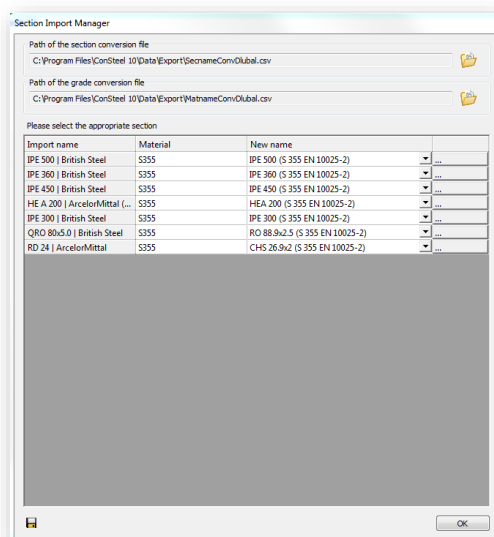
For the import process, the following settings must be made:


- ▶ Path of the file on the user's coordinate must be set by clicking on the  button
- ▶ Unit of the original model file in the other software must be set (mm/cm/m)
- ▶ Direction of the model Z axis must be set, since it may be different in the other software
- ▶ The following model data can be imported
 - Cross sections (cross section parameters, rotation, eccentricities)
 - Nodal supports(rotation, eccentricities)
 - Loadcases
 - Nodal forces
 - Concentrated forces on members
 - Member forces

It is important to know for the proper import process, that only those checkboxes should be checked in, which data is available in the xlsx file, or in other words, the model includes it.



After the settings are made, and clicked on the OK button, the import process will be initiated, and the **SECTION IMPORT MANAGER** will be shown. It is possible to change the conversion file for grades and for sections or edit the section name and grade manually.



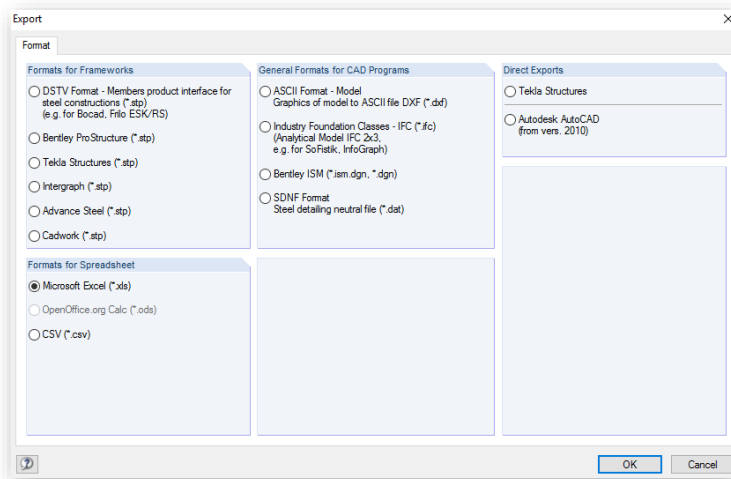
If manual changes have been made the list can be saved () and can be used as a conversion file in future imports. After clicking **OK** button, the model will be exported.

After clicking **OK** on the section import tab, the model will appear in the modelling area. It is also important to know, that the xlsx model export file must be created using English language, otherwise the import process will not work.

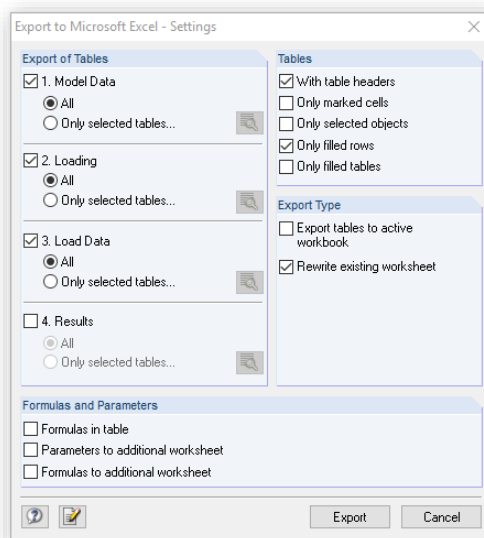
2.8 EXPORTING MODEL DATA FROM DLUBAL RSTAB IN XLSX FORMAT

In order to export model data to an .xlsx file, the following steps are necessary in Dlubal Rstab:

Click on **FILE** menu, **EXPORT** tools, and choose **MICROSOFT EXCEL (*.XLSX)** format from the available options:

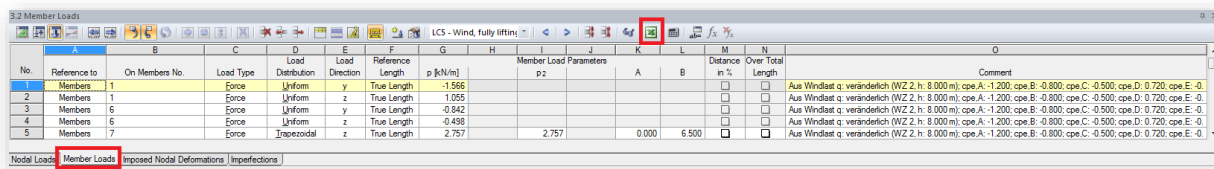



After clicking the **OK** button, the export setting dialog will appear. On the **EXPORT OF TABLES** part, data for the export must be chosen. At **TABLES**, the “*With table headers*” and “*Only filled rows*” has to be checked in. At the **EXPORT TYPE**, “*rewrite existing worksheet*” is suggested to checked in.

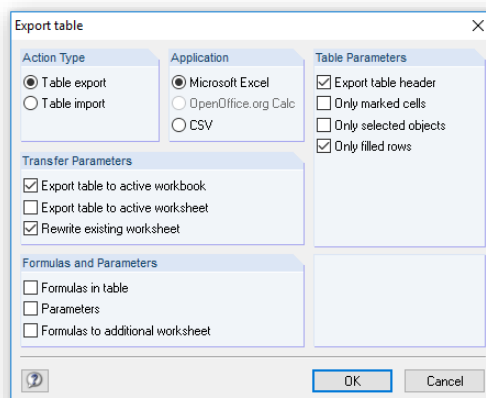


After clicking on the Export button, the Excel (xlsx) file will be generated, and opened. It is important to know, that if loads are desired to be exported too, the excel file should not be closed yet.

To export loads from a model, loadcases must be exported one-by-one manually to the existing excel file. Export of Nodal loads and member loads can be performed on the bottom part of Dlubal main window:



By choosing a loadcase at Nodal loads or Member loads, and clicking on the export to excel () button, the window below will appear:



On the **EXPORT TABLE** dialogue “*Microsoft Excel*” format must be chosen. Also, “*Export table to active workbook*” must be checked in, so the data will be exported to the already opened model data. At **TABLE PARAMETERS**, the “*With table headers*” and “*Only filled rows*” has to be checked in.

After clicking on the **OK** button, the xlsx file can be imported to Consteel.



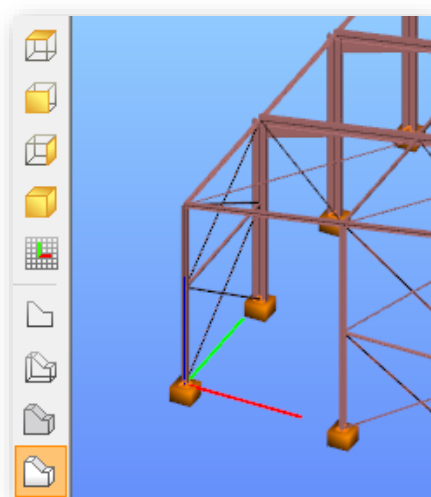
3 MODEL VIEW

3.1 BASICS


The transparent and multipurpose model views are very important to the user since these views provide the first graphical model survey opportunity. Accordingly, the first and most important objective of the model views to feedback the user with the objects placed, yield a visual proof that the right objects are at the right place.

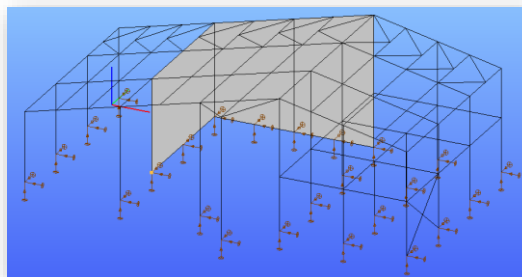
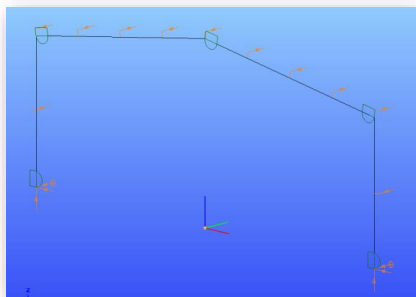
3.2 MODEL VIEWS


The model viewing options are on the left side bar.

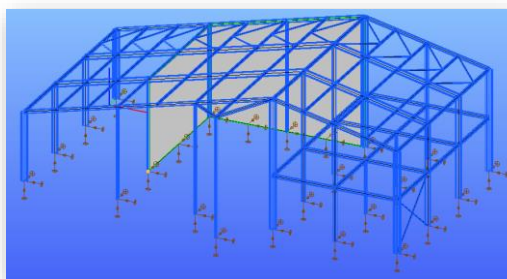
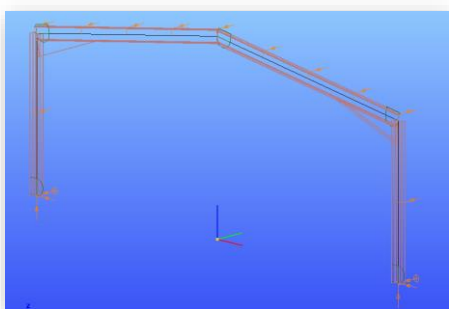



Beyond the usual model views (top view, front view, side view, axonometric view, perpendicular to raster view) there are four visualizing options for the objects used:

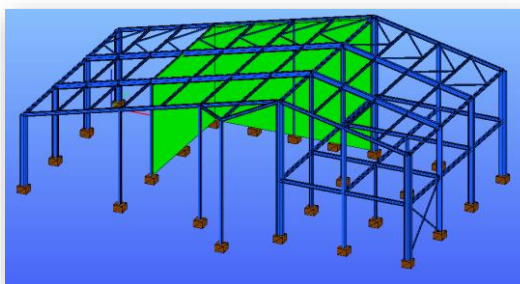
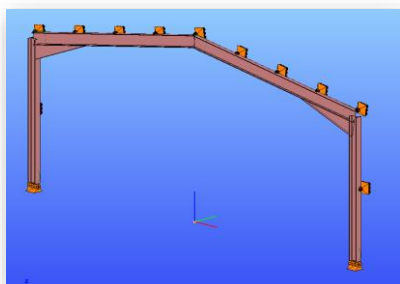
- **line view** : the simplest model view, the bars are represented by single lines, the surfaces by a two-dimensional figure without thickness; the supports are line types. *Recommended to use in the model building phases, since the clear visualization of the member snap points making the placement of supports and loads easier.*




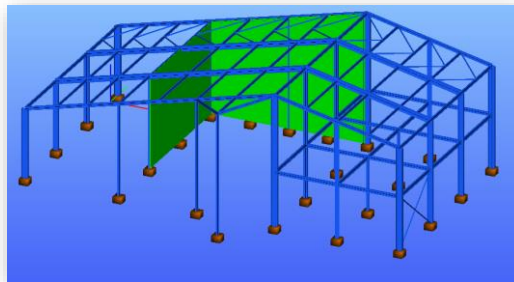
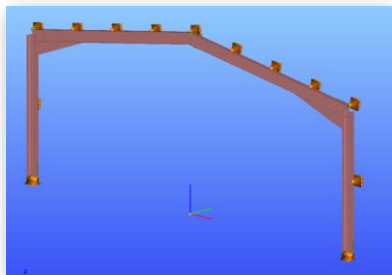
- **wireframe view**  : in the wireframe view the lines of the cross sections and plate thickness appear; the supports are line types.



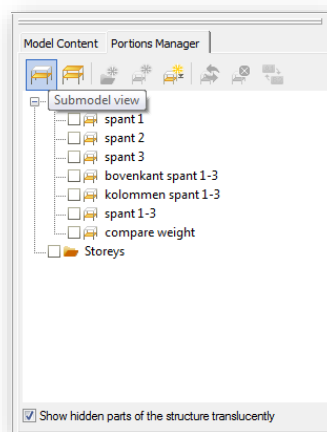
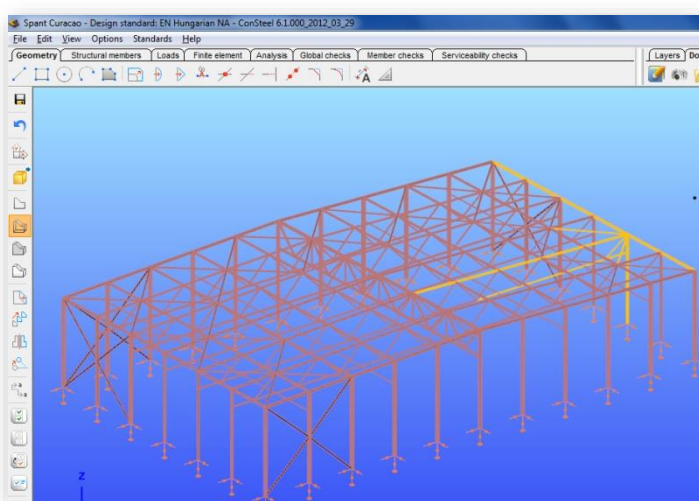
- **hidden line view**  : the cross section and plate thickness appear in a solid form without shading and sparkling effects; the supports are solid types.



- **solid view**  : the cross section and plate thickness appear in a solid form with shading and sparkling effects; the supports are solid types.



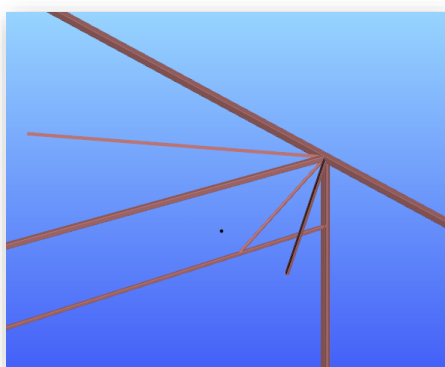
When the full model tends to be more complicated and parts of the model are in focus then the **SUBMODEL VIEW** should be applied.



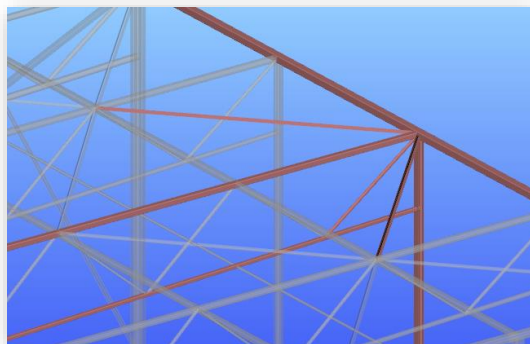
This

of the model,

option shows only the selected parts

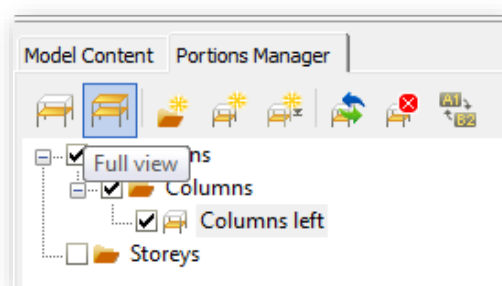


or checked the *Show hidden parts of the structure translucently* checkbox at the bottom of the **PORTIONS MANAGER**.



From **GEOMETRY** to **GLOBAL CHECKS** in every tab the selected submodel will be visible.

To make the whole model visible again click the **FULL VIEW** icon.



3.3 SELECTION

Objects can be selected in the graphical window, in the object tree, or by the additional selection options. As a rule, only the visible objects can be selected graphically, accordingly the same action can result in different selections on different tabs or model views. A selected object is changed to unselect by clicking on it while pressing the **SHIFT** button. The **ESC** button always unselects all objects.

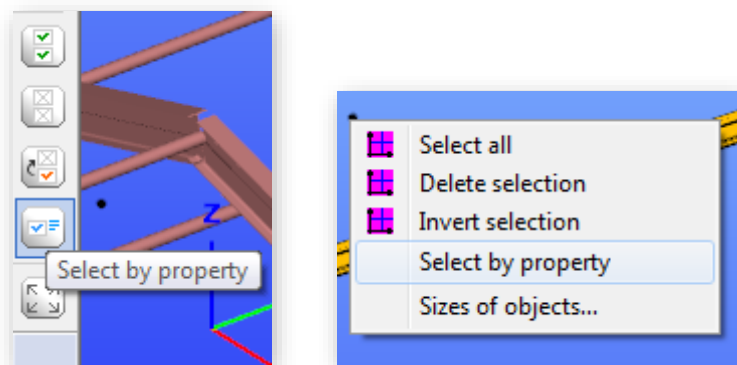
The basic selection modes and their operation are the followings:

- ▶ **simple graphical selection:** click on the object on the graphical window by the left mouse button. All objects will be selected which graphical symbol intersects the imaginary line set up perpendicular to the viewing (camera) plane at the clicking point. It means that the selection depends on the size of the graphical symbol of the objects and note that the covered objects will be selected as well!
- ▶ **window selection:** holding down the left button and moving the mouse will create a window. It is completed when the mouse button is released. The actual size of the window

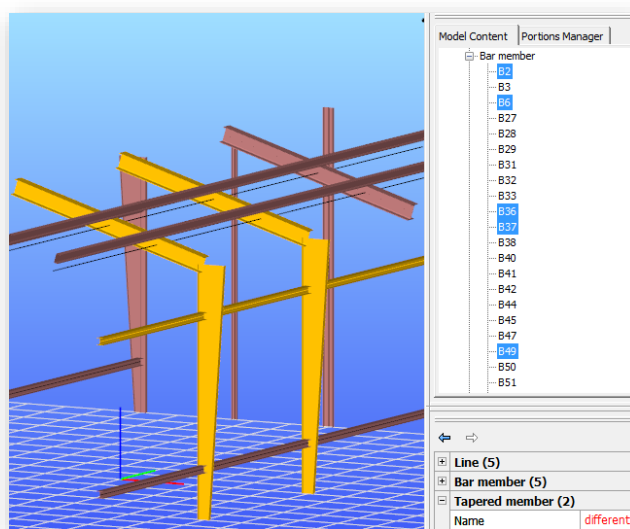


is continually seen on the screen. While drawing the window from left to right, only those members are selected that are within the window with their full size (inclusion window selection). When drawing the windows from right to the left every member is selected no matter how small part is found in the rectangle (section and inclusion window selection).

- **selection by property:** this option can be reached on the left side bar or by right mouse button click on the graphical window. The selection can be made by choosing the desired object and further narrowing is possible by sorting the appropriate parameters out.



- **object tree selection:** select objects by clicking on the elements of the Object Tree.



By clicking the object names in the object tree while holding down the **CTRL** or **SHIFT** key results multiple objects selection. To unselect any of the selected object: hold down the **CTRL** key and click on the object name again in the object tree.

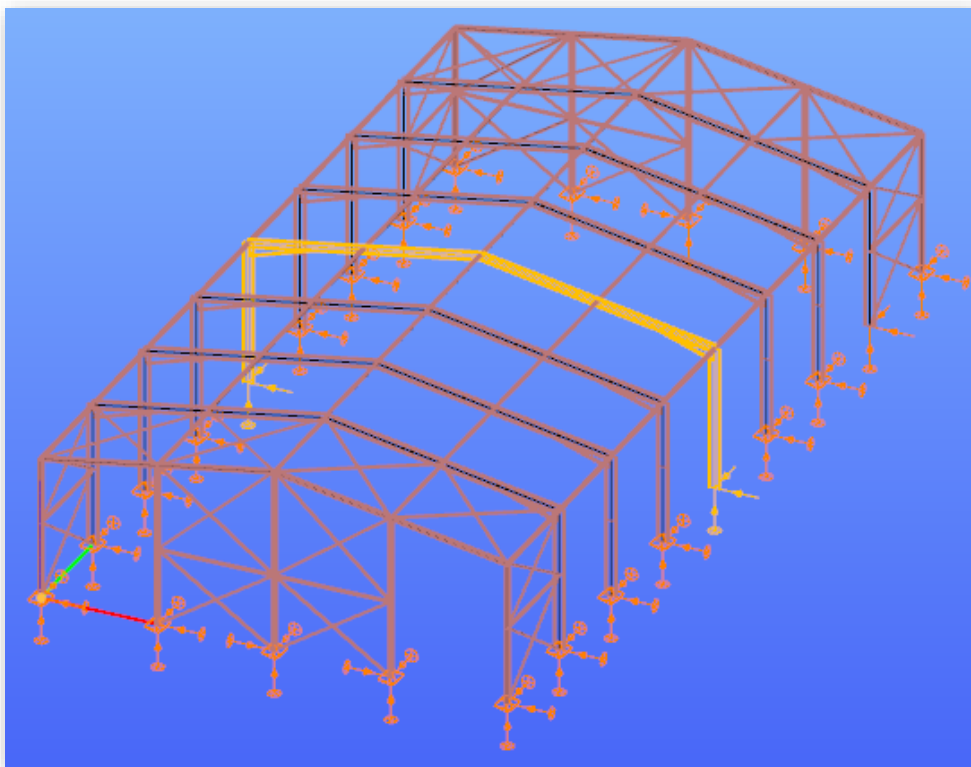
The additional generalized selection options (select all, unselect all, inverse selection) can be found on the left side bar or they can be reached by right mouse button click on the graphical window.



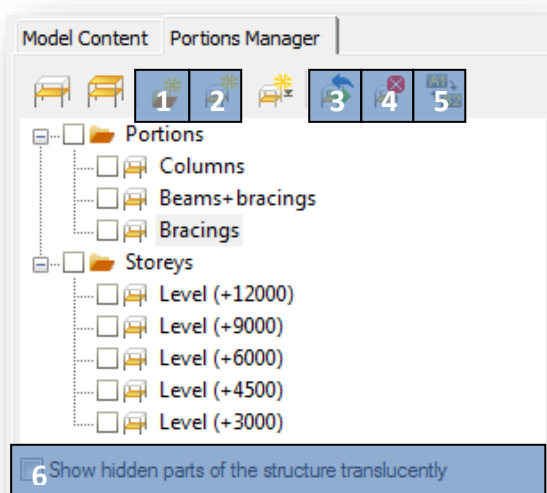
3.4 PORTIONS MANAGER

The **PORTIONS MANAGER** is a great tool to manage different but related parts of the model i.e. floors, columns, bracings, beams, etc. This function can be achieved on the **PORTIONS MANAGER** tab.

New portions can be added by clicking the **NEW PORTION** icon (#2). Before do so, select the parts of the model which will belong to that portion.



The portions can be arranged into folders. New folder can be created by clicking the **NEW FOLDER** icon (#1).

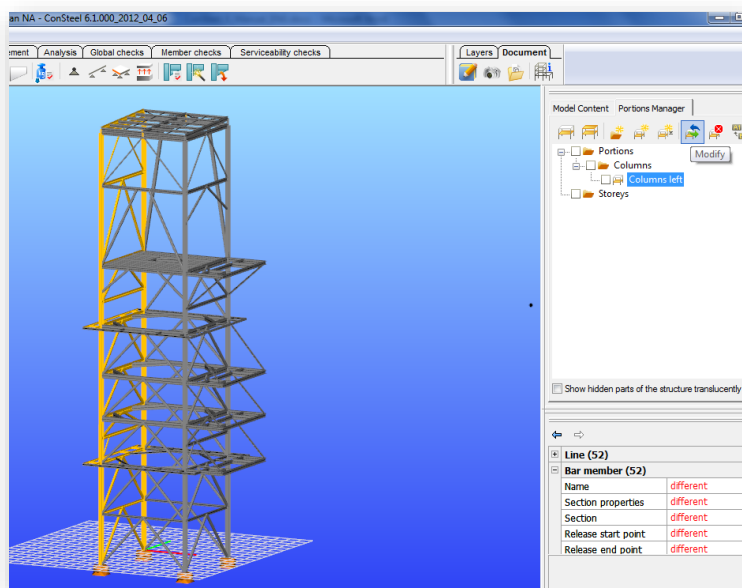


To turn on a portion, check in the checkbox in front of the name of the portion. More portions can be turned on at the same time.

If the *Show hidden parts of the structure translucently* check box (#6) is clicked at bottom of the **PORTIONS MANAGER** tab, then the hidden parts of the model are also shown but those parts are translucent.

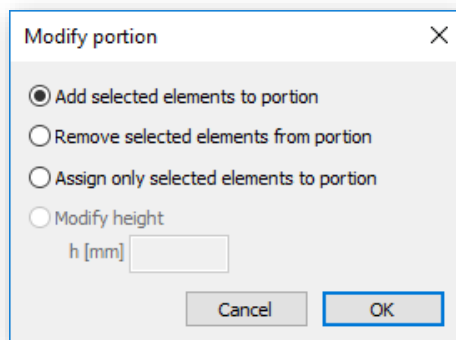
Any objects of the structural model can be part of several portions at the same time.

To modify a previously defined portion, first select the relevant parts of the model which will be the subject of the modification, then click on the name of the portion you are going to modify and finally click on the **MODIFY** icon (#3).





The **MODIFY PORTION** window will appear with the following options:



- ▶ **Add selected elements to portion:** By clicking the **OK** button, the selected members will be added to the active portion. If some of the selected members already belong to this portion, then it will have no additional effect.
- ▶ **Remove selected elements from portion:** All those selected elements will no longer belong to the modified portion.
- ▶ **Assign only the selected elements to portion:** The modified portion will contain only the selected elements.

Renaming the Portion can be done by clicking the name of the portion and click on **RENAME** icon (#5).

Portion can be deleted by clicking the name of the portion and click the **DELETE** button (#4).

3.5 OBJECT NAMES AND RENUMBERING

Names and labels are used for the better organization of the different objects in the model and for the better transparency of the documentation. The names and numbers of the objects are generated automatically while modelling. In some cases (for example creating Joints), the user has the opportunity to name the objects.

The following name and renumbering options are available:

- ▶ **numbering of finite element points** – generated fully automatically, the user can't influence the process.
- ▶ **names of structural element** – these are generated automatically while the user creates or copies structural objects (beam, column, plate, wall). Names consist a prefix and a number (for instance: "B1" for a bar element). These names appear on the object tree in

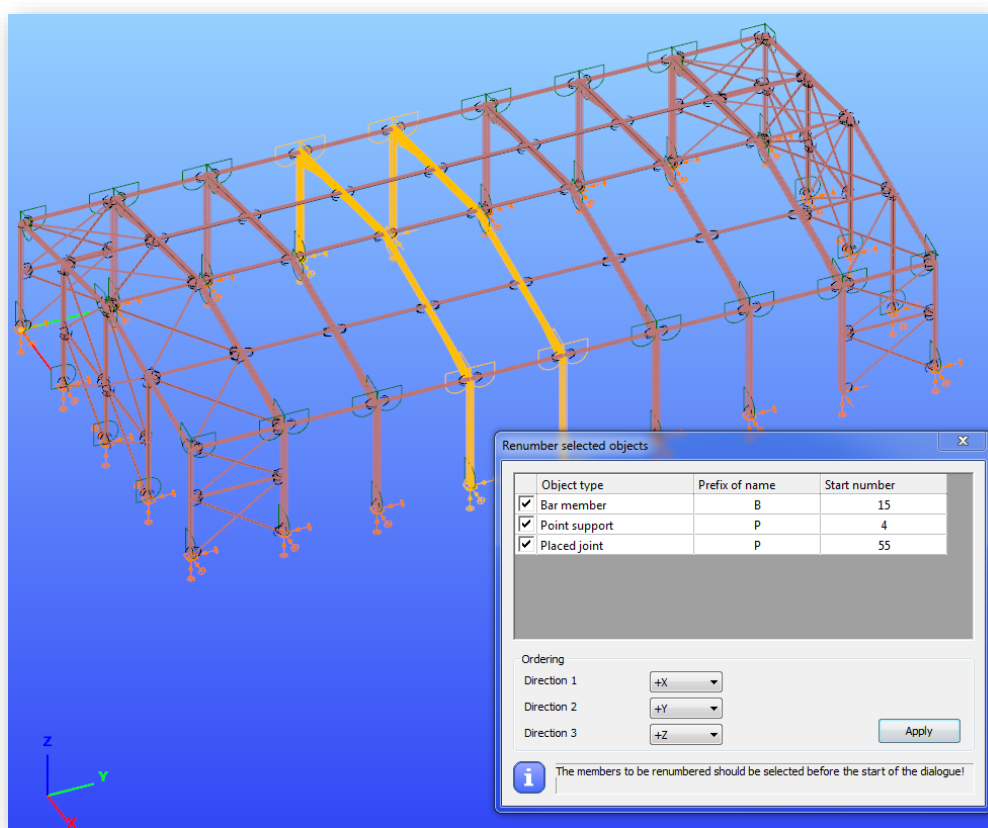


the right-side table. The names can be modified by the **RENUMBER SELECTED OBJECTS** tool on the **STRUCTURAL MEMBERS** tab. Using this function, a specific prefix and a start number can be defined, and a direction can be set in which the renumbering will be processed. On the finite element view these names denote the numbering of the finite elements of the members.

- **names of structural supports, releases, and links** – these names show the type of the placed support, release, or link objects (for instance: “Fixed” or “yy,zz,w”)
- **names of joints** – these names show the user defined names of a placed joint (for instance: “Beam-to-column 01”)

Renumbering the objects

To renumbering the objects first select the relevant objects, then click on the **RENUMBER SELECTED OBJECTS** icon on the **STRUCTURAL MEMBERS** tab.



The **RENUMBER SELECTED OBJECT** window will appear, with the automatically recognized object types contained by the set of selection. With the checkboxes can be selected the different types objects for renumbering.

The following functions can be used for renumbering:



- ▶ Prefix of the name can be defined
- ▶ Start number can be defined
- ▶ Priority of the renumbering can be set in the 3 main directions (X, Y Z)

The new names of the objects will be built up from the given prefix and the new serial number, except the placed joint object type.

Label's visibility

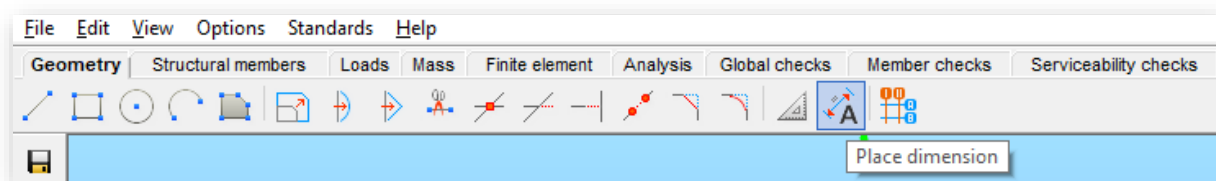
The visibility of the labels can be set on the bottom status bar as it was discussed above (Chapter 1.2.6). The following label options are available:

- ▶ **material** – the used material name of structural members (for instance: "S235")
- ▶ **shape** – the name of the used cross-sections of structural bar members (for instance: "HEA 200")
- ▶ **thickness** – the thickness of the used structural plates or walls
- ▶ **load intensity**
- ▶ **units** – the units of load and thickness if set (for instance: "kN" or "mm")
- ▶ **initial curvature** – the value of the initial curvature on structural bar members
- ▶ **coordinate system** – the names of the local coordinate axes (X,Y,Z)

Additionally, arbitrary text can be assigned to structural elements manually on the ***DIMENSIONING*** dialogue using the last tool.


3.6 DIMENSIONS

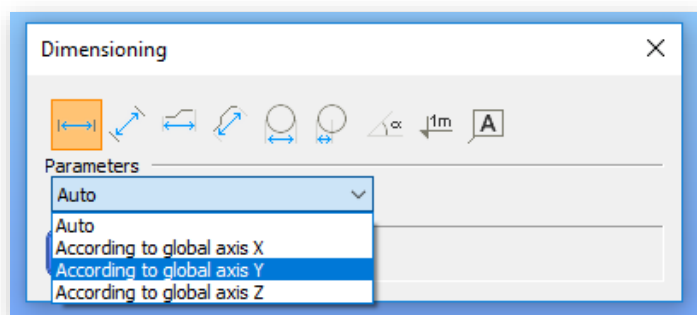
For the documentation of the calculated structural model it is very important to be aware of the exact dimensions of the model. The dimensioning tool can be found on the ***GEOMETRY*** tab.



This provides a great number of different dimensioning options:

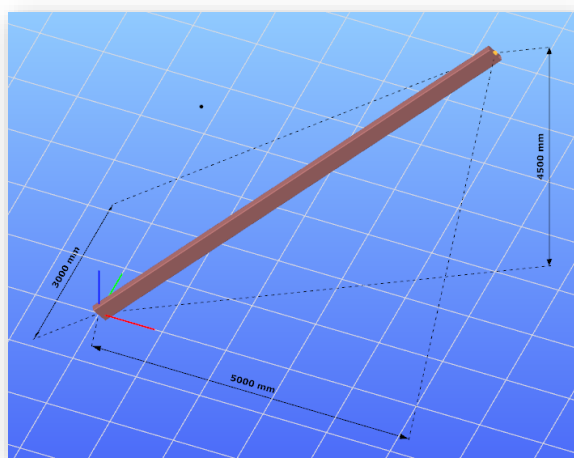



- **Projected dimension of a linear object** : The projected length of the selected linear object onto the global X or Y or Z axis will be dimensioned.



Parameters:

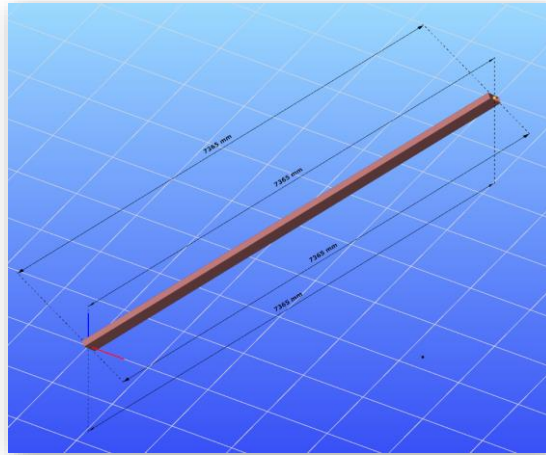
- Auto: moving the mouse, the system detects the desired reference axis.
- According to global axis X: the X axis projection of the length of the linear object.
- According to global axis Y: the Y axis projection of the length of the linear object.
- According to global axis Z: the Z axis projection of the length of the linear object.




- **Lengthwise dimension of a linear object** : The length of the selected linear object can be placed in one of the planes which is defined by centerline of the object and the global coordinate system X,Y plane, and a plane perpendicular to this plane and containing the centerline of the object.


Parameters:

- Auto: moving the mouse, the system is detecting the desired plane.





- **Projected dimension of the distance between two selected points** : The length of the distance between two selected points will be projected onto the global X or Y or Z axis.


Parameters:


- Auto: moving the mouse, the system is detecting the desired reference axis.
 - According to global axis X: the X axis projection of the distance between two selected points.
 - According to global axis Y: the Y axis projection of the distance between two selected points.
 - According to global axis Z: the Z axis projection of the distance between two selected points.
- **Lengthwise dimension between two points** : The distance between the selected two points could be placed in one of the following planes.
 - Plane defined by centerline of the object and the X,Y plane global coordinate system
 - The plane perpendicular to the above plane and containing the centerline of the object.

Parameters:

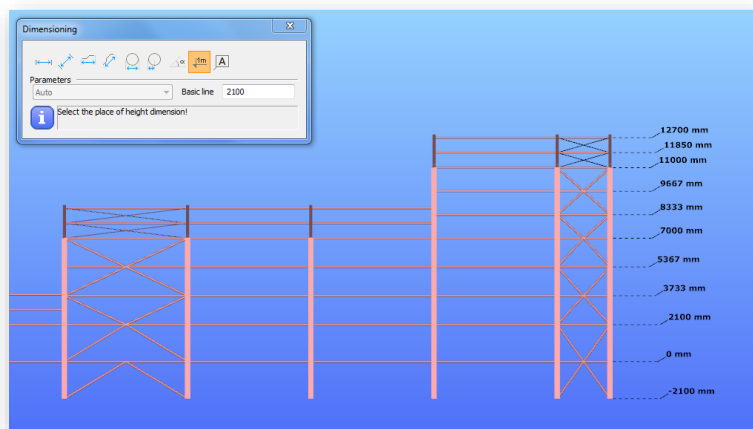
- Auto: moving the mouse, the system detects the desired reference axis.
- **Diameter of a circle** 
 - **Radius of a circle** 




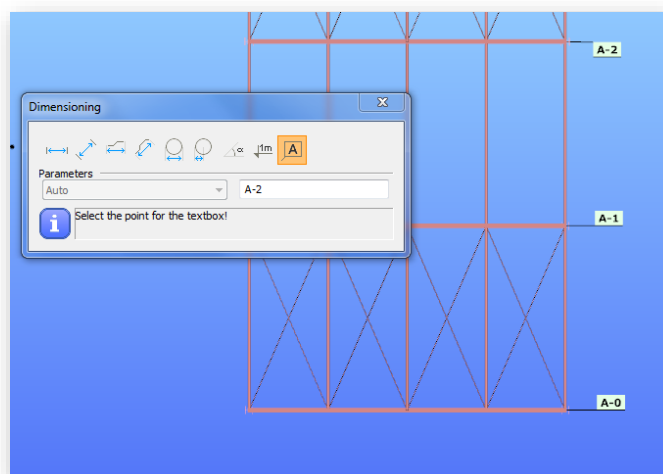
- **Angle of two lines** : After selecting two lines any of the four angles could be dimensioned.

- **Height dimension** : This function helps for quick dimensioning the height positions of selected points relative to global Z direction related to the given value in *Basic line* filed.

The content of the **Basic line** field means the height of the 0 level in the global Z direction. All the picked points will be measured from to this value as a 0.



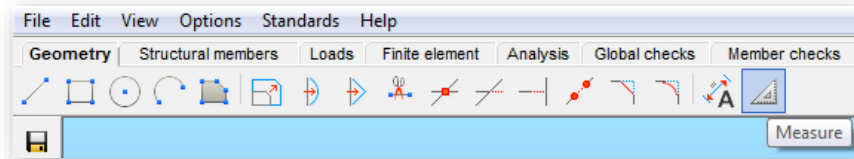
- **Textbox to a given line** : The given text (A-2) in the script field can be placed into the model.



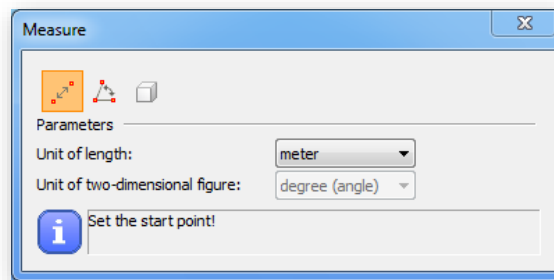
3.7 MEASURE




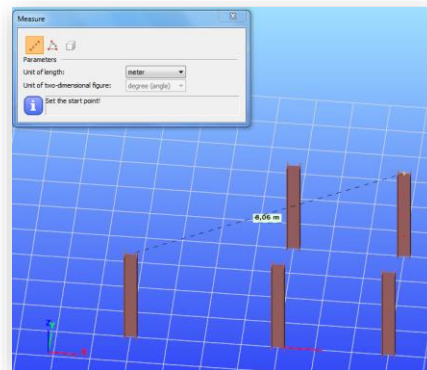
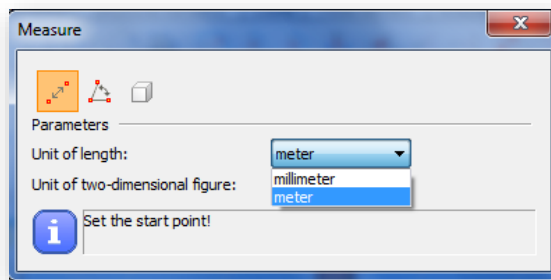
During modelling it is helpful to measure distances and angles. The **MEASURE** tool is found at the end of the **GEOMETRY** tab.




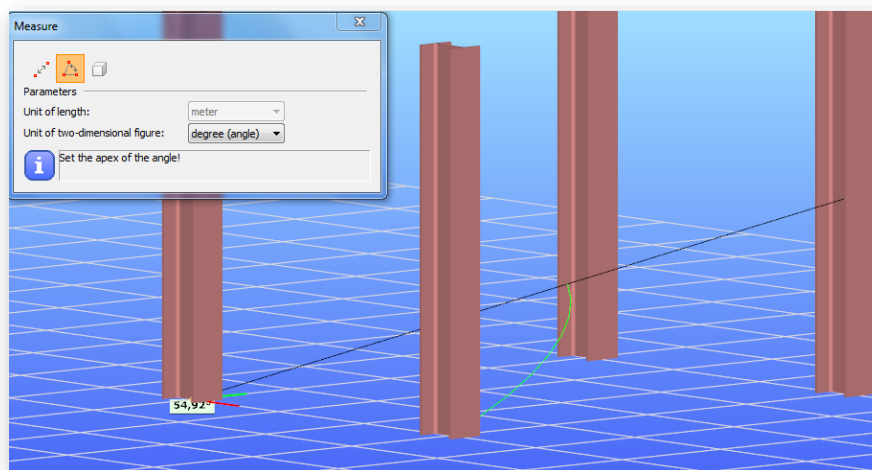
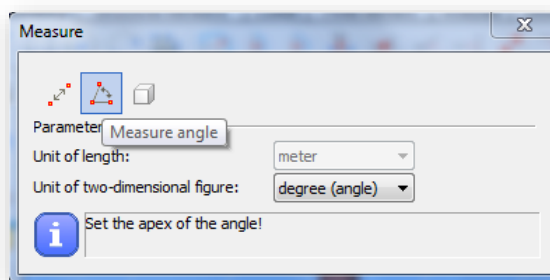
The following window offers the measuring functions:




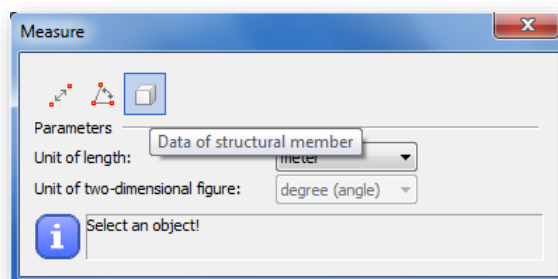
- **Measure distance** : Shows on the screen the measured distance between two picked points in meter or in millimeter, selected from the “unit of length” list box.

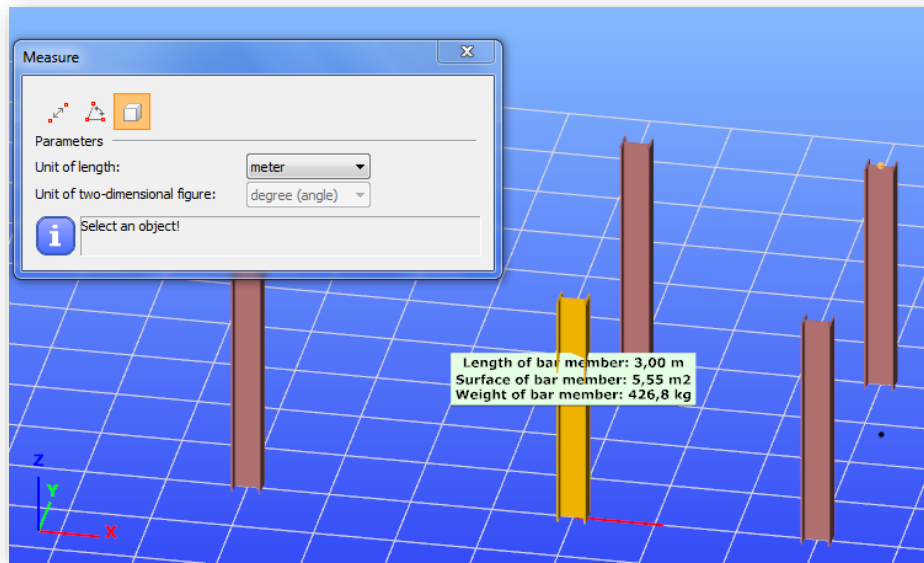


- **Measure angle** : The function measures the angle between two lines defined by clicking three snap points in the 3D space in the plane of the two lines in degree or in radian.



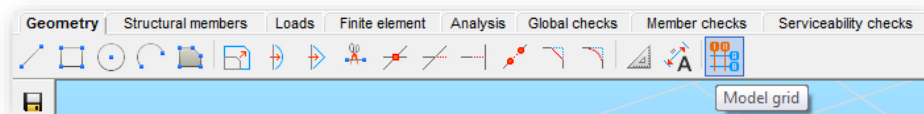
- **Data of structural member** : The function shows on the screen the length, the surface, and the weight of the selected structural member.



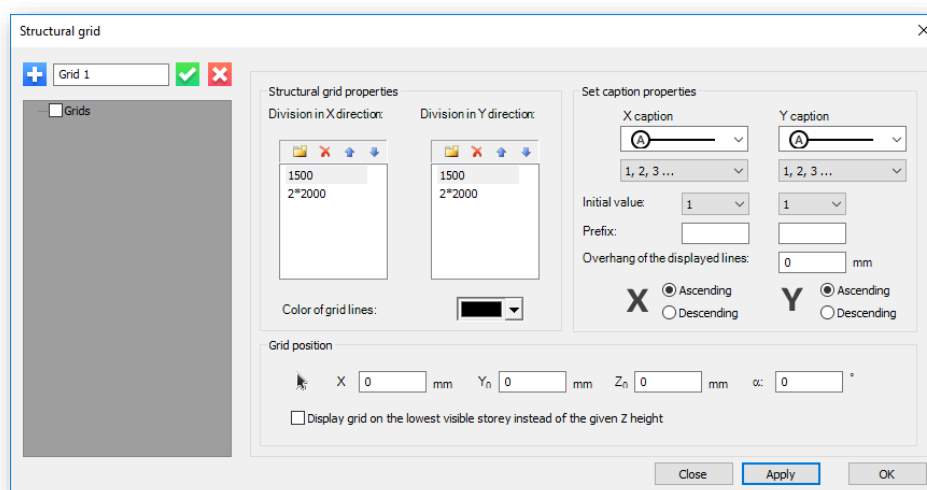


3.8 MODEL GRID

On the **GEOMETRY TAB**, it is possible to create custom **MODEL GRID**.







By clicking on the function, the **STRUCTURAL GRID** dialogue will be opened.








Grid manager functions:



- ▶ Create a new structural grid with the  button
- ▶ Accept grid properties and finalize grid with the  button
- ▶ Modify previously created grid with the  button
- ▶ Delete previously created grid with the  button

Model grid properties:

- ▶ Division of the grid in X and Y direction must be set.
 - New row for the division can be created with the  button.
 - Defined rows can be deleted with the  button.
 - The sequence can be modified with the arrows   button. Values can be defined with single values (1500) or as multiplied values (2*2000)
- ▶ Caption properties can be set both for X and Y directions.
 - It is possible to choose from capital letters, lowercase letters, decimal numbers, and roman numbers too.
 - Initial values can be set from the dropdown menu.
 - Prefix of the captions can be set manually.
 - Captions can be chosen if they desired to be in ascending or descending order both for X and Y directions
- ▶ Grid position can be set at the bottom of the dialogue.
 - Coordinates of the insertion point can be set manually according to the global coordinate system (X0,Y0,Z0), or with a graphical selection on the screen using the arrow  button
 - Rotation of the grid can be set with the definition of the alpha value, according to the global X axis
 - It can also be chosen if the grid is desired to be shown on the lowest visible storey of the model (previously defined storeys are necessary)



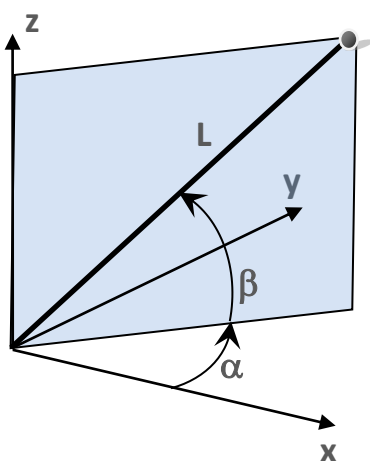
4 DRAWING GEOMETRY

4.1 BASICS

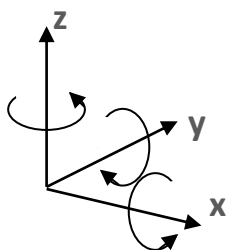
The first step of the modelling phase is the geometry drawing of the structure. In *Consteel* all the geometrical objects can be easily created and modified in a 3D space. Among the basic CAD drawing, modifying, and moving functionality advanced snap options make the modelling efficient. All the CAD functionality is placed on the **GEOMETRY** tab, the further view, select, and snap options are on the side and status bar. Additionally, all the relevant modelling functions are placed on the dialogues of structural members, supports and loads.

4.2 COORDINATE SYSTEMS

For the appropriate modelling and interpretation of the analysis and design results it is of high importance to be aware of the applied coordinate systems. This section summarizes in detail all the coordinate systems used in the *Consteel*.



Two different type of coordinate systems can be used: the rectangular Descartes system (XYZ) and the polar system ($\alpha\beta L$). In the polar system “ α ” denotes the angle between the axis “X” and the vertical plane defined by the axis “Z” and the point, “ β ” denotes the angle between the section line of that plane and the coordinate plane “XY” and the line from the origin to the point, and “L” denotes the distance from the origin. The polar coordinate system is less frequently used so the rest of this section describes the Descartes system.



As a general convention all the Descartes coordinate systems (axes directions and rotation signs) follow the most commonly applied right hand rule. This rule is valid for the definition of geometry and loads as well. The positive moments and rotations are defined as counterclockwise about the axis if it is viewed in front (towards the origin) in both the global and local system.



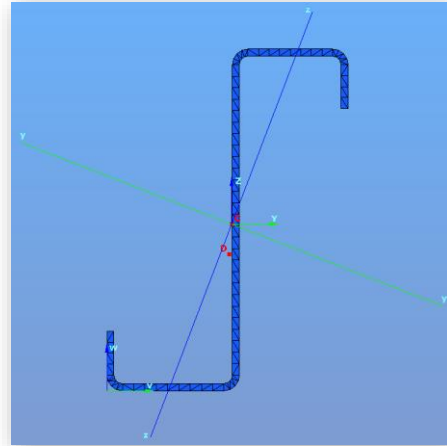
In the further text the following denotations are used:

In case of global geometry (3D structural modelling):

- ▶ X, Y, Z: global coordinate system
- ▶ x, y, z: local coordinate system

In case of cross sections (2D modelling of sections):

- ▶ v, w: section edit coordinate system
- ▶ Y, Z: section edit coordinate system
its origin in the center of gravity of the section
- ▶ y, z: section principal coordinate system

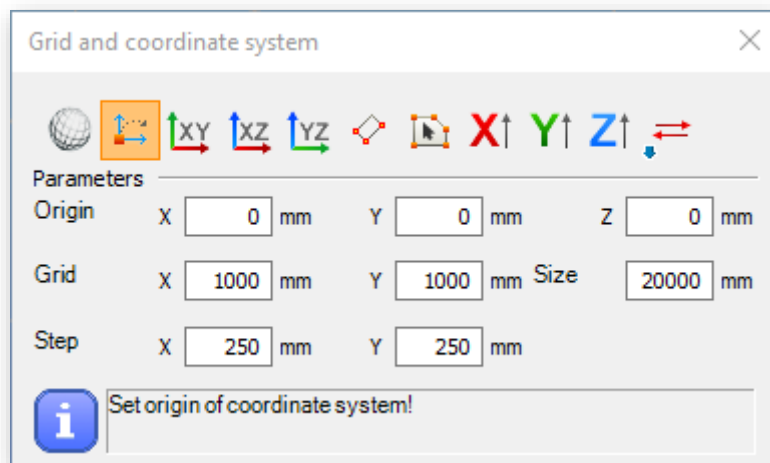


with

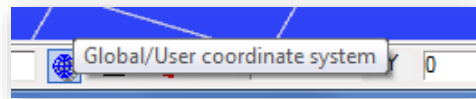
4.2.1 USER COORDINATE SYSTEM

The User coordinate system (UCS) is used for making the modelling easier and faster. The UCS is a specially positioned Descartes system (XYZ).












The tools for creating and modifying the coordinate systems can be reached by the **SET GRID AND COORDINATE SYSTEM** button on the side bar.







The User coordinates system can be switched on (or switch back to the global system) at the bottom status bar







The following creation options are available (from left to right):

- ▶ Switch to global system 
- ▶ Set new origin for the UCS 
- ▶ The "XY" plane of the global system will be the "XY" plane of the UCS 
- ▶ The "XZ" plane of the global system will be the "XY" plane of the UCS 
- ▶ The "YZ" plane of the global system will be the "XY" plane of the UCS 
- ▶ Set the UCS by 3 points: the origin, the direction of "X" and "Y" axis 
- ▶ Set the standing of the UCS identical to the local coordinate system of the selected plane with origin placed into the first node of this plane 
- ▶ Set the direction of the axis "X" by two points 
- ▶ Set the direction of the axis "Y" by two points 
- ▶ Set the direction of the axis "Z" by two points 
- ▶ Reverse the direction of the selected axis 

On the **STRUCTURAL MEMBERS TAB** and in the **SET LOCAL COORDINATE SYSTEMS** () function it is possible to modify the alignment of the local coordinate axes of bar members() , surfaces () or supports() .

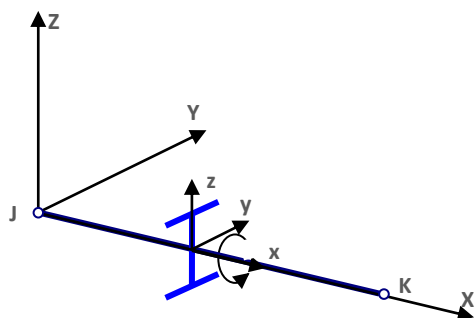
Icons for the modifications on the **SET LOCAL COORDINATE SYSTEMS** dialog are the following (from left to right):

- ▶ Set "X" axis of UCS 
- ▶ Set "Y" axis of UCS 
- ▶ Set "Z" axis of UCS 
- ▶ Set the "Z" axis perpendicular to the surface formed by the connecting beams 

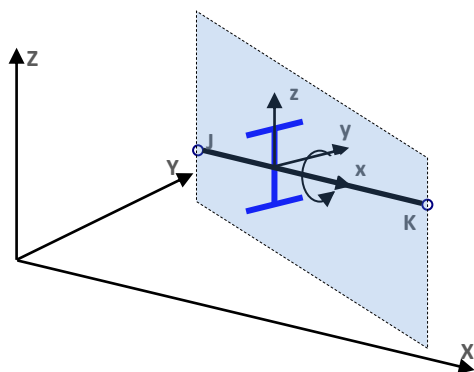


4.2.2 LOCAL COORDINATE SYSTEM OF BAR ELEMENTS

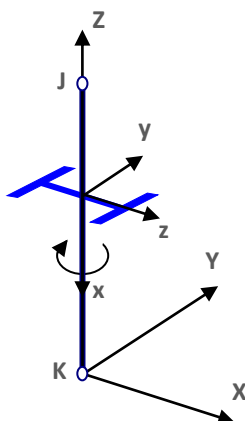
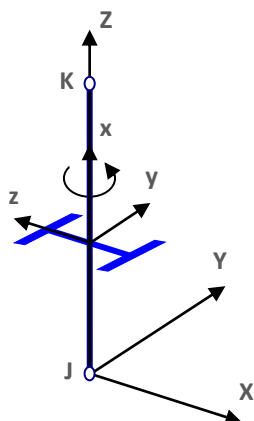
The reference line of bar members defines the axis “x” of the local coordinate system of the bars. The direction of the axis “x” is given by the start (J) and end (K) node of the reference line.



In the basic case the local coordinate system of a bar can be determined considering its reference line (“x”) identical to the global axis “X”. In this case the direction of local axes “y” and “z” are identical to the global axes “Y” and “Z”. The position of the cross section on the bar is the following: the reference line goes through its center of gravity, and the section “YZ” system coincides with the local “yz” system of the bar.

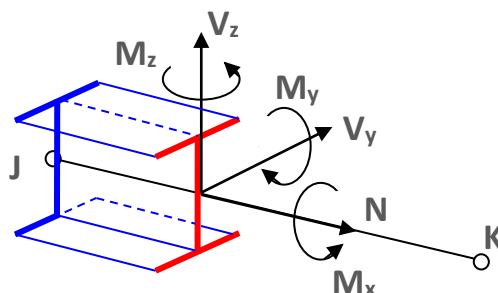


In case of a generally positioned beam member (not column with vertical reference line) the plane defined by the local “xz” system takes always vertical position and the axis “z” points towards the positive “Z” direction. For beams with (single) curvature the axis “x” is always the tangent.



In case of vertical reference line (column members) the local axis “y” has the same direction as the global axis “Y”, the direction of the local axis “z” depends on the placement of the column (position of the start and end points).

The interpretation and signs of the inner forces on a member is defined by its local coordinate system and the mentioned general sign convention as described in the following figure:



4.2.3 LOCAL COORDINATE SYSTEM OF SURFACE ELEMENTS

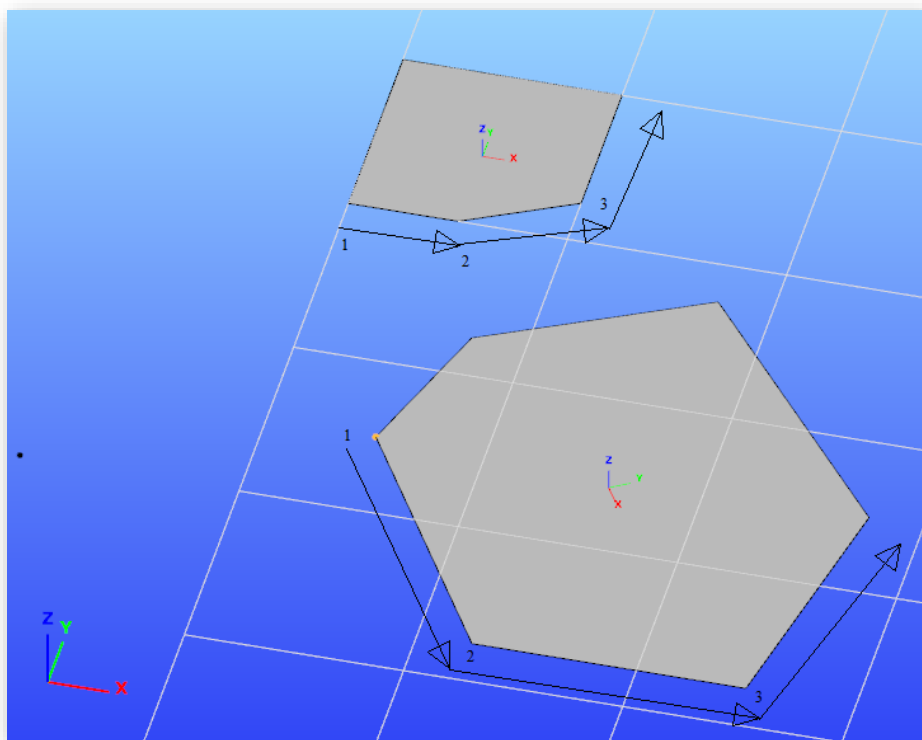
For surface elements the local plane “xy” is defined in the plane of the surface, the axis “z” is perpendicular to that plane and the direction of “+z” is in accordance with the right-hand rule of coordinate systems. The roles of the directions of the local axes of the plane surface elements:

By creating a rectangle shaped plane surface element:

- the axis “x” and “y” are parallel with the edges of the rectangle plane element. The “z” direction created in accordance with the right-hand rule of the coordinate systems.


By creating a plane surface element with polyline border:

- the axis “x” is parallel with the line defined by the first and the second picked points. It is the first edge of the plane surface element.
- the axis “y” points accordingly to the direction of the third picked point. It is the second edge of the created plane surface element.
- The “z” direction created in accordance with the right-hand rule of the coordinate systems.



In case of surface elements, the local coordinate system can be modified using the tools presented in Chapter 4.2.1.

4.3 DEFINING ACTION POINTS

Action points (snap points) can be set by moving the cursor on the  icon on the right side of the bottom status bar. You can find the description about the snap point settings above in **1.2.7 THE STATUS BAR** chapter.

4.4 DRAWING

The functions for drawing described below are collected on the **GEOMETRY** tab.

Draw line



Simple line drawing. First select the start point. Then select the end point.



Polyline drawing. First select the start point. Then select the next points. Press **ESC** to interrupt line drawing.

Draw rectangle with lines



Draw rectangle. Select the corner point. Select the opposite corner.



Draw leaning rectangle in the space. Select the corner point. Select end point of the side of the rectangle. Select third point of the rectangle.

Draw Circle



Draw circle by radius. Select the center-point of the circle. Select the radius of the circle. The circle will be created in the plane containing the center-point and parallel to the actual *UCS*.



Draw circle by diameter. Select the start point. Select the end point. The circle can be created out of the actual *UCS* system.



Draw circle by 3 points. Select first point. Select second point. Select third point. The circle will be created in the plane defined by the three definition points.

Draw Arc

Arcs could be created out of the actual *UCS*.



Draw arc by center-point, start point and angle. Select the center of the arc. Select the start point of the arc. Select the angel of the arc or type it to the dialog window



Draw arc by 3 points. Select the start point. Select the end point. Select a point in the arc.



Draw arc by start point, end point and tangent. Select the start point. Select the end point. Select the other point of the tangent.

Draw two-dimensional plane elements



Draw two-dimensional plane element. Define the geometry of the plane element.



Draw hole. Select the plane element. Define the geometry of the hole (Rectangle, closed polyline, or circle).



Edit a plate element.



Change the direction of the local “x” axes of a plane element by defining two points.

Select the surface. Select the start point. Set the direction with the second point.

The construction modes of the plane elements:



The construction mode of a rectangle type plane element can be selected: rectangle or leaning rectangle.



The construction mode of a circular type of the plane element can be selected: draw circle by radius, by diameter, or circle by 3 points.



Draw polygon (a closed polyline). Set the first point. Set the next points. To close the polygon, press right click on the mouse.

The editing modes of a plate element:



Add a new point to the plane element by breaking the edge. To do this, you need to select the desired edge and then enter the location of the new point.



Delete a point or an arc section of a plane element. In both cases, after deletion, a straight edge is created between adjacent corner points.

4.5 MODIFYING

The four mostly used modifying functions are placed on the left sidebar:



Move point and edge. Select the point and (or) edge to be moved. Set the new position of the point (edge). This function is used for changing the position of any of the end point of a

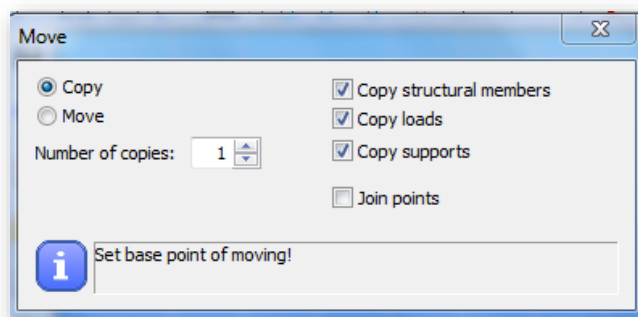


linear or circular element, or to change the position of an edge or a corner point of a polygon, or of hole in a polygon.



Move selected objects. The selected objects can be moved or copied

Select the objects, and click the **MOVE SELECTED OBJECTS** icon:



Select the transformation (Move or Copy). The copy function can be activated by the radio button near the Copy function. The number of copies can be selected.

Set start point of the vector for moving/copying. Set the end point of vector for moving/copying.

The selected members, loads and supports will be moved or copied to the position which is defined by the given vector accordingly to the selected options. The Move/Copy function is independent from the actual UCS.

Effect of the options:

Copy structural members:

Unchecked: Use when only the loads and/or the supports of the structural member need to be copied or moved.

Checked: Default. Structural members will be copied or moved.

Copy loads:

Unchecked: The loads will not be copied with the selected structural members.

Checked: The loads will be copied with the selected structural members.

Copy supports:

Unchecked: The supports of the selected structural members will not be copied.



Checked: The supports of the selected structural members will be copied. (In case of the selection set does not contain at least one selected member, then the selected supports will not be copied.)

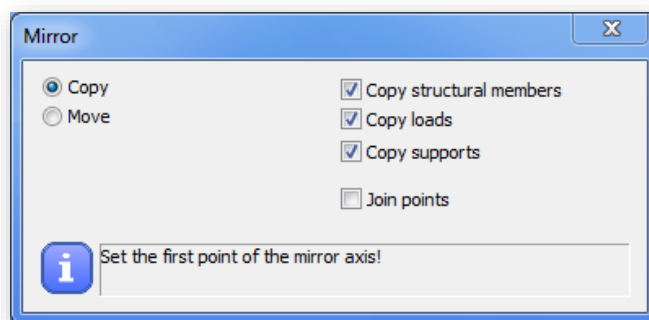
Join point:

If the **Join points** box is checked then the end points of the copied objects will be connected with lines.



Mirror selected objects. The two given points represent mirroring axis will be projected into the actual *UCS* system and the mirroring will be performed in the actual *UCS* symmetrically to the axis of mirroring.

As first step select the *UCS* for mirroring (if it is needed), select objects to be mirrored and click on the **MIRROR SELECTED OBJECTS** icon.

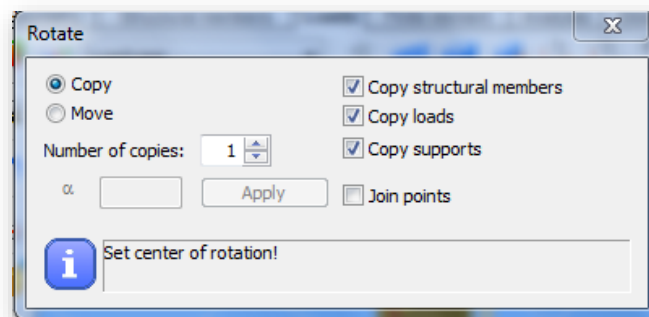


Selecting the mirror line by picking two points for the mirror axis, the selected objects will be moved or copy to the mirrored position.

The effects of the options are the same as it was described above.



Rotate selected objects. Select the objects for rotation.





Select the Move or Copy option for the transformation. The number of copies can be selected. Set the center of rotation. Set reference point of rotation. Set the direction point or type in the rotation angle and click on the **APPLY** button.

The effects of the options are the same as it was described above.

The further modifying functions are on the *GEOMETRY* tab:



Sizing of the selected objects. Select objects for sizing. Set the sizing center, the sizing reference point, and the sizing multiplier point (the distances of the sizing reference point and the sizing multiplier point to the sizing origin point determines the sizing factor). The sizing will be performed. The length (and depending on the sizing origin maybe the position) of the objects will be changed. The length of the line-loads will be changed proportionally.



Refract the selected line element. Select the edge to refract and the insert point along the axis of the selected object. Set the new position of the selected point. The original object will be broken into two parts.

The coordinates of the new position of the selected point also can be given manually accordingly to the selected coordinate system.



Curve selected line element. Select the edge for bend. Set the insert point.

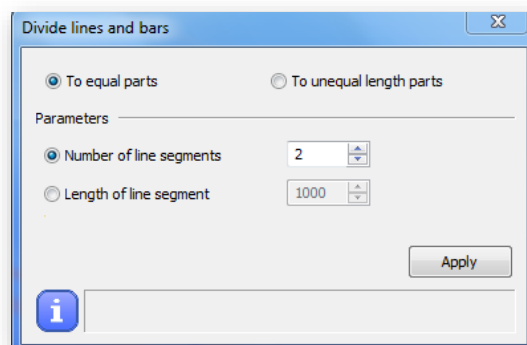


Straighten selected arc. The selected arc segment of a plane element will be deleted and substituted by a straight edge.



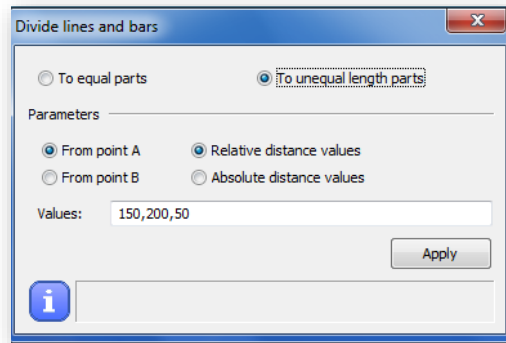
Divide selected objects. Lines and bars can be divided into equal or unequal parts.

By selecting the **To equal parts** option, the number of the segments or the length of the segments can be set.





By selecting the two unequal parts option a series of relative or absolute lengths can be defined measured from A or B endpoint of the object.



Break two selected objects. Select the two intersected objects to break. Both objects will be broken by the intersection point. It works with linear and curved objects, also with plate elements.



Trim selected line or plate element by cutting edge or plate. Select cutting edge or plate. Select the part to be trimmed. It works both with linear and curved objects, also with plate elements.



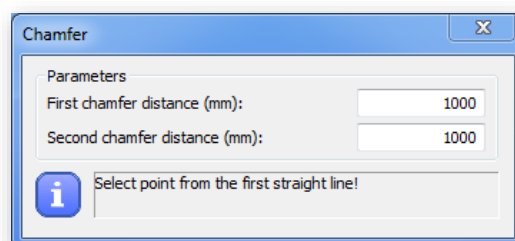
Extend selected line or plate elements to limit line or plate. Selecting the limit line or plate and click on the linear or plate object to be extended to the limit line or plate. It works with plate elements only, if the edges of the extended plate element do not cross each other.



Divide by trim. Cut out a part of the selected element. Select object for cut out. Select start point and the end point of the segment of the cut out.

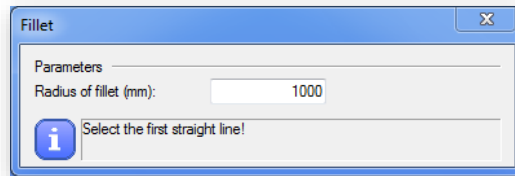


Chamfer of two selected linear element. Select the first and the second linear element. The chamfer will be applied according to the order of selection.





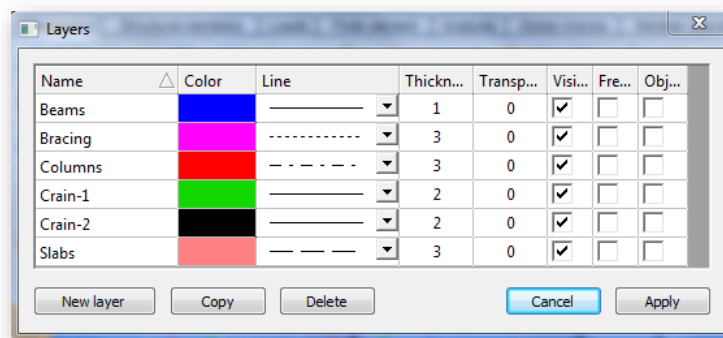
Filleting of the edge of the section of two line elements. Select the first and the second linear element. Chose a fillet radius.



4.6 LAYERS



The layers dialog window can be used for:



- ▶ Create new layers
- ▶ Copy existing layer-definition to a new layer
- ▶ Delete layers
- ▶ Edit properties of existing layers (color, line style, thickness, and transparency)
- ▶ Turn the visibility of layers on and off
- ▶ Freeze layers from activity whilst keeping them visible
- ▶ Turn on and off own style. If Objects of own style checkbox is turned OFF then all the objects on the layer use the selected color, line style, thickness etc. If it is turned ON (default setting) then all the objects use the global style.

All CAD systems have a layer concept of some sort. Objects are placed on appropriate layers as a practical way of managing the objects within the model.





5 STRUCTURAL MODELLING

5.1 BASICS

From the beginning of *Consteel* great emphasis was taken on the user-friendly structural modelling to build the structural model using real structural elements. Accordingly, the *user model*, using whole structural members (beams with haunches, tapered columns, tension braces, slabs etc.) is completely separated from the *calculation model*, which is an automatically generated sophisticated finite element model used by the structural analysis and design. It follows that the engineer does not need to deal with the calculation model; he/she can concentrate solely on the building the real structural model.



IT SHOULD BE KEPT IN MIND THAT THE ENGINEER SHOULD BE AWARE OF THE FEATURES, POSSIBILITIES AND LIMITATIONS OF THE APPLIED ANALYSIS MODEL ALREADY AT THE MODELLING STAGE BECAUSE THE MISUNDERSTANDING OF THE MODELLING OPPORTUNITIES CAN LEAD TO UNEXPECTED ANALYSIS AND DESIGN RESULTS.

All the functionality connecting with the structural modelling are placed on the **STRUCTURAL MEMBERS** tab. Due to the high importance and wide range of modelling possibilities the functions of the cross-sections and joints are collected in separate modules **CSSECTION** (Chapter 10) and **CSJOINT** (Chapter 14).

5.2 LINE MEMBERS

The line members can be modelled with steel thin-walled, reinforced concrete, and composite cross-section. The members – depending on the placement – can be columns or beams. The column is a special positioned line member, which is always vertical, so the placement is simpler, because only the height should be defined.

The dialogue allows the following modelling options for creating members:



Draw the reference line of the member



draw as a line segment or continuous line



draw as an arc by centerpoint, startpoint and angle, 3 points or startpoint, endpoint and tangent

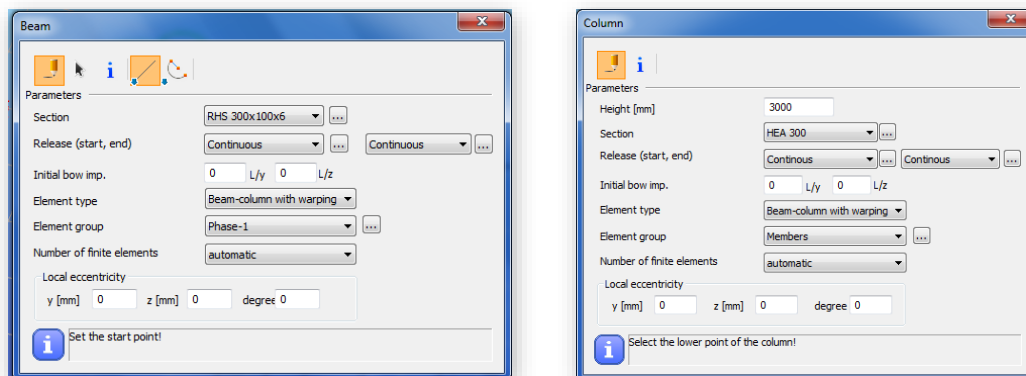



Select an existing line for the section as a reference line of a member

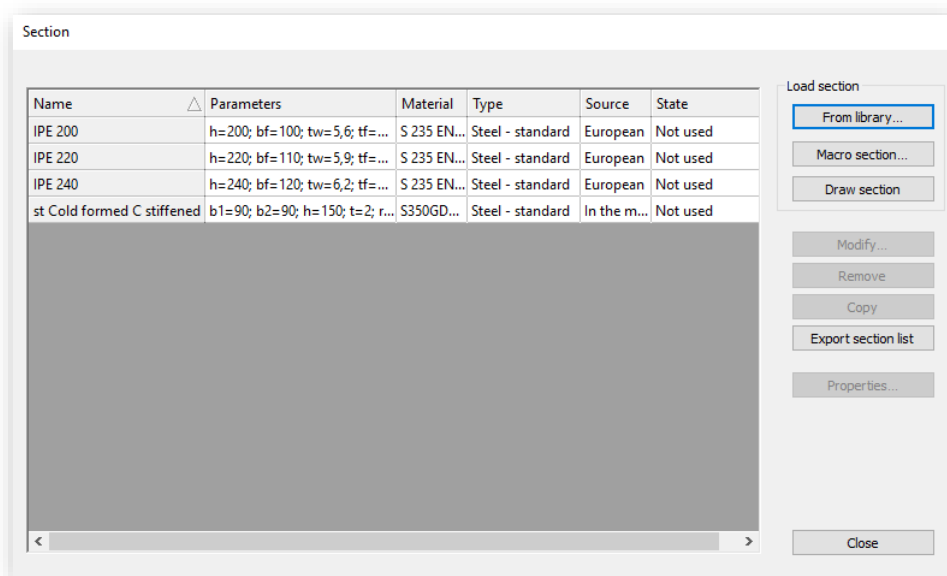



Read out the parameter of an existing member by clicking on it and assigning those parameters to the one to be created

Member parameters can be defined in the middle part of the dialog:



- **Section:** before creating a beam or column member the cross-sections should be loaded, and the appropriate section can be selected from the combo including the loaded sections. If no section has been loaded in advance the **SECTION** dialogue can be called by pressing the three dots button () next to the combo. For more information about section administration see the next chapters. See Chapter 10 for details on the section models and standard tests used in Consteel.



- **Release (start, end):** predefined releases can be assigned to the ends of the members. If new release type is needed the **RELEASE** dialogue can be called by pressing the  button next to the combo.

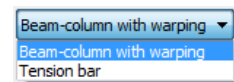


- *Initial bow imp.*: half-sine wave shaped initial crookedness can be defined in the two local direction perpendicular to the member reference axis ("y,z") with the given amplitude at the mid-length.

- *Element type*:

Section made from steel:

Two choices are possible *Beam-column with warping* and *Tension bar*, these types influence the finite element type used in the analysis. The

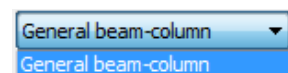


beam-column with warping is a special element with 14 degree of freedom, including the warping of the thin-walled cross section. It is an important effect in case of structures with standard, open steel profiles.

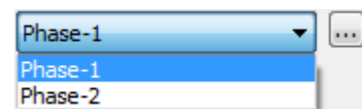
The *tension bar* can only resist tensional axial force (no bending or torsional moments and shear) if it got compression the analysis neglects its effect.

Reinforce concrete or Composite sections:

There is only one choice, the *General beam-column* type this is the commonly used 12 degree of freedom finite element.

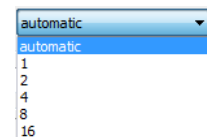


- *Element group*: the members can be sorted out into element groups for various purposes (selection, dominant results, sensitivity analysis etc.).



if new element group is needed the **GROUPS OF STRUCTURAL MEMBERS** dialogue can be called by pressing the button next to the combo.

- *Number of finite elements*: the required number of finite elements used on the member in the analysis can be set. The default *automatic* option gives a sufficient result in the most cases.



- *Local eccentricity*: member eccentricity can be defined in the local coordinate system ("y, z") of the member, and the section can be rotated about the local coordinate "x".
- At the bottom of this dialog there is an instruction and command area for guiding the user.



IT SHOULD BE NOTED THAT NOT ONLY THE ECCENTRIC AXIAL FORCE PRODUCES INFLUENCE IN THE ANALYSIS (ADDITIONAL BENDING MOMENTS) BUT THE ECCENTRIC BENDING AND TORSIONAL MOMENTS (ADDITIONAL BENDING AND TORSIONAL MOMENTS AND **BIMOMENT**)!

5.2.1. STEEL MEMBERS

As the first step of line member modelling, cross sections must be loaded into the model. This can be performed either from the **SECTION ADMINISTRATOR** directly, either from the **BEAM** dialogue. In Consteel 13, in addition to the cross-sections in the standard section database and the macro section, it also allows you to load drawn (unique) sections.



It is important to note that in Consteel, material quality is an attribute of the cross-section, therefore it must be defined when loading the cross-section!

5.2.1.1. CROSS SECTION LIBRARIES

In **CONSTEEL 13**, the following standard cross section libraries are available:

- ▶ Standard (European) cross section library
- ▶ American section library (metric and imperial)
- ▶ British section library
- ▶ Chinese section library
- ▶ Russian section library
- ▶ Manufacturers 'profiles (catalogues of individual manufacturers' profiles)

5.2.1.2. MACRO SECTIONS

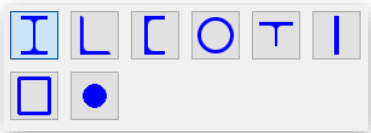
In **CONSTEEL 13**, the following macro sections are available in 4 groups:

1) Sheet welded types



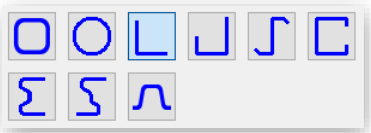
- ▶ Welded I or H section
- ▶ Welded box section
- ▶ Welded Maltese cross section
- ▶ Welded half Maltese cross section
- ▶ Welded hat section
- ▶ Welded T
- ▶ WQ section
- ▶ Slant flange welded I or H section
- ▶ C section

2) Hot rolled types



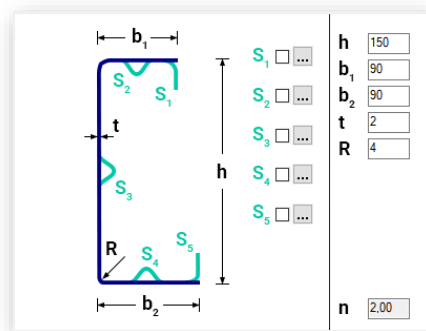
- ▶ Rolled I or H shape (with parallel flange)
- ▶ Rolled angle (parallel leg)
- ▶ Rolled channel (parallel flange)
- ▶ CHS shape
- ▶ T shape (half I)
- ▶ Plate
- ▶ Round bar
- ▶ RHS

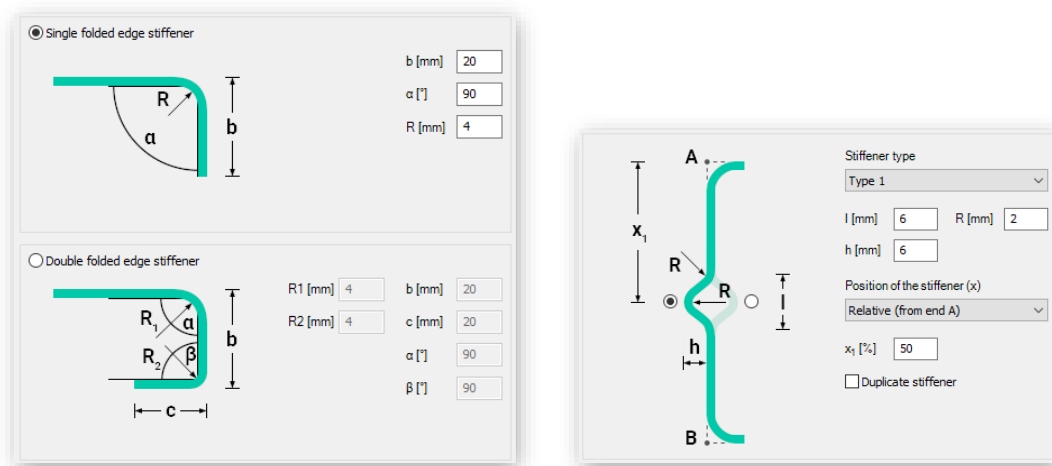
3) Cold-formed types



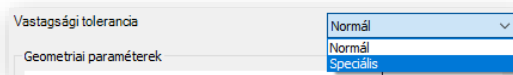
- ▶ RHS
- ▶ CHS
- ▶ L profile
- ▶ unsymmetrical U section
- ▶ Z shape
- ▶ C shape
- ▶ Sigma section
- ▶ Zeta section
- ▶ Slope omega section

In the case of cold-formed macros, it is also possible to provide stiffeners for the last 5 profile types. On the flanges once or twice bent edge stiffeners, and two different types of intermediate stiffeners can be defined. On the webs three different types of intermediate stiffeners can be defined. In the case of web stiffeners, it is also possible to double the stiffeners. The stiffeners defined this way are taken into account in the calculation of distortional buckling as defined in EN 1993-1-3.



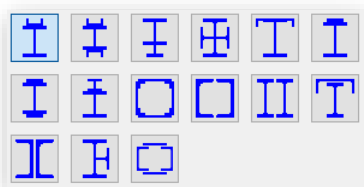


For cold formed macro sections, if they are made of coated material, the thickness tolerance category as defined in EN 10143 shall also be provided. There are two categories: normal and special. Accordingly, the design wall thickness of the cross section is calculated according to EN 1993-1-3 section 3.2.4. In general construction practice, such sections are most often made of coated steel sheets according to the aforementioned EN 10143 standard, and therefore these macros are based on the thickness tolerance categories defined in this standard.



IMPORTANT, THAT IF THE DESIGNER DOES NOT CHOSE THE COATED MATERIAL FROM THE DATABASE AND THAT THE SELECTED MATERIAL HAS A THICKNESS TOLERANCE MORE THAN 5%, IN THIS CASE THE CALCULATION WILL NOT BE EXACT. TO AVOID THIS, YOU MUST IMPORT THE CROSS SECTION INTO THE SECTION DRAWER MODULE AND PROVIDE THE REAL THICKNESS TOLERANCE. (THE SECTION DRAWER SEE IN THE FOLLOWING CHAPTER!)

4) Compound types



- ▶ I or H shape reinforced by channel at one flange
- ▶ I or H shape reinforced by channels at both flanges
- ▶ I or H shape reinforced by half I or H
- ▶ I or H shape reinforced by half I or H shapes at web



- ▶ I or H shape reinforced by angels at flange
- ▶ I or H shape reinforced by plates at flanges
- ▶ I or H shape reinforced by I or H shape at flange
- ▶ Closed shape with angles and plates
- ▶ Closed 2U
- ▶ Closed 2I
- ▶ I plus U
- ▶ I from 2U
- ▶ Half Maltese
- ▶ Battened section

5.2.1.3. SECTION DRAWER

In Consteel 13, the third option for creating a section is section drawing in the **SECTION DRAFTER** module. The function can be started by pressing the **DRAW SECTION** button in the **SECTION ADMINISTRATION** dialog box.

As a first step, after the command has been executed, you will need to select a section type and material quality in a pop-up window and enter the section name. There are two types of cross-sections:

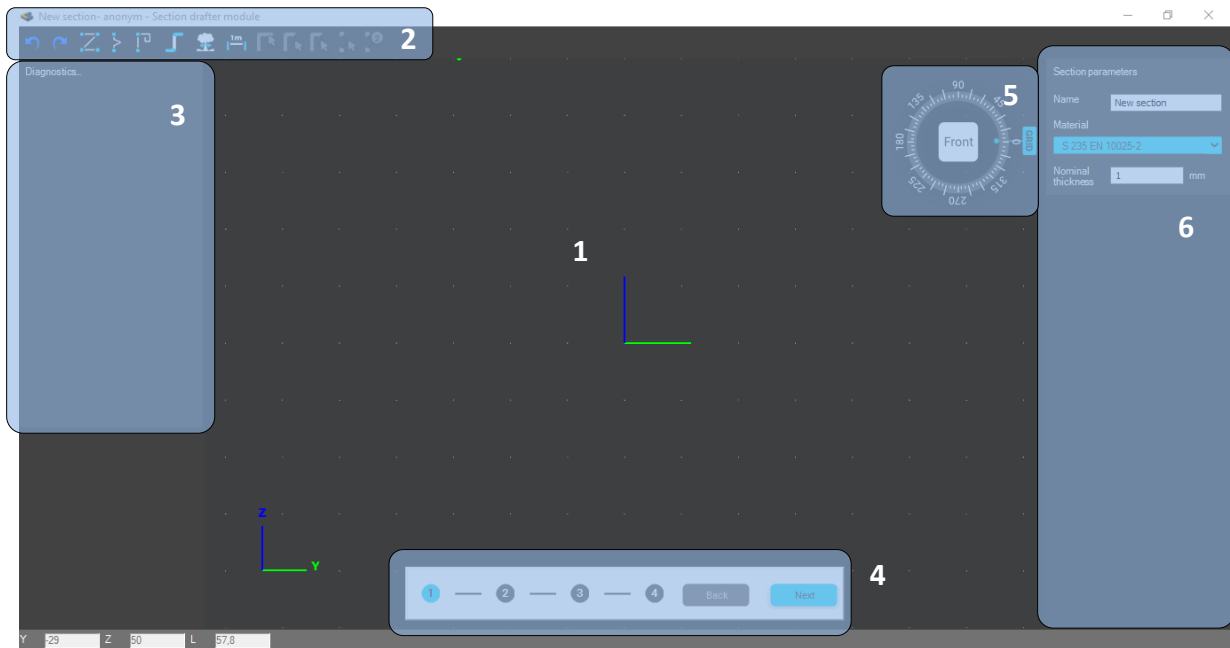
- ▶ Cold formed section
- ▶ General thin-walled section

The type of cross section has a fundamental influence on its later operation. With a **cold formed section**, you can create sections with only one line, which have a uniform wall thickness, automatically create a curve between segments, and cannot be closed. In addition to the strength, local and global stability tests, the program also takes into account the effective cross-sectional reduction due to distortional buckling, in accordance with EN 1993-1-3.

In the case of general thin-walled sections, sheets of different thicknesses may be used, the section need not be drawn on a single line, and single-closed sections may also be made. This type is basically used to create sheet welded sections. For these sections, only strength, local and global stability tests can be performed.

After selecting the segment type, clicking on the **NEXT** button opens a separate window for the **SECTION DRAFTER MODULE**, the contents of which are slightly different depending on the type of section you choose.

The profile drawing window is structured as follows:



1# Drawing Area

2# Commands

3# Diagnostic Messages: Displays various warning and error messages

4# Navigation: Use the **BACK** and **NEXT** buttons to move between the different phases of the section drawing

5# User Interface Settings: There are four tabs on the pop-up window that provide parameters and switches for adjusting the **VISIBILITY**, **GRID**, **SNAP**, and **OBJECT SIZES**.

6# Specify Parameters: always displays parameter panels for the current function and the selected item.

5.2.1.3.1. DRAWING OF COLD FORMED SECTIONS

Cold formed sections are defined in 4 phases.






- (1) Drawing of the geometry
- (2) Specify design parameters for strength and global stability tests
- (3) Specify design parameters for local buckling tests
- (4) Defining stiffeners

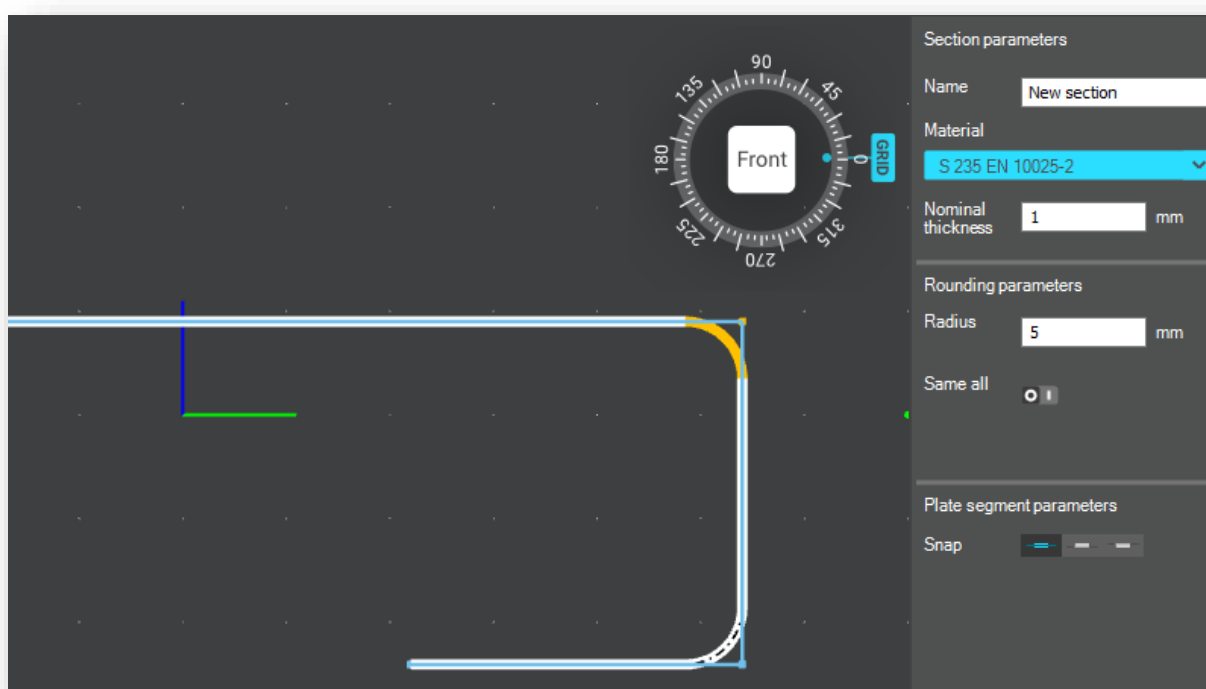
(1) Drawing of the geometry



The section geometry is edited in the first phase. Stiffeners can be easily and quickly drawn using macros. It is also possible to import a previously loaded cross section.



DRAW POLYLINE shortcut to start editing geometry. Drawing can also be done by selecting endpoints in the drawing space or by entering coordinates in the **DRAW LINE** pop-up window. Coordinates can be specified in Cartesian  or Polar  coordinates, local  or global . In the case of local input, the coordinate system is rotated according to the grid angle, in the case of global input the coordinate system does not change. The positioning of the plate segments relative to the drawn reference line (offset)  can be centered, left, or right aligned. You can change this during drawing or later, one by one, in the **PLATE SEGMENT PARAMETERS** panel on the sidebar. Roundings are created automatically when you draw plate segments. The radius of roundings can be modified subsequently, by selecting the curvature, individually in the sidebar, or uniformly over the entire section. You can also enter the nominal sheet thickness here.



In the section drawing window, after typing each parameter, you must also press ENTER for the entered value to take effect!

You can continue drawing plate segments only from one endpoint. When you have finished drawing, you can exit the command by pressing the ESC key or by clicking the EXIT button. If you want to edit the drawing, you can delete and redraw that section to fix the problem.



The following two commands will launch the **INTERMEDIATE STIFFENER** and **EDGE STIFFENER** macros. There are three types of intermediate stiffeners and two types of edge stiffeners. A panel for specifying the geometry parameters of the stiffener appears in the right sidebar. You can also specify which side of the segment the stiffener have to be placed. After the command is executed, pointing to a plate segment with the cursor, the stiffener corresponding to the set parameters appears. After adjusting the parameters, you can place the stiffener by clicking on the desired location. After positioning, by selecting the stiffener, the parameters, and in case of intermediate stiffeners the positions remain adjustable. Note that these commands are just macros to make the drawing process easier. The plate segments drawn in this way, only after defining in Phase 4, actually become code compliant stiffeners.



With the **IMPORT SECTION** command, you can import and further edit a previously created library, macro, or drawn section. Obviously, only a cold formed, one-line drawing can be imported. After the command has been issued, a window will pop up showing the sections that are suitable for importing. Pressing the **NEXT** button loads the selected section. If you have a previously drawn geometry, the program will warn you that current section you have drawn so far will be deleted. The section imported retains all its geometry and design parameters and remains editable.



The **EXPLODE SECTION** command converts the drawn stiffeners and roundings into individual line and arc segments. After the exploding, also for these elements, only the thickness and offset can be changed, not their size and position. By exploding, elements previously defined as one segment, turn into separate segments whose classification can be defined independently.



The **PLACE DIMENSION** command is used to apply dimension lines to each segment of the section. There are two icons in the pop-up window that allow you to choose how to place the dimension line:



Dimension Placement in Cartesian Coordinate System. You can specify dimension lines in the Y or Z direction.



Placement of dimension line parallel to the line segment.

To place a dimension line, click on one of the line segments and click again to place the dimension line in the desired position.

(2) Specify design parameters for strength and global stability tests

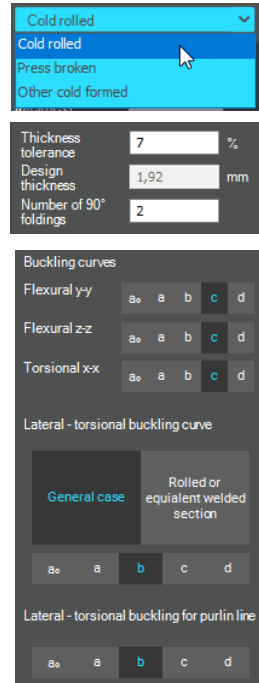


After the geometry has been drawn, the standard parameters required for the strength and global stability analysis must be set.

In the first drop-down menu, you must choose the manufacturing type of the cross section. It can be cold rolled, press broken or other cold formed.

After that the thickness tolerance required to calculate the design wall thickness and the number of the 90° bends must be entered. The number of bends is automatically calculated when a macro profile is imported. In the case of a drawn section, this field must be completed by hand.

Next, the flexural and torsional buckling curves must be selected. If the section is later used on a line member which is part of a **PURLIN LINE** object, the lowest curve selected in the *Lateral-torsional buckling for purlin line* field will be considered in the analysis.

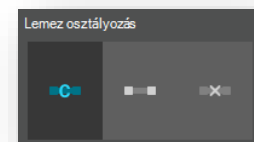





(3) Specify design parameters for local buckling tests



Moving to the third phase, the drawing area displays the lengths of the segments used to calculate effective length (b_p). By selecting a segment, you can specify on the sidebar whether, and in which direction, that segment should be considered in the calculation of the shear buckling.

The following field specifies how the segment is to be considered in the classification. There are three options to choose from:



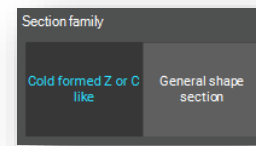
- ▶ Automatic classification and efficient length calculation  (default)
- ▶ Ignore classification and consider total length 
- ▶ Ignore classification and do not consider the plate in the effective cross section 



(4) Defining stiffeners



For the drawn stiffeners to be standard compliant stiffeners in the calculation, they need to be defined at this phase. The first step is to decide whether the section is cold-formed Z or C like section or whether it is a general shape. You can choose by using the radio buttons in the sidebar.



When choosing a Z or C like profile, the calculation takes into account the stress of the other flange as well as the stiffness of the web when supporting the flange. To do this, of course, you need to specify which parts of the section make up the lower and upper belts, and the web, and you must add its length. By choosing a general shape section, the edge stiffeners are calculated independently of each other.

A further important difference is that only a line member created with a Z-C like section can later be used to in a **PURLIN LINE**, **PURLIN SUPPORT ZONE**, or **PURLIN OVERLAP**. (See Chapter 5.12.)

A new panel appears next to the left-hand diagnostic panel, which shows the stiffeners in a tree structure.

To specify the stiffeners, use the icons on the command line in the top left of the window:



SELECT NON-STIFFENED FLANGE: Only applicable for Z or C like

sections. If one of the flanges is unstiffened, this command defines this flange. You must select the line segments of the unstiffened flange, and then click on **ENTER** or press the ENTER key to finish entering.

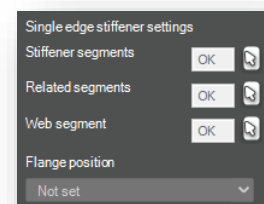


SELECT EDGE STIFFENER AND DOUBLE EDGE


STIFFENER: Follow the instructions in the popup window to define the stiffener in 4 steps. The first step is to select the segment(s) that make up the stiffener by framing or clicking on it, and then click **ENTER** or press ENTER key to finish the entry.

Then, select the flange which must be stiffened, and press ENTER again to complete the operation. The next step is to

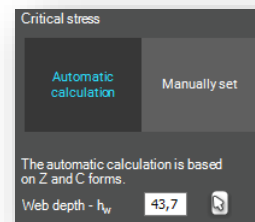
specify the segment that forms the web, and finally determine the length of the web by two points. Each step must be completed in the same way with ENTER. The process steps can be followed in the right panel where OK will be displayed on all three lines when correctly entered.





If the section is set to Z or C, the position of the belt must also be entered in the drop-down menu at any step of the process. Click the arrow icon  to re-enter a component.

Finally, the critical stress of the stiffener must be specified in the lowest section of the panel. Here you can choose between automatic calculation or manual input. It is important that the automatic calculation only works with Z or C like sections, as the Eurocode gives solutions only for such cases.



SELECT INTERMEDIATE STIFFENER AND DOUBLE INTERMEDIATE STIFFENER: Like the process of defining edge stiffener, you must select the segments that make up the stiffener and press ENTER to accept the entry. No further steps are required; however, the critical stress of the stiffener must be specified.

The stiffeners can be selected after input and their parameters can be changed or they are able to be deleted by pressing the DEL key.

Finally, you can close the section drawing by pressing the **SAVE EXIT** button on the phase indicator panel.



5.2.1.3.2. GENERAL THIN-WALLED SECTIONS

General thin-wall sections are defined in 3 phases.

- (1) Drawing of the geometry
- (2) Specify design parameters for strength and global stability tests
- (3) Specify design parameters for local buckling tests

(1) Drawing of the geometry



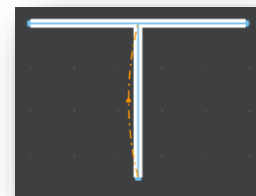
Fewer commands are available for editing by this type of sections since it is not possible to draw and define stiffeners. The editing process is similar to the previous one.



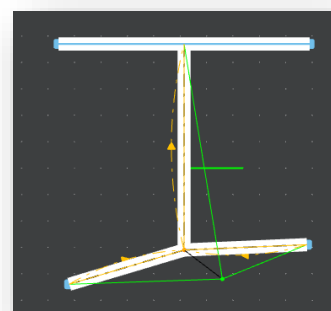
The dialog used for the **DRAW LINE** command is the same as the dialog for the cold-formed section, see the previous subchapter for details.



Due to the nature of the section, the drawing differs from the previous one since each segment can be given different thicknesses and a closed segment can also be created. When drawing from an endpoint and clicking on an intermediate point of an already drawn segment will cause the line drawing to "skip" to that point and continue editing from that point. The so-called "Dummy" segments required for section modelling are also created, which appear on the screen as a brown dashed curved line.



MOVE POINT AND EDGE can be used to move an end point or an entire segment. If you select a point, the next step is to enter the endpoint of the move immediately, if selecting an edge, first click on the start point and then the end point of the move.



The **IMPORT SECTION** command works exactly as described in the previous part. See there for details.



The **PLACE DIMENSION** command works exactly as described in the previous part. See there for details.

(2) Specify design parameters for strength and global stability tests



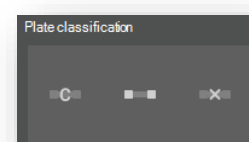
After the geometry has been done, the standard parameters required for the strength and global stability boundaries must be provided. Compared to the previous subchapter, it is not possible to specify a thickness tolerance here, nor is it possible to define a purlin line buckling curve, since these sections cannot be used for a purlin line object.

(3) Specify design parameters for local buckling tests



By moving to the third and final phase, the classification of the segments must be made in the same way as described in the previous section. See details in the previous chapter.

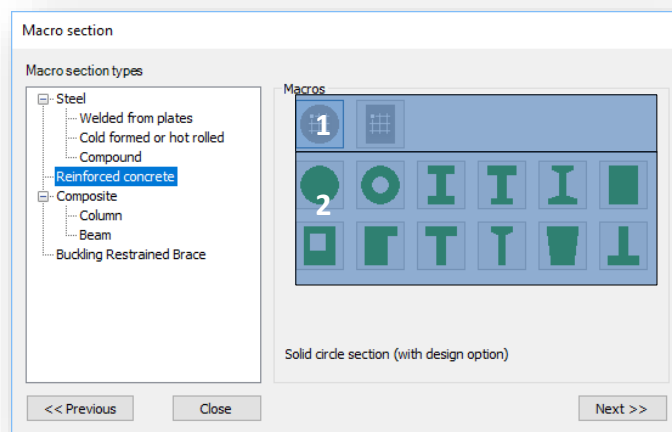
You can finish editing with the **SAVE EXIT** button.





5.2.2. REINFORCED CONCRETE MEMBERS

Definition of reinforced macro sections can be performed from the **MACRO DIALOGUE**. There are two main types of reinforced concrete sections. **SECTIONS WITH DESIGN OPTION** (#1) and **SECTIONS WITHOUT DESIGN OPTION** (#2).




5.2.2.1 REINFORCED CONCRETE CROSS SECTIONS WITH DESIGN OPTION

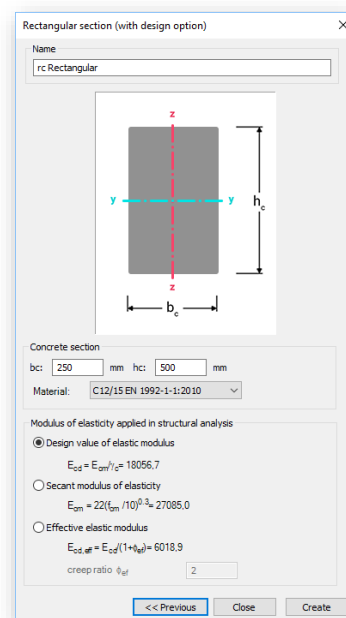
REINFORCED CONCRETE CROSS SECTIONS WITH DESIGN OPTION, are represented with a gray cross section pictogram on the **MACRO SECTION** dialogue. In Consteel 13, there are two section types with design option:

- ▶ Solid circle section
- ▶ Rectangular section

After choosing one of the available cross sections, on the section dialogue, only the overall dimensions, the concrete material grade and the modulus of elasticity applied in the structural analysis must be set.


Because the reinforcement distribution may vary along the span of the concrete member, definition of the reinforcement settings must be made through a dedicated

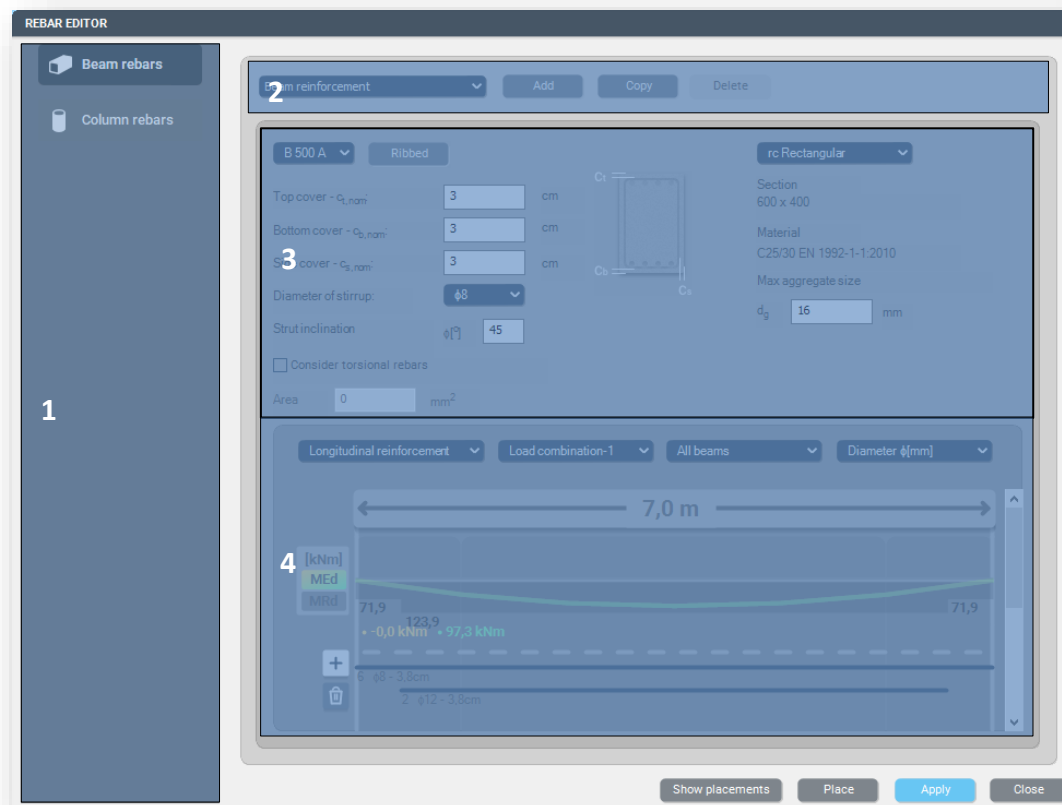
REBAR EDITOR () function, which can be found on the **STRUCTURAL MEMBERS TAB**.





5.2.2.1.1 BEAM REINFORCEMENT DEFINITION

Creation of beam reinforcement objects can be created if the Beam rebars option is selected on the left panel of the **REBAR EDITOR** dialogue. The **REBAR EDITOR** () dialogue can be found on the **STRUCTURAL MEMBERS TAB**





- ▶ #2 - If there are reinforced concrete cross sections with design option are loaded into the model, new beam reinforcement objects can be created by pressing the **ADD** button. Switching between different reinforcement objects works by selecting one from the dropdown menu. If a reinforcement object is copied, the copied object will inherit the parameters of the original object. The **DELETE** button will delete the actively selected reinforcement object only.
- ▶ #3 – On the middle part of the dialogue, the cross section can be selected, for which the reinforcement settings are desired to be set on the other parts of the dialogue. The overall dimensions, and the material grade will be written below the dropdown menu of the selected cross section.
- ▶ #4 – The bottom part of the dialogue, is a multifunctional panel. Here, the longitudinal and transverse directional rebars can be defined, envelope diagrams for bending and shear is defined, predesign values like (M_{rd} and V_{rd}) is shown and detailing rules are checked. Main functions of the panel in details:

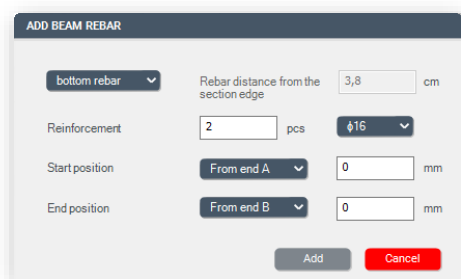




- Graphical display: After a reinforcement object is placed on a concrete member using the **PLACE** button, the length of the member on which the object is applied is highlighted. If there are available analysis results for the member, the bending moment and shear diagrams are shown on the panel, both for individual load combinations with the dropdown menus, and as envelope diagrams. Switching between the bending and shear diagrams can be performed with the upper left dropdown menu. M_{ed} and V_{ed} values are also shown

M_{rd} , V_{rd} , $V_{rd,c}$ and $V_{rd,max}$ values are also represented on the panel, if there are applied longitudinal and shear reinforcements (more on that below).

Unfilled detailing rules are also highlighted as warnings at the bottom of the panel.

- Adding longitudinal rebars: If the **LONGITUDINAL REINFORCEMENT** option is selected in the upper left dropdown menu, using the **+** button it is possible to add rebars to the member. On the **ADD BEAM REBAR** dialogue, position, quantity, and diameter settings must be given. After pressing the **ADD** button, the graphical representation of the rebars will appear on the graphical display. Deletion of a rebar can be performed by pressing the  button and choosing the rebar with the  sign.



- Adding stirrups: If the **TRANSVERSE REINFORCEMENT** option is selected in the upper left dropdown menu, using the **+** button it is possible to add stirrups to the member. On the **ADD BEAM REBAR** dialogue, only the spacing and the start-end position must be defined. Diameter of the stirrups must be given on the main rebar editor dialogue. After pressing the **ADD** button, the graphical representation of the rebars will appear on the graphical display. Deletion of a rebar can be performed by pressing the  button and choosing the rebar with the  sign.



ADD BEAM REBAR

Stirrup spacing: 100 mm

Start position: From end A 0 mm

End position: From end B 0 mm

Add Cancel

A reinforcement object can be placed on more members if the members has the same parameters (length and cross section) using the **PLACE** button.

If a reinforcement object is placed on more members with different lengths, a copy of the original reinforcement object will automatically be created for each member with a different length.

5.2.2.1.2 COLUMN REINFORCEMENT DEFINITION

By choosing the **COLUMN REBAR** option (#1) on the left side panel of the **REBAR EDITOR** dialogue, column reinforcement related data will be available on the dialogue.

REBAR EDITOR

1 Column rebars

2 Column reinforcement

3 Section: rc Rectangular, Section: 500 x 250, Material: C12/15 EN 1992-1-1:2010

4 Main reinforcement: B 500 A, $\phi 25$, Nominal concrete cover: 3 cm, Diameter of stirrup: 8 mm, Stirrup spacing: 20 cm, Max aggregate size: 16 mm

5 Reinforcement scheme: Additional longitudinal side reinforcement: ☒ y side, $\phi 16$ 2 pcs, even, start distance, y distance: 40 mm, ☒ z side, $\phi 12$ 3 pcs, even, start distance, z distance: 40 mm

6 Design parameters: Design parameters

Show placements Place Apply Close

- #2 – If there are loaded cross sections in the model with design option, new reinforcement object can be created using the **ADD** button. A reinforcement object is created by default, but any number of objects can be created. Switching between them



is possible using the dropdown menu, **DELETION** and **COPY** can be performed using the dedicated buttons.

- ▶ **#3** – In the dropdown menu the available reinforced concrete cross sections will be listed, which has design option. Overall dimensions and material grade are listed below the chosen cross section, while the graphical representation of the section is shown at the middle panel (#5).
- ▶ **#4** – At the left side of the dialogue, parameters of the main reinforcement (concrete cover, diameter, material grade), and parameters of the stirrups can be adjusted (diameter, spacing)
- ▶ **#5** – At the middle part of the dialogue, the cross section which is selected at the right panel (#3) is shown, with the dynamic representation of the reinforcements. On this panel, additional reinforcements can be added both for y and z directions, by checking the checkboxes at the bottom part, and defining the parameters for spacings, and diameters and quantity.
- ▶ **#6** – In order to be able to run the design process (discussed in detail at **CHAPTER 9.4 REINFORCE CONCRETE DESIGN**) for the column, additional design parameters must be set for the column. By clicking the (...) button, the design parameters will be opened, where all the necessary parameters are listed, and can be set individually. Design parameters are separate objects, what means that more sets of parameters can be created, saved, and used for the reinforcement object. The required parameters are buckling, curvature calculation and shear check parameters:

5.2.2.2. REINFORCED CONCRETE CROSS SECTIONS WITHOUT DESIGN OPTION

Members in the model, which are defined with **REINFORCED CONCRETE CROSS SECTIONS WITHOUT DESIGN OPTION** are not allowed to use in the standard checks at the global checks



tab. Members with these types of cross sections can provide analysis results (see **CHAPTER 8.6**), and the resistance surface (see **CHAPTER 10.4.5.2**), which of course takes into account the effect of the applied reinforcements of the cross section on the side of stiffness.

Available cross sections are:

- ▶ Solid circle section
- ▶ Ring shaped section
- ▶ Double symmetric I section
- ▶ Singly symmetric I section
- ▶ I section with tapered flange width
- ▶ Rectangular section
- ▶ Rectangular section with hole
- ▶ Rectangular section with tab
- ▶ T shaped section
- ▶ T shaped section with tapered flange width
- ▶ Trapezoid section
- ▶ Converse T shaped section

When defining the sections, overall dimensions, concrete material grade, reinforcement parameters and the applied stiffness during the analysis must be set.

Singly symmetric I section

Name: rc I 1x symm.

Concrete section

bt: 400 mm tt: 150 mm Material: C12/15 EN 1992-1-1

bb: 300 mm tb: 150 mm

hs: 600 mm s: 100 mm

Reinforcement

Material: B 500 A Cover - aty: 20 mm Cover - aby: 20 mm

Upper bars - number of rows: 1

Mem...	Diameter of re...	Number of r...	Cover - az t (m...
1. row	16	4	20

Number of lower bar rows: 1

Mem...	Diameter of re...	Number of r...	Cover - az b (m...
1. row	16	4	20

Modulus of elasticity applied in structural analysis

☐ Secant modulus of elasticity $E_{sm} = 22(f_{cm}/10)^{2/3} = 27085.0$

☒ Design value of elastic modulus $E_{cd} = E_{sm}/\gamma_c = 18056.7$

☐ Effective elastic modulus $E_{cd,eff} = E_{cd}(1 + \eta_{eff}) = 6018.9$

creep ratio η_{eff} : 2

☐ Nominal stiffness calculation according to EN 1992-1-1 5.21 formula

factor for the effects of shrinkage, creep, cracking K_0 : 0.5

Factor for contribution of reinforcement K_0 : 1

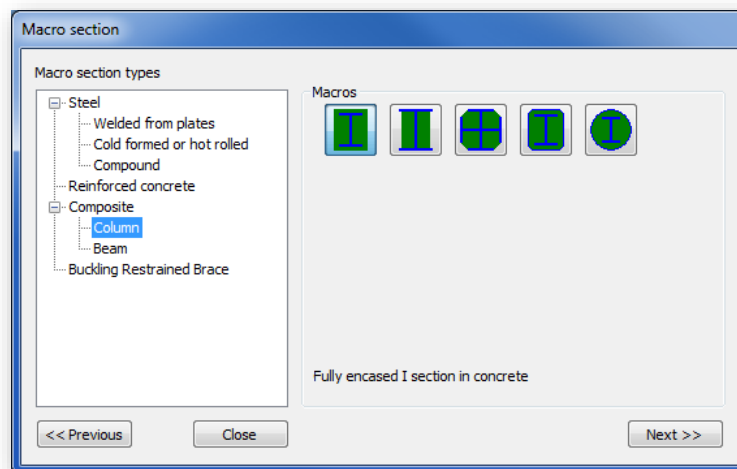
<< Previous Close Create

5.2.3. COMPOSITE COLUMNS

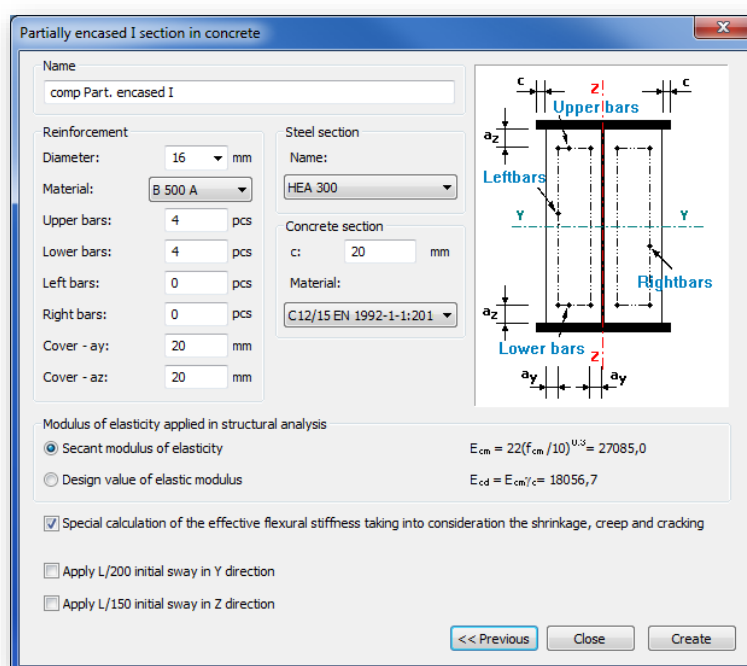
The first step is to define a composite column cross-section. Five types of cross-section are available: fully encased I section in concrete, partially encased I section in concrete, encased Maltese cross-section in concrete, fully encased I section in hollow section and fully encased I



section in circular hollow section. The cross-section macros can be found among the **MACRO SECTIONS**.



During the creation of the cross-section the parameters of the concrete section, reinforcement and the encased steel section must be set.



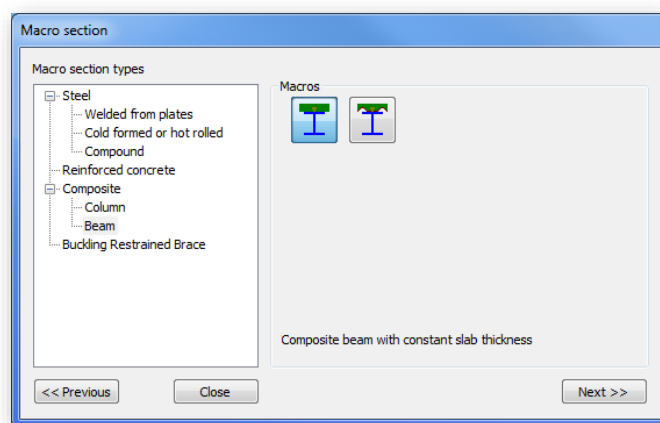
For the structural analysis two types of elastic modulus can be used which can be selected on the middle part of the cross-section creation dialog.

Standard initial sways also can be defined in y and z directions for the cross-section. If the initial sways are applied than the cross-section check is enough according to the EuroCode. Stability check is not necessary.

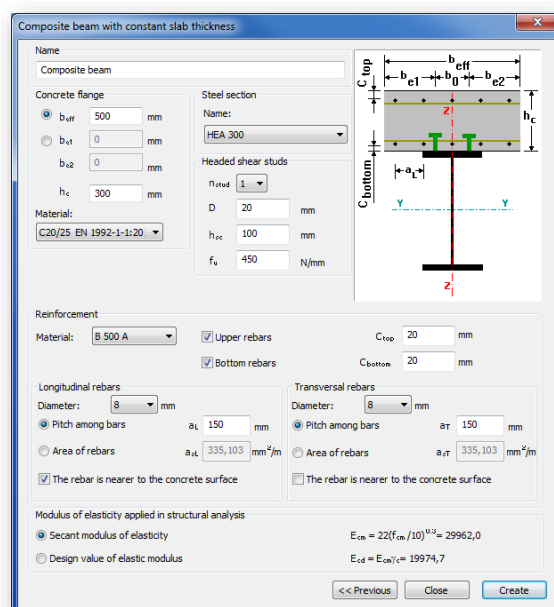


5.2.4 COMPOSITE BEAMS

The first step is to define a composite beam cross-section. There are two types available: composite beam with solid concrete slab and composite beam with profiled steel sheeting. The cross-section macros can be found among the **MACRO SECTIONS**.



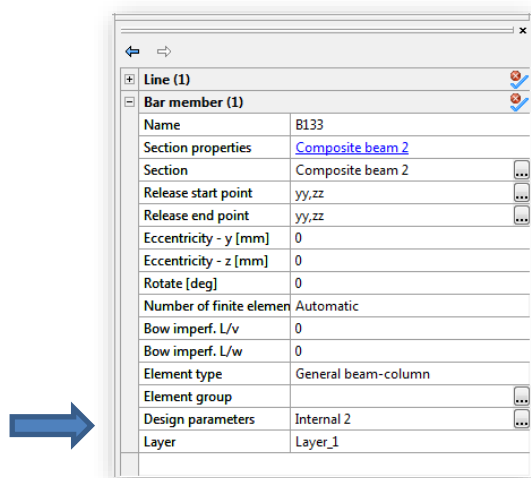
When creating a new composite cross-section, the effective breadth must be defined. It is important to know that during the analysis the actual effective breadth is automatically calculated based on the design parameters. The effective breadth which must be set at the cross-section creation is used in the graphics and for determining the self-weight of the beam. It is also possible to create an edge composite beam with different width in left and right side. Rebars can be easily defined either with pitch or with area (mm^2/m).



After the composite cross-section is defined it can be used for member creation the same way as a steel cross-section.

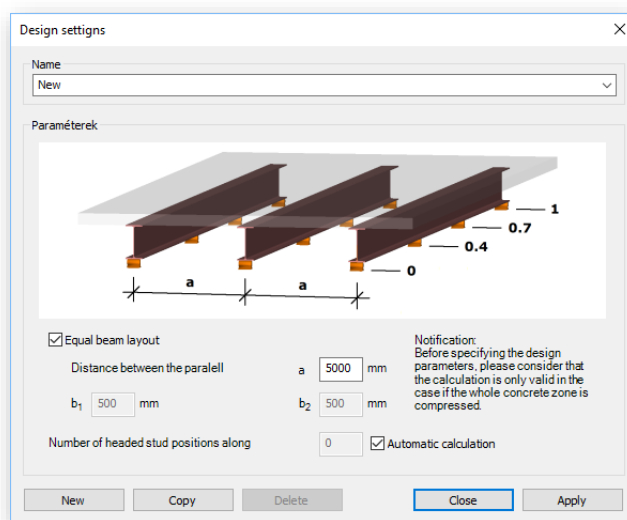


Before running the analysis select the composite beam(s) and set the **DESIGN PARAMETERS** on the **OBJECT PROPERTIES**.




In the **DESIGN SETTINGS WINDOW**, you can set the distance between parallel beams, the number of shear studs, the type of analysis, moment redistribution and the support point positions along the member. The support position table can be automatically filled up by clicking on the button above the table.

You can create more design parameters and assign them to different members. You can also use more design parameters to easily switch between them to find the best parameters or to simply compare different settings.







5.2.5 HAUNCHED MEMBERS

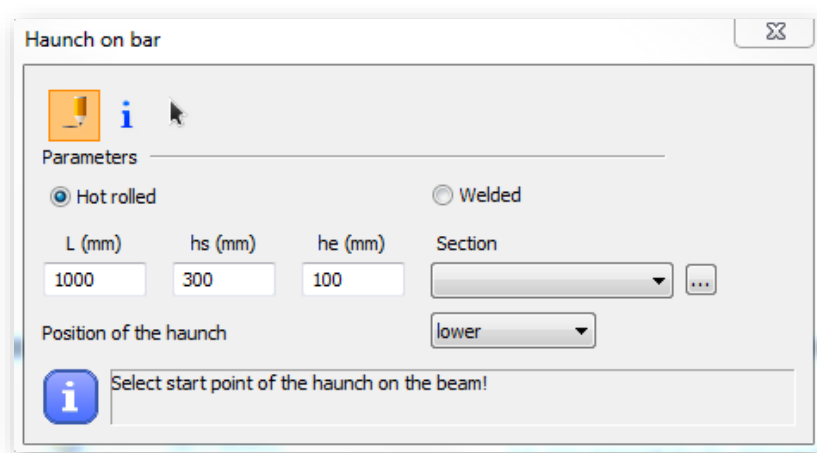
The created members can be strengthened, if necessary, by using the **HAUNCH** function ().

The haunch can only be used for members with I type (IPE, HEA, welded I) sections, and the shape of the haunch is considered as half of a welded or hot-rolled I section (with one flange) with decreasing web height.

In case of welded haunch, on the dialogue panel the length (L), start height (h_s), end height (h_e) web thickness (t_w), flange width (b), flange thickness (t_f) and the characteristics of the haunch should be set.

In case of hot rolled haunch, on the dialogue panel the Length (L), start height (h_s), end height (h_e), the section (roll radius) and the characteristics of the haunch should be set. With a click on the () button, sections can be loaded from the section administrator.

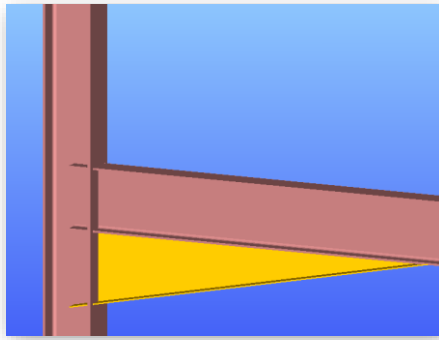
With the black arrow button () the geometrical parameters of the haunches can be loaded from the selected beam.



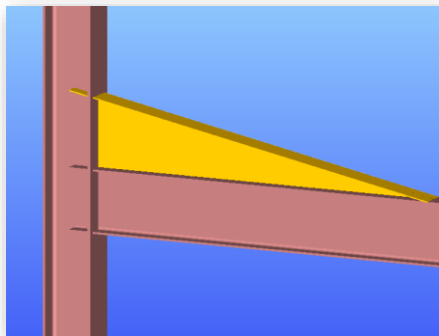
The position of the haunch is set by simply clicking on the member the start point (where the height of the haunch is full) and the direction point of the haunch on the member. It should be noted that if the start point is a common end point of more members (this is the usual case, for instance at a beam-to-column connection point) then this point should be approached and clicked on the member to be haunched. The characteristics of the haunch denote the appropriate side of the haunch on the member according to the direction of its local “z” axis. In the case of usual beam position, it results the followings:



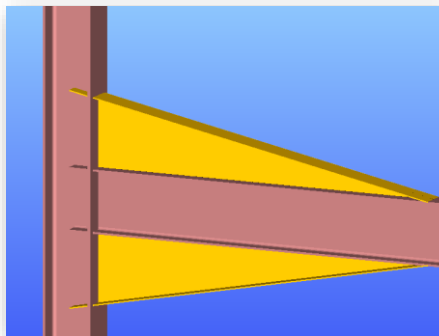
► lower



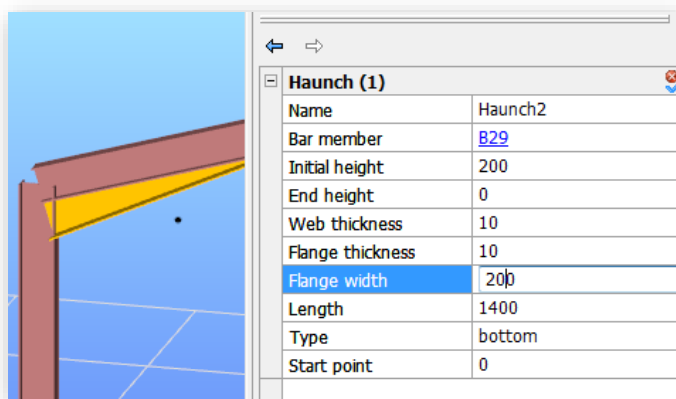
► upper



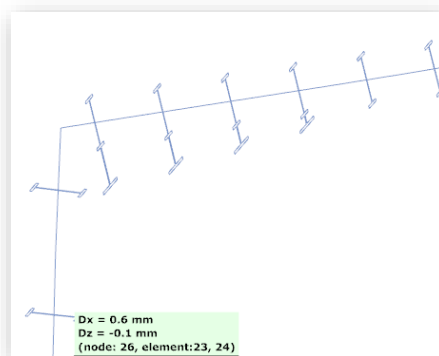
► symmetric



THE HAUNCHES CAN BE SELECTED AND MODIFIED IN THE PARAMETER TABLE AS SEPARATE OBJECTS.



IMPORTANT TO KNOW THAT FOR THE HAUNCHED PART OF THE MEMBER NEW SECTIONS ARE CREATED DURING THE AUTOMATIC FINITE ELEMENT GENERATION WHICH CONSIST OF THE ORIGINAL SECTION AND THE HAUNCH WITH APPROPRIATE WEB HEIGHT. THESE NEW SECTIONS ARE PLACED ECCENTRICALLY ON THE REFERENCE LINE OF THE MEMBER (EXCEPT THE SYMMETRICAL HAUNCH TYPE).




THIS ECCENTRICITY CAUSES ADDITIONAL EFFECTS IN THE ANALYSIS RESULTS DUE TO THE ECCENTRIC POSITION OF THE SECTIONAL FORCES (FOR INSTANCE AT THE BEAM-TO-COLUMN CONNECTION POINT OF A FRAME WITH HAUNCHED BEAMS AND/OR COLUMNS THE EQUILIBRIUM OF THE IN-PLANE BENDING MOMENTS EXISTS ONLY IF THE ADDITIONAL MOMENTS FROM THE ECCENTRIC AXIAL FORCES ARE TAKEN INTO ACCOUNT)

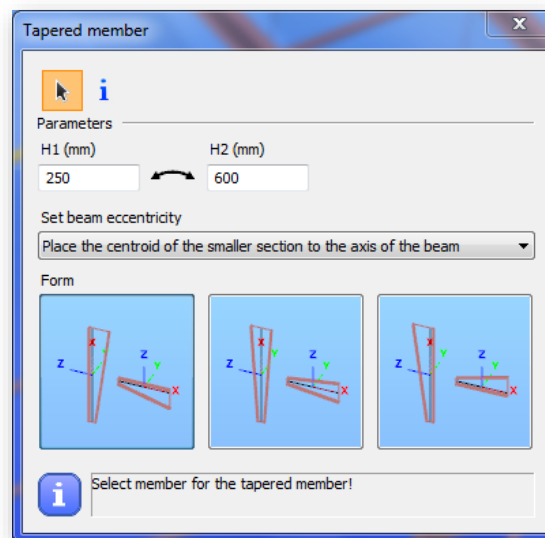
5.2.6 TAPERED MEMBERS

Tapered members are frequently used in the economic design of steel framed structures, so the fast and simple modelling of tapered members is of high importance. For the definition of a tapered member first a line member with welded I or H, box, or cold formed C section should be created in the model.


Hot rolled and other shape of Macro section can't be tapered.



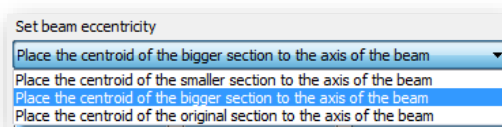
With the **TAPERED MEMBER** function () the section height of these sections can be set to linearly varying along the member length.



First the user must specify the parameters and beam eccentricity options for the member to be tapered on the **TAPERED MEMBER** dialogue.

Specify the start (H1) and end section height (H2) independently of the original section height of the cross-section. The start value for section height applied at the start point of the member, the end value applied at the other end. To change the H1 and H2 values click the  icon. The values will be changed, and selecting again the member for tapering, the sizes of the tapering will change adequately.

The rules for the beam eccentricity of the tapered member relates to the axis of the originally positioned member to be tapered.



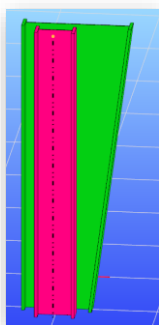
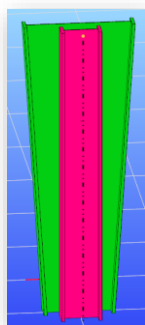
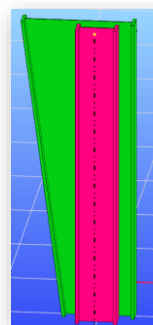
1. *Place the centroid of the smaller section to the axis of the beam:* the center of smaller H value of the tapered member will be positioned to the axis of the original beam
2. *Place the centroid of the bigger section to the axis of the beam:* the center of bigger H value of the tapered member will be positioned to the axis of the original beam
3. *Place the centroid of the original section to the axis of the beam:* the edge of the tapered member is coincident with the original member end and the tapering will start from this position.



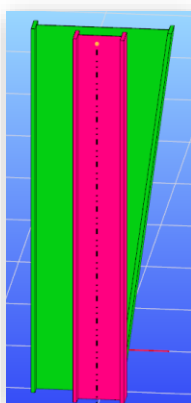
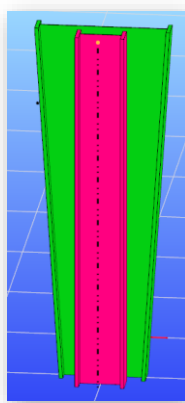
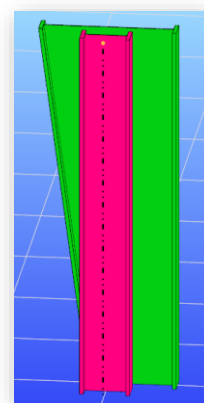
The relative position of the tapering can be $-z$ (the left side of the tapered member will be parallel to the axis of the originally placed member), symmetric or $+z$ (the right side of the tapered member will be parallel to the axis of the originally placed member). These definitions regulate the directions of the offset of the given height values along the local “z” axis of the tapered beam.

Below shown the effect of the different relative positioning by the chosen eccentricity:

1. *Place the centroid of the smaller section to the axis of the beam:* the center of smaller H value of the tapered member will be positioned to the axis of the original beam

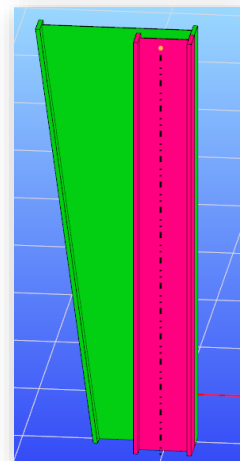
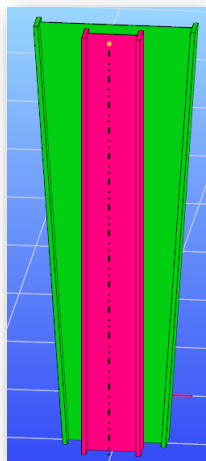
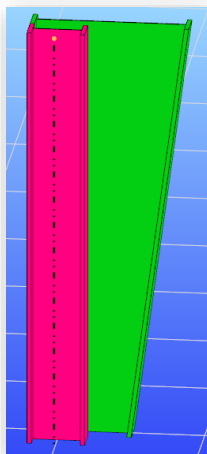
 $-z$ ***symmetric*** **$+z$** 


2. *Place the centroid of the bigger section to the axis of the beam:* the center of bigger H value of the tapered member will be positioned to the axis of the original beam

 $-z$ ***symmetric*** **$+z$** 

3. *Place the centroid of the original section to the axis of the beam:* The edge of the tapered member is coincident with the original member end the tapering starts from this position

 $-z$ ***symmetric*** **$+z$**



Activating the  icon, by clicking an earlier created tapered member in the model, the values, the eccentricity, and the relative positioning will be read out of that clicked and appear in the dialog box. By clicking another member for taper, these parameters will be applied.





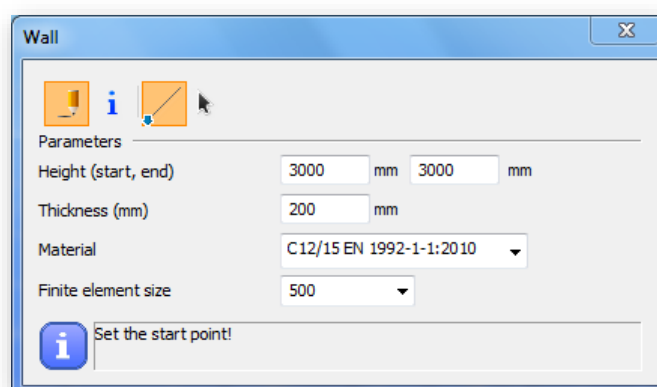
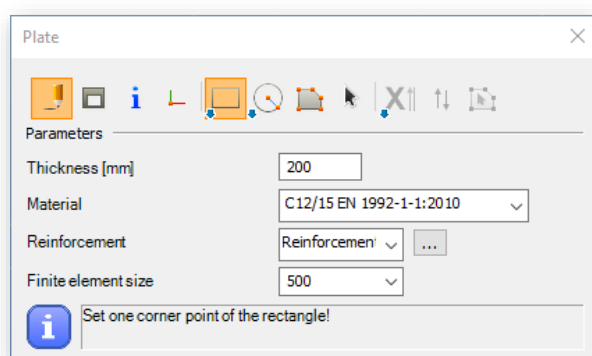
IN CASE OF SELECTING A TAPERED MEMBER NOT ONLY THE MEMBER BUT THE TAPERING WILL BE SELECTED AUTOMATICALLY AND CAN BE MODIFIED IN THE PARAMETER TABLE AS SEPARATE OBJECT.

IMPORTANT TO KNOW THAT FOR THE TAPERED MEMBERS NEW SECTIONS ARE CREATED DURING THE AUTOMATIC FINITE ELEMENT GENERATION WITH APPROPRIATE SECTION HEIGHTS. THESE NEW SECTIONS ARE PLACED ECCENTRICALLY ON THE REFERENCE LINE OF THE MEMBER (EXCEPT THE SYMMETRICAL TAPERING). THIS ECCENTRICITY CAUSES ADDITIONAL EFFECTS IN THE ANALYSIS RESULTS DUE TO THE ECCENTRIC POSITION OF THE SECTIONAL FORCES (FOR INSTANCE AT THE BEAM-TO-COLUMN CONNECTION POINT OF A FRAME WITH TAPERED BEAMS AND/OR COLUMNS THE EQUILIBRIUM OF THE IN-PLANE BENDING MOMENTS EXISTS ONLY IF THE ADDITIONAL MOMENTS FROM THE ECCENTRIC AXIAL FORCES ARE TAKEN INTO ACCOUNT)



5.3 SURFACE MEMBERS

Plane surface members with uniform thickness can be modelled. Two options are available for surface member modelling: the arbitrary shaped and positioned *plate member* (); and the vertical and square *wall member* (). The latter one is a modelling aid for the frequently used definition of walls since only the reference base line and the two height values should be defined.

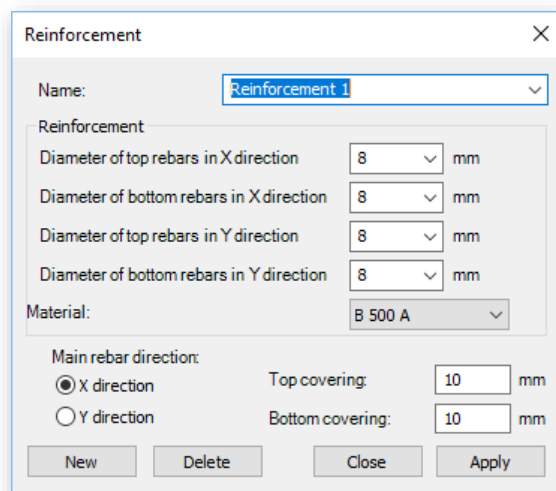


In the **PLATE** and **WALL** definition panels the drawing functions are collected to create the plate with the desired shape. Arbitrarily shaped holes can be defined in existing plate members. Three parameters can be set: the thickness, the material, and the finite element size of the surface member. The finite element size is an approximate target maximum size for the finite element mesh used for the calculation of surface members.



5.3.1 PLATE REINFORCEMENT


In case of concrete **PLATES**, reinforcements can be added to the model at the reinforcement dropdown menu, or by clicking on the (...) button. Diameters, covering and material can be set on the **REINFORCEMENT** dialogue:

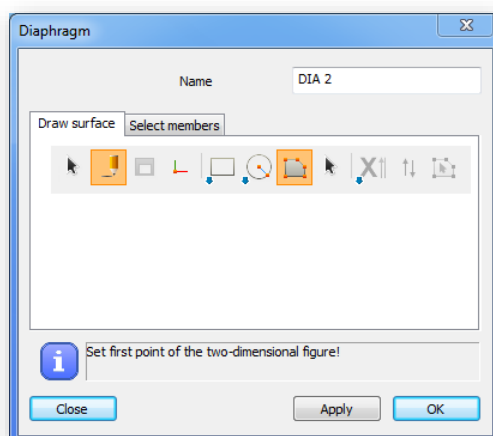


The 'Reinforcement' dialog box is used to configure reinforcement settings. It includes a 'Name' dropdown set to 'Reinforcement 1'. Under the 'Reinforcement' section, there are four dropdown menus for rebar diameters: 'Diameter of top rebars in X direction' (8 mm), 'Diameter of bottom rebars in X direction' (8 mm), 'Diameter of top rebars in Y direction' (8 mm), and 'Diameter of bottom rebars in Y direction' (8 mm). The 'Material' dropdown is set to 'B 500 A'. The 'Main rebar direction' section has two radio buttons: 'X direction' (selected) and 'Y direction'. To the right, 'Top covering' and 'Bottom covering' are both set to 10 mm. At the bottom are buttons for 'New', 'Delete', 'Close', and 'Apply'.

5.4 DIAPHRAGM






In-plane rigid element can be defined on the model in arbitrary planar. The added members' distance from each other will be same in the plane of the diaphragm element. With diaphragm element the in-plane rigid structural elements for example slab, trapezoid sheet can be modelled.

After clicking on the **DIAPHRAGM** () icon on the **STRUCTURAL MEMBERS** tab a dialog window appears.



The 'Diaphragm' dialog box is used to define a diaphragm element. It has a 'Name' field set to 'DIA 2'. Below this are two tabs: 'Draw surface' and 'Select members'. The 'Draw surface' tab is active, showing a toolbar with various drawing tools. At the bottom, there is an information icon and a message: 'Set first point of the two-dimensional figure!'. Buttons for 'Close', 'Apply', and 'OK' are at the bottom right.




Just like in the two-dimensional figure drawing there are different possibilities to draw the surface: draw a rectangle () , draw leaning rectangle () , draw circle () , draw polygon () . With the select function () previously created **LOAD TRANSFER SURFACE** can be select to use as a diaphragm also.

After drawing the surface, it is possible to select the members which are added to the diaphragm or all the planer members can add.

DIAPHRAGM element can be used also as a **LOAD TRANSFER SURFACE** and surface loads can be placed on it.

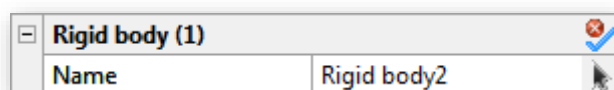
5.5 RIGID BODY

Arbitrary rigid body line can be defined on the model. Separate structural members can be linked with the rigid body.

Before clicking on the **RIGID BODY** () icon on the **STRUCTURAL MEMBERS** tab, the lines, members, and surface edges must be selected which should be converted to rigid body. By clicking on the **APPLY** button, the rigid body is created.

5.5.1 MODIFYING RIGID BODY

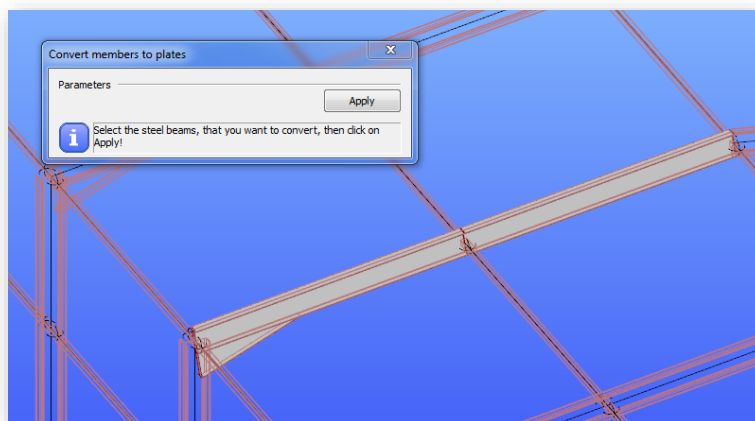
RIGID BODY can be modified by selecting it and changing the lines, members, and surface edges selection on the property bar. With the black arrow, previously selected members can be removed from the selection or new members can be added.



5.6 CONVERT MEMBERS TO PLATES

The selected members can be automatically converted to plates with **CONVERT MEMBERS**

TO PLATES function () .



The following members with section can be converted to plates:

- ▶ Hot-rolled I, H, and tube section
- ▶ Cold formed C, Z, and tube section
- ▶ Welded I, H, and box section

By clicking on the **APPLY** button the selected members will be converted to plates. During the conversion the given eccentricities are considered therefore the eccentric loads and supports will be in the same position after the conversion. Attaching nodes of the connecting members, haunches and tapered members are automatically converted.

In case of hot-rolled sections not only the flanges and web are converted to plates but also the neck area with a suitable additional plate element. Therefore, the section properties of the original member and the converted are the same.

5.7 FRAME CORNER WIZARD



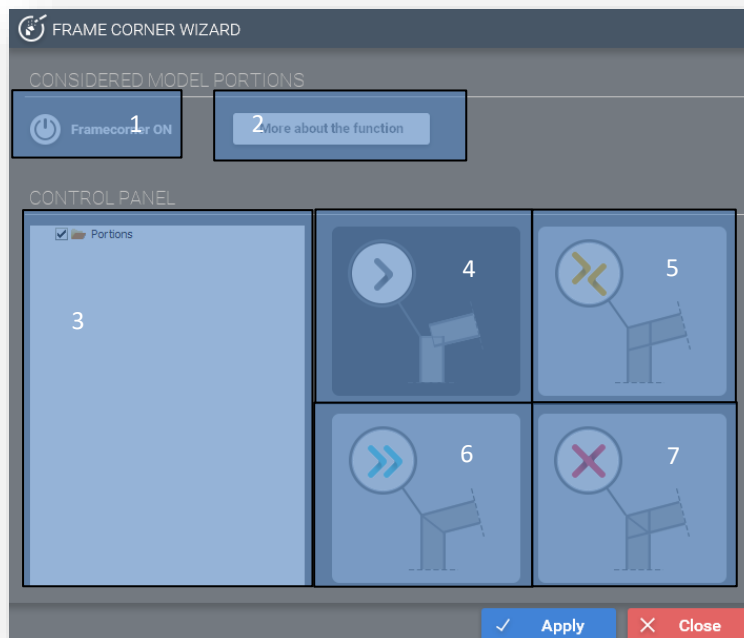
The **FRAME CORNER WIZARD** is an optional function for modelling and calculation of the corner regions of structural models more realistically considering the overlapping of connected members. The function automatically identifies the corner zones and applies special treatment for the geometrical modelling, buckling analysis, plastic analysis, and global checks.

The main mechanical background is that these – generally stiffened – corner zones have usually significantly different behavior than the connected beam members. Since these zones



are very short the behavior is influenced dominantly by the shear effect while the connected members have beam-column behavior with dominant bending effect.

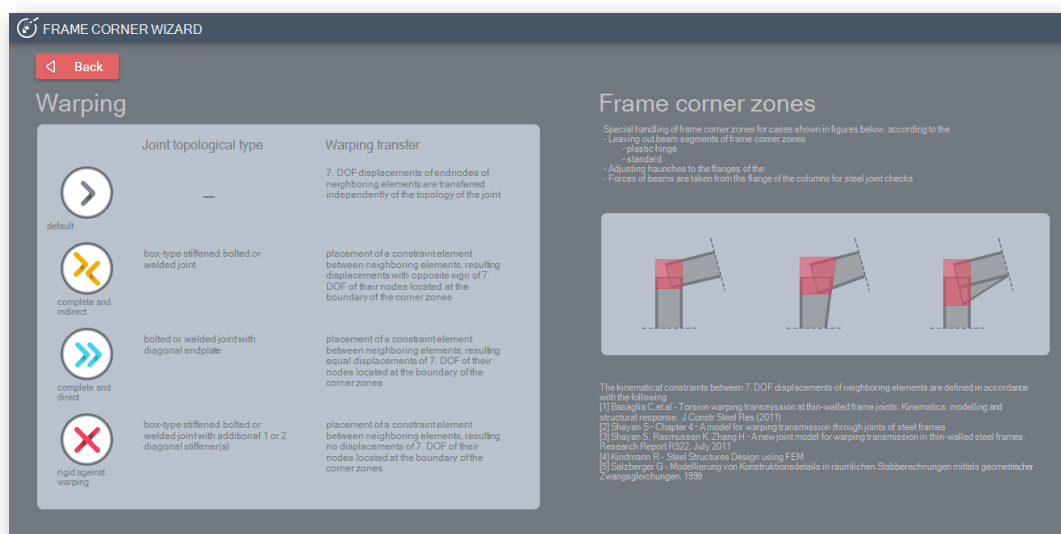
Functions of the frame corner wizard dialogue:



- #1 - With the button frame corner recognition can be turned on, and off.: By turning on frame corner recognition, frame corner definition can be started. Already defined frame corners can be turned off by clicking the button and turned on again if it is desired.
- #2 - With the more about the function button, a new panel will open, where detailed information about the function is available.
- #3 - Displays the model portion tree, in which it can be decided that what type of frame corner should be applied on which portion. It is important to note, that special frame corners (#5, #6, #7) can only be placed on model portions. The default frame corner type can be applied on the whole model. To place a special frame corner, it is necessary to select a model portion, and then with a click on a type of frame corner and on the apply button, the frame corner will be placed on the model.
- #4 - Default frame corner: 7. DOF displacements of end nodes of neighboring elements are transferred independently of the topology of the joint



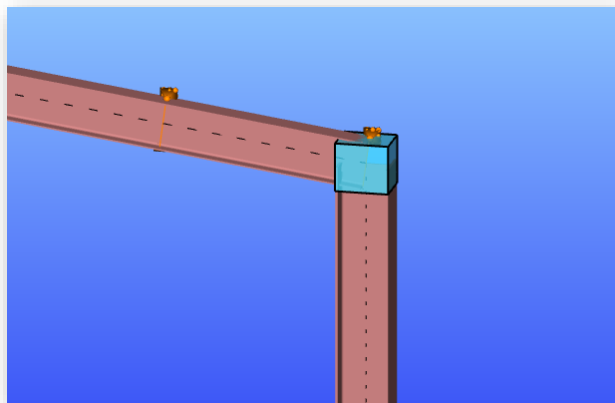
- #5 - Box-type stiffened bolted or welded joint: Placement of a constraint element between neighboring elements, resulting displacements with opposite sign of 7. DOF of their nodes located at the boundary of the corner zones.
- #6 - Bolted or welded joint with diagonal endplate: Placement of a constraint element between neighboring elements, resulting equal displacements of 7. DOF of their nodes located at the boundary of the corner zones.
- #7 - Box-type stiffened bolted or welded joint with additional 1 or 2 diagonal stiffener(s): Placement of a constraint element between neighboring elements, resulting no displacements of 7. DOF of their nodes located at the boundary of the corner zones.



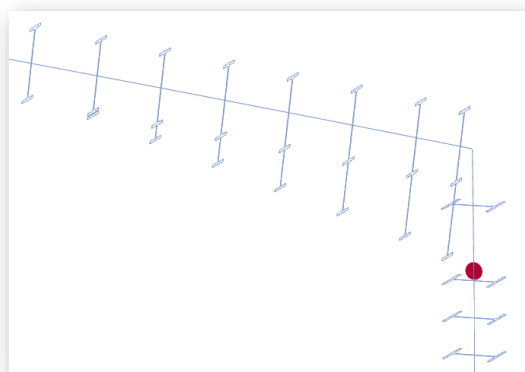
After clicking on the **APPLY** button the program detects the overlapping zones of the members in the identified connection nodes including occurrent eccentricities, haunches, or tapered members.

The member segments inside the overlapping zones are separated and handled specifically:

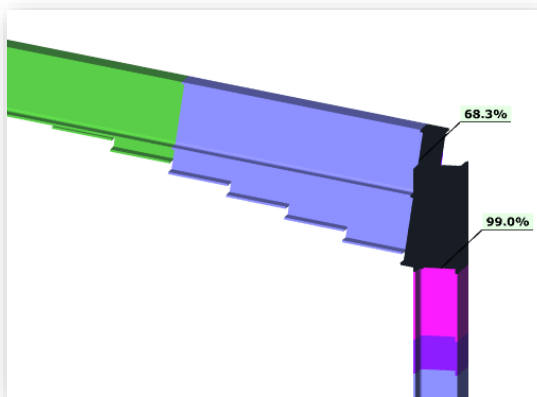
- **Geometry:** the haunch is started at the end of the truncated member (at the end of the overlapping member segment). In this way the real dimensions and position of the haunch is modelled



- *Buckling analysis*: the finite elements belonging to the beam segments inside the overlapping nodes are left out from the buckling analysis (as it would be an unselected model portion). The reason is that in this zone member buckling cannot occur, and the effective buckling lengths of the members start outside of this zone
- *Plastic analysis*: the plastic hinges cannot be formed inside the corner zone. Accordingly, the plastic hinges are formed at the theoretically exact positions (for instance on the column below the haunch) and not in the connection node where the “virtual” bending moment is the highest



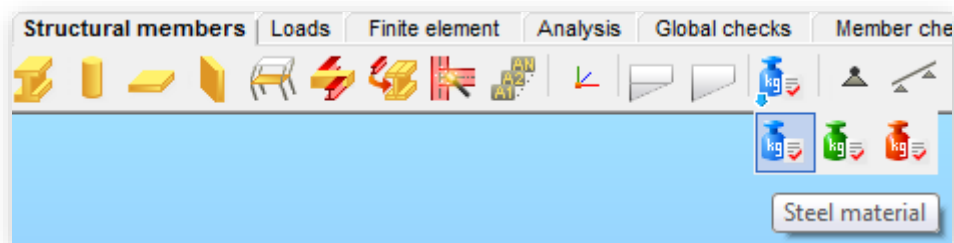
- *Global checks*: the global checks (including section and stability checks) are performed only for the member parts outside of the corner zone. In this way the “virtual” peaks of the bending moments at the connection nodes inside the corner zones (which has no real mechanical meaning) are left out from the design checks and members are checked for the real, considerably bending moment (and the corresponding other internal force) values.



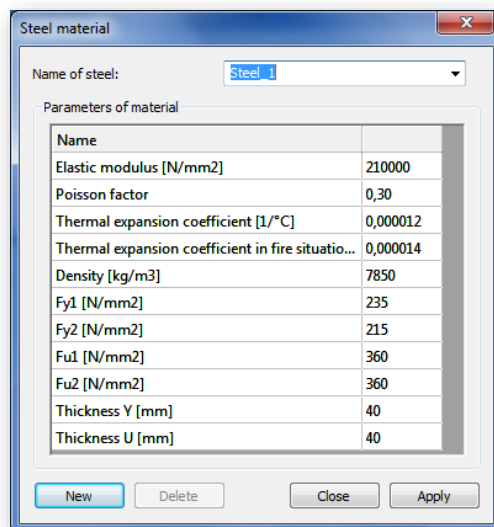
- *Connection design:* similarly to the earlier point the design bending moment and shear force values for the connection design are taken from the end of the truncated members where a beam-to-column connection is applied to the connection node where corner zone is defined

5.8 MATERIALS

New material grades can be defined as one of the three different types of material: steel, concrete, and concrete reinforcement.



The latter is only used for the rebar reinforcement of concrete or composite cross sections. The material parameters are taken from the appropriate Structural Eurocode chapters (EN 1993-1-1 for steel and EN 1992-1-1 for concrete and reinforcement), and the default – indelible – material types are set with the standard values. New materials can also be created with arbitrary parameters.



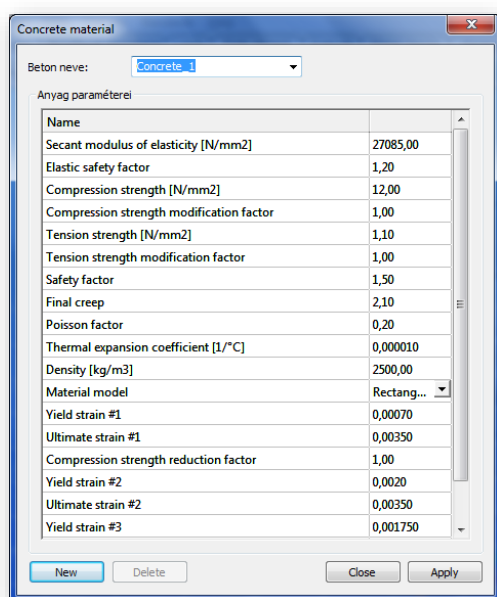
Steel material

Name of steel:

Parameters of material

Name	
Elastic modulus [N/mm ²]	210000
Poisson factor	0,30
Thermal expansion coefficient [1/°C]	0,000012
Thermal expansion coefficient in fire situatio...	0,000014
Density [kg/m ³]	7850
Fy1 [N/mm ²]	235
Fy2 [N/mm ²]	215
Fu1 [N/mm ²]	360
Fu2 [N/mm ²]	360
Thickness Y [mm]	40
Thickness U [mm]	40

In Consteel only elastic material is considered in the analysis, so the calculation results are only affected by the elastic modulus, Poisson factor, density (if the self-weight of the structure is considered) and temperature expansion factor (if temperature load or fire is applied). In case of concrete material, the *Effective elastic modulus* is used in the analysis as it defined in the EC 2.

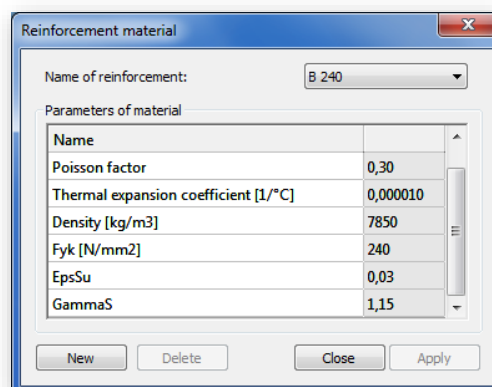


Concrete material

Beton neve:

Anyag paraméterei

Name	
Secant modulus of elasticity [N/mm ²]	27085,00
Elastic safety factor	1,20
Compression strength [N/mm ²]	12,00
Compression strength modification factor	1,00
Tension strength [N/mm ²]	1,10
Tension strength modification factor	1,00
Safety factor	1,50
Final creep	2,10
Poisson factor	0,20
Thermal expansion coefficient [1/°C]	0,000010
Density [kg/m ³]	2500,00
Material model	Rectang...
Yield strain #1	0,00070
Ultimate strain #1	0,00350
Compression strength reduction factor	1,00
Yield strain #2	0,0020
Ultimate strain #2	0,00350
Yield strain #3	0,001750



Reinforcement material

Name of reinforcement:

Parameters of material

Name	
Poisson factor	0,30
Thermal expansion coefficient [1/°C]	0,000010
Density [kg/m ³]	7850
Fyk [N/mm ²]	240
EpsSu	0,03
GammaS	1,15



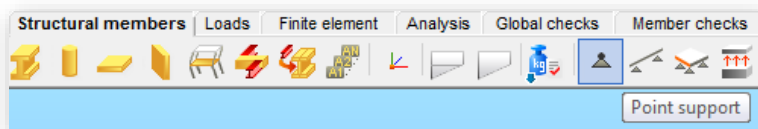
IMPORTANT TO NOTE THAT IN CASE OF BAR MEMBERS (BEAMS, COLUMNS) THE MATERIAL IS THE PARAMETER OF THE CROSS SECTION OF THE MEMBER, SO THE CURRENT MODIFICATION SHOULD BE APPLIED FOR THE APPROPRIATE CROSS SECTION. THIS FEATURE ALLOWS THE DEFINITION OF CROSS SECTIONS WITH MULTIPLE MATERIALS (E.G. COMPOSITE SECTION). ACCORDINGLY, IF






IDENTICAL CROSS SECTIONS WITH DIFFERENT MATERIAL ARE LIKED TO BE USED IN ONE MODEL
THEN MULTIPLE CROSS SECTION DEFINITION IS NEEDED!

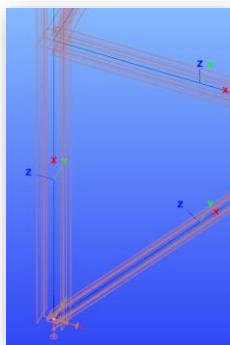
5.9 SUPPORTS

There are three types of supports in *Consteel*: point support, line support, and surface support.



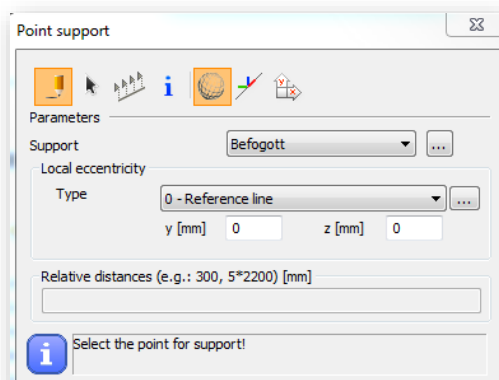
Supports can be placed according to the Point loads can be placed according to the **Global** (), **Local** () or the **User coordinate system** ().


Placing supports according to the member local coordinate system is very useful feature when working with sloping members. The visibility of the local coordinate system can be turned on with the *Visibility of the coordinate systems* option and the name of the axes can be shown on the screen using the appropriate options of the *Visibility of labels* functions.




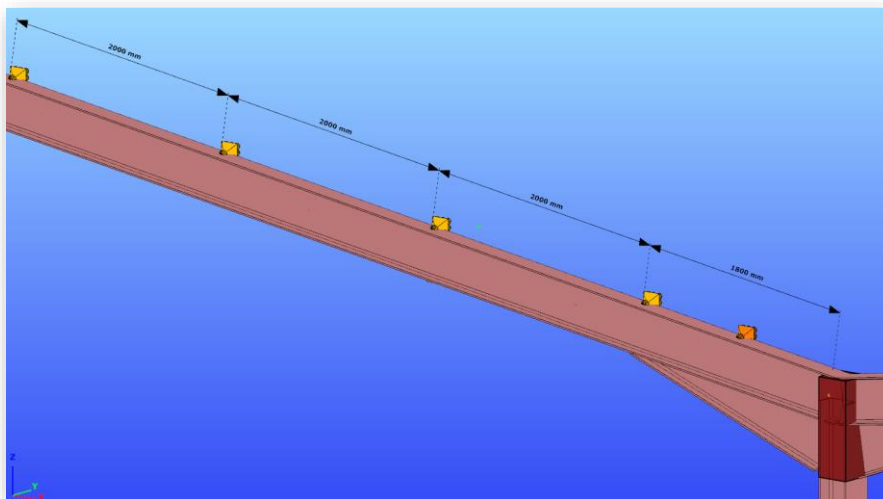


5.9.1 POINT SUPPORT ()



Point supports can be placed on any part of a line member or surface member (predefined points are not needed; end points or snap points can be used). With the black arrow button () **MULTIPLE PLACING** is possible with window selection.

With the **MULTIPLE SUPPORT** placement function (), more supports can be placed along a bar member at once by defining the relative distances between the support points. Support placement starts from the start point (End A) of the member. If there is an applied frame corner on the member, the first distance will be measured from the edge of the corner zone.






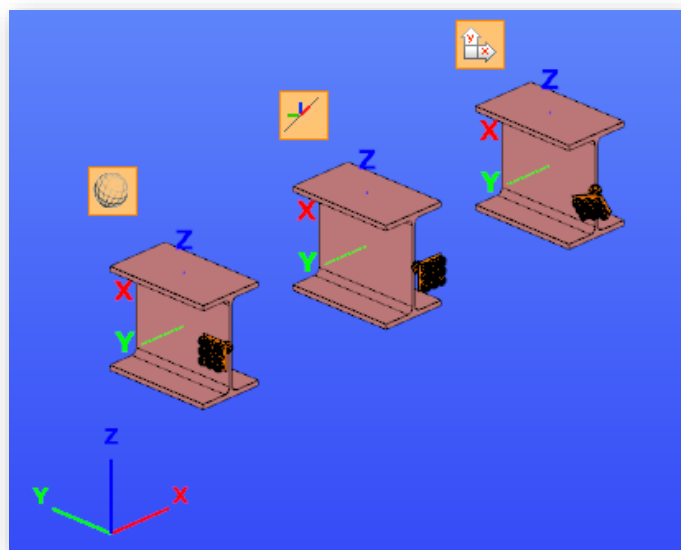
Supports placed with multiple support function will act like one object. Relative distances can be edited later at any time at the object properties by selecting the multiple support.




Point support (1)	
Name	P84
Support	Încastrat
Action point	
Ref. line of ecc.	main model, id=463
Eccentricity reference	0 - Reference line
Eccentricity - y	0
Eccentricity - z	0
Distances	300 5*2200

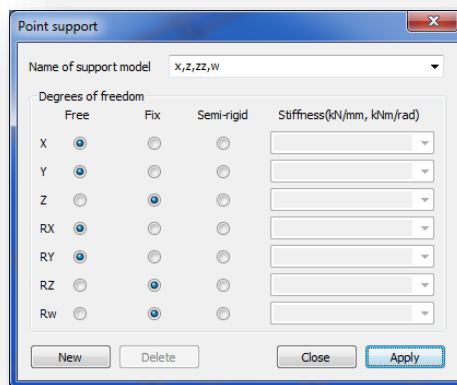
After selecting the coordinate system, the type of the support must be selected from the list-box. There are several point support types predefined.

By positioning, the used coordinate system determines the orientation of constrains of the support. Using the **Global** () , **Local** () or the **User coordinate system** () the orientations of the constrains represented by the support will be different:



By changing the eccentricity of the supported object, the support will keep the orientation to the coordinate system which was used by placing the support.

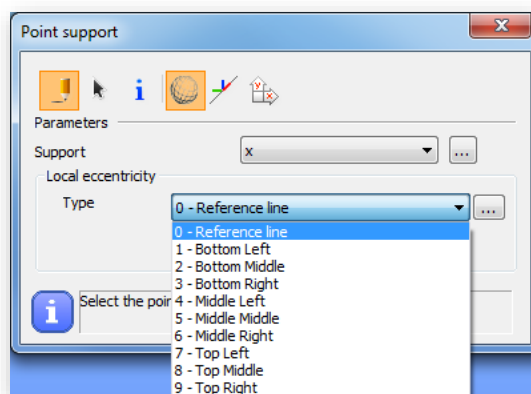
If any special supports are needed during the modelling process different from the predefined support types, then click on the support definition button (). With the **NEW** button new type of point support can be defined. 7 DOFs (Degrees of Freedom) can be set to free, fix or semi-rigid. For semi-rigid DOF the stiffness must also be set in kN/mm, or kNmm/rad.




The support type names can be clearly understood. For instance, “x,y,z, xx” means any movement is fixed in x, y and z direction and the rotation around x axis is also fixed. All the rest DOFs are free.

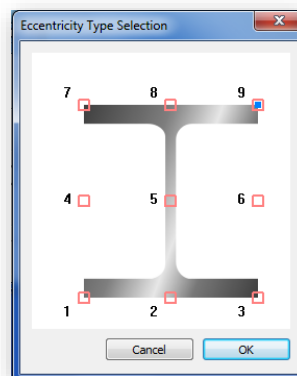
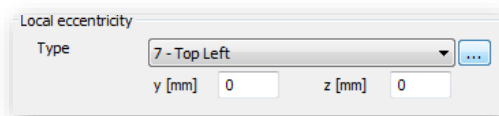
Local eccentricity can also be defined to the supports:

(This feature can be used for example for modelling the support effect of the bracing which is not connected to the reference line of the member but supporting the flange of the beam.)

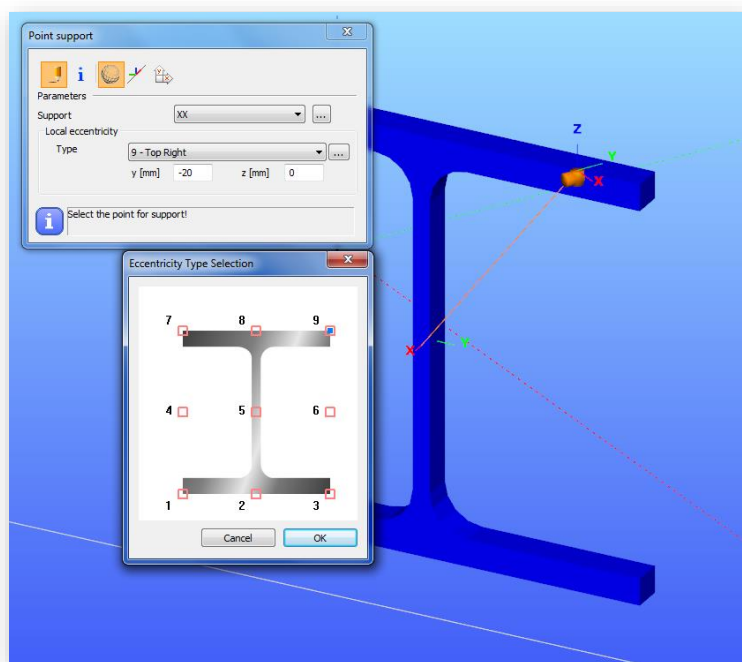


The eccentricity of the support can be defined **relative to the reference line** of a section, or **relative to the section geometry**. The “0 - Reference line” local eccentricity type can be selected only from this list-box.

Support eccentricity **relative to the section geometry** can be specified in two ways. The first way is: select one of the typical point of the section geometry (1-9) from the list, the second way is select one of the typical point (1-9) of the section relative position of the support by clicking the position on the graphical imitation of a section (click the  button left to the list):



Giving value for the y or z parameters for local eccentricity these values will be added to the above selected position.



Changing the eccentricity of the supported object the new position of the support will be calculated accordingly.

Depending on the type of the selected local eccentricity used by placing the support the transformation rules are the following:

By selecting the “0 – Reference line” eccentricity type:

Placing a support with this eccentricity type, for example changing the “y” eccentricity of the supported object, the support will keep its position relative to the reference line, not to the section. By changing the “Rotation angle” attribute of the supported object, the reference line also rotates, and the position of the support will rotate too.

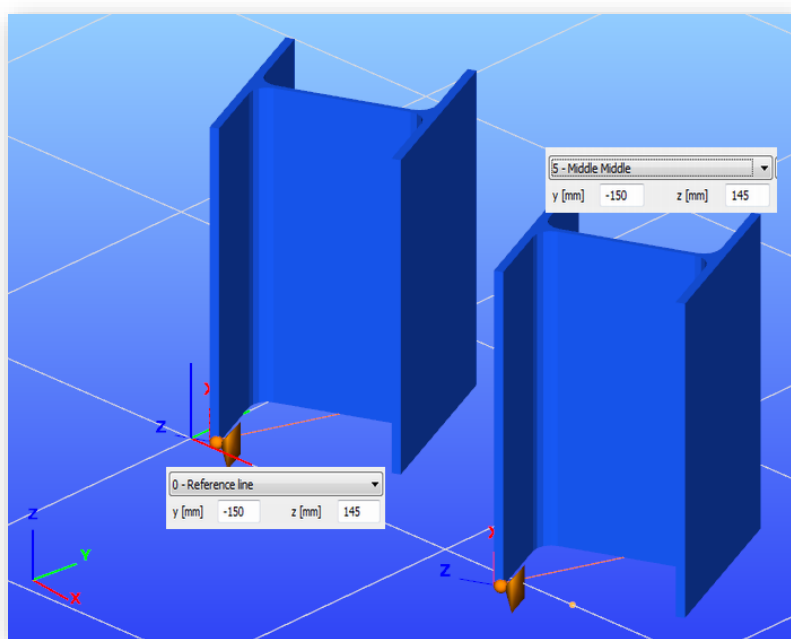


By selecting the 1 -9 eccentricity type:

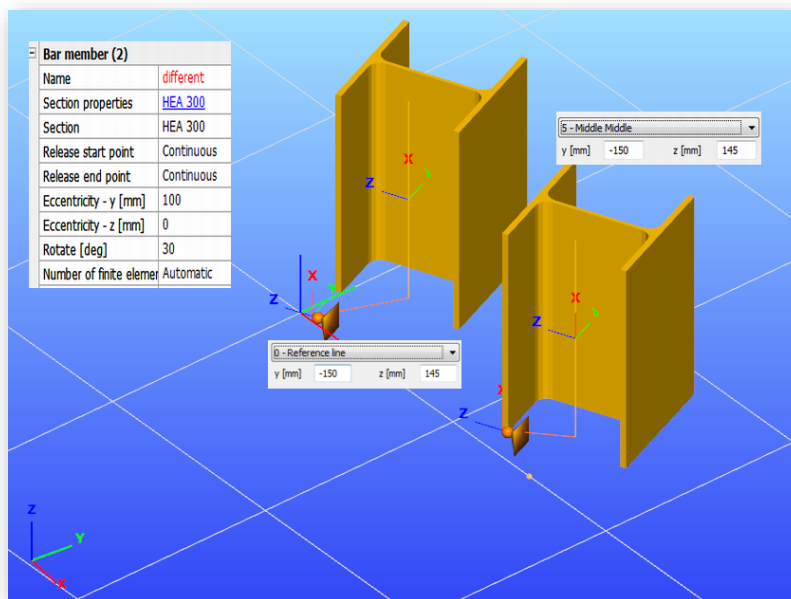
Placing a support with any of these eccentricity types, for example changing the “y” eccentricity of the supported object, the support will keep its position relative to the section. By changing the “Rotation angle” attribute of the supported object, the position of the support will rotate too.

Example for the different types of eccentricity:

1. Example: Both supports were placed with -150mm eccentricity in the y direction, but left case was defined relative to the reference line of a section and the right case was defined relative to the middle-middle point of the section geometry.

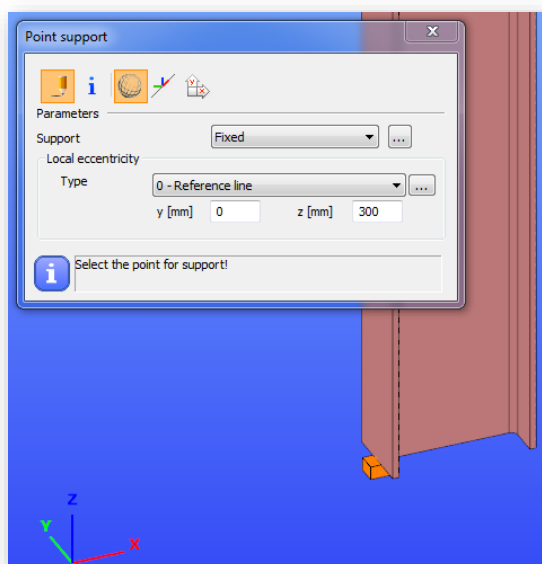


If the eccentricity of the columns is changed to $y = 100\text{mm}$, the new position of the supports is as follows:

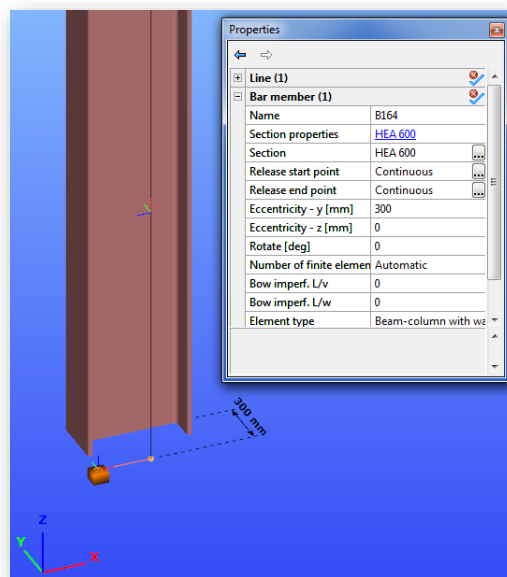


In case of the left case the position of the support did not change, because the position of the reference line of the column also did not change, but in case of the right case the support was moved with the points of the section of the column.

2. *Example:* The support is placed according to the global coordinate system; the eccentricity is 300 mm in the z direction of the local coordinate system of the supported column from the reference line.

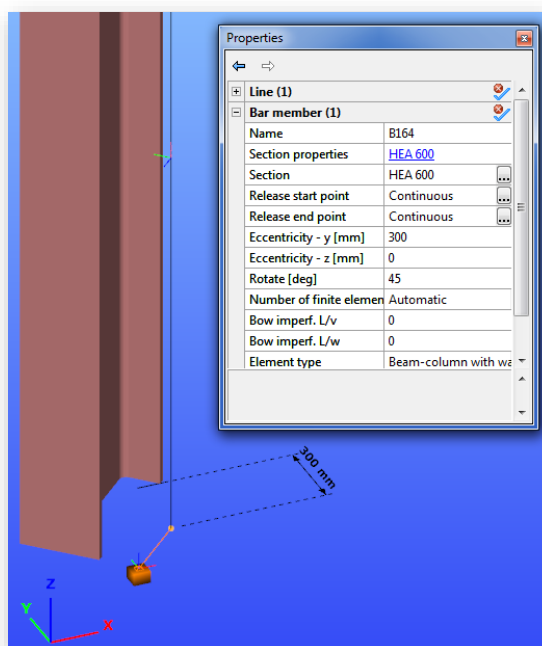


If the column is moved with 300mm in the y direction in the local coordinate system, then the position of the support will not change.

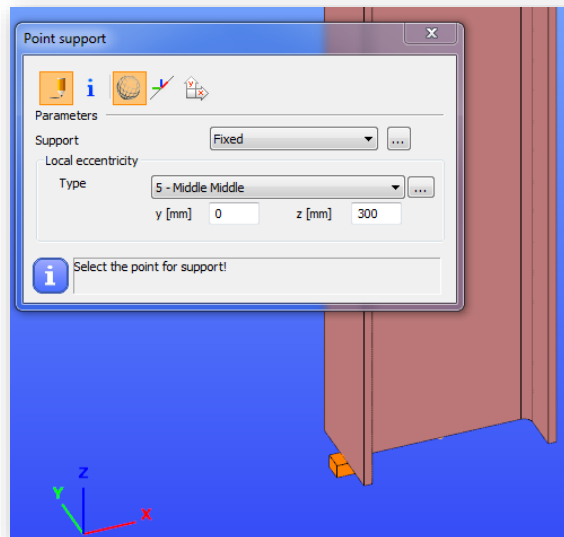


The support keeps its original relative position to the centerline of the column.

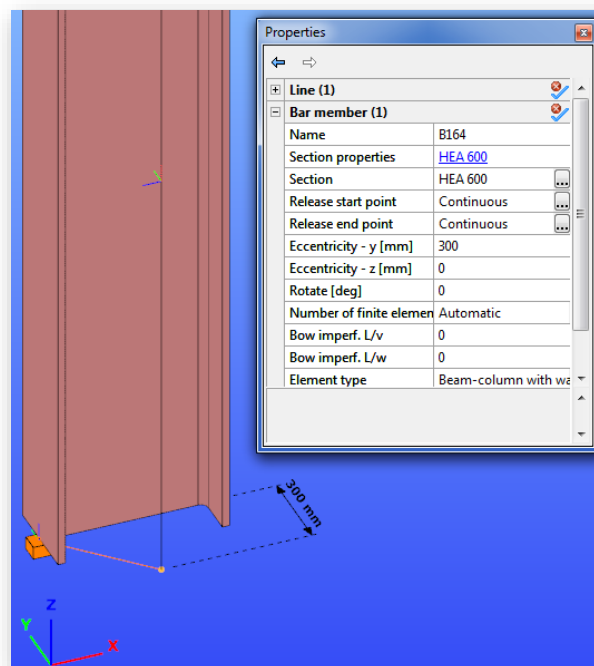
If the column is rotated with 45 degrees, the support is also rotated accordingly, but it keeps the directions of its local axis parallel to the axis of the global coordinate system, which was selected by for positioning the support.



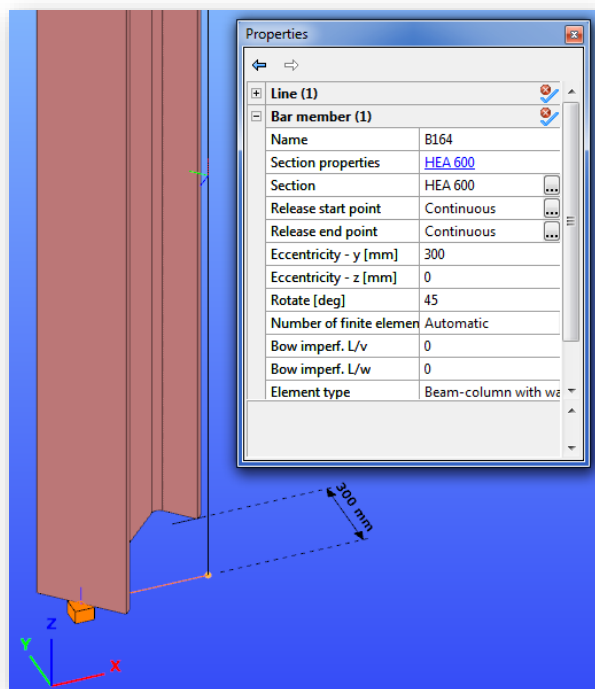
3. *Example:* The support is placed according to the global coordinate system, the eccentricity is 300mm in the z direction of the local coordinate system of the supported column relative to the middle-middle point of the section geometry.



If the column is moved with 300mm in the y direction in the local coordinate system, then the support moves with the column.



If the column is rotated with 45 degree, then the support moves together with the column.



Selecting any of the above eccentricity types for positioning a support, changing the eccentricity of the supported object, the support will keep the originally given relative position from the new position of the supported object, and will keep the orientation defined by the applied coordinate system for placing this support.

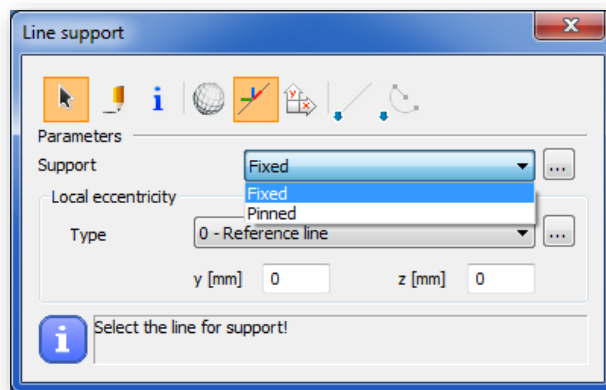



WARNING!

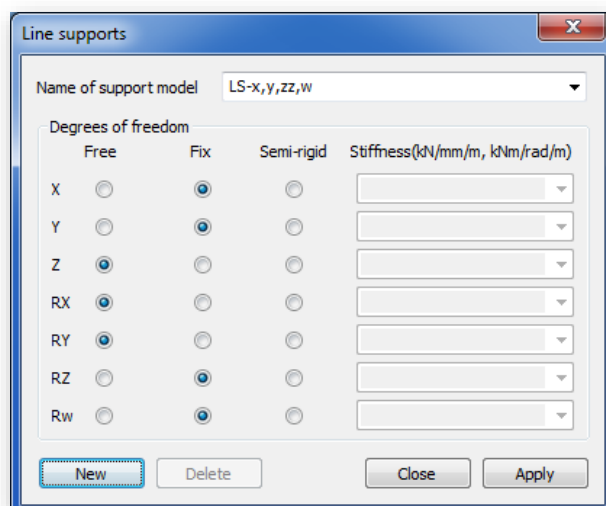
BE AWARE THAT SINCE THE FINITE ELEMENT FOR THE STEEL BEAMS AND COLUMNS HAS 7 DOFs THE POINT SUPPORT ALSO HAS 7 DOFs, THE 7TH DOF REPRESENTS THE WARPING OF THE CROSS SECTION. ACCORDINGLY, IF A CROSS SECTION ON A CERTAIN PLACE IS CONSIDERED TO FIXED FOR WARPING (FOR INSTANCE IN HEAVILY STIFFENED JOINTS) THE 7TH DOF SHOULD BE FIXED. IN JOINTS CONSISTING SEVERAL MEMBERS (ESPECIALLY WHEN MEMBER ECCENTRICITIES ARE PRESENT) IT IS RECOMMENDED TO APPLY WARPING SUPPORT!

5.9.2 LINE SUPPORT ()


Line supports can be assigned to existing lines (line members or edge of surface members) or to lines drawn for the support only (for instance on a surface).



There are two default types for line supports the Fixed and the Pinned. With the  button it is also possible to define a new line support by giving the attributes of constraints as it is needed.



By positioning a line support the effect of the applied coordinate system and local eccentricity type are the same as for the point support.

The select function ():

The line support will be placed to the selected edge of a surface (an edge of boundary or an edge of a hole), or to an axis of a beam.


The draw function: 

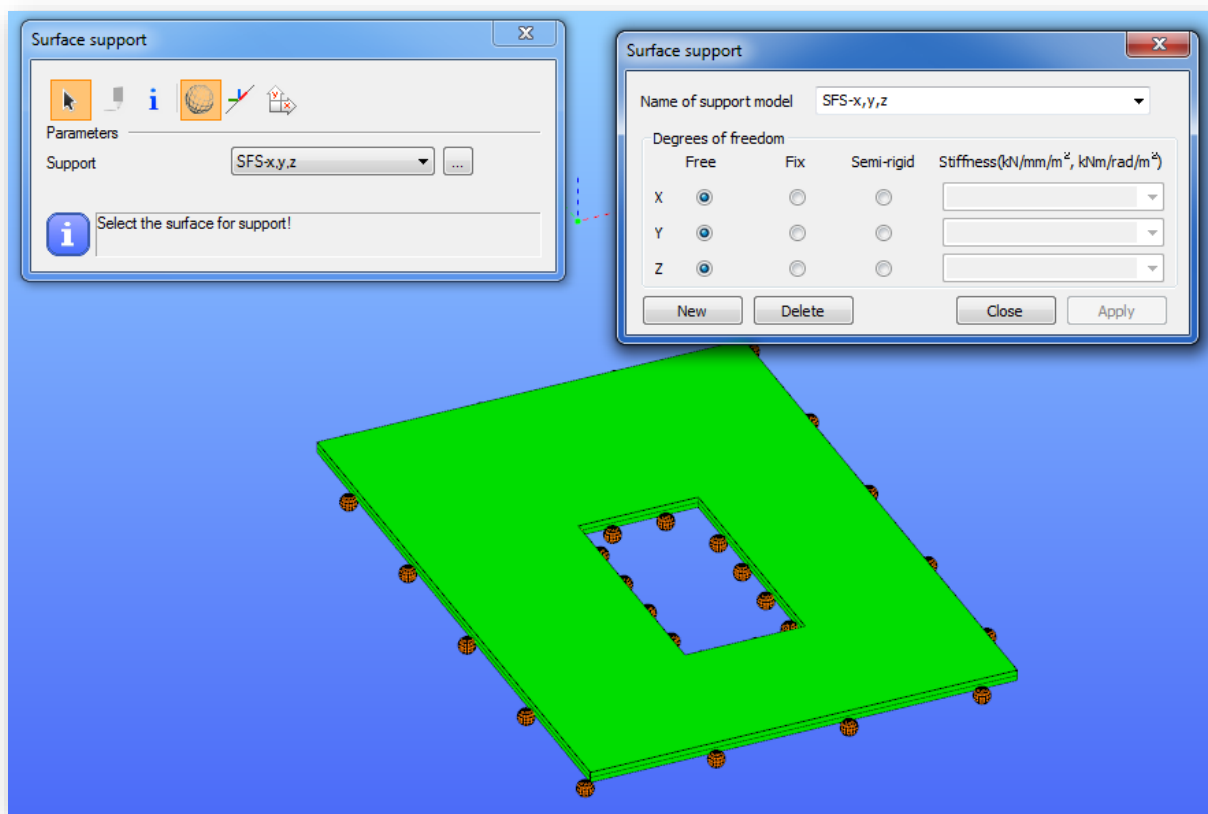
The line support will be placed between the first and the second point defined by the draw function on the surface or on an axis of a beam.



5.9.3 SURFACE SUPPORT


Surface supports can be assigned to existing surfaces.

There are no predefined supports for supporting surfaces. By pressing the  button, the user can create new surface support types for specifying 3 constrains.



By clicking on a plate object, all the surface of this selected object will be supported by the support.


5.10 LINK ELEMENTS

Link element () can be used to connect elements which are not directly connected to each other.

Parameters of the link element can be defined in the middle part of the dialog:

- *Position of connection*: this parameter defines the place where the continuity acts in the percentage of the length of the link element. Value can be between 0 and 1
- *Rotation*: rotation value defines the angle of the link element in degrees

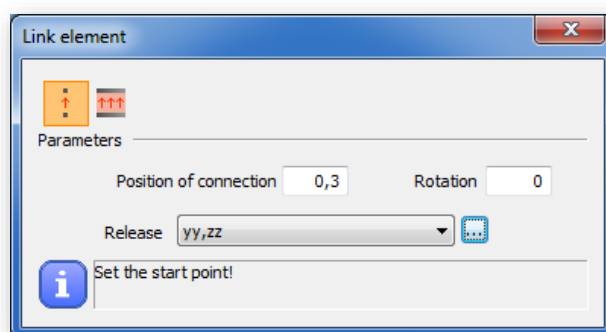


- **Release:** predefined releases can be assigned to the specified position. If new release type is needed the **RELEASE** dialogue can be called by pressing the  button next to the combo

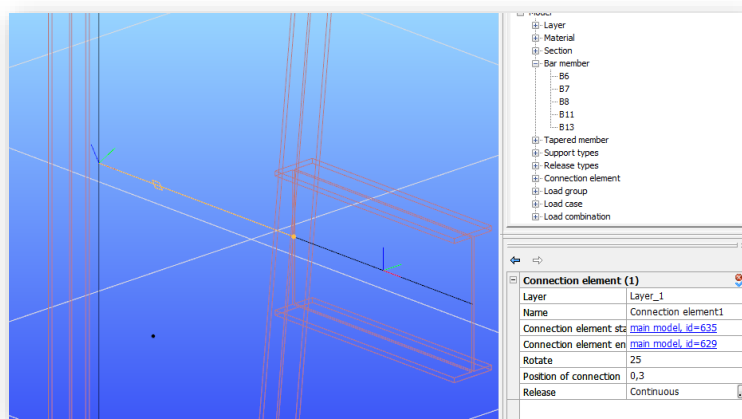
There are two different types of link element.

5.10.1 CONNECT TWO STRUCTURAL POINTS ()

This type of link element can be used to connect two structural points.



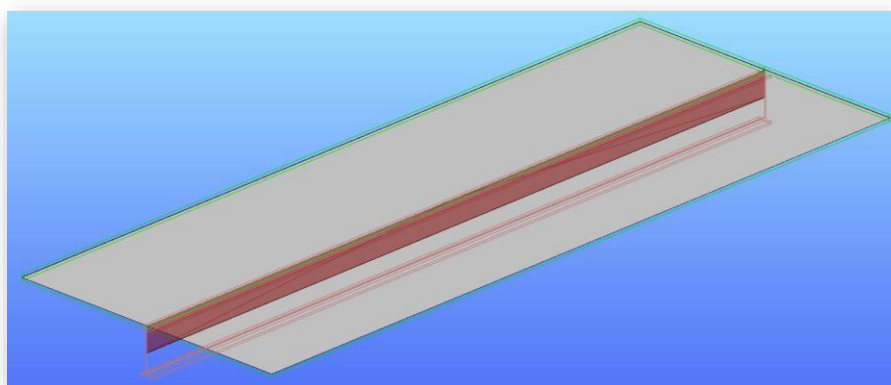
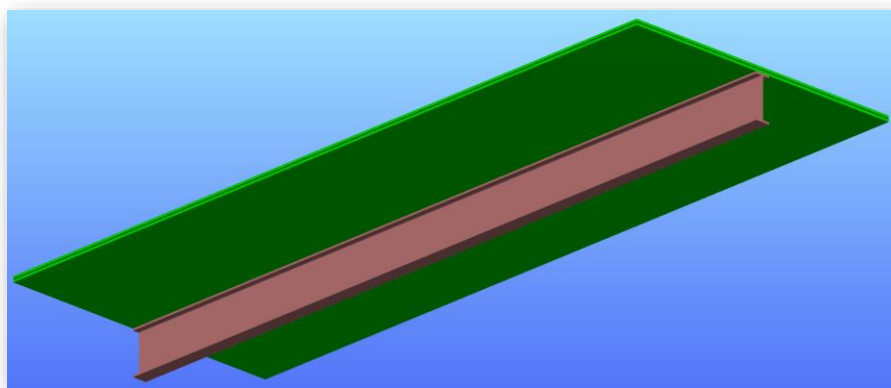
For example, if there is a cantilever on a relatively high tapered column (see image below) it is advisable to connect it not directly to the reference line of the column but with the link element. If it is connected the way like that, the analysis and design results will be more accurate, and the modelling will be more exact.



5.10.2 CONNECT TWO STRUCTURAL EDGES THAT ARE EQUAL LENGTH AND PARALLEL ()

Equal length and parallel edges and members can be connected with this kind of link element.

This type of link element can be used for example when connecting a slab eccentrically to a beam.

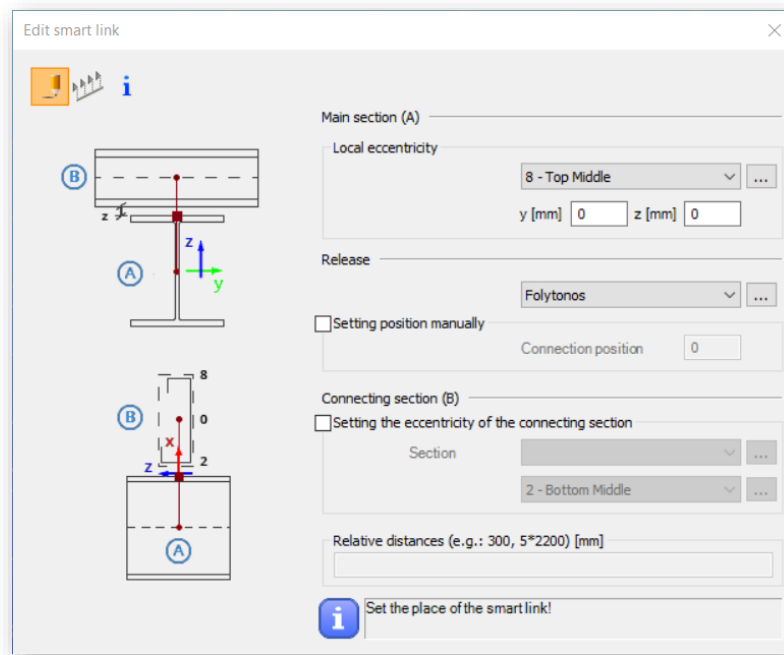


5.10.3 SMART LINK ()

The new type of smart link element makes it easier to handle geometric changes between connected members. The element follows the geometric changes (movement, rotation, section change) of the member on which it is placed (**MAIN SECTION**). In addition, the other member connected to it (**CONNECTING SECTION**) also follows the changes of the link element and thus the main section.

A typical application is the connection between a main beam and the purlin. With this object we can place link elements at specific points on the main beam, to the end point of which we can easily connect members later, based on the predefined eccentricity parameters between them. In the event of any change in geometry or profile, the smart link element follows the modification of the main beam, together with the member attached to it.

After starting the command, the **EDIT SMART LINK** dialog box appears:



1 In the Main Section (A) field must be specified the local eccentricity of the link element relative to a notable point on the main section.

2 In the *Release* field must be set the continuity of the connection element by choosing from existing types or creating a new type. The connection point between the two members can be specified manually by selecting the "Setting position manually" checkbox or automatically by leaving it blank. In this case the position will always be at the edge of the profile of the main section.

3 In the *Connecting section (B)* field, you can specify an eccentricity increment for the link element by specifying the connecting section. The program determines the length of the link element, taking into account the height of the section specified here and the section reference point.

There are two options for placing the smart link element(s).



With this function, the link elements can be placed one by one by clicking on a specific point on the member. The placed smart link element is always parallel to the Z axis of the member.



For group placement, you must first enter the placement distances measured from the start point of the member at the bottom of the dialog box, and then click on a member to place it. If that cannot be placed on that particular member (e.g. because the member is not long enough), the program will not perform the operation and a warning message of "A smart link cannot be defined with these settings of the Main section!" will inform you.



IT IS IMPORTANT TO KNOW THAT THE SMART LINK ELEMENTS CANNOT BE COPIED TOGETHER WITH THE MEMBERS CURRENTLY. WHEN COPYING A MEMBER CONTAINING SMART LINKS ALREADY PLACED ON IT, THE SMART LINKS WILL NOT BE COPIED TOGETHER, BUT THEY HAVE TO BE SELECTED AND COPIED SEPARATELY.

5.11 SHEAR FIELD

With the new object, the stiffening effect of trapezoid sheeting can be considered in buckling analysis.



It is important to note, that the trapezoidal decking must be fixed in an appropriate way to the underlying structure (all 4 sides on the trapezoidal decking) to be able to calculate proper results.

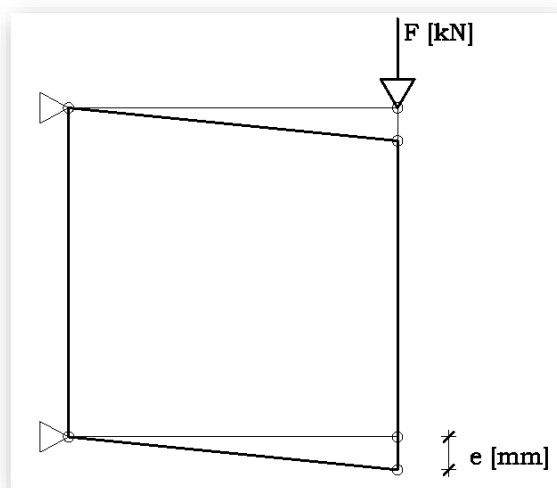
5.11.1 DEFINITION OF SHEAR STIFFNESS

On the picture below, the interpretation of shear stiffness can be seen, where “e” is the displacement of the shear diaphragm on the effect of a given F [kN] force. Shear elasticity by definition:

$$C = \frac{e}{F} : \text{Shear elasticity [mm/kN]}$$

Reciprocal of the shear elasticity gives the shear stiffness, which is signed by S:

$$S = \frac{F}{e} : \text{Shear stiffness [kN/mm]}$$

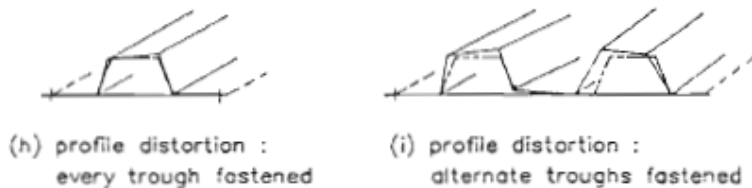


Shear diaphragm deformation to a given force [1]

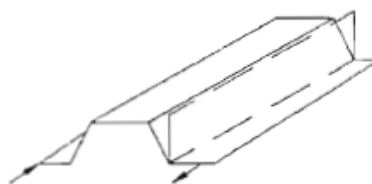


Shear stiffness of a trapezoidal sheet consists of the following components:

- Deformation of the profile:

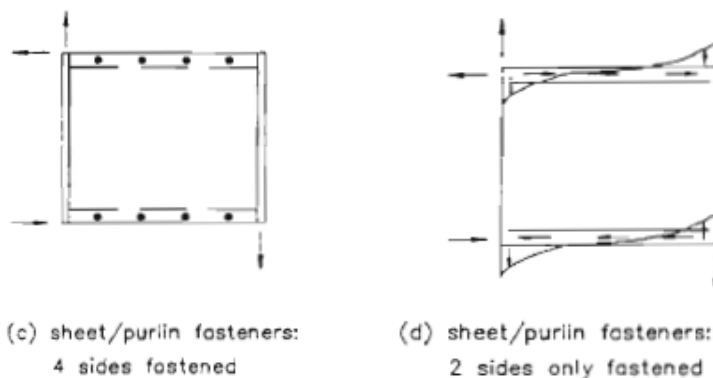


- Shear deformation in the sheet:

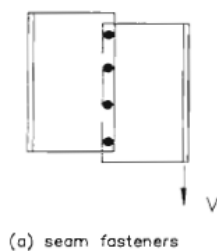


(j) shear strain in sheeting

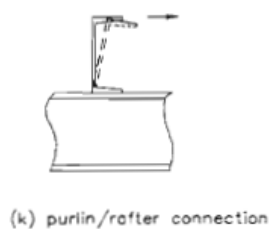
- Slip of the fastening elements:



- Displacement of the connections

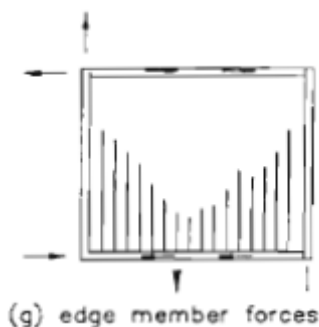


- Displacement of the beam-purlin connection





- Axial deformation in the longitudinal edge members:



The summation of the 6 different components above, gives the value of the shear elasticity (C). Reciprocal of the shear elasticity is the shear stiffness (S), which can be taken into consideration during the buckling analysis.

5.11.2 CALCULATION OF SHEAR STIFFNESS

To the determination of shear stiffnesses, different German trapezoidal sheet manufacturers developed their own calculation methodologies for their own products. Each method can only be used for the product for which it was developed for.

The following methods are implemented in the software:

- Hoesch
- Fischer
- Arcelor
- EuroCode

5.11.2.1 DETERMINATION OF SHEAR STIFFNESS IN CASE OF PANELS PRODUCED BY HOESCH

The recommended method uses the following formula (DIN 18807, Schardt/Strehl method):

$$S = \frac{10^4}{K_1 + \frac{K_2}{L}} * a \quad (1)$$

S: stiffness of the shear field [kN]

K₁: parameter specific to the selected panel [m/kN]

K₂: parameter specific to the selected [m²/kN]

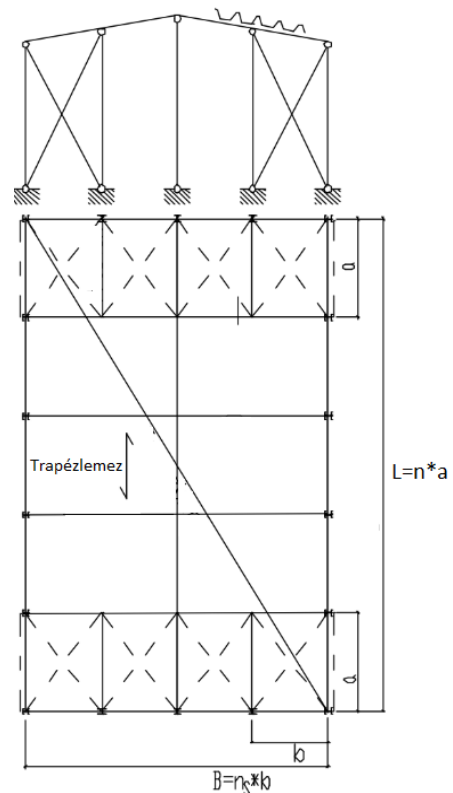
L: length of the shear field parallel to the direction of the panel ribs [m]

a: applicable effective width [m]

The figure shows the sketch of a general building showing the dimensions used in the previous formula. The method assumes that panels on all 4 edges along the boundary of the considered shear field are fixed to supporting structures with adequate spacing.

The values K_1 and K_2 have been specified by the producer for each panel type in function of its thickness. These values can be found on the website of the producer or in official application certificates. Important to note, that such certificates have a certain validity of application, therefore it is always recommended to double check the validity of the values considered by Consteel.

The S value determined with formula (1) is valid if the trapezoidal sheet is fixed at each rib to the supporting structure. The S value shall be multiplied with 0,2 in case of fixations in every second rib only.



5.11.2.2 DETERMINATION OF SHEAR STIFFNESS IN CASE OF PANELS PRODUCED BY FISCHER

The recommended method uses the following formula (improved Schradt/Strehl method) (2). The formula contains 3 additional parameters (K_1^* , K_2^* and e_L) in comparison with the classical method, to consider the effect of the fixations of the panels.

$$S = \frac{1}{(K_1 + K_1^* e_L) + \frac{K_2 + K_2^*}{L}} * a \quad (2)$$

S: stiffness of the shear field [kN]

K_1 : parameter specific to the selected panel [$10^{-4} \cdot \text{m/kN}$]

K_2 : parameter specific to the selected panel [$10^{-4} \cdot \text{m}^2/\text{kN}$]

K_1^* : parameter specific to the selected panel [$10^{-4} \cdot 1/\text{kN}$]

K_2^* : parameter specific to the selected panel [$10^{-4} \cdot \text{m}^2/\text{kN}$]

e_L : distance between fixations lengthwise [m]

a: applicable effective width [m]

The method assumes that panels on all 4 edges along the boundary of the considered shear field are fixed to supporting structures with adequate spacing.



The S value determined with formula (2) is valid if the trapezoidal sheet is fixed at each rib to the supporting structure. The S value shall be multiplied with 0,2 in case of fixations in every second rib only.

5.11.2.3 DETERMINATION OF SHEAR STIFFNESS IN CASE OF PANELS PRODUCED BY ARCELOR

The recommended method by Arcelor uses the following formula (3) (Bryan/Davies):

$$S = \frac{10^4}{\left[(K_1' * \alpha_2 + K_1^* e_L) + \frac{(K_2' * \alpha_1 * \alpha_4 + K_2^* \alpha_3)}{L_s} \right]} * a \quad (3)$$

S: stiffness of the shear field [kN]

K_1' : parameter specific to the selected panel [m/kN]

K_2' : parameter specific to the selected panel [m²/kN]

K_1^* : parameter specific to the selected panel [1/kN]

K_2^* : parameter specific to the selected panel [m²/kN]

L_s : length of the shear field parallel to the direction of the panel ribs [m]

$\alpha_1, \alpha_2, \alpha_3$: additional parameters depending on the number of panel spans defined in tables

α_4 : additional parameter depending on the number of panels splices lengthwise

a: applicable effective width [m]

The method assumes that panels on all 4 edges along the boundary of the considered shear field are fixed to supporting structures with adequate spacing.

The S value determined with formula (2) is valid if the trapezoidal sheet is fixed at each rib to the supporting structure. The S value shall be multiplied with 0,2 in case of fixations in every second rib only.

5.11.2.4 DETERMINATION OF SHEAR STIFFNESS ACCORDING TO EUROCODE 3

The recommended method uses the following formula (4)

$$S = \left(1000 * \sqrt{t^3} * \left(50 + 10 * \sqrt[3]{b_{roof}} \right) * \frac{1}{h_w} \right) * a \quad (4)$$

S: stiffness of the shear field [kN]

t: thickness of the panel [mm]

h_w : depth of the panel [mm]



a: applicable effective width [m]

b_{roof} : length of the shear field parallel to the direction of the panel ribs (width of the roof) [mm]

The method doesn't require that panels are fixed on all 4 edges along the boundary of the considered shear field are fixed to supporting structures. As a minimum fixation to directly stabilized structures (2 sides) with adequate spacing is required.

The S value determined with formula (4) is valid if the trapezoidal sheet is fixed at each rib to the supporting structure. The S value shall be multiplied with 0,2 in case of fixations in every second rib only.

5.11.3 SHEAR FIELD STIFFNESS DEFINITION

The dialog of the **SHEAR FIELD STIFFNESS DEFINITION** can be opened with the  button of the **STRUCTURAL MEMBERS** tab.

Shear field stiffness definition

5

Parameters

1 Shear field stiffness value

s Set value manually... 0 kN/m

2 Effective width (a) 1 m

3 Local eccentricity

Type 0 - Reference line z [mm] 0


Position of S along the line (X₁) From end A 0 mm

Position of S along the line (X₂) From end B 0 mm

4

Select the edge!




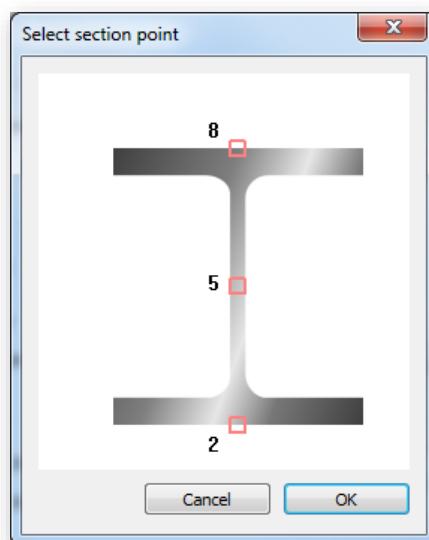
#1 - Value of shear stiffness can be defined manually, or if the () button is clicked, on the ***SHEAR FIELD STIFFNESS CALCULATION*** (see chapter **5.11.3.1**) it can be calculated automatically.

#2 - Definition of effective width parameter

#3 - Local eccentricity of the shear field to the member on which it will be placed:

0. Reference line
2. Bottom - Middle
5. Middle - Middle
8. Top - Middle

By clicking on the  button, action point of eccentricity can be defined graphically on a section illustration.




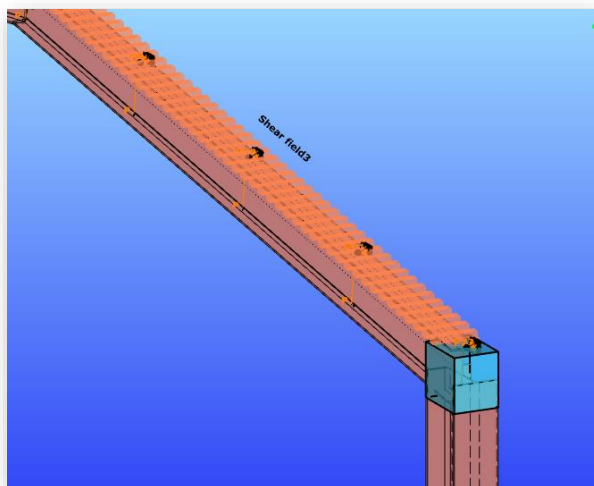
#4 -Position of the ***SHEAR FIELD*** along the bar member on which it will be placed:

1. X_1 :
 - a. From end A of the member: Distance X_1 is measured from the start point of the member
 - b. From end B of the member: Distance X_1 is measured from the end point of the member
2. X_2 :
 - a. From end A of the member: Distance X_1 is measured from the start point of the member
 - b. From end B of the member: Distance X_1 is measured from the end point of the member



c. Relative: Defining X2 according relatively to X1

#5 - With the  button, members can be selected in the model, on which the **SHEAR FIELD** should be applied.



5.11.3.1 SHEAR FIELD STIFFNESS CALCULATION

Shear field stiffness calculation

Name of shear field: ShearField_1

Profile of trapezoid plate: FI 165/250/Special fi

Applied calculation: Schardt/Strehl improved

Properties of shear field

Fixing: ☒ each rib ☐ each second rib

Shear panel length (L_s): 6 m

Fixing distance (e_L): 3 m

Number of bays: 1

Number of longitudinal splices (n_s): 1

Shear field stiffness value: 576 kN/m


Method can only be used, if all 4 edges of the shear panel are connected to the substructure.

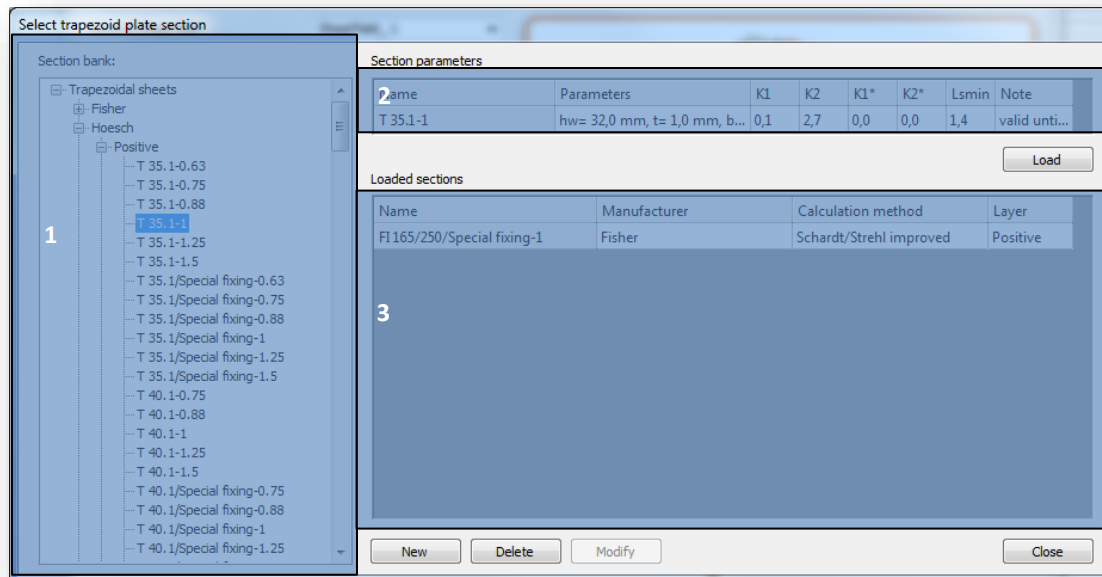
Diagram illustrating the shear field stiffness calculation parameters: L , b_s , L_s , a_s , and the formula $a = a_s \cdot \frac{L_s}{L}$.

Buttons: New, Delete, Close, Apply

Definition of the parameters of a new **SHEAR FIELD** object can be started after the **NEW** button is clicked.



As a first step, a trapezoidal plate profile must be loaded into the model on the **SELECT TRAPEZOID PLATE SECTION** dialogue by clicking on the three dots button (). The parts of the dialogue are the following:



#1 -Trapezoidal sheet section bank: Sections are collected by manufacturers in the tree structure.

#2 -Section parameters: Properties of the selected trapezoidal sheet in the tree structure (#1) is represented in this table.

#3 -After a section is selected in the section tree (#1), the **LOAD** button must be clicked to load into the **LOADED SECTIONS** table. Loaded sections can be used for the calculation of shear stiffness on the **SHEAR FIELD STIFFNESS CALCULATION** dialogue.

With the **DELETE** button, previously loaded trapezoidal sheet cross sections can be deleted.

By clicking the **NEW** button, manual trapezoidal sheets can be defined. On the **MACRO SECTION** dialogue, geometric parameters can be defined, and the custom sheet can be renamed, and saved.



Macro section

Name: Trapezoidal sheets

Manufacturer: Manufacturer

Fixing: ☒ Positive layer ☐ Negative layer

Note: Valid

Calculation method: Schardt/Strehl/DIN 18807

Geometrical parameters

Diagram labels: b_u , h_p , b_b , b_r , t_p

b_b	33	mm	K_1	0,242	m ⁴ /kN
b_u	106	mm	K_2	7,871	m ⁴ /kN
b_r	207	mm	K_1^{*}	0	m ⁴ /kN
t	0,63	mm	K_2^{*}	0	m ⁴ /kN
h_w	32	mm	L_{min}	0	m

Close Apply

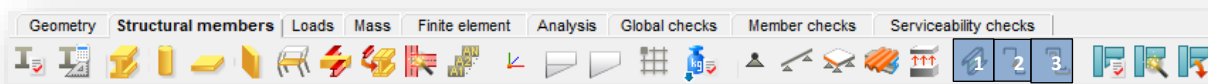
The following parameters must be defined for the shear stiffness calculation:

- ▶ Applied method for the calculation:
 - Schardt/Strehl/DIN 18807 method
 - Schardt/Strehl improved method
 - Bryan/Davies method
 - EC based method
- ▶ Fixing:
 - Positive layer
 - Negative layer
- ▶ Geometric and section specific parameters

According to the properties of the manually defined or loaded trapezoidal sheet section, shear field stiffness value will be calculated automatically on the ***SHEAR FIELD STIFFNESS CALCULATION*** dialogue.

5.12 PURLINS

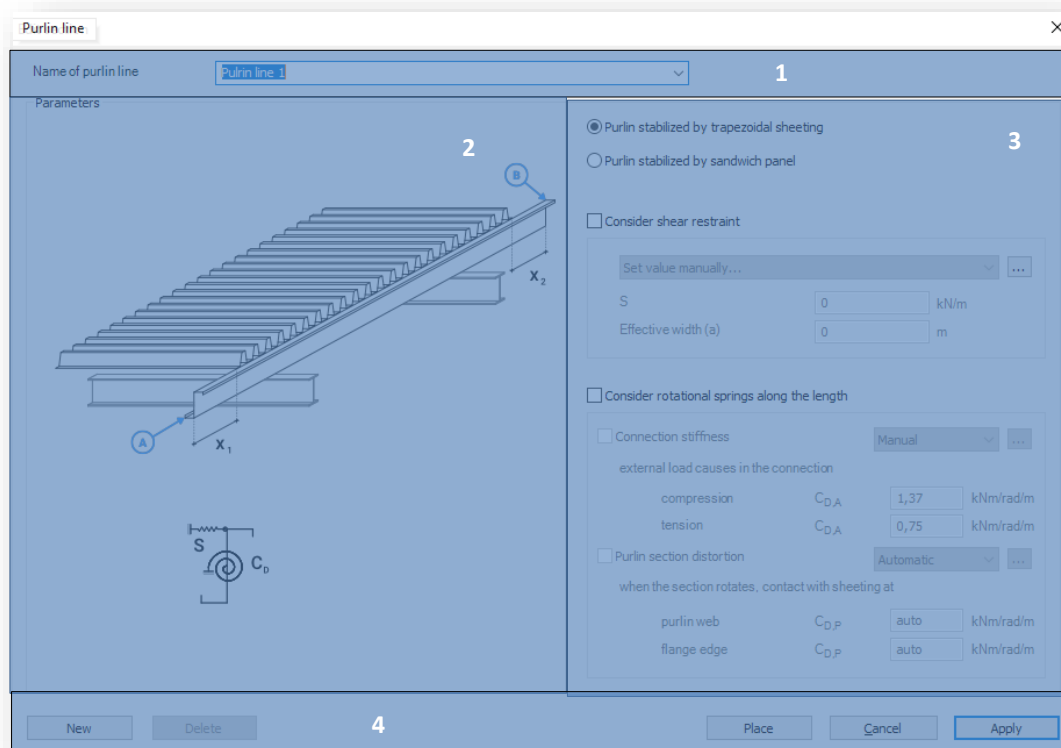
The functions related to the calculation of the purlins are separated into 3 large units



- #1 - **PLACE PURLIN LINE**: to specify the purlin line object.
- #2 - **PLACE SUPPORT ZONE**: to specify the geometry of the support zone of the purlins
- #3 - **PLACE PURLIN OVERLAP**: to specify the overlap zone of the purlins

5.12.1 PLACE PURLIN LINE

Four additional dialog panels are directly linked to the main dialog window of the purlin line object, which will be described later.

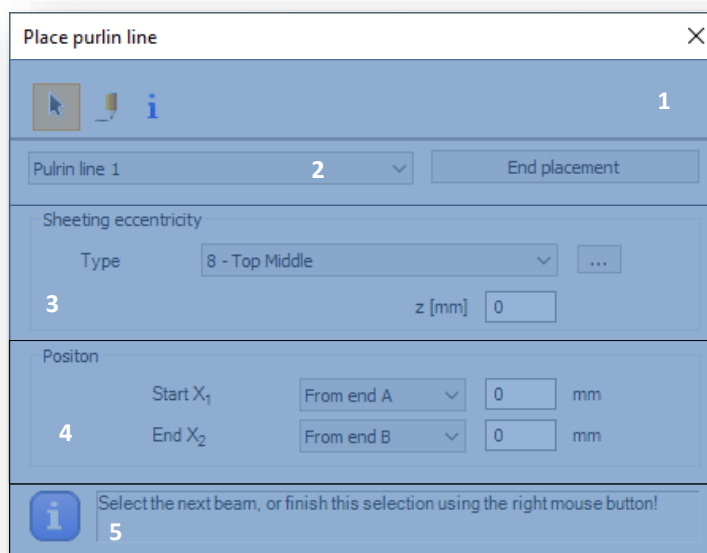





5.12.1.1 FUNCTIONS

- #1 - Specify the name of a purlin line object: The name of the object in the edit box can be specified as text and number characters
- #2 - Explanatory drawing: figure for the interpretation of notations and parameters
- #3 - Specification of the supports: for providing stiffens of the supporting sheeting
- #4 - Command line:
 - ▶ Create **NEW** purlin line object
 - ▶ **DELETE** the existing purlin line object
 - ▶ **PLACE** the actual purlin line object into the model
 - ▶ **APPLY** the actual settings

THE **PLACE** command opens the following dialog window:



- #1 - Choose the type of the placing: select object or draw
- #2 - Select the purlin line object from the drop-down list
- #3 - Sheeting eccentricity: set the eccentricity in the Z direction manually or automatically:
 - ▶ By selecting from the drop-down list:
 - Top middle
 - Bottom middle
 - ▶ Graphically by clicking on () icon ([5.9](#))



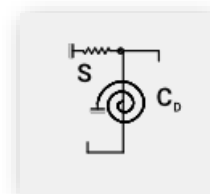
Clicking the **END PLACEMENT** command stops the command and closes the dialog.

- #4 - Enter position: at a given distance from endpoint A or B (in mm)
- #5 - Info panel: to display instructions

5.12.1.2 THE ROLE OF THE SPRINGS

The support effect of the cover can be very significant in the bearing capacity of the purlins. This effect can be derived from the stiffness of the elements attached to the purlins and is modelled in the form of springs. There are two types of springs to consider:

- Translational (shear) spring: Derived from the shear stiffness of the trapezoidal sheet (S)
- Rotational spring: derived from connection stiffness and distortion of the profile (C_D)




5.12.1.3 TRANSLATIONAL SPRING

The translational spring is optional. Before you enter, you need to choose the type of cover put on the purlins, which can be of two types:

- Trapezoidal sheeting
- Sandwich panel

The contents of the dialog box change according to the selection.

If trapezoidal sheeting is selected, the shear stiffness can be entered manually along with the effective width, or automatically by clicking () and using the shear box dialog shown above (see Section 5.11).

For sandwich panel cover, shear stiffness can only be entered manually.

Dialog box for trapezoidal sheeting stabilization:

- ☒ Purlin stabilized by trapezoidal sheeting
- ☐ Purlin stabilized by sandwich panel
- ☐ Consider shear restraint
- Set value manually... (dropdown menu with three dots icon)
- S 0 kN/m
- Effective width (a) 0 m

Dialog box for sandwich panel stabilization:


- ☐ Purlin stabilized by trapezoidal sheeting
- ☒ Purlin stabilized by sandwich panel
- ☒ Consider shear restraint
- S 500 kN

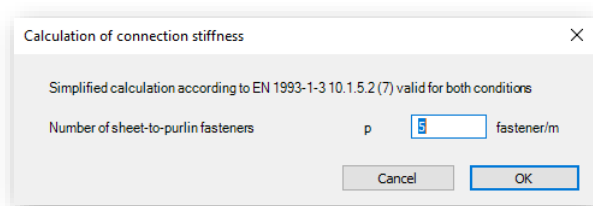


5.12.1.4 ROTATIONAL SPRING

As with the translational spring, the rotational spring is also optional. The rotational spring consists of two components (connection stiffness and profile distortion). In the final spring stiffness, the reciprocal of the components is summarized. In the case of zero stiffness or inactive checkboxes, the stiffness of a given component is reset to zero.

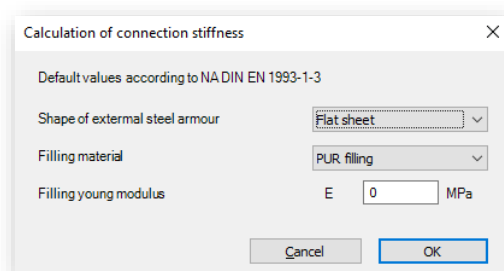
1. Connection stiffness:

In the case of trapezoidal sheeting, and selecting automatic calculation, clicking on (), the connection stiffness is calculated using the simplified method of Eurocode. In the pop-up window, you only need to specify the number of fasteners per meter:



When selecting a sandwich panel covering, more data is required to automatically calculate connection stiffness:


- ▶ External steel shield shape:
 - Plain sheets
 - Trapezoidal sheet
- ▶ Type of insulating material:
 - PUR
 - Mineral wool
- ▶ Elastic modulus of insulating material in MPa

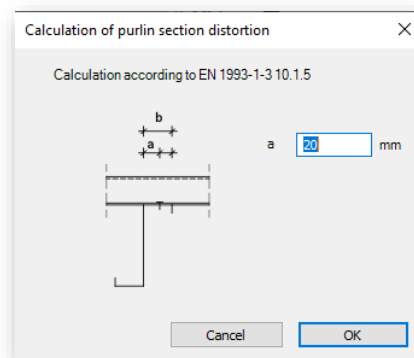


In case of manual input, the spring stiffeners must be entered in the case of the tensile or compressive forces exerted on the connections.



2. Profile distortion

The stiffness is defined in the same way as connection stiffness. For automatic calculation  in the pop-up window one must only enter the distance between the fastener and the rib-to-belt connection in mm. The calculation is in accordance with EN 1993 - 1- 3 10.1.5, as noted on the panel.



For manual input, it is necessary to specify the value of the stiffness component due to distortion in the following two cases:

- ▶ After deformation, the purlin contacts with sheeting at the web
- ▶ After the deformation, the purlin contacts with sheeting at the flange edge

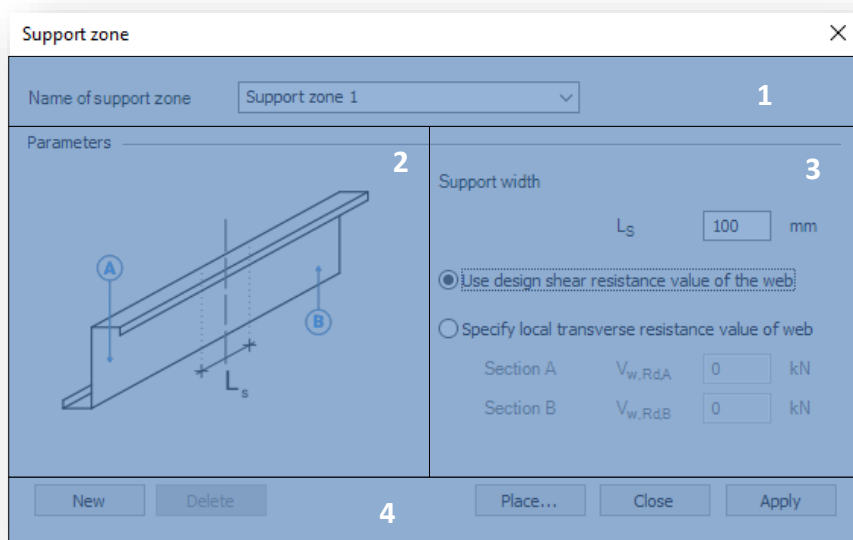
ATTENTION!



THE PURLIN DESIGN ONLY WORKS WITH Z AND C TYPE PROFILES. IT IS NOT POSSIBLE TO PUT PURLIN LINE OBJECT TO OTHER TYPE OF COLD-FORMED FACTORY PROFILES OR NOT Z OR C TYPE USER PROFILES.

5.12.2 SUPPORT ZONE

The Support zone is a function for specifying geometrical parameters for the support point of a purlin.





#1 - Specify the name of the support zone: the name of the object can be specified as text and number characters

#2 - Explanatory drawing: figure for the interpretation of notations and parameters

#3 - Specify the geometry and bearing capacity of the support zone:

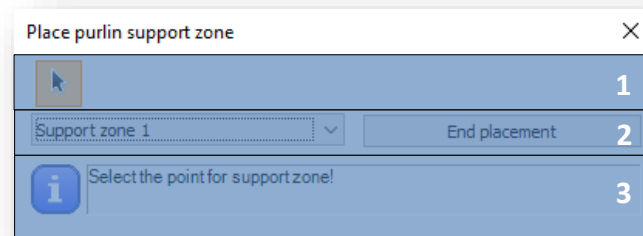
- ▶ Support width in mm
- ▶ Selection of load capacity used in calculation:
 - Use design shear resistance value of the web
 - Specify local transverse resistance value of the web
 - Resistance of profile A [kN]
 - Resistance of profile B [kN]

The local transverse resistance shall be determined manually in accordance with EC 1993 - 1 - 3 Section 6.1.7.

#4 - Command line:

- ▶ Create **NEW** support zone object
- ▶ **DELETE** the existing support zone object
- ▶ **PLACE** the actual support zone object into the model
- ▶ **APPLY** the actual settings

THE **PLACE** command opens the following dialog window



#1 - Type of placing: selecting object

#2 - Select the support zone object from the drop-down list

Clicking the **END PLACEMENT** command stops the command and closes the dialog

#3 - Info panel: to display instructions



5.12.3 PURLIN OVERLAP ZONE

The standard distinguishes between two main types of overlap joints. For both types of joints, there are unique formulas for the calculation of load-bearing capacity required for design.

- ▶ Purlin overlap joint
- ▶ Joint with coupling element

Currently, only overlap joint is available in the program. A dialog is directly connected to the dialog.

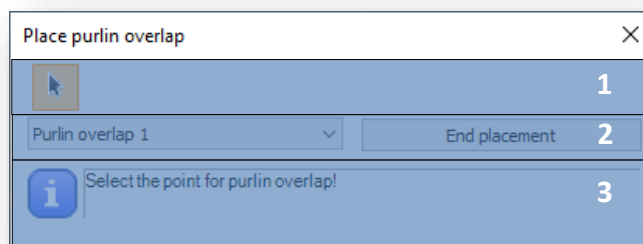
#1 - Specify the name of the overlap zone: the name of the object can be specified as text and number characters

#2 - Explanatory drawing: figure for the interpretation of notations and parameters



- #3 - Specify the length of the overlap: Specify the length of the overlapping section of each rod element, either as a distance value (in mm) or as a percentage of the rod length (%).
- #4 - Distribution of stiffness of the combined gross section between the two members.
- #5 - Support zone: it is possible to define a support zone at the same time as the overlap as described above.
- #6 - Command line:
- ▶ Create **NEW** purlin overlap object
 - ▶ **DELETE** the existing purlin overlap object
 - ▶ **PLACE** the actual purlin overlap object into the model
 - ▶ **APPLY** the actual settings

THE **PLACE** command opens the following dialog window



- ▶ #1 - Type of placing: selecting object
- ▶ #2 - Select the support zone object from the drop-down list

Clicking the **END PLACEMENT** command stops the command and closes the dialog

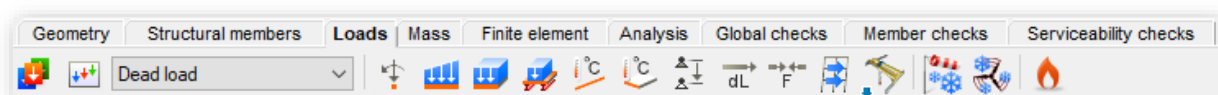
- ▶ #3 - Info panel: to display instructions




6 STRUCTURAL LOADS

6.1 BASICS

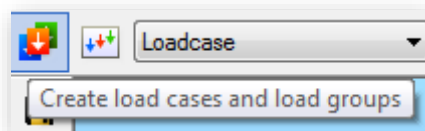
The definition of loading on a structural model is one of the most important modelling phases. Contrary to the modelling of structural members the load modelling is minutely controlled and supported by the structural codes and standards since the appropriate definition of loads ensures the major part in the reliability of structural performance. In *Consteel* several types of loading options help the engineer in this work. In accordance with the modelling of structural member the engineer can work with the load types and options defined and handled in the structural standards and the applied loads are automatically converted into finite element loads for the calculation model. All the loading functionality connecting with the load modelling is placed on the **LOADS** tab.



6.2 LOAD CASES AND LOAD GROUPS

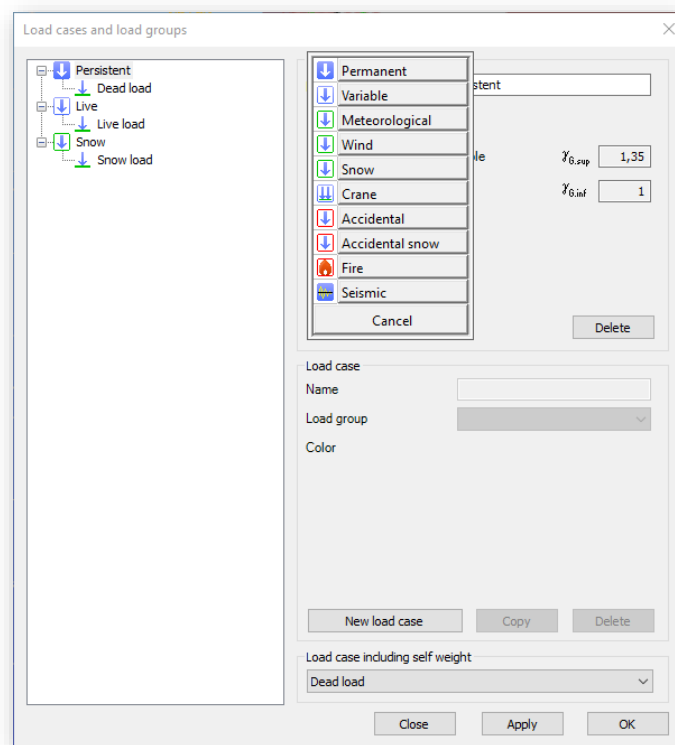
Before place any loads in the model load cases and load groups () must be defined. As a default, one load group and one load case have been defined in Consteel for quick calculations.

In a Load group several load cases can be defined. Properly specified load groups needed to automatically generate load combinations.

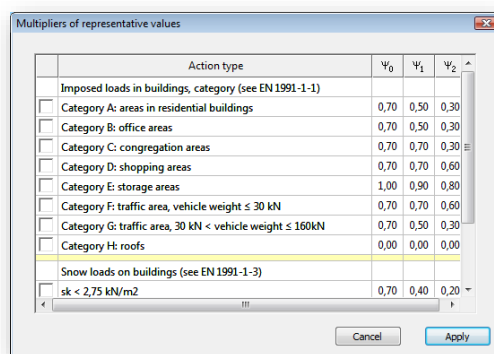


There are 9 different load group types in *Consteel*: Permanent, Variable, Meteorological, Wind, Snow, Crane, Accidental, Accidental snow, Fire, Seismic.

By clicking on the **NEW** button, the standard load-groups will appear. Selecting one of the names, a new load group is created.



For each load group safety and combination factors must be given. The combination factors can be edited manually or can be selected on the **STANDARD VALUES** of factors dialog. On the dialog typical cases can be selected which are provided by the EuroCode and the Spanish EAE standard. Factor values are dependent from the selected NA.





Consteel can add the structure's dead load to one of the load cases if necessary. To do so please select the appropriate load case at the bottom right corner of the dialog.



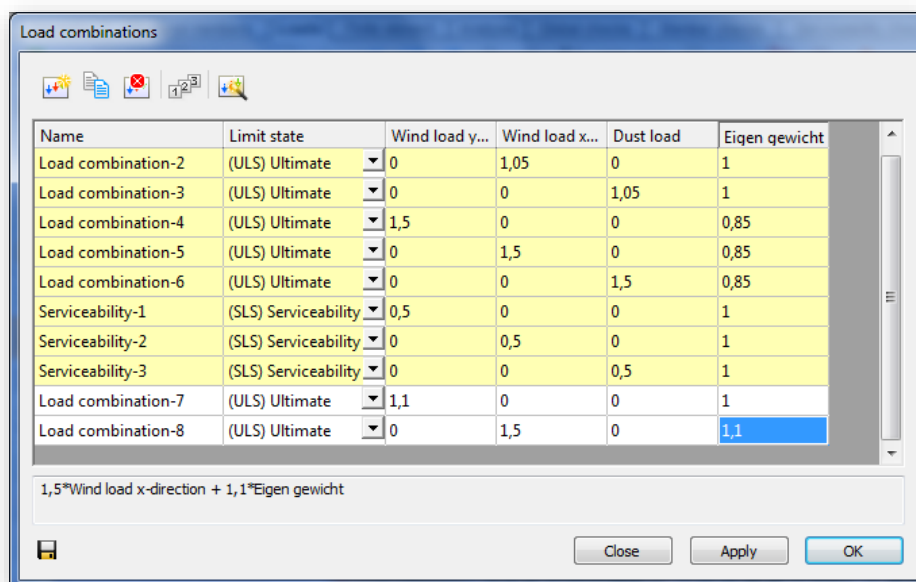
6.3 LOAD COMBINATION

According to the actual structural design code load combinations must be set from load cases.

Load combinations () can be created manually by giving the safety and combination factors manually for each load case or can be created automatically by using the **AUTOMATIC LOAD COMBINATION GENERATION** () function of *Consteel*.

It is possible to edit multiple safety factors at a time: select safety factors and right click over it.

Cell contents can be copied and pasted. On the table, select the cells that you want to copy and press **CTRL+C**. Select the upper-left cell of the paste area and press **CTRL+V**. Cell contents can be copied from MS Excel and from other spreadsheet applications also.

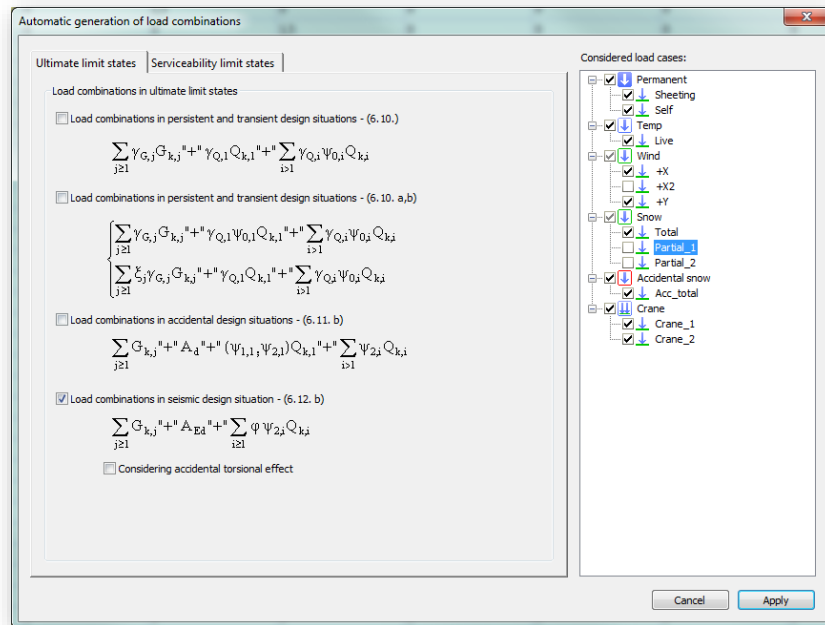


Name	Limit state	Wind load y...	Wind load x...	Dust load	Eigen gewicht
Load combination-2	(ULS) Ultimate	0	1,05	0	1
Load combination-3	(ULS) Ultimate	0	0	1,05	1
Load combination-4	(ULS) Ultimate	1,5	0	0	0,85
Load combination-5	(ULS) Ultimate	0	1,5	0	0,85
Load combination-6	(ULS) Ultimate	0	0	1,5	0,85
Serviceability-1	(SLS) Serviceability	0,5	0	0	1
Serviceability-2	(SLS) Serviceability	0	0,5	0	1
Serviceability-3	(SLS) Serviceability	0	0	0,5	1
Load combination-7	(ULS) Ultimate	1,1	0	0	1
Load combination-8	(ULS) Ultimate	0	1,5	0	1,1

1,5*Wind load x-direction + 1,1*Eigen gewicht

The yellow rows in the load combination table are the automatically generated combinations. The white ones are manually edited.

Huge number of load combinations needs long period of time to calculate in the analysis. So, it is good to keep the number of the load combinations to the minimum. If the automatic load combination feature is used in *Consteel* it is advisable to filter the unnecessary loadcases before the generation. At the **TREE CONTROL** of the right side of the **AUTOMATIC GENERATION OF LOAD COMBINATIONS** dialogue, consideration of the loadcases for the load combination generation can be decided. A **TICKED CHECKBOX** means, that the loadcase will be used for the load combination generation:

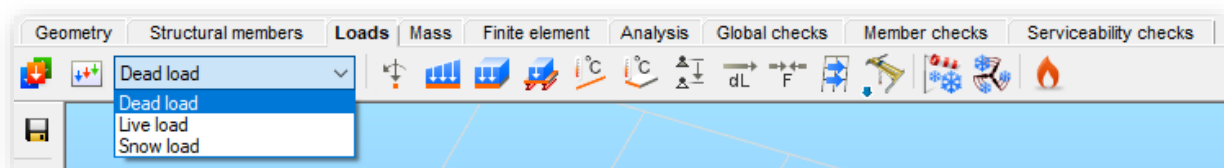


After the generation of load combinations, deletion of those rows which cannot be relevant is also a possible way to minimize calculation time. To do so, select the load combination (multiple LC-s can be selected with using **CTRL** or **SHIFT** buttons) and click on the **DELETE LOAD COMBINATION** icon.

It is important to set the limit state correctly because design checks will be made to Ultimate (ULS) load combinations and serviceability check are performed for Serviceability (SLS) combinations.

6.4 LOAD TYPES




Any placed load will belong to the load case selected from the list.

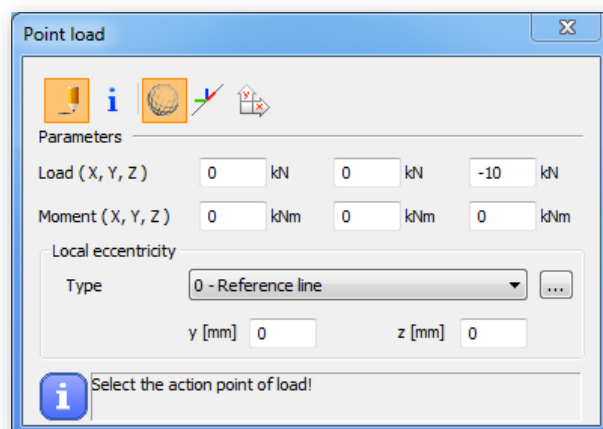


6.4.1 POINT LOAD ()

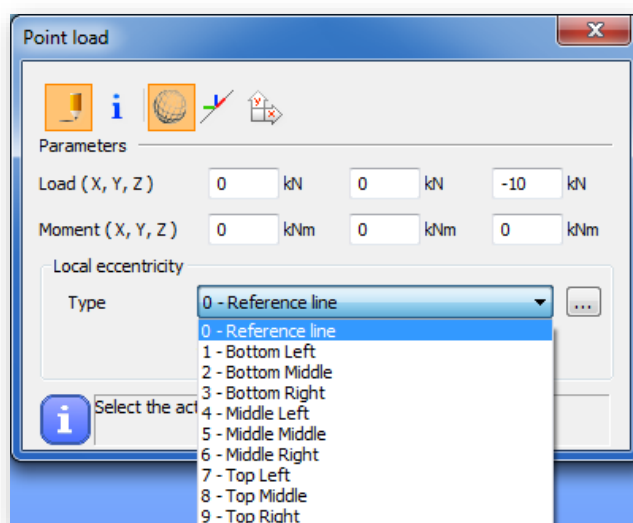
Point loads can be placed on any part of a line member or surface member (predefined points are not needed; end points or snap points can be used).



Point loads can be placed according to the **Global** () , **Local** () or the **User coordinate system** () .







Eccentricity can be applied on the point load also. The effect of the selected coordinate system, the applied local eccentricity type and values are the same as point support (see chapter 5.9.1).

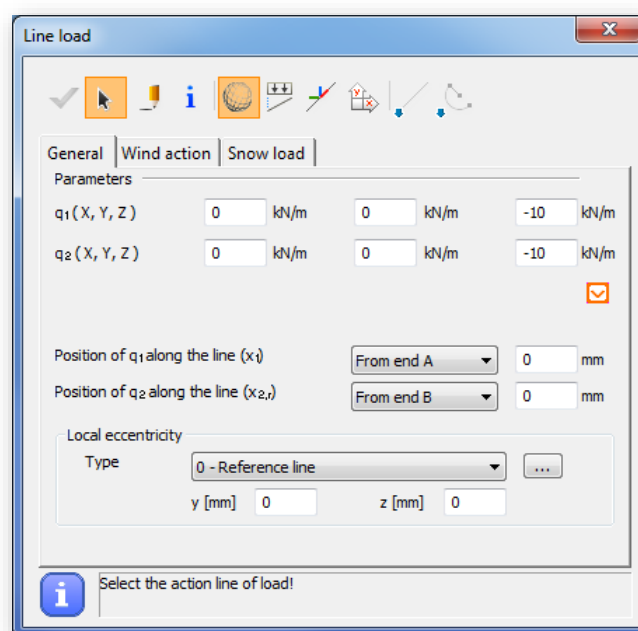






6.4.2 LINE LOAD



Line loads can be assigned to existing lines (line members or edge of surface members) or to lines drawn for the loads only (for instance on a surface).

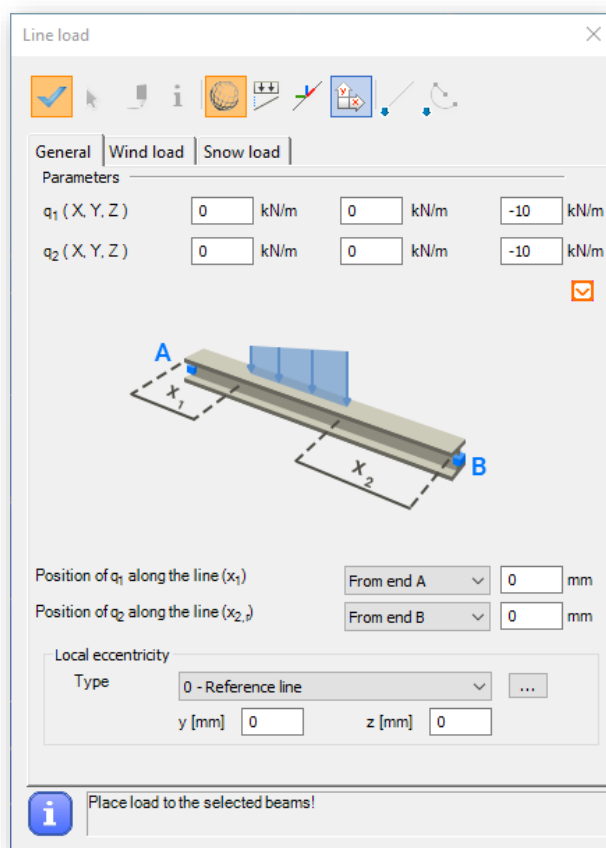
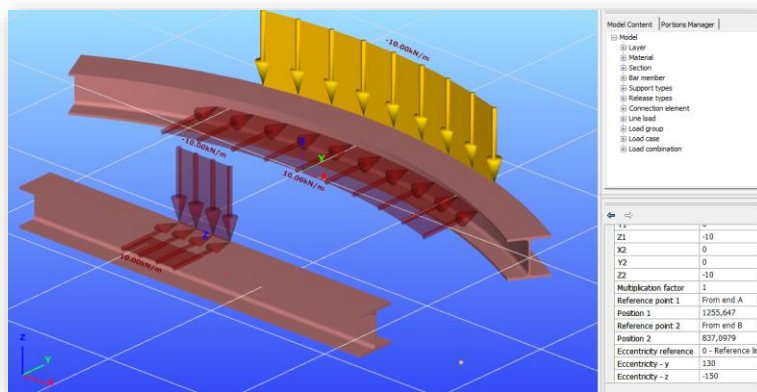
Line loads can be placed according to the **Global** () , **Local** () , **User coordinate system** () and **Global projection system** () which is commonly used when modelling the snow load.



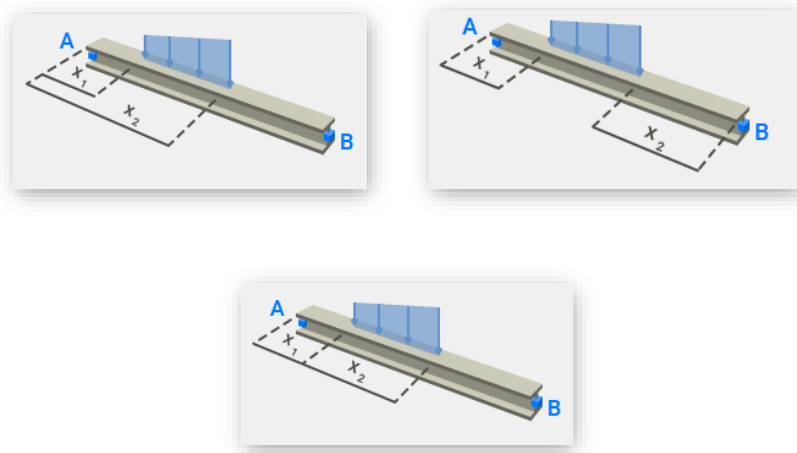
To place a line load, click on the member using the select function () . Line load can be applied to multiple members at the same time by using **PLACE LOADS** icon () . This case the members must be selected before clicking on the **LINE LOAD** icon on **LOADS** tab.

If just a partial line load needs to be applied along the member then there are two ways to apply:

1. The first way is to use the draw function () and set the start point and the end point of the line load. This function can be used both for linear and curved members in accordance with the selected drawing function () .

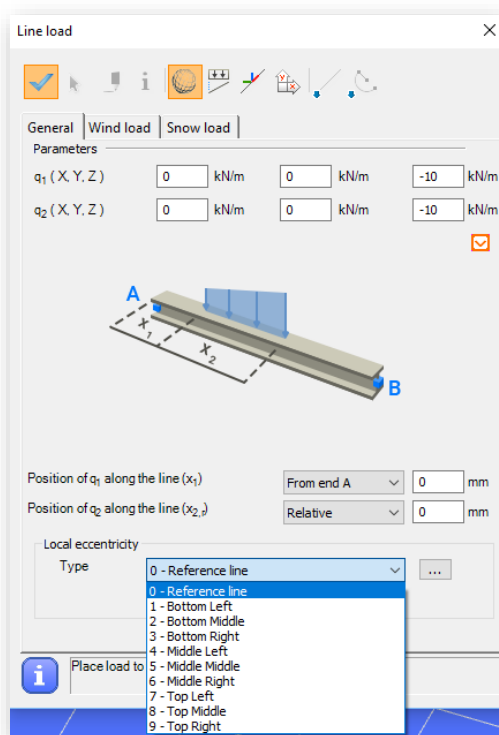



- The second way is to give the exact distances of the start and end points of the line load from the member's end points. Using the setting of Position of q_1 , q_2 , there are $2 \times 3 = 6$ possible options to define a partial line load. The "Position of q_1 " set to "From end A" has 3 options, and setting it to "From end B" has also 3 options:



This is a flexible way for numerical input the line load positions.

Eccentricity can be applied on the line load also. The effect of the selected coordinate system, the applied local eccentricity type and values are the same as point support (see chapter 5.9.1).



By clicking the  icon, the attributes of the selected line load fill out the parameters of the line load window, even if it was set by the draw function.



6.4.2.1 LINE WIND LOAD

Line wind load is a great tool to apply wind load to members easily. It saves time because only the basic data must be added and *Consteel* automatically calculates the appropriate wind load.

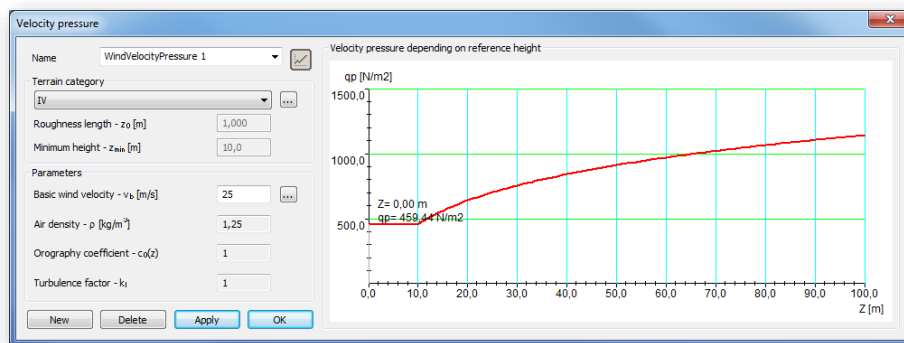
Before clicking on the **LINE LOAD** icon, as a first step the member(s) must be selected where the line wind load will be placed.

The line wind load related functions can be found on the **WIND LOAD** tab of **LINE LOAD** dialog.

The dialog box is titled "Line load" and has three tabs: "General", "Wind action", and "Snow load". The "Wind action" tab is selected. Under the "Parameters" section, there are three fields: "Velocity pressure - q_p [kN/m²]" with a value of 0,459 and a three-dot button; "Internal pressure - c_{pi} " with a value of 0,2 and a three-dot button; and "Extrenal pressure - c_{pe} " with a three-dot button. Below these is a table with two columns: "Load intensity [kN/m]" and "Length [m]". The table contains four rows of data, each with a checkmark in the first column. The "Direction of placement" section has two radio buttons: "Axis z" (selected) and "Axis y". The "Local eccentricity" section has a "Type" dropdown menu set to "0 - Reference line" and a three-dot button. Below this are two input fields: "y [mm]" with a value of 0 and "z [mm]" with a value of 0. At the bottom left is an information icon, and at the bottom right is a text box that says "Place load to the selected beams!".

Load intensity [kN/m]	Length [m]
-4,234	1,460
-2,203	13,597
-2,203	1,460
-2,203	13,597

As a first parameter, the *Velocity pressure* has to be added, or by clicking on the three dots button (...), previously created *Velocity pressure* functions can be selected from the dropdown menu or by clicking on the three dots button (...) a new EuroCode *Velocity pressure* function can be created according to the selected National Annex to use to calculate the proper *Velocity pressure*.



Internal pressure can be taken into account by check in the checkbox. C_{pi} value can be set manually or by clicking on the three dots button (...) and use the Internal pressure calculator function. To calculate the value, two EuroCode methods can be used.

External pressure can be set by clicking on the three dots button (...).

External pressure coefficients

Global wind parameters: WindGlobal 1

Surface type: Duopitch roof

Constant parameter

#	h [m]	d ₁ [m]	α [°]
1	7,300	30,000	4,999

Wind direction dependent

Wind direction [°]: 0 b [m]: 50 d [m]: 20

Loaded area - A [m²]: 10 e [m]: 14500

Schematic zone figure with sizes

The position of the frame (x/b): 0,1 Frame distance [m]: 6

Actual Cpe values EN 1991-1-4:2007 Table 7.4

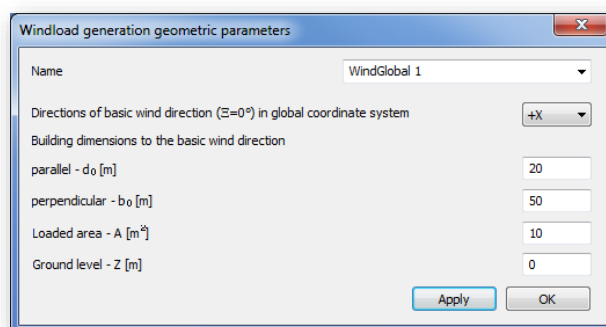
#	α	F	G	H	I	J
1	4,999	-1,700	-1,200	-0,600	-0,600	-0,600
1	4,999	0,000	0,000	0,000	0,200	0,200

Case 1

Close OK



To calculate the correct *External Pressure* values, it is necessary to give geometrical parameters of the whole building. Geometrical parameters can be set on the *Global wind parameters* dialog.



Besides the building dimensions, the direction of the basic wind in global coordinate system must be selected from the dropdown menu and the ground level can be set if the lowest point of the model will not be on the ground.

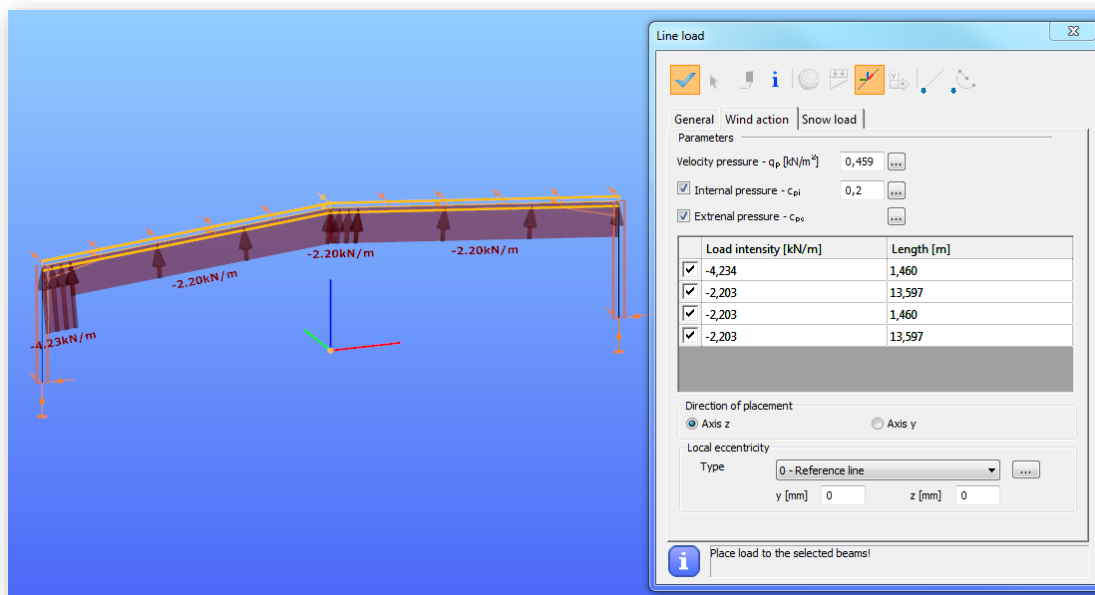
As a next step one of the standard *Surface type* (wall, flat roof, duopitch roof, etc.) must be selected from the dropdown menu. If the proper surface is selected, then all the necessary parameters from the previously selected member(s) are loaded and the actual c_{pe} values are calculated.

To create line wind load it is necessary to set the *Position of the frame in the building* and to set the *Frame distance*.

As a last step the proper wind load cases must be selected from the dropdown menu, on the bottom of the **EXTERNAL PRESSURE COEFFICIENTS DIALOG**.

By clicking on the **OK** button, the line wind loads are created.

Pressing the **PLACE LOADS** icon () on the **LINE LOAD** dialog the created line wind loads are placed on the selected member(s).



FOR THE CORRECT LINE WIND LOAD PLACEMENT, IT IS NECESSARY TO SET THE DIRECTION OF THE USED LOCAL COORDINATE AXIS (AXIS Z, OR Y) TO POINT OUT FROM THE BUILDING.

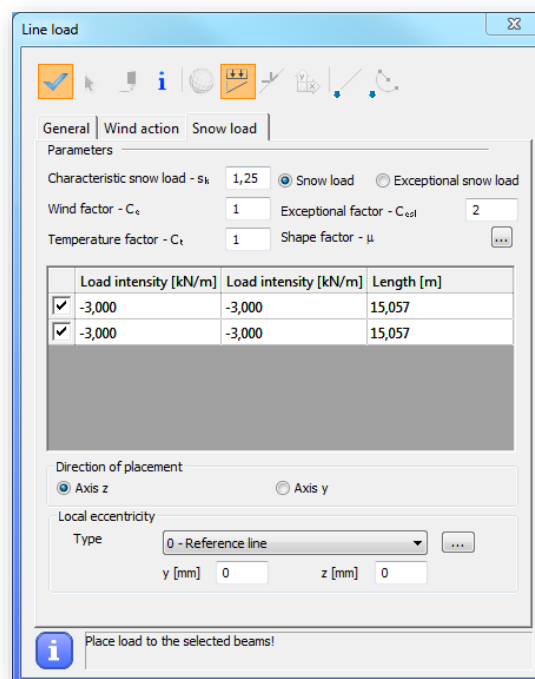
6.4.2.2 LINE SNOW LOAD

Line snow load is a great tool to apply snow load to members easily. It saves time because only the basic data must be added and *Consteel* automatically calculates the appropriate snow load.

Before clicking on the **LINE LOAD** icon, as a first step the member(s) must be selected where the line snow load will be placed.

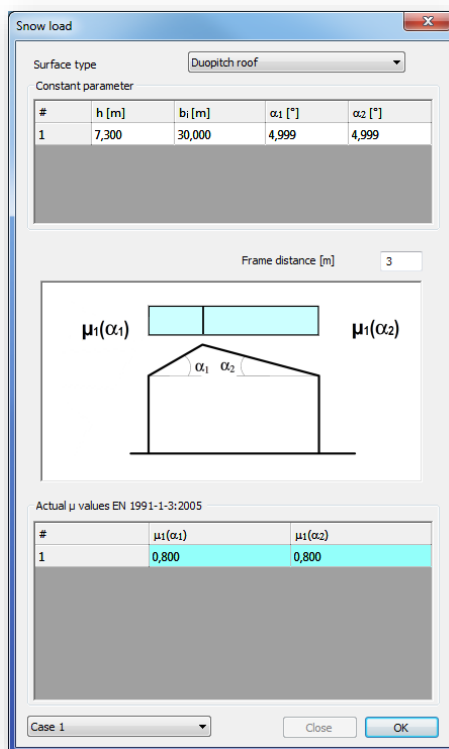
The line snow load related functions can be found on the **SNOW LOAD** tab of **LINE LOAD** dialog.

The snow load parameters are automatically loaded from the selected NA, but all of these can be modified manually.





As a first step the *Shape factor* must be set, by clicking on the three dots button (⋮).



The 'Snow load' dialog box is shown. It has a title bar with a close button. Inside, there is a 'Surface type' dropdown menu set to 'Duopitch roof'. Below it is a 'Constant parameter' table with columns: #, h [m], b₁ [m], α₁ [°], and α₂ [°]. The first row contains the values 1, 7,300, 30,000, 4,999, and 4,999. Below the table is a 'Frame distance [m]' input field set to 3. In the center is a diagram of a duopitch roof with labels μ₁(α₁) and μ₁(α₂) for the two slopes, and α₁ and α₂ for the angles. Below the diagram is an 'Actual μ values EN 1991-1-3:2005' table with columns: #, μ₁(α₁), and μ₁(α₂). The first row contains the values 1, 0,800, and 0,800. At the bottom, there is a 'Case 1' dropdown menu, a 'Close' button, and an 'OK' button.

#	h [m]	b ₁ [m]	α ₁ [°]	α ₂ [°]
1	7,300	30,000	4,999	4,999

Frame distance [m] 3

μ₁(α₁) μ₁(α₂)

α₁ α₂

#	μ ₁ (α ₁)	μ ₁ (α ₂)
1	0,800	0,800

Case 1 Close OK

To define the shape factor, it is necessary to select the *Surface type* (flat roof, duopitch roof, etc.) from the dropdown menu. If the *Surface type* is selected, then the parameters of the previously selected member(s) are automatically loaded, and the shape factor is calculated.

As a last step the proper snow load cases must be selected from the dropdown menu, on the bottom of the **SNOW LOAD DIALOG**.

By clicking on the **OK** button, the line snow loads are created.

Pressing the **PLACE LOADS** icon (✓) on the **LINE LOAD** dialog the created line snow loads are placed on the selected member(s).

6.4.3 SURFACE LOAD (📦)


Surface load can be defined in three ways. No surface moment loads can be placed.


1. **Uniform** surface load
2. **Linearly varying** surface load
3. **Wind** load

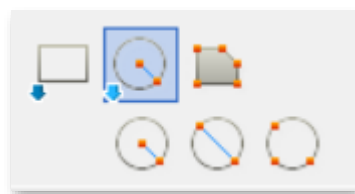
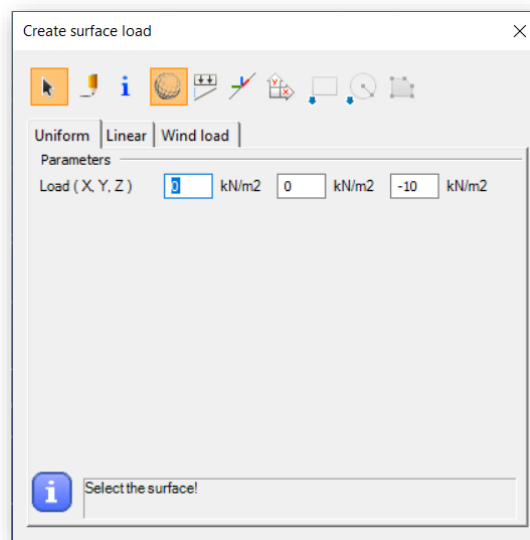


6.4.3.1 UNIFORM SURFACE LOAD

The load can be defined in two ways, similarly to the definition of line load.

Using the selection function () the intensity of the load must be entered in the dialog, then the load can be applied to the entire surface(s) by clicking on them.

For partially surface loads the drawing () function must be selected. The last 3 shortcuts will then be active, with which it is possible to draw rectangular, circular, or polygonal surfaces.



To place the load, first select the surface to be loaded and then draw the boundary edges of the load according to the instructions in the information field of the dialog. In the case of a polygon load, after entering the last corner point, you can use the right mouse button to complete the load definition.

6.4.3.2 LINEARLY VARYING SURFACE LOAD


To define a linearly varying surface load, you must first specify the direction of the load in the top line of the dialog.

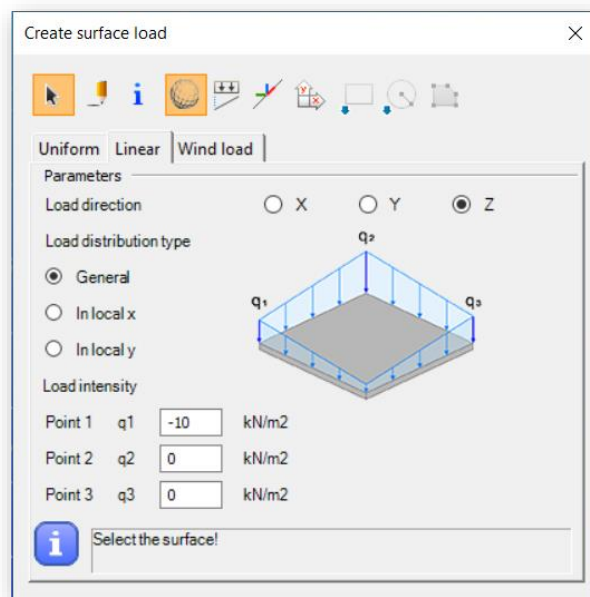
There are three ways to specify the change in load intensity (load distribution type):

- **General:** the intensity of the load is determined by the intensity values given at 3 arbitrary points on the surface, which must be entered at the bottom of the dialog box (q1, q2, q3).
- **In local x:** two points and their corresponding intensity values must be entered. The value of the load changes parallel to the local x-axis of the surface.
- **In local y:** like the previous one, but along the local y-axis.




After entering the data, the surface must first be selected to place the load onto, and then, depending on the type of load distribution, 2 or 3 points must be clicked on the surface, at which points the previously given intensity values apply.

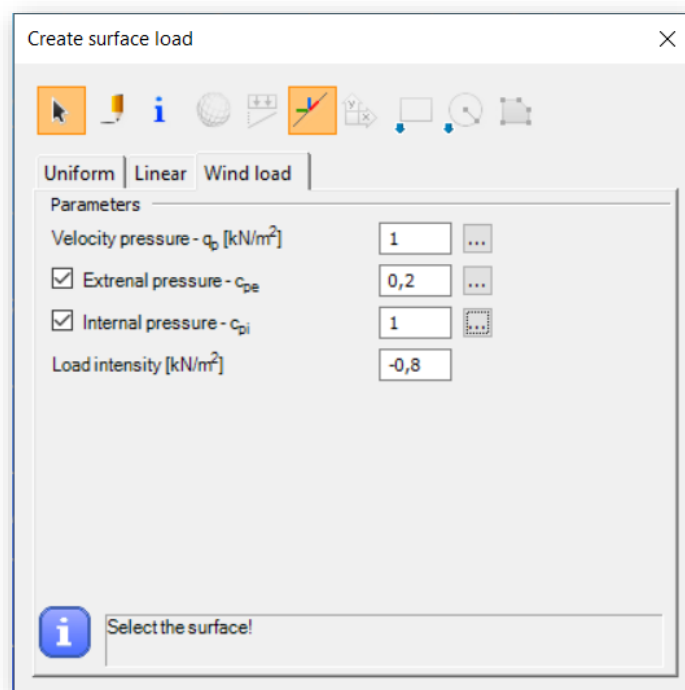
In the case of a drawn () load specification, after selecting the surface, first draw the loaded part of the surface as described in the previous point, and then enter the intensity determining points.



6.4.3.3 WIND LOAD

At present, surface wind load can only be defined for **LOAD TRANSFER SURFACE** (see section 6.4.4).

The definition of the surface wind load should begin by specifying the velocity pressure and the external and internal shape coefficients. For a description of the dialogs () for each parameter, see the line wind load section (see section 6.4.2.1). After setting the parameters, the load can be placed on the surface by clicking on it.

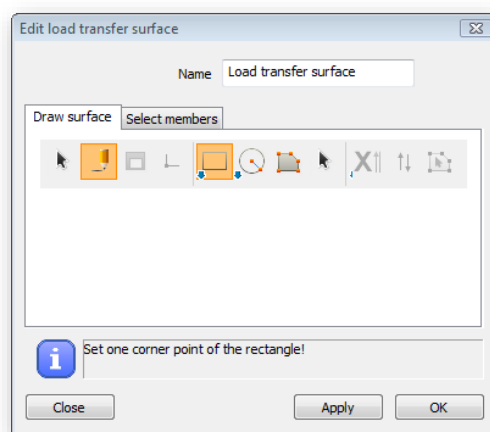




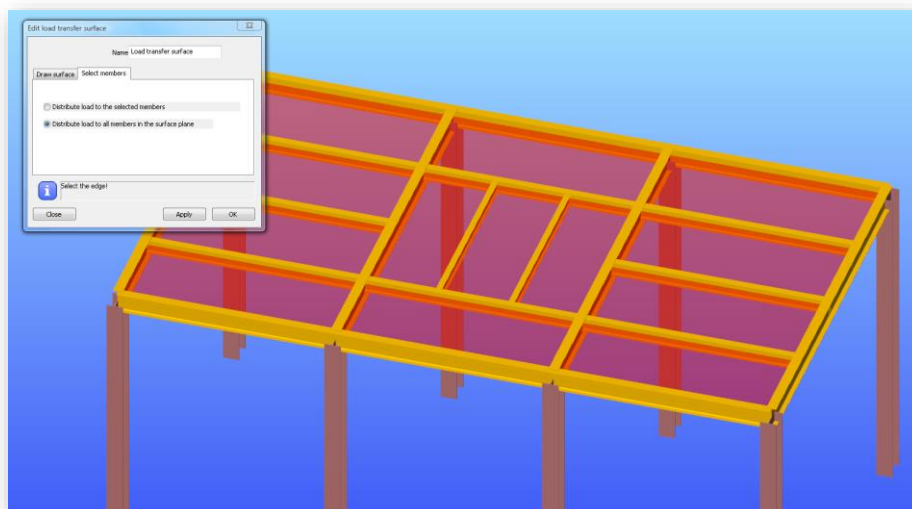
6.4.4 LOAD TRANSFER SURFACE ()

Load transfer surface is a special surface which distributes surface loads to members as line loads. This is very useful in those cases when surface load needs to be distributed to members, like floor loads, snow, and wind load, etc.


After clicking on the **LOAD TRANSFER SURFACE** () icon on the **LOADS** tab a dialog window appears.

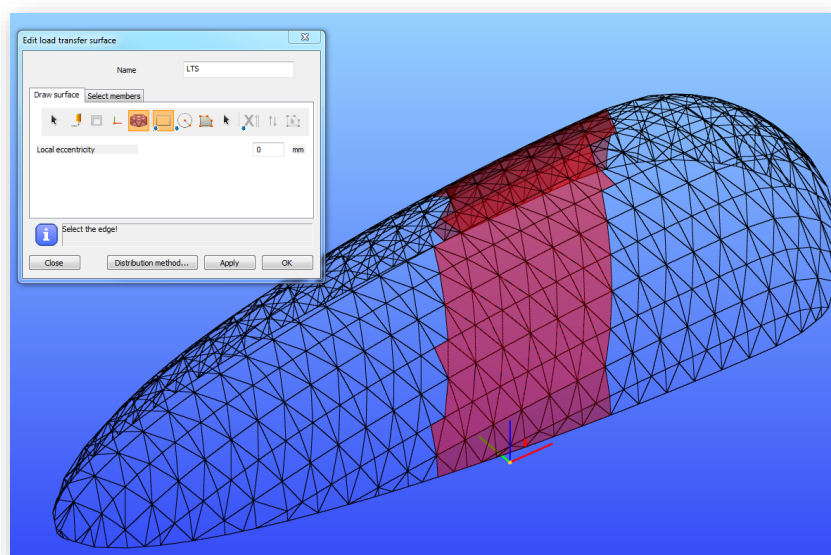


Just like in the two-dimensional figure drawing there are different possibilities to draw the surface: draw a rectangle, draw leaning rectangle, draw circle, draw polygon. After drawing the surface, it is possible to select the members to which the surface distributes the load. There are two options: distribute load to the selected members or distribute load to all members covered by the surface in the surface plane. If second option is clicked, then the appropriate members will be highlighted. If none of the options is clicked, then the second one will be applied as a default.



It is possible to choose the first option and select members for carrying the surface load or remove members from the selection using the SHIFT + Left click. After the corresponding members have been selected and **OK** is clicked then the surface is created.

It is also possible to use the **MULTIPLE PLACEMENT OF LOAD TRANSFER SURFACES** by clicking on the () icon. This function is used to define multiple load transfer surfaces with a simple selection (rectangle selection, or by clicking the border edges). Edges of a load transfer surface must be in the one plane.

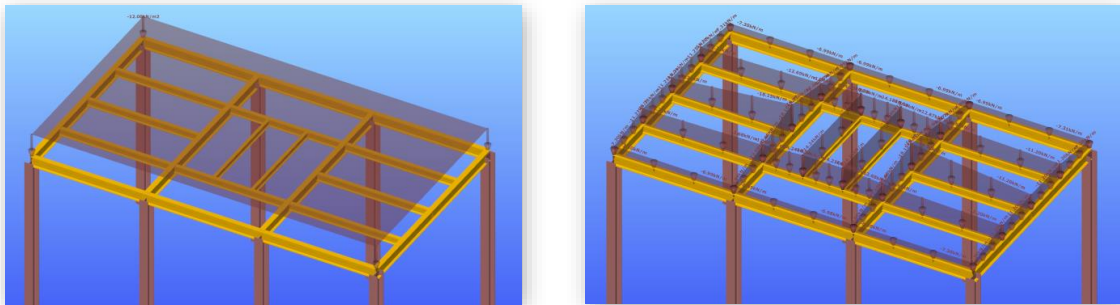


It is important to know, that the maximum number of edges that can be selected in one step, is currently limited in 200. If the selected edges exceed the limit of 200, a notification will be shown on the **EDIT LOAD TRANSFER SURFACE DIALOG**.

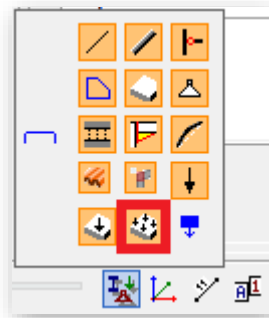


Surface load can be placed by using the method described in chapter 6.4.3.

There are two visibility options: view the surface load or view the distributed load.



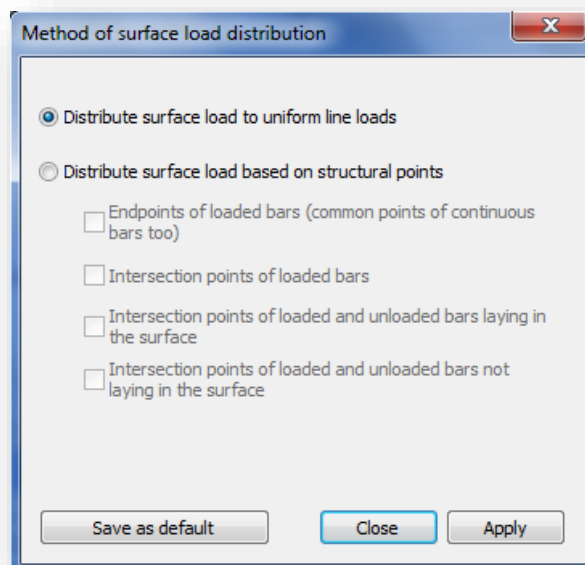
Changing the views is possible by clicking on the dedicated icon which can be found among the visibility of graphics symbols setting.



There are two possible methods to convert surface load to the selected members:

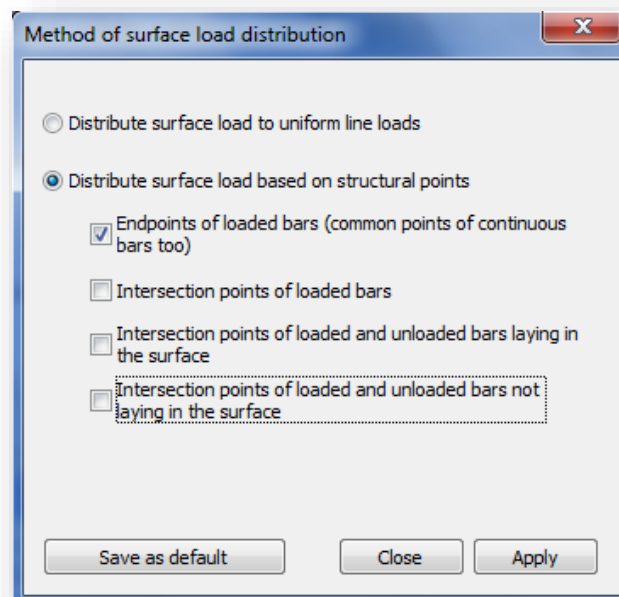
Converting surface loads to uniform line loads is performed by a meeting the following requirements:

- ▶ the resultant force of all the line loads is the same as for the surface load
- ▶ the line loads are *constant* on all the selected members



Converting the surface load to line loads based on structural points has the following background:

- (1) the surface load is first converted to concentrated point loads acting on the selected structural points using the Delaunay triangulation technique
- (2) the concentrated loads are then converted to line loads on the selected members meeting with the following requirements:
 - ▶ the resultant force of all the line loads is the same as for the surface load
 - ▶ the line loads are *linear* on all the selected members
 - ▶ the end value of the line loads on the selected structural points for all the selected members are equal

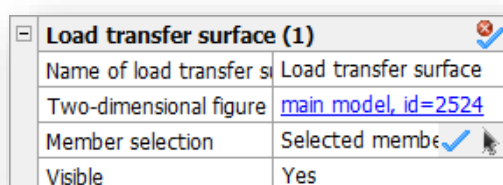


The basic working method is the following:

First create the load transfer surface. Select the members which it distributes load to or accept the default setting which is distribute loads to all planar members. Apply surface loads to the surface at every load case where it is necessary.

6.4.4.1 MODIFYING LOAD TRANSFER SURFACE



Load transfer surface can be modified by selecting it and changing the properties in the property bar. Member selection can be easily modified from the planar members to selected members. It is possible to highlight the previously selected members by clicking on the blue thick.



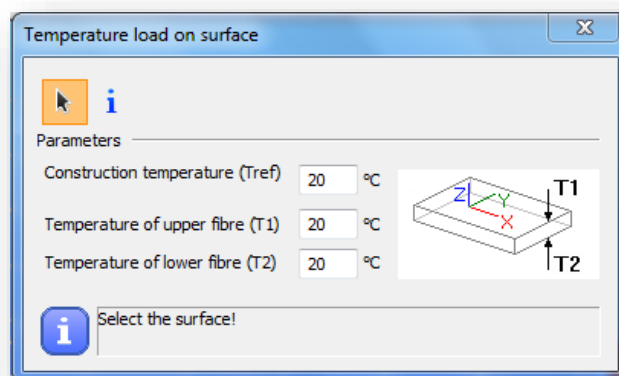
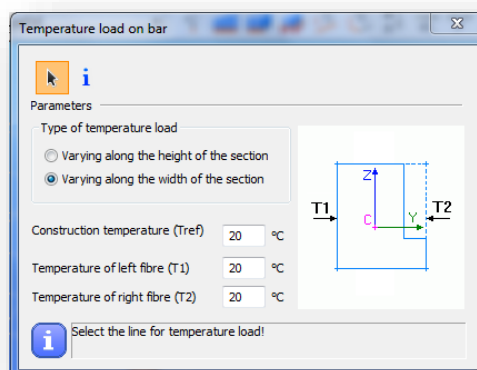
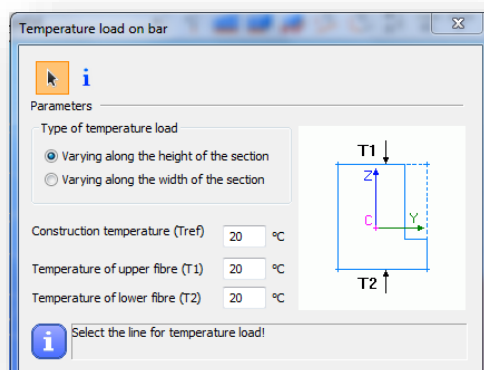
If selected members option is chosen and then the black arrow is clicked, then previously selected members can be removed from the selection or new members can be added.



6.4.5 TEMPERATURE LOAD



Temperature loads can be defined to members  or to surfaces .

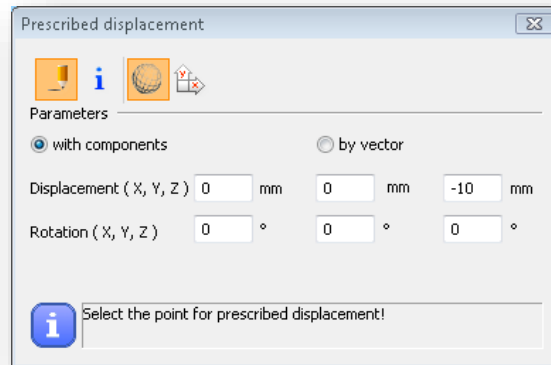
First choose the type of the temperature load: the temperature can change along the cross-section's height or the width. Then add the construction temperature (reference temperature) and the upper and lower temperature of the cross section. The last step is to select the member where you would like to apply the load.




6.4.6 PRESCRIBED DISPLACEMENT

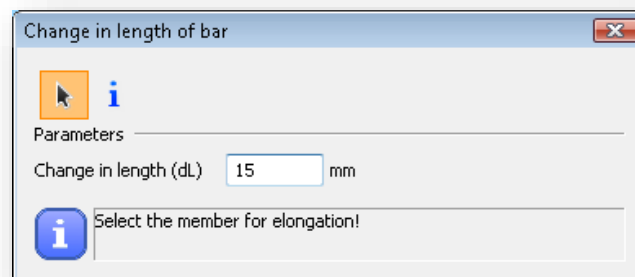
Prescribed displacement can be applied for point supports.


It can be placed according to the **Global** , or the **User coordinate system**  and can be given with components or by vector.

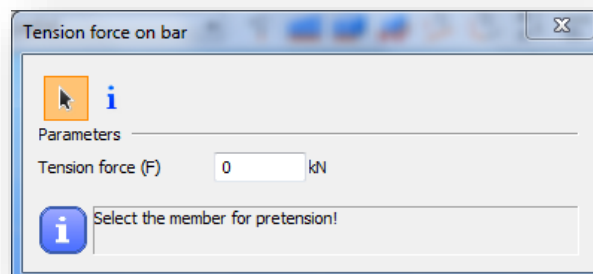


6.4.7 CHANGE IN LENGTH () , TENSION FORCE ()

The change of the original member system length can be set and applied as a load on bar members with the **CHANGE IN LENGTH** () function. With this function prestress effect can be modelling.

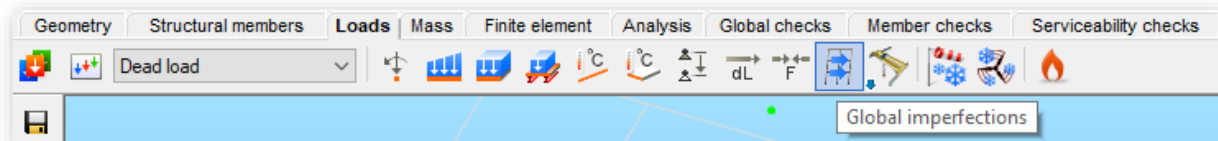



Tension force can be applied on bar members as a load with the **TENSION FORCE** () function.





6.5 GLOBAL IMPERFECTIONS



Three types of global imperfection can be applied on the model with the **GLOBAL IMPERFECTION** () function. Several numbers of imperfections can be created, but only one can be used for the analysis at the same time. Used imperfection can be set for the analysis at the **ANALYSIS TAB's SET ANALYSIS PARAMETERS** dialog (chapter 8.4).

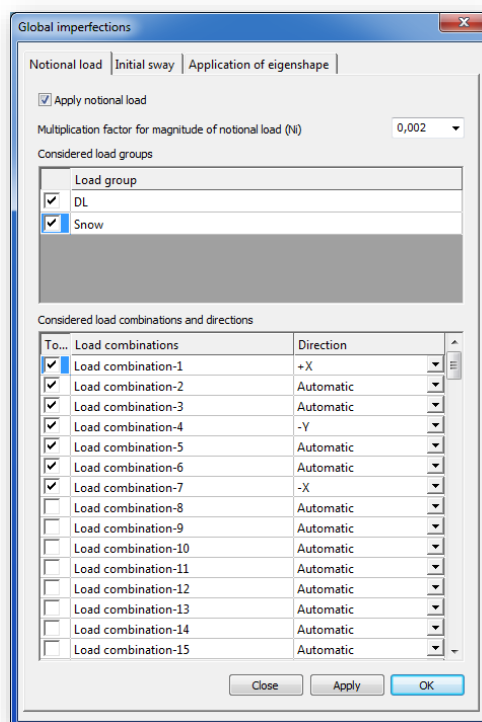
6.5.1 NOTIONAL LOAD

Initial imperfections can be considered by the application of notional loads.

Based on the selected load groups, the notional loads will be generated automatically in the selected load combinations. Direction of the notional loads can be defined automatically or can be set for every load combination.

Multiplication factor for magnitude of notional load (N_i) can be selected from the dropdown menu or can be type manually. This factor means how much percentage of the selected loads will be act as a notional load. Value can be between 0 and 1.

Pressing the **APPLY** or the **OK** button the notional load will be created.





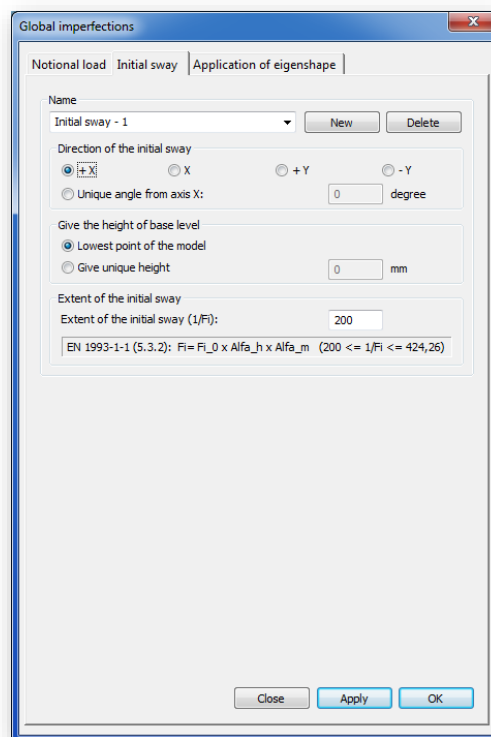
6.5.2 INITIAL SWAY

Initial sway can be set for the whole model.

With the **NEW** button several initial sway can be created or can be deleted by the **DELETE** button.

To create an initial sway, the direction, height of base level and the extent of initial sway ($1/F_i$) must be given.

Pressing the **APPLY** or the **OK** button the initial sway will be created.



6.5.3 APPLICATION OF EIGENSHAPE

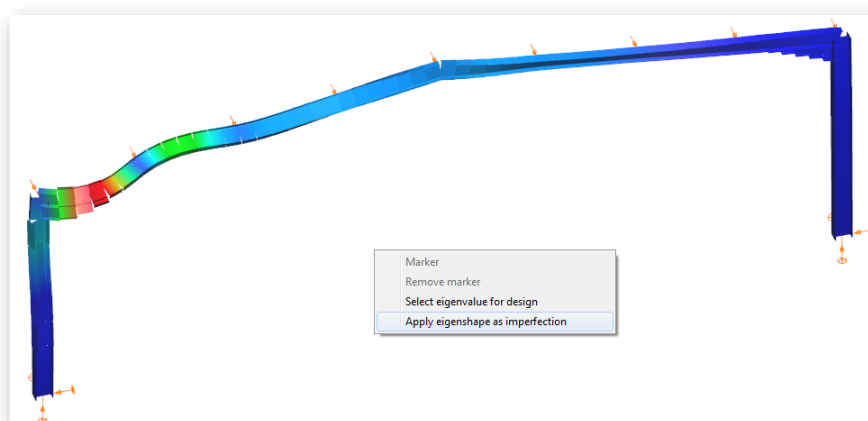
Previously calculated buckling modes can be applied universally as a geometric imperfection for all the load combinations. Even more buckling modes, as an imperfection case, can be easily superposed as one imperfection.

6.5.3.1 APPLY EIGENSHAPES

Previously performed buckling analysis is needed to apply an eigenshape as an imperfection.

On the **ANALYSIS** tab's Buckling result view either calculated buckling mode can set as imperfection.

After selecting the proper eigenshape, and by clicking in the graphical area with right mouse button and choosing the *Apply eigenshapes as an imperfection* option, the parameters of the imperfection can set.





On the setting dialog the following parameters can be set:


- ▶ *Imperfection group*: any eigenshape will belong to an imperfection group, which can be selected from the list. One imperfection group can contain more than one eigenshapes. If more than one eigenshapes are in an imperfection group, then the effect of the eigenshapes will be added together during the application. With the **NEW GROUP** button, a new group can be created.
- ▶ *Name of imperfection case*: unique name can be added for the imperfection
- ▶ *Type of imperfection*:
 - Overall: imperfection case will be used for all the load combination
 - Local: imperfection will be used just for the origin load combination which occurred the selected buckling mode
- ▶ *Modelling of imperfection*:
 - Complete: buckling mode will be applied on the model with all the freedom (node displacement, rotation, warping)
 - Nodal disp.: only the nodal displacement will be applied as imperfection
- ▶ *Sign of amplitude*:
 - Automatic: direction of the imperfection will be set properly for each of the load combinations; in case of normal way selection, for local imperfection type, only the manual option is available
 - Manual: direction of the imperfection will be accordingly to the sign of the given amplitude value
- ▶ *Type of amplitude*:
 - *mm value*: maximum displacement value of the eigenshape can be given in mm. The other displacement values will be commensurable to the given amplitude.
 - *multiplication factor*: the calculated displacement values can be multiplied with this factor
- ▶ *Value of amplitude*: value of the previously selected amplitude type must be given



Pressing the **OK** button, the eigenshape is applied as an imperfection with the set parameters.

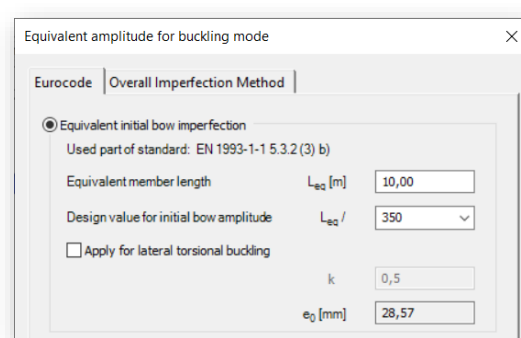
6.5.3.2 AUTOMATIC AMPLITUDE CALCULATION

Applying any imperfection, it is always a problem how to define the proper amplitude to have safe but economic results. The Eurocode EN 1993-1-1 gives some limited guidance for certain cases, based on these guidelines and self-developed procedures, Consteel can automatically determine the amplitude of imperfection using three different methods.

Click the three-dot icon () next to the *Value of Amplitude* field in the dialog shown above. A new dialog box will appear where you can choose from the three possible amplitude calculation methods.

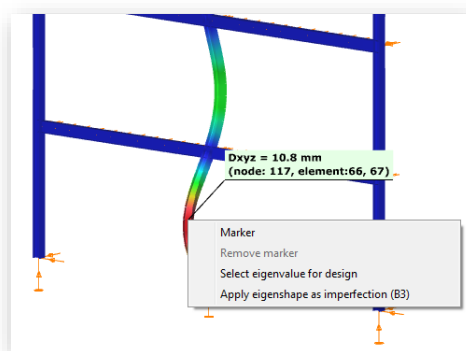
► *Equivalent initial bow imperfection*

This option is based on the table EN 1993-1-1 5.3.2 (3)b where initial bow amplitude ratios are defined depending on the corresponding buckling curve of the selected member. To evaluate the proper amplitude, the equivalent member length should also be specified (which is not necessarily equal to the system length of the selected member...) and the calculated value is displayed in mm. For lateral torsional buckling problem an additional multiplication factor (k) can be defined for the amplitude. It is important to note that these values are officially valid only for simply supported straight, prismatic members with uniform compression (or bending), for other situation the user has to consider the special support, geometry or loading effects when defining the initial bow. Finally, the calculated value (e_0) is accepted by the **OK** button which automatically gets into the *Value of amplitude* input field.



► *Equivalent imperfection based on the elastic critical buckling shape*

This option is based on the rules of EN 1993-1-1 5.3.2 (11). Since these rules are strongly connected to member parameters (cross-section type, shape, properties, buckling curve etc.) the first task is the selection of a reference member which would be the suitable base for the amplitude calculations. This can be done by right click on the selected member and then choose the *Apply eigenshape as imperfection* where, as a feedback the name of the





selected member is also appearing (e.g. B3). The selected member should be the dominant one in the certain buckling mode.

This method calculates fully automatically the amplitude value based on the selected axis of buckling with the following steps:

1. Calculation of the internal forces at the FE nodes of the member from the deformed shape equal to the selected buckling mode
2. Determination of the critical position where the relevant bending moment (M_y or M_z calculated in 1.) is the highest
3. Read the following information at the critical position:
 - i. Normal force value [N_{Ed}] from the first order analysis (without imperfection) – this value must be compression
 - ii. Relevant bending moment [M_y or M_z later displayed as M^I denoted as $EI\eta_{cr,max}$ in the standard]
 - iii. Cross section properties [class for compression, yield stress, area, relevant section modulus (W_y or W_z), relevant buckling curve]

Finally, the calculated value ($\eta_{init,max}$) is accepted by the **OK** button which automatically gets into the 'Value of amplitude' input field. This calculation is only applicable to buckling problems of a dominantly compressed member but with arbitrary support condition.

Equivalent imperfection based on the elastic critical buckling shape

Used part of standard: EN 1993-1-1 5.3.2 (11)

Axis of buckling: y

Parameters	
N_{Ed}	-104,8 kN
N_{Rk}	3 723,2 kN
M_{Rk}	1 119,0 kNm
α_{eff}	35,539
α_{cr}	1,320
λ	5,189
α	0,340
γ	0,035
e_0	509,78 mm
N^I	-0,1 kN
M^I	-2,8 kNm
$\eta_{init,max}$	895,60 mm

Cancel OK

► Overall Imperfection Method (OIM)

Consteel's new, self-developed method for automatically determining the amplitude of imperfection, in full compliance with Eurocode regulations. A second-order analysis based on imperfection scaled by this method and a cross-section design give the same utilization result as the conventional reduction factor method. This new method developed at Consteel is a fully generalized solution for the case of a simply-supported prismatic column loaded with centric concentrated force, which can be used for any non-uniformly or eccentrically loaded, arbitrarily supported member even with variable cross-section, and is fully compatible with EC. For example, for the above-mentioned simple case, the result is 100% equal to the result of the conventional reduction factor method.



Equivalent amplitude for buckling mode

Eurocode Overall Imperfection Method

☒ Overall Imperfection Method

Parameters	
Standard	EN1993-1-1
Load Combination	ULS1
+ Linear buckling analysis results	
+ Equivalent reference member data	
+ Standard buckling curve data	
- Equivalent geometric amplitude data	
$\alpha_{\text{rec},\text{eq}}$	2,508
δ_{eq}	0,578
$V_{\text{eq,max,D}}$	20,54 mm
$W_{\text{eq,max,D}}$	0,004 mm
$\theta_{\text{eq,max,D}}$	2,514 °

Cancel OK

6.5.3.3 MANAGING EIGENSHAPES

Previously created imperfection groups and imperfection cases (applied eigenshapes) can be managed on the **GLOBAL IMPERFECTIONS** dialog's **APPLICATION OF EIGENSHAPE** tab.

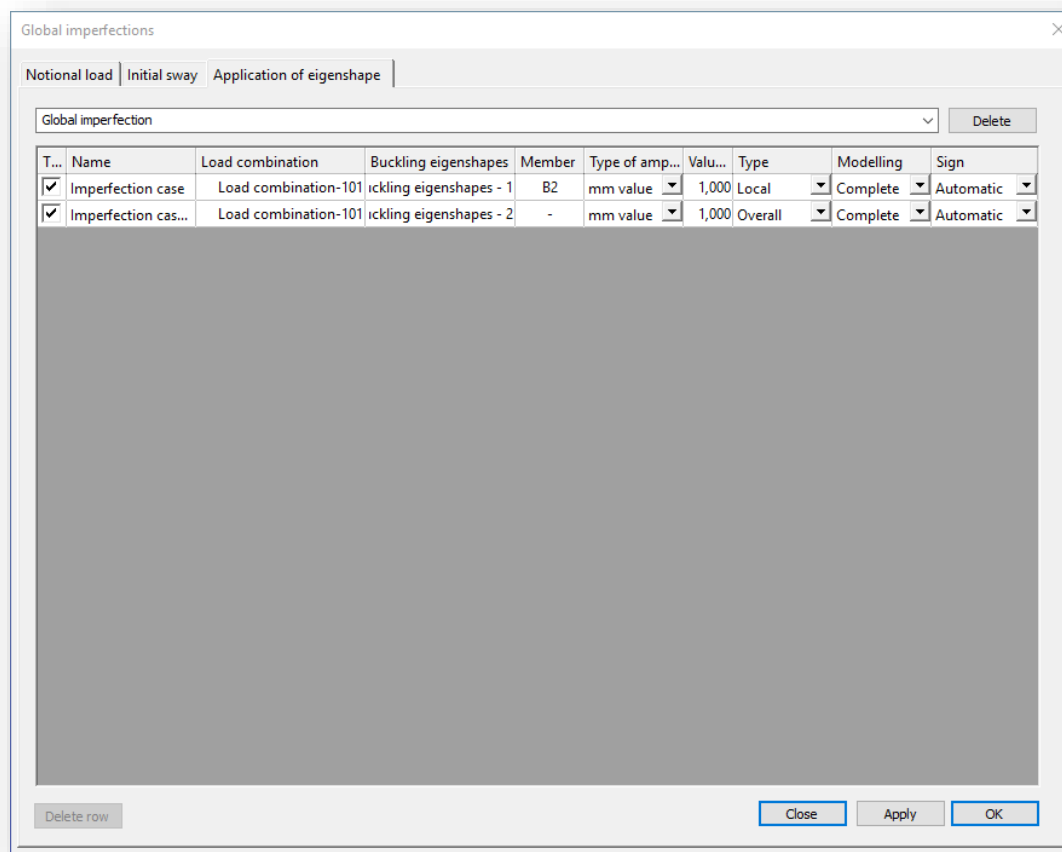
By the first dropdown menu, imperfection groups can be switched, and whole imperfection group can be deleted with the **DELETE** button.

In the middle part of the dialog can be seen the imperfection cases (applied eigenshapes) in the selected imperfection group. With the checkboxes in the first column each imperfection



cases can be turn off and on. In the following columns, all the previously set parameters can be checked and modified.

With the **DELETE ROW** button, the selected imperfection cases can be deleted from the imperfection group.



The dialog box titled "Global imperfections" contains three tabs: "Notional load", "Initial sway", and "Application of eigenshape". The "Application of eigenshape" tab is active. At the top, there is a dropdown menu labeled "Global imperfection" and a "Delete" button. Below this is a table with the following columns: "T...", "Name", "Load combination", "Buckling eigenshapes", "Member", "Type of amp...", "Valu...", "Type", "Modelling", and "Sign". The table contains two rows, both with checkboxes in the "T..." column.

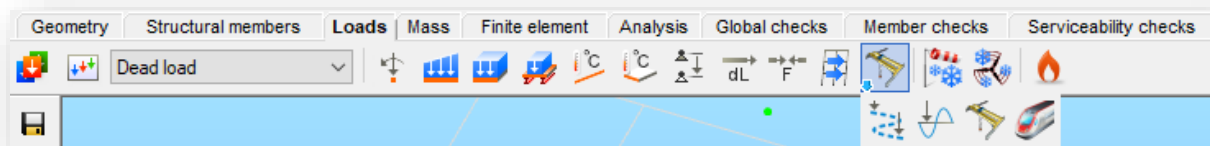
T...	Name	Load combination	Buckling eigenshapes	Member	Type of amp...	Valu...	Type	Modelling	Sign
<input checked="" type="checkbox"/>	Imperfection case	Load combination-101	icking eigenshapes - 1	B2	mm value	1,000	Local	Complete	Automatic
<input checked="" type="checkbox"/>	Imperfection cas...	Load combination-101	icking eigenshapes - 2	-	mm value	1,000	Overall	Complete	Automatic

At the bottom of the dialog, there is a "Delete row" button on the left and "Close", "Apply", and "OK" buttons on the right.



6.6 MOVING LOAD

EuroCode based or user defined crane and train load can be created and placed on the model manually or by the loading of an influence graph.





6.6.1 MOVING LOAD PATH ()

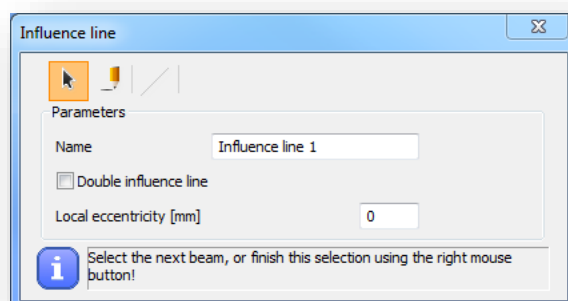
To place a moving load on the model or to calculate influence graph, as a first step it is necessary to create **MOVING LOAD PATH** on those members where the load will be placed or moved.

Members must be in one line and must be connected.

Moving load path can be defined one-by-one () or by drawing ().

In case of one-by-one selection (), all the members must be selected with the left mouse button where the **MOVING LOAD PATH** should be applied. At the end, the selection function must be closed by clicking with the right mouse button.

In case of drawing () the start and the end point of the drawing line must be picked. **MOVING LOAD PATH** will be applied on all of members which are lying under the drawing line.

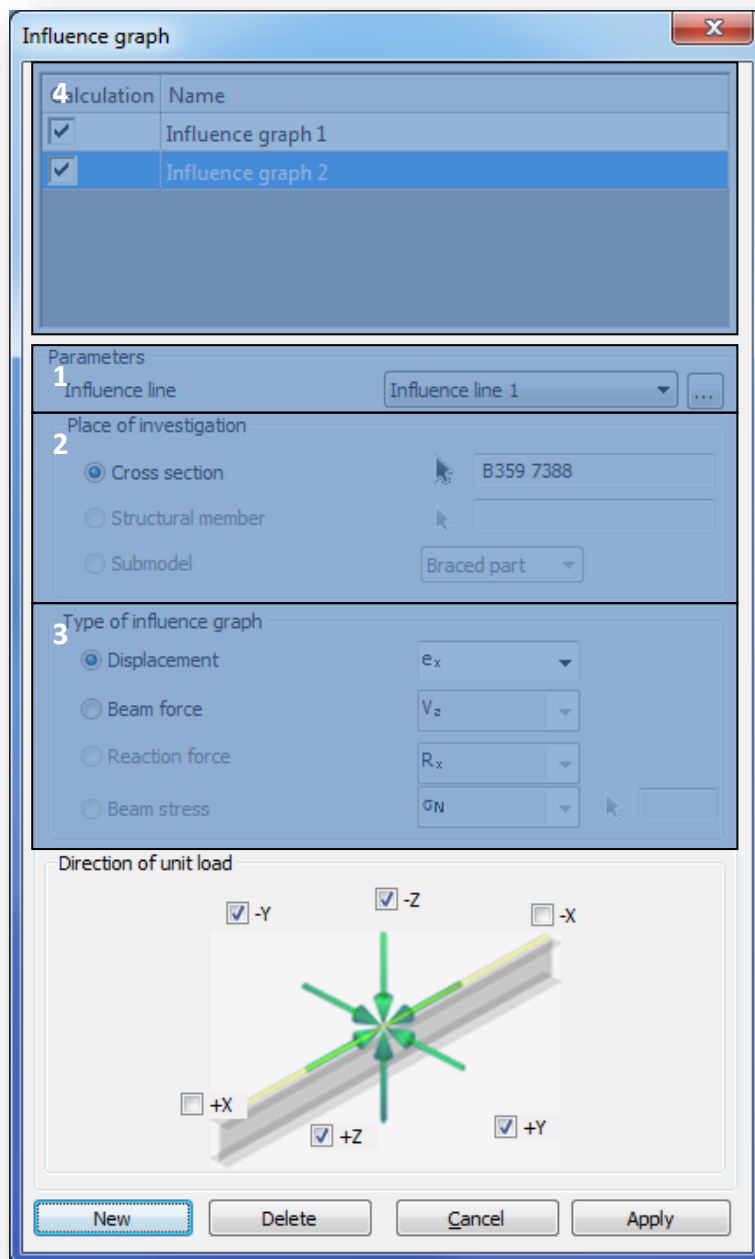



Double moving load path can be created by clicking in the checkbox.




6.6.2 INFLUENCE GRAPH

To run *Influence graph* analysis, it is necessary to set the **INFLUENCE GRAPH** parameters.



As a first step one of the previously created influence line must be selected from the dropdown menu (#1) where the unit load will move. If there is not any influence line, then with the three-dot button () , a new one can be created.



As a next step, the place of the investigation (#2) must be selected with black arrow button (). In the current version of *Consteel*, a cross section of an arbitrary member can be selected. Not just those members can be selected that are part of the selected influence line.

Three types of influence graph can be analyzed (#3):

- ▶ Displacement
 - Displacement in local x, y, and z axis
 - Rotation around local x, y, and z axis
- ▶ Internal force
 - Major (M_y) and minor (M_z) axis bending moment
 - Normal force (N)
 - Major (V_y) and minor (V_z) axis shear
 - Torsion (T)
 - Bimoment (B)
- ▶ Reaction force
 - Reaction force in the global X, Y and Z axis
 - Reaction moment around the global X, Y and Z axis

As a last step the direction of the unit load must be chosen. Simultaneously more direction can be chosen, but separate graph will belong to for each direction.

By clicking on the **APPLY** button, the influence graph setting is created.

With the **NEW** button another influence graph setting can be created.

6.6.2.1 MANAGING INFLUENCE GRAPHS

Previously created influence graphs can be managed in the table part of the dialog (#4). All the previously created influence graphs can be seen and selected.

After the selection, all parameters can be modified with the **APPLY** button.

The selected influence graph(s) can be deleted by pressing **DELETE** button.

With the checkboxes in the *Calculation* column, influence graph(s) can be switched on/off for calculation.

6.6.2.2 ANALYZE INFLUENCE GRAPH

To run Influence graph analysis, see **CHAPTER 8 STRUCTURAL ANALYSIS** below!

6.6.3 CRANE LOAD ()



Three types of overhead traveling crane load can be defined:

- ▶ Standard: fully EN 1991-3 based
- ▶ Standard load based: EN 1991-3 standard defined wheel loads must set. Group of loads are created by *Consteel*
- ▶ User defined: direct wheel loads must be set for each wheel

The screenshot shows a software dialog box titled 'Crane load 1'. It has a 'Name' field at the top containing 'Crane load 1'. Below this is a 'Type of crane' section with three radio button options: 'Standard' (which is selected), 'Standard load based', and 'User defined'.



6.6.3.1 STANDARD

For the fully EN 1993-3 based standard crane load, the geometrical parameters (#1), loadings (#2), and the driving properties (#3) must be set. The wheel loads are automatically calculated.

Crane load

Name: Crane load 1

Type of crane: ☒ Standard ☐ Standard load based ☐ User defined

Geometrical properties

1 Line span - L: 21,3 m

Minimal distance of the trolley - e_{min} : 0 m

Number of axes: 4

Axis	1	2	3	4
a_i [m]	0,0	1,2	1,0	1,2

Loading properties

2 Self weight of crane bridge - Q_{C1} : 70 kN

Self weight of trolley - Q_{C2} : 15 kN

Elevated weight - Q_k : 180 kN

Dynamic factors

Driving properties

3 Number of single wheel drives: 2

Wheel drive: ☒ Central ☐ Individual

Crane system: CFF

Friction factor: 0,2

Guiding device type: ☒ Flanged wheel ☐ Guide pin

Distance of pins along the driving direction - a_{ext} : 0 mm

Distance of pins from the outer wheels along the driving direction - e_{ext} : 0 mm

Largest gap between the pin and the rail - x : 10 mm

Additional gap from the abrasion of the pin and the rail - y : 5 mm

Wheel loads

4 1. Loadcase

	1, 1	1, 2	2, 3	2, 4	3, 5	3, 6	4, 7	4, 8
F_x	2,338	2,338	0,000	0,000	0,000	0,000	0,000	0,000
F_y	1,423	9,352	0,000	0,000	0,000	0,000	-1,423	-9,352
F_z	-63,250	-9,625	-63,250	-9,625	-63,250	-9,625	-63,250	-9,625

New Delete Place load Cancel Apply

The following geometrical properties (#1) can be set:

- Crane span – L [m]: span of the crane bridge
- Minimal distance of the trolley – e_{min} [m]: minimum distance between the trolley and the crane girder
- Number of axes: Numbers of the axes of the crane bridge must be set from the dropdown menu. Minimum number of the axis is 2, maximum is 10. Distances between the axes also must be set.



In case of loading properties (#2), the self-weight of the crane bridge (Q_{c1}) and the trolley (Q_{c2}) and the elevated weight (Q_h) must be set. By pressing the **DYNAMIC FACTORS** button, the default value of the factors can be seen. Factors can be modified manually.

The following driving properties (#3) must be set:

- ▶ Wheel drive: number of the driven wheels and the system of the wheel drive (central or individual)
- ▶ Crane system: to select the proper EuroCode care system, please see the definition of the crane systems in the relevant part of the EN 1991-3
- ▶ Friction factor: friction factor between the rail and the wheels
- ▶ Guiding device: two types of guiding device can be chosen, flanged wheels and guide pins. According to the selection, the necessary geometrical parameters of the guiding device must be set

The automatically calculated wheel loads for each load case can be seen in the table (#4). The load cases can be changed with the dropdown menu.

In the name of the wheels, the first prefix means the number of the axis; the second means the number of the wheel.



6.6.3.2 STANDARD LOAD BASED

For the standard load-based crane load, the numbers of the axis and the standard wheel loads must be set.

The dialog box is titled "Crane load" and contains the following sections:

- Name:** Crane load 1
- Type of crane:** ☐ Standard ☒ Standard load based ☐ User defined
- Geometrical properties:**
 - Number of axes:** 2
 - Axis:** 1, 2
 - a_i [m]:** 0,0, 2,5
- Wheel loads:**

	1, 1	1, 2	2, 3	2, 4
Q _o	0,000	0,000	0,000	0,000
Q _h	0,000	0,000	0,000	0,000
H _t	0,000	0,000	0,000	0,000
H _l	0,000	0,000	0,000	0,000
H _s	0,000	0,000	0,000	0,000
H _{ss}	0,000	0,000	0,000	0,000
H _{ts}	0,000	0,000	0,000	0,000
- Dynamic factors:** (button)
- Wheel loads:** (dropdown menu: 1. Loadcase)

	1, 1	1, 2	2, 3	2, 4
F _x	0,000	0,000	0,000	0,000
F _y	0,000	0,000	0,000	0,000
F _z	-0,000	-0,000	-0,000	-0,000

Buttons at the bottom: New, Delete, Place load, Cancel, Apply.

In the geometrical properties field (#1) the number of the axes of the crane bridge must be set from the dropdown menu. Minimum number of the axis is 2, maximum is 10. Distances between the axes also must be set.

In the second field (#2) the EuroCode based wheel loads must be set for each wheel. By pressing the **DYNAMIC FACTORS** button, the default value of the factors can be seen. Factors can be modified manually.

The automatically calculated wheel loads for each load case can be seen in the table (#3). The load cases can be changed with the dropdown menu.



In the name of the wheels, the first prefix means the number of the axis; the second means the number of the wheel.

6.6.3.3 USER DEFINED

For the user defined crane load the following parameters must be set:

- ▶ The numbers of the axes of the crane bridge must be set from the dropdown menu. Minimum number of the axis is 2, maximum is 10. Distances between the axes also have to be set.
- ▶ Three directions (F_x , F_y and F_z) of the wheel loads have to be set for each wheel

The dialog box 'Crane load' contains the following sections:

- Name:** Crane load 1
- Type of crane:** ☐ Standard, ☐ Standard load based, ☒ User defined
- Geometrical properties:**
 - Number of axes:** 2
 - | Axis | 1 | 2 |
|-----------|-----|-----|
| a_i [m] | 0,0 | 0,4 |
- Wheel loads:**

	1, 1	1, 2	2, 3	2, 4	3, 5	3, 6	4, 7	4, 8
F_x	2,338	2,338	0,000	0,000	0,000	0,000	0,000	0,000
F_y	1,423	9,352	0,000	0,000	0,000	0,000	-1,423	-9,352
F_z	-63,250	-9,625	-63,250	-9,625	-63,250	-9,625	-63,250	-9,625

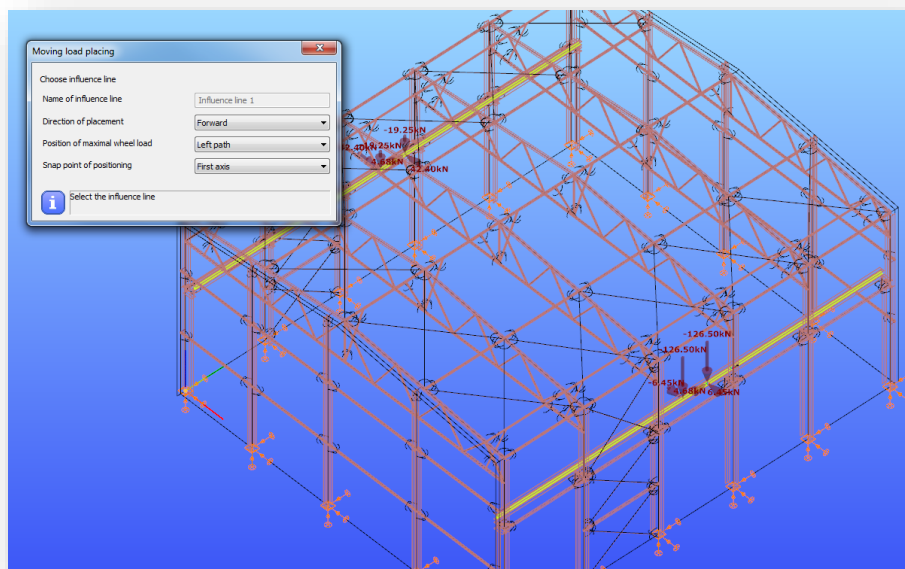
Buttons at the bottom: New, Delete, Place load, Cancel, Apply.

6.6.3.4 PLACING CRANE LOAD

There is two ways to place crane load on the model, but before placing with the **APPLY** button the defined crane load has to be saved.

Placing crane load manually

By pressing the **PLACE LOAD** button on the bottom of the **CRANE LOAD** dialog, the selected loadcase can be place manually on the model.



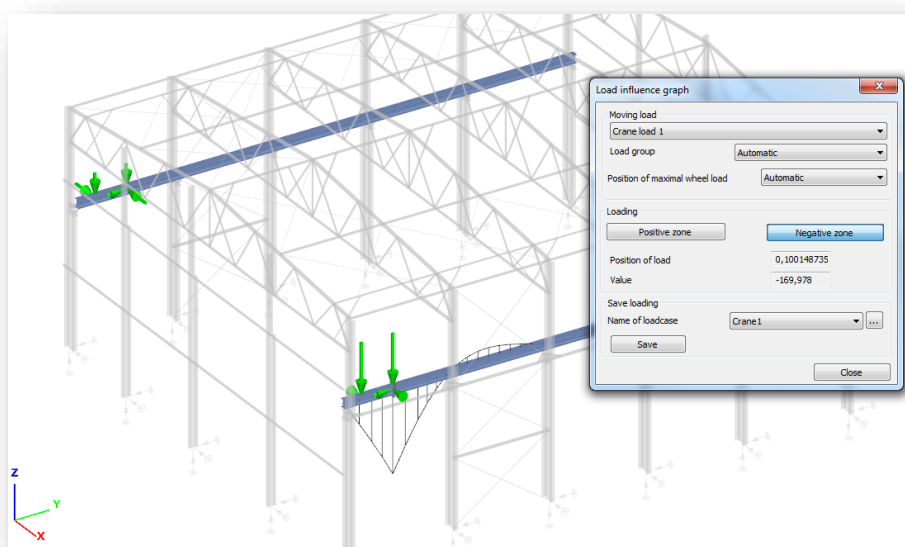
At first an influence line has to be chosen with the left mouse button. After the loads have to be placed along selected influence line by pressing the left mouse button.

Direction of the placement, position of the maximal wheel load and the snap point of the positioning can be selected from the dropdown menus.

Placing crane load by loading influence graph

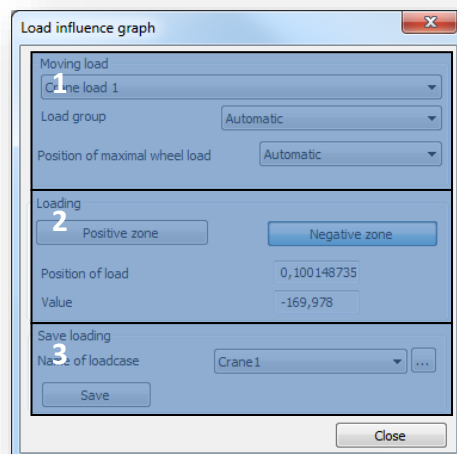
Crane load can be placed on the model by loading an influence graph.

To analyze an influence graph please see Chapter 6.6.2 and Chapter 8.





To place a crane load by loading an influence graph, please select the *Influence graph* analysis type from the first dropdown menu on the **ANALYSIS** tab and click with the right mouse button on the graphical area and select **LOAD INFLUENCE** line from the appeared menu.



In the *Moving load* field (#1) the loading properties can be set:

- ▶ From the first dropdown menu, one of the previously created crane loads can be selected to place
- ▶ Load group: in case of standard or standard load base crane, EuroCode load groups are automatically created. Influence graph can be loaded by the selected load groups or by the dominant if the *Automatic* function is selected from the dropdown menu
- ▶ Position of maximal wheel load: vertical wheel loads depend on the position of the trolley. Maximum vertical wheel load could be on the left or the right path, or the dominant position can be automatically detected if the *Automatic* function is selected from the dropdown menu

With the **POSITIVE ZONE** and **NEGATIVE ZONE** buttons in the *Loading field* (#2), the influence graph can be loaded. If the **POSITIVE ZONE** button is used then the loading is give the maximum positive value in the section, if the **NEGATIVE ZONE** button is used then the loading is give the maximum negative value in the section. The position of the load and the current value in the section are appeared.

The placed load can be saved to a load case by the function of the *Save loading field* (#3). With the dropdown menu, one of the previously created load cases can be select to save or with the three-dot button a new one can be created. With the **SAVE** button the placed load can be saved to the selected load case.

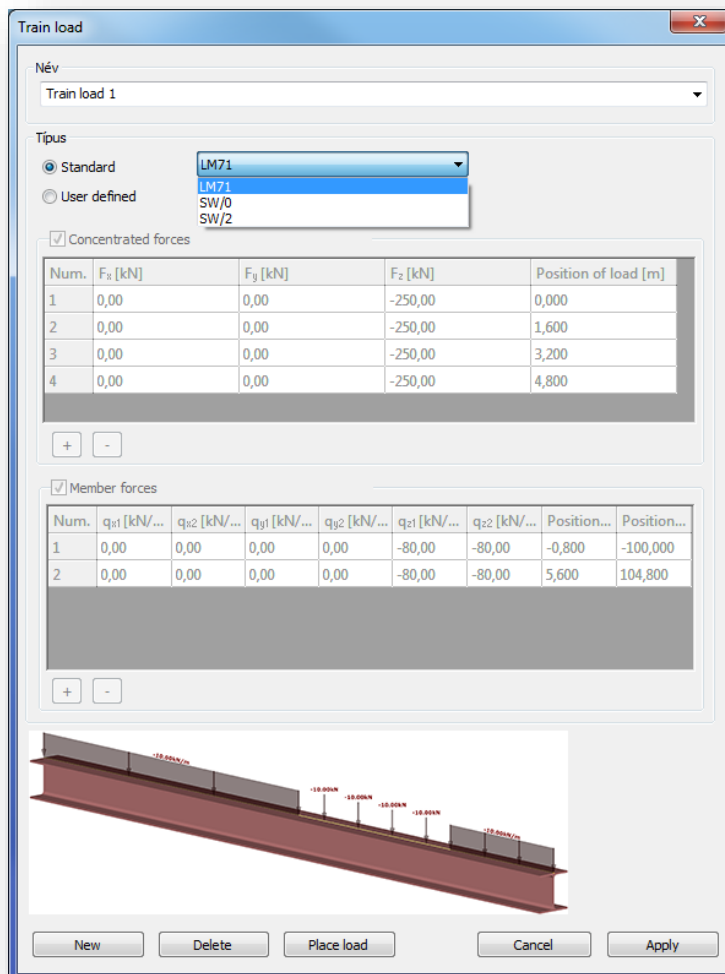


6.6.4 TRAIN LOAD

Two types of train load can be created and placed on the model.

Standard

From the dropdown menu three types of EuroCode defined train load can be selected. In the tables the properties of the selected one can be seen.



Train load

Név: Train load 1

Típus: ☒ Standard ☐ User defined

LM71
LM71
SW/0
SW/2

☒ Concentrated forces

Num.	F _x [kN]	F _y [kN]	F _z [kN]	Position of load [m]
1	0,00	0,00	-250,00	0,000
2	0,00	0,00	-250,00	1,600
3	0,00	0,00	-250,00	3,200
4	0,00	0,00	-250,00	4,800

+ -

☒ Member forces



Num.	qx1 [kN/...]	qx2 [kN/...]	qy1 [kN/...]	qy2 [kN/...]	qz1 [kN/...]	qz2 [kN/...]	Position...	Position...
1	0,00	0,00	0,00	0,00	-80,00	-80,00	-0,800	-100,000
2	0,00	0,00	0,00	0,00	-80,00	-80,00	5,600	104,800

+ -

3D visualization of train load on a beam.

New Delete Place load Cancel Apply

User defined

In case of *User defined*, the concentrate and line load tables are editable. With the plus  and minus  buttons a new row can be added to the table and the selected row can be removed from the table.

In case of concentrate load the three directions and the position of the load can be set.



In case of line load the intensity of load can be set on the start and the end point in the three directions, and the position of the end points can be set.

The placing of the train load is the same as for the crane load. Please see Chapter 6.6.3.4.

6.7 METEOROLOGICAL LOAD GENERATOR

All of the meteorological load generator related functions (**METEOROLOGICAL SURFACE**



METEOROLOGICAL LOAD GENERATOR ) can be found on the **LOADS** tab.

Meteorological load generator can generate wind and snow load for the most common type of structures according to the following standards:

- ▶ Wind
 - EuroCode 1 (EN 1991-4)
 - Spanish standard (SE-AE)
- ▶ Snow
 - EuroCode 1 (EN 1991-3)

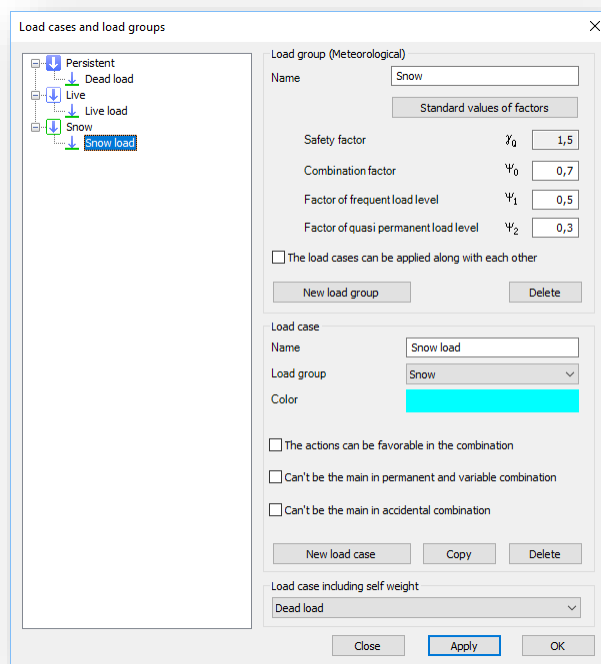


HEIGHTS OF THE STRUCTURE (h) FOR GENERATING WIND LOADS ARE CALCULATED FROM THE GLOBAL $z=0$ LEVEL. THEREFORE, THE STRUCTURAL MODEL HAS TO BE PLACED TO ITS REAL HEIGHT IN THE MODELLING AREA MEASURED FROM THE GLOBAL $z=0$ LEVEL. FOR EXAMPLE LOWEST EDGE OF A WINDWARD WALL CANNOT BE PLACED BELOW THE GLOBAL $z=0$ LEVEL, OR IF THE MODEL IS A ROOF OF A BUILDING, THEN THE ROOF MUST BE PLACED IN THE REAL HEIGHT MEASURED FROM THE GLOBAL $z=0$ LEVEL.

6.7.1 LOAD GROUPS AND LOAD CASES

Load groups and load cases are automatically created during the generation process according to the placed meteorological surfaces and the selected wind directions.

Safety factors and coefficient factors are loaded from the selected national NA.

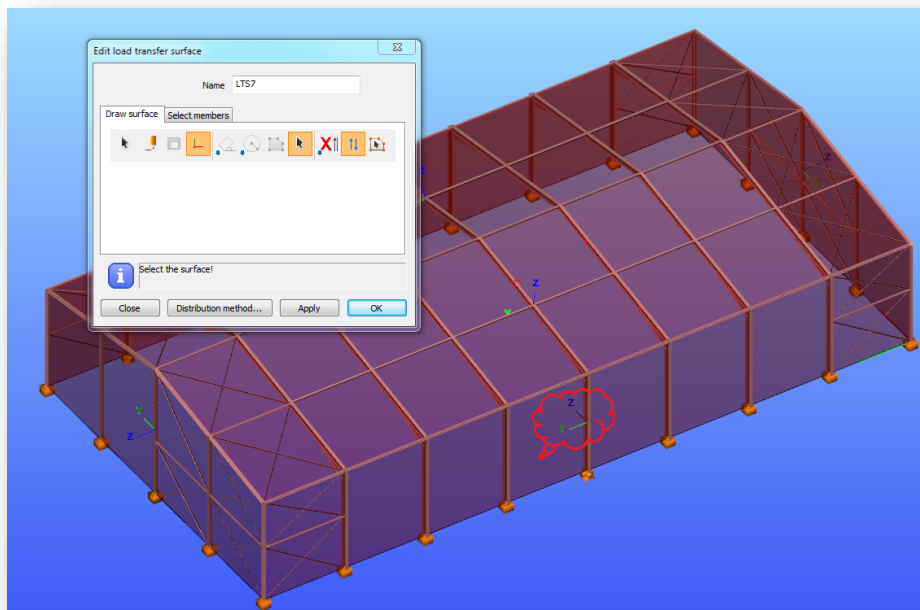



6.7.2 METEOROLOGICAL SURFACES

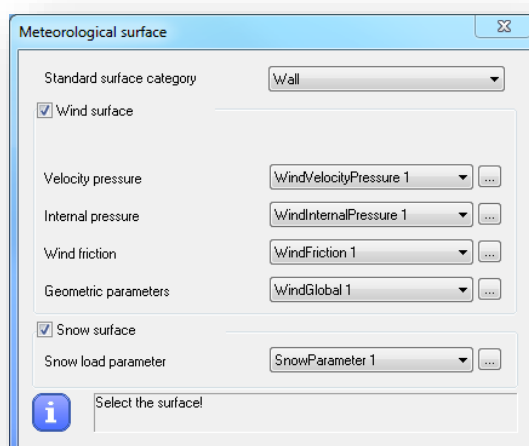
The first step to generate meteorological load is to place meteorological surfaces on the model. Meteorological surfaces contain all of the information and parameters what are necessary for the load generation.

Meteorological surfaces can be placed on any load transfer surface. It is advised to cover all meteorological load attacked sides of the model with load transfer surfaces.

It is important to check the local axes directions of the load transfer surfaces. All z (blue) axes must point out of the building. If modification is necessary, then it is recommended to use the *invert z axis* tool on the **EDIT LOAD TRANSFER SURFACE** dialog (see image below).



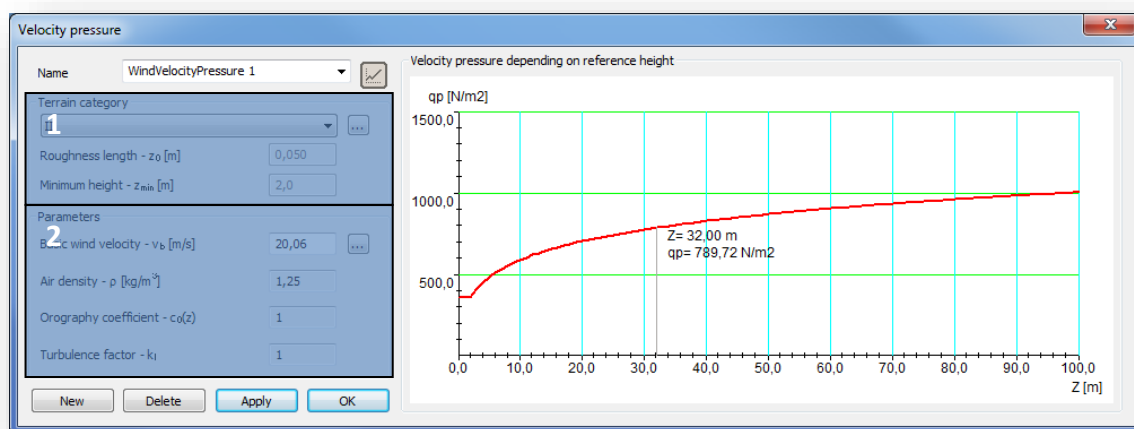
Before placing the meteorological surfaces, all of the necessary parameters have to be set on the **METEOROLOGICAL SURFACE** () dialog.





6.7.2.1 WIND SURFACE

Velocity pressure



For the velocity pressure the following two parameters have to be set:

► Terrain category (#1)

From the dropdown menu the proper category can be selected or by clicking the three-dot button (⋮) the standard definition of the categories can be seen.

Roughness length (z_0) and the minimum height (z_{min}) are loaded from the selected national NA.

► Parameters (#2)

All of the parameters are loaded from the selected national NA, only the basic wind velocity (v_b) has to be set. By clicking the three-dot button (⋮) the fundamental value ($v_{b,0}$) of wind velocity also can set manual or by using one of the implemented win map. In this case the basic wind velocity pressure is automatically calculated.

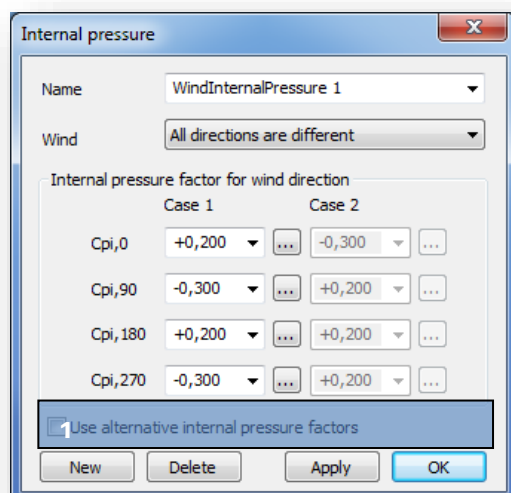


VELOCITY PRESSURE DIALOG AND THE NECESSARY PARAMETERS COULD BE DIFFERENT ACCORDING TO THE SELECTED EUROCODE NATIONAL ANNEX

Internal pressure

Internal pressure can be set for the generation:

- ▶ Pressure could be different in all wind directions
- ▶ Pressure could be equal in all wind directions
- ▶ Or, pressure could be equal in couples



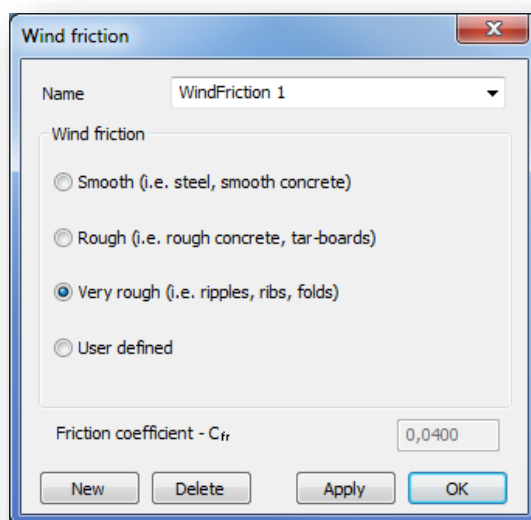


The value can set manually, or the extreme values can be selected from the dropdown menus, or by clicking the three-dot button (⋮) one of the EuroCode internal pressure calculator method can be used.

With the checkbox (#1) alternative internal pressure can be set in all wind direction.

Wind friction

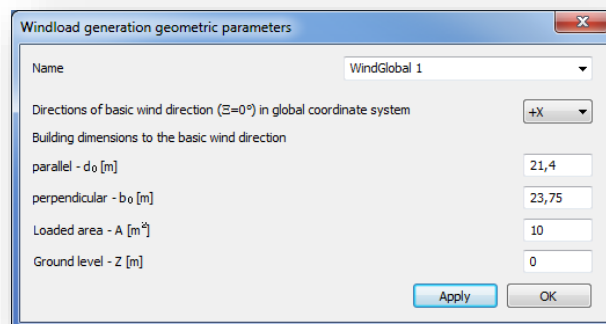
For wind friction, just the friction coefficient has to be set by selecting one of the national NA defined category or selecting the user defined.



Geometrical parameters

The following geometrical parameters have to be set:

- ▶ Direction of the basic wind in global coordinate system. The basic wind direction is the 0° wind direction.
- ▶ Building dimensions to the basic wind direction
- ▶ Loaded area (A) of the wind load. If the loaded area is equal or bigger than 10m² then *Consteel* use c_{pe10} in the generation. If the area is equal or smaller than 1m² then *Consteel* use c_{pe1} in the generation. Between the two values *Consteel* interpolates between c_{pe10} and c_{pe1} acc. to the EuroCode rule.
- ▶ Ground level. *Consteel* measures the height of the structure from the global Z=0 level for the wind load generation. Therefore, the structure base level is not equal with the ground level, but the structure is placed on the global Z=0 level in *Consteel*, the difference has to be set manually in the ground level field.

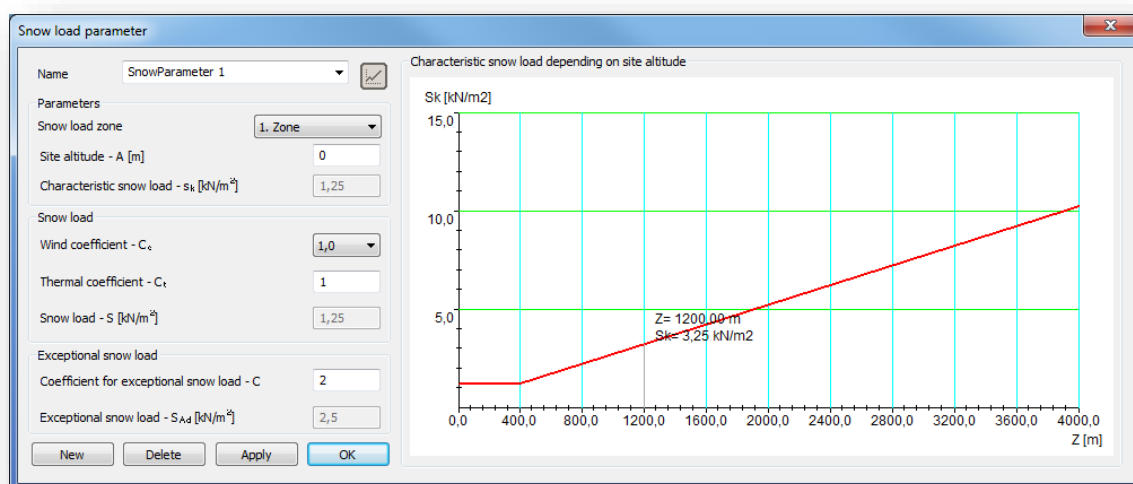


6.7.2.2 SNOW SURFACE

On the Snow load parameter dialog, the following parameters have to be set:

- ▶ Snow load zone (if it is necessary according to the selected NA)
- ▶ Site altitude (if it is necessary according to the selected NA)
- ▶ Wind (C_e) and thermal coefficient (C_t)
- ▶ Coefficient for exceptional snow load

The basic values are loaded from the selected national NA.





6.7.2.3 PLACING METEOROLOGICAL SURFACE

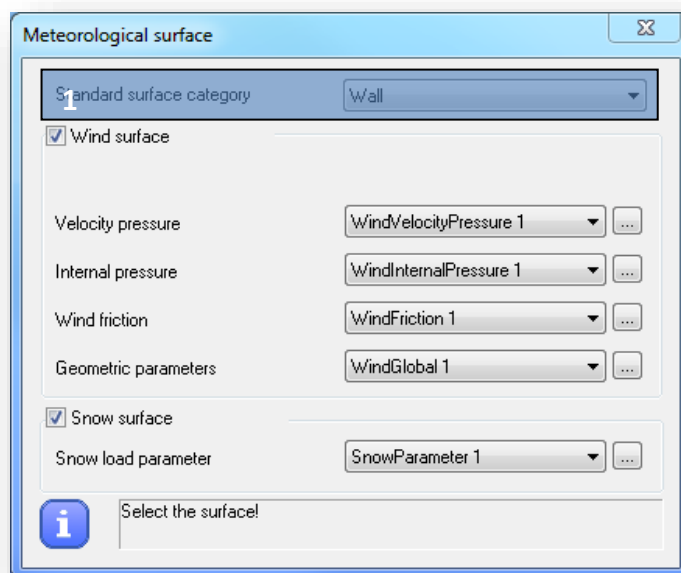
After all of the necessary parameters were set, meteorological surfaces can be placed on the 3D model.

From the dropdown menu (#1), the relevant standard surface category has to be chosen and a load transfer surface has to be selected with the left button of the mouse.



The following symbol will be appeared on the load transfer surface, after the successful placement:

- ▶ Wind surface: 
- ▶ Snow surface:  (just on roofs)



The following standard categories can be selected from the menu (#1):

- ▶ Wall
- ▶ Flat roof (sharp eaves)
- ▶ Flat roof (with parapets)
- ▶ Flat roof (curved eaves)
- ▶ Flat roof (mansard eaves)
- ▶ Monopitch roof
- ▶ Duopitch roof

In case of duopitch roof not just one load transfer surface, but two connected load transfer surfaces have to be selected.

By selecting the symbol, meteorological load surface can be modified in the **OBJECT PROPERTIES** window.



Wind surface (1)	
Name	WindSurface1
Surface type	Duopitch roof
Define zones	Standard ...
Geometric parameters	WindGlobal 1
Internal pressure	WindInternalPressure 1
Wind friction	WindFriction 1
Velocity pressure [kN/m ²]	WindVelocityPressure 1
Snow surface (1)	
Name	SnowSurface1
Surface type	Duopitch roof
Geometric parameters	SnowParameter 1

In case of Wind surface, by clicking the three dots button in the Define zone row, the **WIND ZONE VIEWER** dialog open, where the calculated wind zones and c_{pe} values can be seen and checked.

Wind zone viewer

Constant parameter

Loaded area - A [m²] 10

Building height - h [m] 12,05 Pitch angle α [°] 5,71059

Wind direction dependent

Wind direction [°] 0 b [m] 23,75 e [m] 23,75

Basic wind direction 0 d [m] 21,4 h/d 0,563084

Schematic zone figure with sizes

Standard Cpe table EN 1991-1-4:2007 Table 7.4

α	F,10	F,1	G,10	G,1	H,10	H,1	I,10	I,1	J,10	J,1
5,000	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6	-0,6	0,2	0,2
5,000	0,0	0,0	0,0	0,0	0,0	0,0	-0,6	-0,6	-0,6	-0,6
15,000	-0,9	-2,0	-0,8	-1,5	-0,3	-0,3	-0,4	-0,4	-1,0	-1,5
15,000	0,2	0,2	0,2	0,2	0,2	0,2	0,0	0,0	0,0	0,0

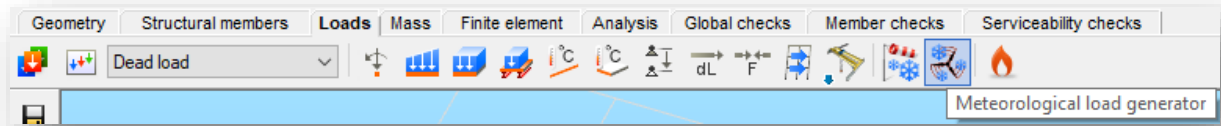
Actual Cpe values

α	F	G	H	I	J
5,711	-1,643	-1,172	-0,579	-0,586	-0,628
5,711	0,014	0,014	0,014	0,000	0,186

Close Apply OK

6.7.3 METEOROLOGICAL LOAD GENERATOR

Meteorological load generator function can be found on the **LOADS** tab.



The function can be used to automatically generate wind and snow loads based on the wind surface settings (internal pressure, velocity pressure, wind friction, geometric parameters) and snow surface settings (snow load parameters).

Each direction and surface can be turned on and off for generation by clicking on the checkboxes.

Meteorological load generator

Wind load

Name	Category	Type	Status	<input checked="" type="checkbox"/> 0	<input checked="" type="checkbox"/> 90	<input checked="" type="checkbox"/> 180	<input checked="" type="checkbox"/> 270	Generate
Internal pressure				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wind friction				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
WindSurface1	Wall	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
WindSurface2	Wall	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
WindSurface3	Wall	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
WindSurface4	Wall	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
WindSurface5	Duopitch roof	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Snow load

Name	Category	Type	Status		Generate
Generate exceptional l...					<input type="checkbox"/>
SnowSurface1	Duopitch roof	Standard	Valid	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Cancel OK

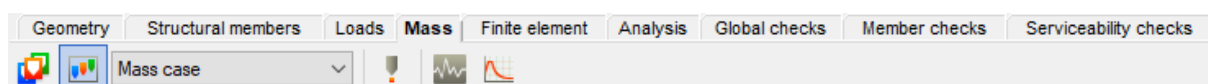
By clicking on the **OK** button, the meteorological load generation will be performed. The necessary load groups and load cases will be created automatically.




7 MASSES

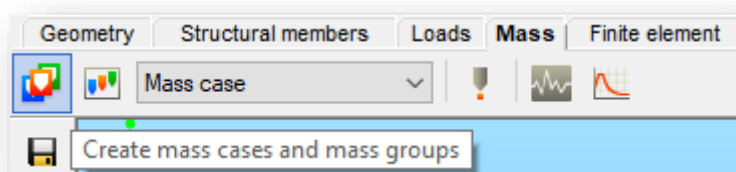
7.1 BASICS

In Consteel 13, the upper bar has changed, since a new tab, Masses were added, which contains such functions, which are necessary for dynamic calculations. Mass cases, and mass combinations can be created for masses which were placed on the model manually or converted from loads into masses.



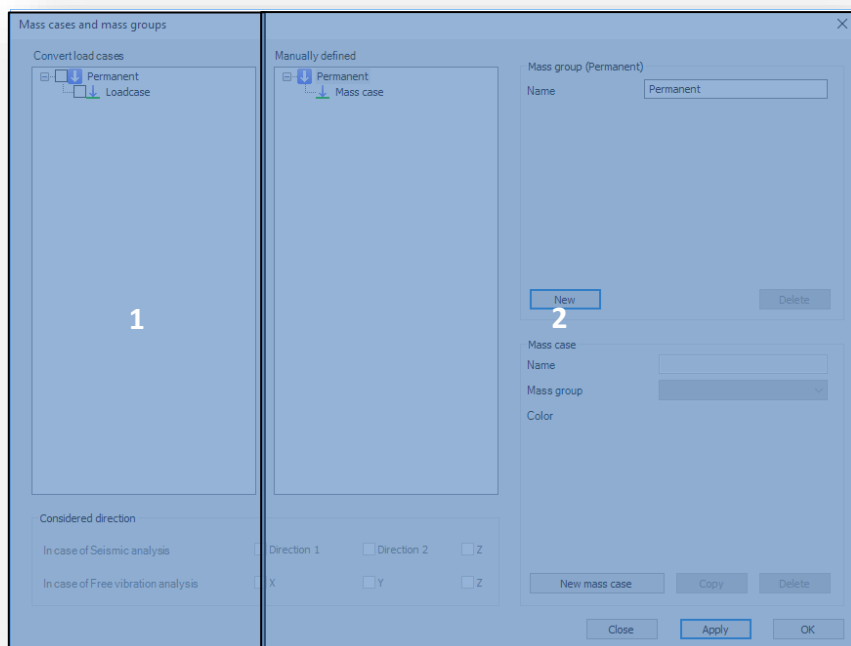
7.2 MASS CASES AND MASS GROUPS

Masses on the structure, just like in the case of loads, has to be grouped together in mass cases and mass groups. Before defining masses on the structure, groups and cases should be defined with using the **CREATE MASS CASES AND MASS GROUPS** () function.



The dialogue can be separated into two main parts:

On the left side of the dialogue (#1), loadcases which were defined on the **LOADS** tab can be converted automatically into masses for the dynamic calculations. On the right side of the dialogue (#2), mass groups and cases can be defined manually.

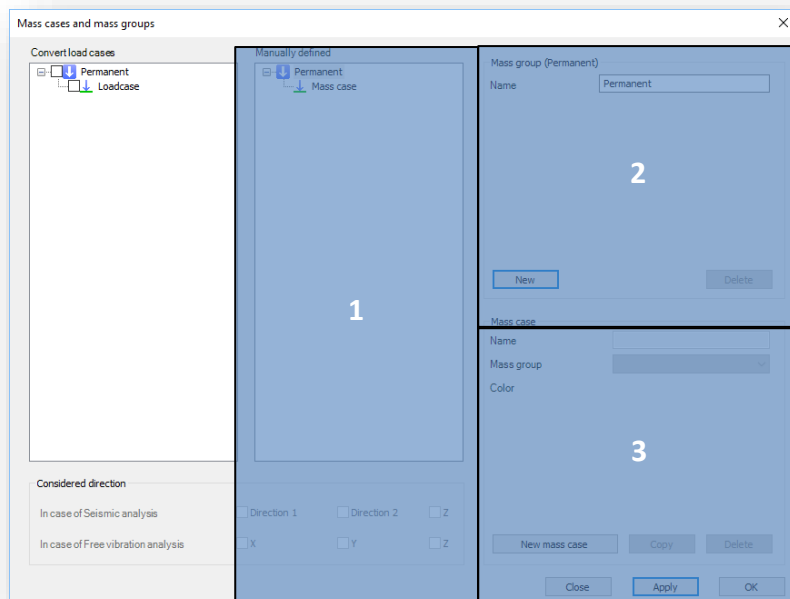


7.2.1. CONVERTING LOADS INTO MASSES

Loads placed on the Loads tab can be converted into masses on the left side of the Mass cases and mass groups dialogue. The tree panel will automatically be filled up with the previously created permanent, variable and snow load groups and their corresponding loadcases. If a checkbox of a loadcase is clicked, it will be converted into mass, after pressing the **OK** or **APPLY** button on the dialogue.

7.2.2. MANUAL DEFINITION OF MASS GROUPS AND MASS CASES

MASS CASES AND MASS GROUPS can be created manually, on the right side of the dialogue, just like in the cases of load cases and load groups.



With the **NEW** button on the *Mass groups* (#2) part of the dialogue, new mass groups can be added to the *Manually defined* tree panel. Permanent, Variable and Snow mass groups can be created. After choosing the correct type, a new element will be added to the tree panel (#1), as a mass group.

With the **NEW MASS CASE** button on the Mass case panel (#3), cases can be added to a previously selected mass group in the tree panel. Any number of mass cases can be added to a mass group. Color of each mass case can be set manually with the color palette, which will be used for the graphical object representation in the modelling area.

Each mass case can be moved from a mass group to another, using the drag-and-drop feature of the tree panel (#1).

7.2.3. CONSIDERED DIRECTION OF MASSES

Both for masses converted from loadcases, and for masses defined manually, the direction in which they will be taken into consideration during the dynamic calculations can be set, on the bottom of the **MASS CASES AND MASS GROUPS DIALOGUE** using the checkboxes, after the selection of a mass case in the tree. In case of seismic analysis, only the global Z direction can be turned off, while in the case of vibration analysis, any direction is free to switch on or off (X,Y,Z).



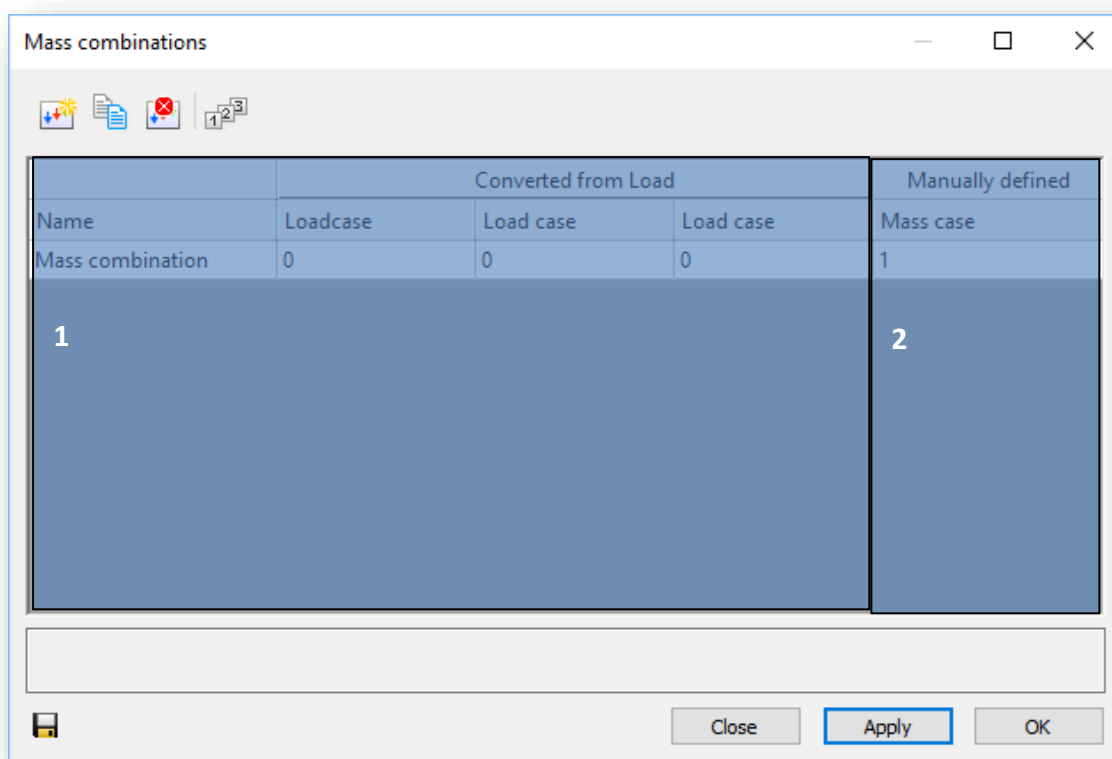
7.3 DEFINITION OF MASS COMBINATIONS

Definition of **MASS COMBINATIONS** works like the **LOAD COMBINATION** definition (**CHAPTER 6.3**), but without the possibility to generate mass combinations automatically. Factors for each mass cases have to be set manually to create a mass combination.


The grid of the mass combinations dialogue can be separated into two parts:

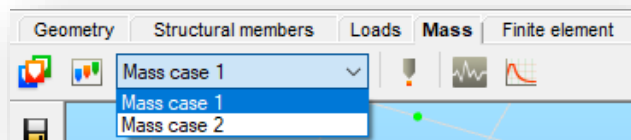
#1 – List of mass cases converted from loads

#2 – List of mass cases defined manually

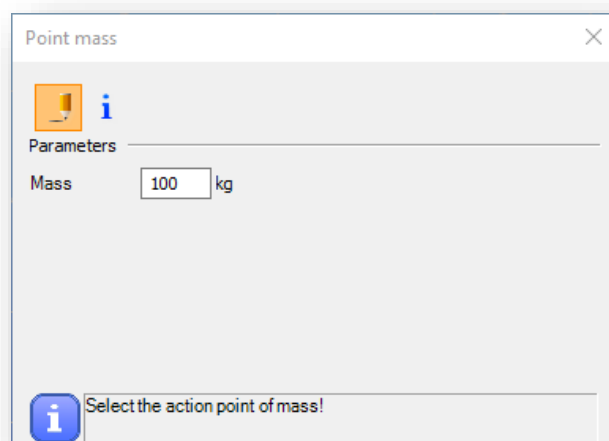


7.4 CREATING POINT MASSES

POINT MASS () objects can be placed on any point of the structure. Every placed point load will be automatically assigned to the active mass case of the mass case dropdown menu.




Point mass can be placed on any point of any bar members, snap points, start and end points and intermediate points are all available. After giving the value of the mass in kg dimension, it can be placed with a simple click on the desired member.



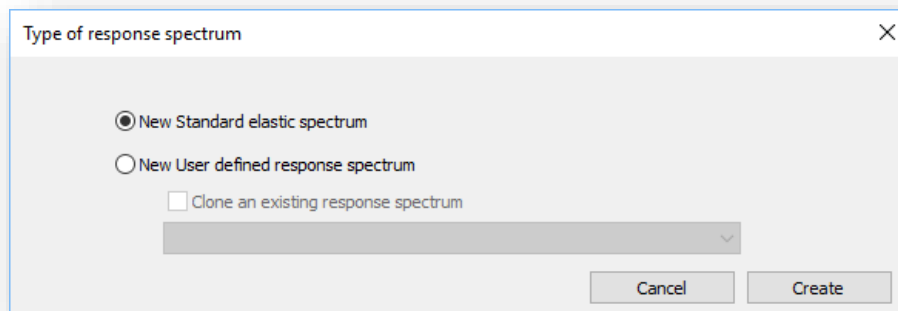
7.5 SEISMIC EFFECT

To see the detailed description of the usage of the **SEISMIC EFFECT**, please go to **CHAPTER 12 EARTHQUAKE ANALYSIS!**

7.6 CREATING RESPONSE SPECTRUMS

With the **CREATE RESPONSE SPECTRUM** () function, two type of response spectra can be defined:

- Standard elastic spectrum: Response spectrum definition according to the selected standard and national annex. Parameters for the definition may varies in case of different annexes.
- User defined response spectrum: Response spectrum definition by defining the points of the spectrum manually

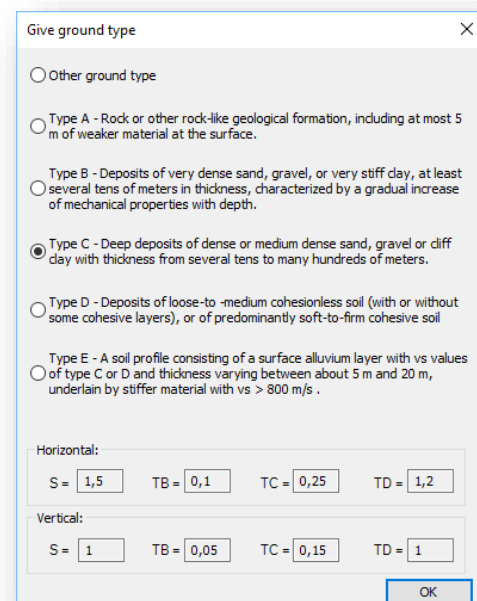


7.6.1. NEW STANDARD ELASTIC RESPONSE SPECTRUM

By choosing the **NEW STANDARD ELASTIC SPECTRUM** option, the spectrum can be created according to the active national which can be used later for response spectrum analysis, and earthquake calculations.

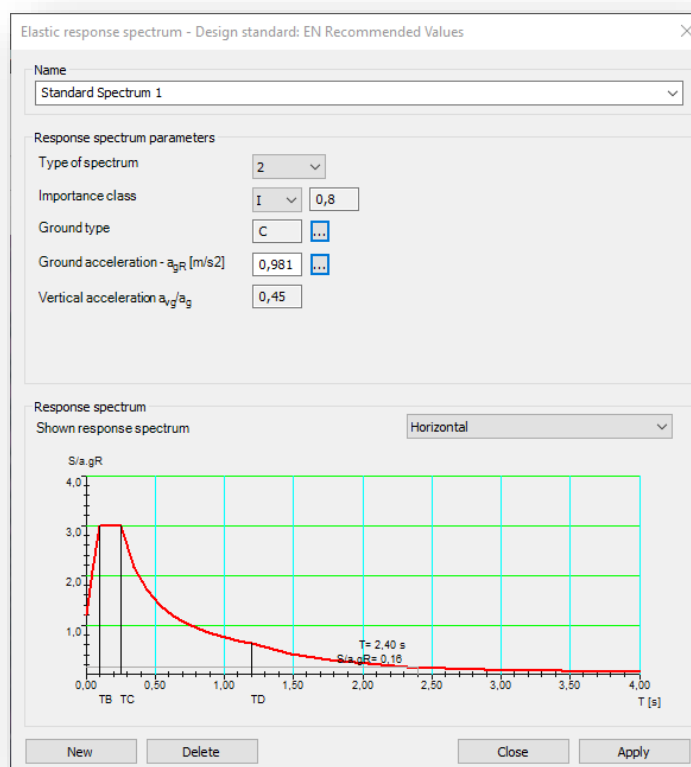
According to the recommended values of *EuroCode*, the following parameters are necessary for the definition of an elastic response spectrum:

- *Type of spectrum*: the dropdown menu is filled up with the possible types of the active annex
- *Importance class*: with the dropdown menu, the importance class of the structure can be selected. Value for each selected class is written into the edit box, next to the dropdown menu, according to the selected annex
- *Ground type*: with the (...) button, the type of the ground below the structure can be selected. At the bottom of the pop-up dialogue, all of the parameters are represented with their values, according to the active annex
- *Ground acceleration* - a_{gR} [m/s^2]: can be defined manually through the edit box, or by clicking on the (...) button, it can be chosen by clicking on a region on the built-in maps:





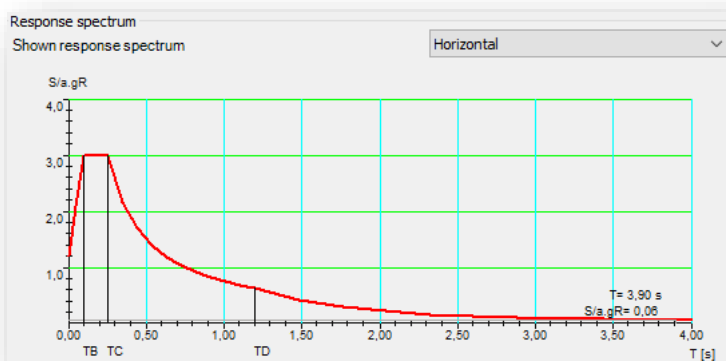
- Vertical acceleration - a_{vg}/a_g : cannot be edited, it is for informative purposes. It shows the actual used value according to the active annex.



On the bottom of the Elastic response spectrum dialogue, the defined spectrum is given graphically too. By hovering the cursor above the graph, the value of each point can be

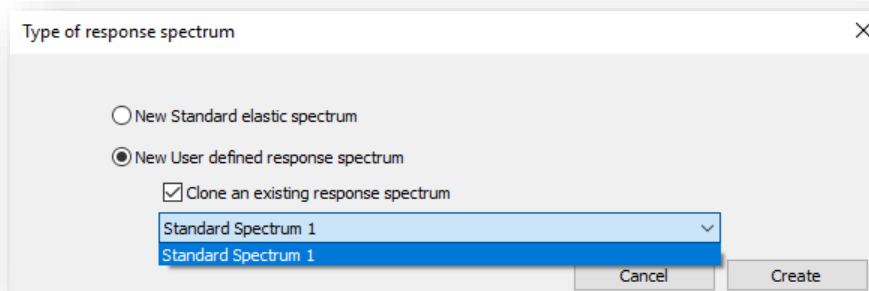


obtained. Switching between vertical/horizontal spectrums can be performed using the dropdown menu.



7.6.2. NEW USER DEFINED RESPONSE SPECTRUM

Consteel provides two ways for the definition of **NEW USER DEFINED RESPONSE SPECTRUMS**:



1. Response spectrum can be created manually from scratch, by simply clicking on the **CREATE** button
2. Response spectrum creation based on an existing standard spectrum, by cloning and modifying it. If the **CLONE AN EXISTING RESPONSE SPECTRUM** checkbox is checked in, the dropdown menu of the previously defined spectrums will become active. By choosing a standard response spectrum, and clicking on the **CREATE** button, modification of the selected spectrum can be started.

7.6.2.1 MANUAL DEFINITION OF RESPONSE SPECTRUM

After selecting the **NEW USER DEFINED RESPONSE SPECTRUM** option, and clicking on the **CREATE** button, the creation dialogue will appear.



Response spectrum

Name
User Defined Spectrum 2

Response spectrum parameters

1
Ground acceleration - a [m/s^2] 0,981 ... Vertical acceleration a_v/a 0,45

☒ Design response spectrum ☐ Elastic response spectrum

2
Edit spectrum points
Horizontal and vertical

3
Same in all directions

4
[Icon]

5
[Icon]

Num.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T [s]	0,00	0,05	0,10	0,18	0,25	0,34	0,44	0,54	0,63	0,73	0,82	0,92	1,01	1,11	1,20
S/a	1,500	2,625	3,750	3,750	3,750	2,717	2,131	1,752	1,488	1,293	1,143	1,025	0,928	0,848	0,78

< >

Response spectrum

S/a

T [s]



New Delete Close Apply

On the *Response spectrum parameters* part (#1), the following parameters has to be set:

- *Ground acceleration - a [m/s^2]*: can be defined manually through the edit box, or by clicking on the (...) button, it can be chosen by clicking on a region on the built-in maps.
- *Vertical acceleration a_v/a : ratio of the vertical/horizontal acceleration* can be set in the edit box
- *Type of the response spectrum*: Design or Elastic response spectrum can be chosen. Design response spectrum will be used in design situations, while elastic response spectrum will be used in case of serviceability situations


In the *Edit spectrum points* part of the dialogue, the graph of the response spectrum can be defined, by giving the time parameter in seconds, and the corresponding spectrum value divided by the acceleration.



Any number of columns can be added to the spectrum definition grid. By pressing the  (#5), new columns can be added. Using the  (#4), columns can be deleted.

A newly defined user response spectrum is the same in all (X,Y,Z) directions. If it is necessary, different spectrums can be defined for each direction, using the dropdown menu on the dialogue.

The data of the spectrum can be saved in *.csv and *.txt format, using the  (#4) button.

Previously created and saved spectrums can be imported using the  (#4) button

7.6.2.2 MANUAL DEFINITION OF RESPONSE SPECTRUM, BASED ON A CLONED STANDARD SPECTRUM

After selecting the **NEW USER DEFINED RESPONSE SPECTRUM** by cloning an existing response spectrum, and pressing the **CREATE** button, the modification of the selected standard spectrum can be started. All points of the standard design spectrum will automatically be loaded into the table of the definition dialogue, where any point and parameter are free for to edit.

All of the modification options are the same as it is written in chapter **MANUAL DEFINITION OF RESPONSE SPECTRUM, CHAPTER 7.6.2.1**



8 STRUCTURAL ANALYSIS

8.1 BASICS

The analysis of the structural model can be the most “black box” type phase of the design process for the engineer, and additionally the modern structural standards usually define the appropriate and required analysis type for the used design formula. The Consteel applies the finite element method for all the calculations using two beam-column element types (traditional 12 DOF Timoshenko and 14 DOF thin-walled including warping of the section) and two shell elements (triangle and quadrilateral). The great variety of calculation possibilities includes first and complete second order (not only $P-\delta$ effect) analysis; flexural-, torsional-, and lateral-torsional buckling solutions; local buckling analysis of slender steel members built from shell elements; static and dynamic eigenvalue analysis and earthquake calculation based on elastic response spectrum and modal analysis. The exceptionally fast and robust equation solvers yield optimal calculation time even for unusually huge models. The functionalities connected with the structural analysis are placed on two tabs: the **FINITE ELEMENT** and **ANALYSIS** tab. On the **FINITE ELEMENT** tab mesh generation options are available for surface elements, and the generated finite element model can be viewed. Usually this step can be skipped since in the first step of the analysis the finite element mesh generation is automatically performed.

8.2 FINITE ELEMENTS

8.2.1 BASICS

The mechanical performance of the calculated model is always highly influenced and limited by the applied finite element type. The considered displacements, forces, shape functions, second order effects within the finite element model basically determine the quality of the analysis, the expectable results and accordingly the applicable standard verification methods. On the other hand the engineer should be aware of the important characteristics of the used finite elements already at the model building phase in order to avoid the non-expected structural behavior and calculate the mechanical performance of the imagined structure as accurate as possible. In *Consteel* all the finite element models always have the real 3D behavior; there are no options for special reduced degree of freedom calculations (plane frames, plate or membrane surfaces etc.) if it is required appropriate support and/or load system should be applied. All the defined loads and supports are converted to nodal forces by

load cases and nodal supports, no forces or supports are considered along the finite elements, this feature is taken into account during the automatic FE mesh generation.

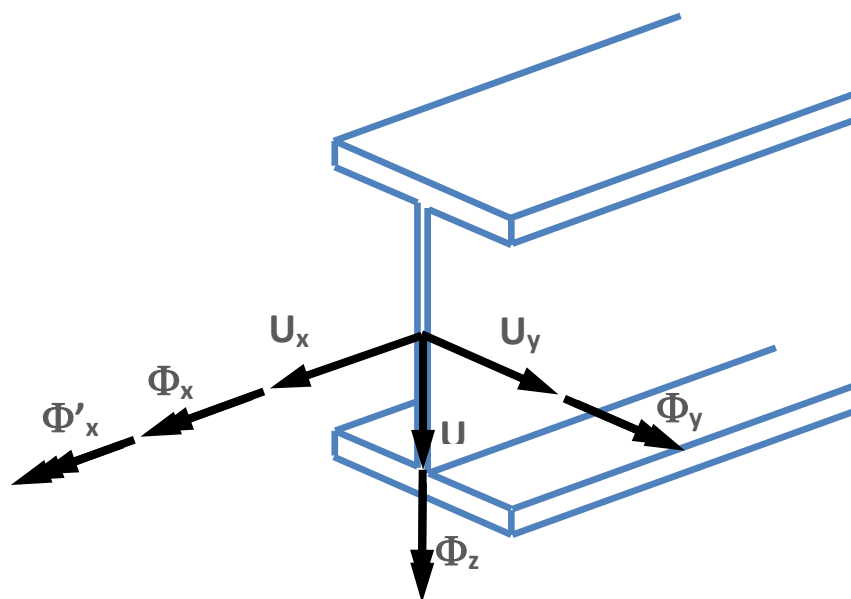
The subsequent sections do not intend to introduce the deep theory behind the applied finite elements – it can be found in the literature – only the most significant features are presented and explained which are important to know for the appropriate interpretation of the results.

8.2.2 LINE ELEMENTS

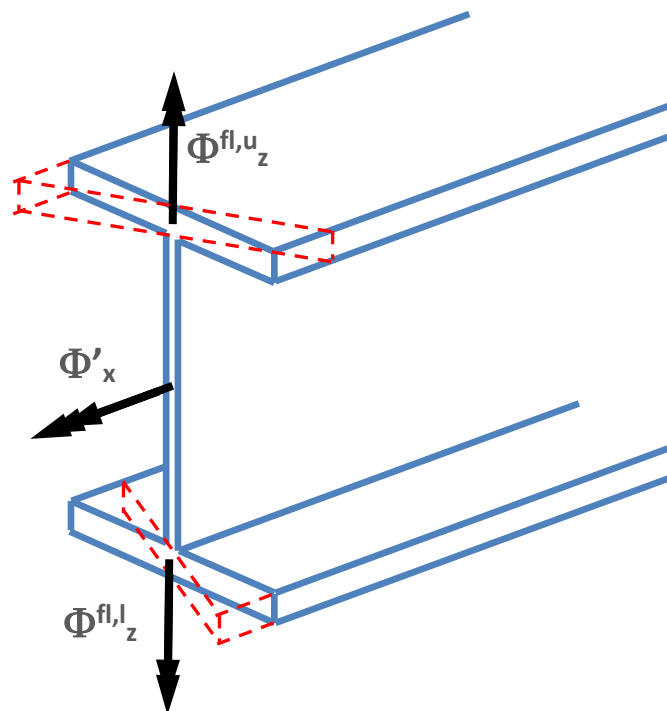
There are three options for line elements:

- ▶ a 6 degrees-of-freedom (6DOF) general beam-column element for the bars subjected to axial force, shear force, bending moment, torsion, or any interaction of these
- ▶ a 7 degrees-of-freedom (7DOF) beam-column with warping element for the bars subjected same as 6DOF element + warping effect
- ▶ a tension-only (TO) element for bars subjected by tension force

The 7DOF element is specially developed for thin-walled members where the warping of the cross-section is of high importance in the behavior, this effect is considered by the 7th DOF. In the following figure the considered nodal displacements are illustrated:



The first 6 DOF are the conventional displacements (U_x , U_y , U_z) and rotations (Φ_x , Φ_y , Φ_z) according to the local coordinate system of the member (see section **4.2 COORDINATE SYSTEMS**). What needs more explanation is the 7th DOF which is mathematically the first derivative of the twist about the longitudinal axis (Φ'_x); mechanically it represents the warping of the section which is straight consequence of torsion on thin-walled members. The next figure illustrates the warping effect of I shaped cross-section when the flanges step out of the original plane of the section.



In this case the warping DOF can be considered as a dual and opposite rotation of the flanges about the axis perpendicular to their width (in this case the local axis “z”).

Since steel members are usually relatively slender various modes of global stability failure can occur: flexural buckling, torsional buckling, lateral-torsional buckling and any interactions of these, all modes can be calculated by the 7DOF element. It is a quite important and advantageous feature in the stability design of these members but since the accurate calculation of all the torsional modes is highly dependent on the 7th warping DOF it is essential to consider this effect already in the modelling phase (see chapter **5 STRUCTURAL MODELLING** for the modelling warnings).

The TO elements have only 1 DOF which is the longitudinal displacement (U_x). These elements are considered in the calculation only if they are subjected to tension accordingly the calculations are iterative in nature. At first an analysis is performed considering all the TO elements modeled by one finite element. Next a force check is executed on the TO elements and the compressed ones are neglected from the model and a new calculation is initiated. It is continued until all the TO elements have tension. This model configuration is taken into account in the eigenvalue calculations.



SINCE THE EIGENVALUE CALCULATIONS CANNOT BE PERFORMED ITERATIVELY IT MAY HAPPEN THAT IN THE EIGENSHAPE THE TO ELEMENT GETS COMPRESSION I.E. ITS LENGTH SHORTENS. IN THIS CASE IF THIS EFFECT IS SIGNIFICANT AND SHOULD BE AVOIDED A NEW EIGENVALUE ANALYSIS SHOULD BE RUN WITHOUT THE TO ELEMENT.



8.3 MODEL CHECK (DIAGNOSTICS)

In *Consteel* there is a possibility to perform a model check previous to executing any calculations. This function automatically runs before starting the finite element mesh generation or analysis but can be initiated any time (switching the “Diagnostics” on the **VIEW** menu and run) examining the recent state of the model. There are two kinds of diagnostics messages:

- ▶ **ERROR**: the errors make the calculations impossible or meaningless to execute so the detected errors stop further calculations
- ▶ **WARNING**: the warnings allow the calculations but notice the possible errors

One part of the model checks is performed on the user model (basic check), where basic requirements for the normal performance of a model are controlled; the other part is performed on the generated finite element model (pre-calculation check).

The following basic checks are performed:

- ▶ existence of load on the structure
- ▶ existence of support on the structure
- ▶ length of bars, line loads and line supports
- ▶ value for the thickness and finite element size for surface members
- ▶ overlap, length and compatibility of haunches
- ▶ multiple supports on the same place
- ▶ compatibility of tension bars

The following pre-calculation checks are performed:

- ▶ overhang of line loads and line supports
- ▶ point loads and point supports are not on the model
- ▶ overlap of surface members
- ▶ overlap of bar members
- ▶ very small distance (< 5 mm) between points or lines of surfaces, bars, loads or supports (the limit distance can be set in the **OPTIONS** menu)

The object which the errors or warnings are detected can be selected and deleted from the diagnostics results table (in the middle of the right tables).



8.4 ANALYSIS SETTINGS

The required analysis types can be set on the **SET ANALYSIS PARAMETERS** dialogue, which has one **OVERVIEW PAGE**, and four subpages for the three type of separated analysis settings for the better transparency. These four types of analysis settings are:

- ▶ **GLOBAL SETTINGS** (with Subpage of global settings **8.4.2.**)
- ▶ **STATICAL ANALYSIS** (with Subpage of load cases **8.4.3**, Subpage of load combinations **8.4.4.**)
- ▶ **DYNAMIC ANALYSIS** (with Subpage of dynamic analysis **8.4.5.**)

8.4.1 OVERVIEW PAGE

On the so-called **OVERVIEW PAGE** settings of the analysis are applied on all load cases/load combinations etc.

For a better transparency the analysis settings are ordered in separated groups.

The screenshot shows the 'Set analysis parameters' dialog box with the following sections:

- 1 Global settings**
 - Global imperfection: - No -
 - ☐ Include connection stiffness
 - ☐ Cold formed purlin design mode
- 2 Statical analysis**
 - Load cases**
 - ☐ Elastic analysis of load cases
 - ☐ Second order analysis of buckling mode based imperfection load cases
 - ☐ Elastic analysis of basic values of reactions for foundation checks
 - Load combinations**
 - Type of calculation: Elastic
 - Ultimate limit states**
 - ☒ First order analysis
 - ☒ Second order analysis
 - ☒ Buckling analysis
 - ☒ Buckling sensitivity
 - ☒ Imperfection sensitivity
 - Serviceability limit states**
 - ☐ First order analysis
 - ☐ Second order analysis
 - ☐ Use effective section properties
 - Influence graphs**
 - ☐ Elastic analysis of influence graphs
- 3 Dynamic analysis**
 - ☐ Free vibration analysis
 - ☐ Response spectrum analysis

Buttons at the bottom: Cancel, Calculation, Apply.




Settings of the **Global settings** group (#1) are applied for the whole model:

- ▶ With the **global imperfection** dropdown menu previously created Global imperfection (see. chapter 6.5) can be set for the model. Only one global imperfection group can be applied in the same time
- ▶ **Include connection stiffness**: with this checkbox the previously created and placed joints' stiffness can be used during the calculation. By turning on the checkbox, connection stiffnesses will be applied on all of the load combinations in the model.
- ▶ By activating the **Cold formed purlin design mode**, all parameters that have been previously defined with the help of purlin design functions can be taken into account in the analysis, such as lateral support provided by the sheeting, in the case of purlin overlap, the stiffness of the overlap section.

For further settings, the **SUBPAGE OF GLOBAL SETTINGS** can be opened with the  button.


Settings of the **Statical analysis** group (#2):

- ▶ Load cases group
 - **Elastic analysis of load cases**: with this checkbox selected the analysis results can be viewed also for the separate load cases in addition to the load combinations. It is only valid for elastic calculations.
 - **Second order analysis of buckling mode based imperfection load cases**: the results of the buckling mode based imperfection loads can be viewed separately for each imperfection in the imperfection group if this checkbox is selected.
 - **Elastic analysis of basic values of reactions for foundation checks**: for the special load combinations necessary for the foundation design in **CSJOINT**, the third checkbox should be checked. **SUBPAGE OF LOAD CASES** can be accessed with the  button.
- ▶ In the Load combination group,
 - the type of analysis can be selected from the dropdown menu. Basically two types of analysis can be performed: 1) elastic: all the elements have linear elastic material following the Hook-law, 2) plastic: plastic hinge analysis considering the concentrated plastification of special cross sections due to bending moment, detailed description is in chapter **8.5.2**.
 - Necessary analysis types (first or second order) can be set separately for the ULS and the SLS load combinations.
 - With the Buckling and Buckling sensitivity analysis checkbox the calculation of the buckling analysis can be decided. If buckling analysis is turned on 10



eigenshapes will be calculated for each load combinations by default. The number of the eigenshapes can be modified in the subpage.

- The imperfection sensitivity test must be switched on if we want to apply the eigenshape-based imperfection load on the structure, scaled by the Overall Imperfection Method (OIM) described in 6.5.3.2.

Further options of the above analysis types and individual selection of the load combinations see the **SUBPAGE OF LOAD COMBINATIONS** with the  button.

► Settings of the **Influence graphs** group

Settings of the **Dynamic analysis** group (#3:)

- In the Dynamic analysis group, the parameters of the dynamic analysis can be set. Free vibration analysis and Modal Response Spectrum Analysis (*Seismic MRSA*) can be calculated.

For further settings, the **SUBPAGE OF DYNAMIC ANALYSIS** can be opened with the  button.



8.4.2 SUBPAGE OF GLOBAL SETTINGS

Set analysis parameters

Back

Import stiffness of semi-rigid connections in the analysis by load combinations

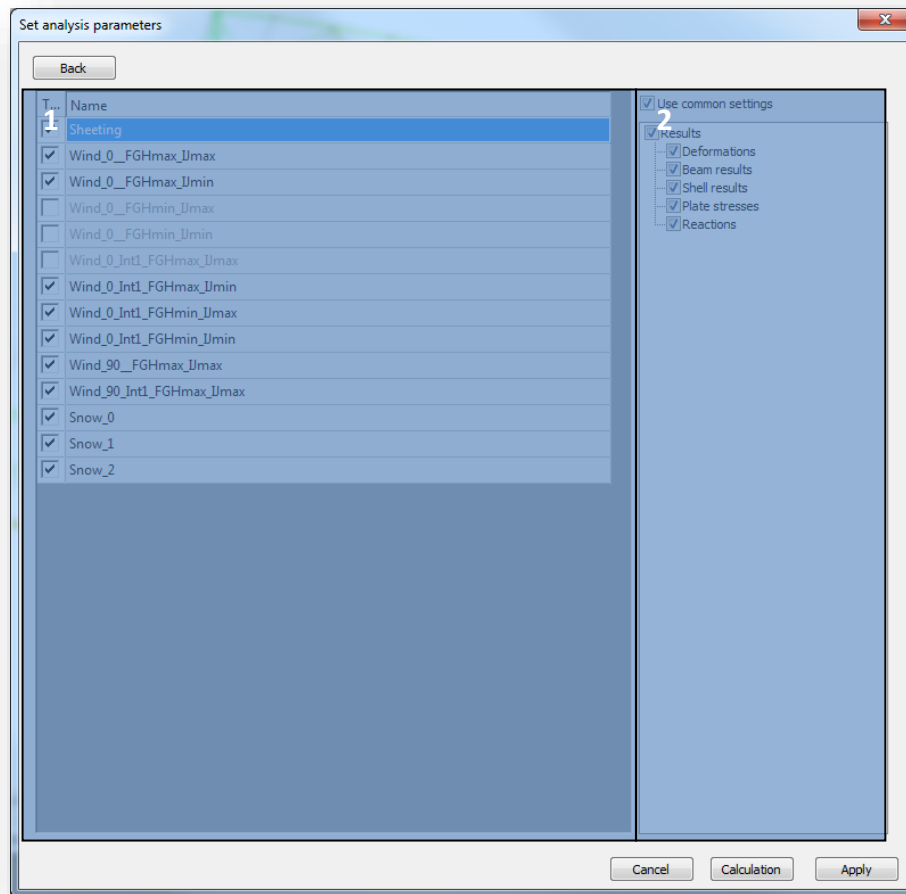
Load combinations	Apply connection stiffness	Use S_{red} instead of S_{lim}/η
(ULS) Load combination-1	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-2	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-3	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-5	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-6	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-7	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-8	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-9	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-10	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-11	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-12	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-13	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-14	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-15	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-16	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-17	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-18	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-19	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-20	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-21	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-22	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-23	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-24	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-25	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-26	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(ULS) Load combination-27	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Cancel Calculation Apply

On this subpage, previously created and placed joints' stiffness can be applied in the calculation in the selected load combinations. With the checkboxes in the second column secant stiffness can be used instead of initial stiffness.



8.4.3 SUBPAGE OF LOAD CASES



This subpage has two main parts:

► The load cases table (#1)

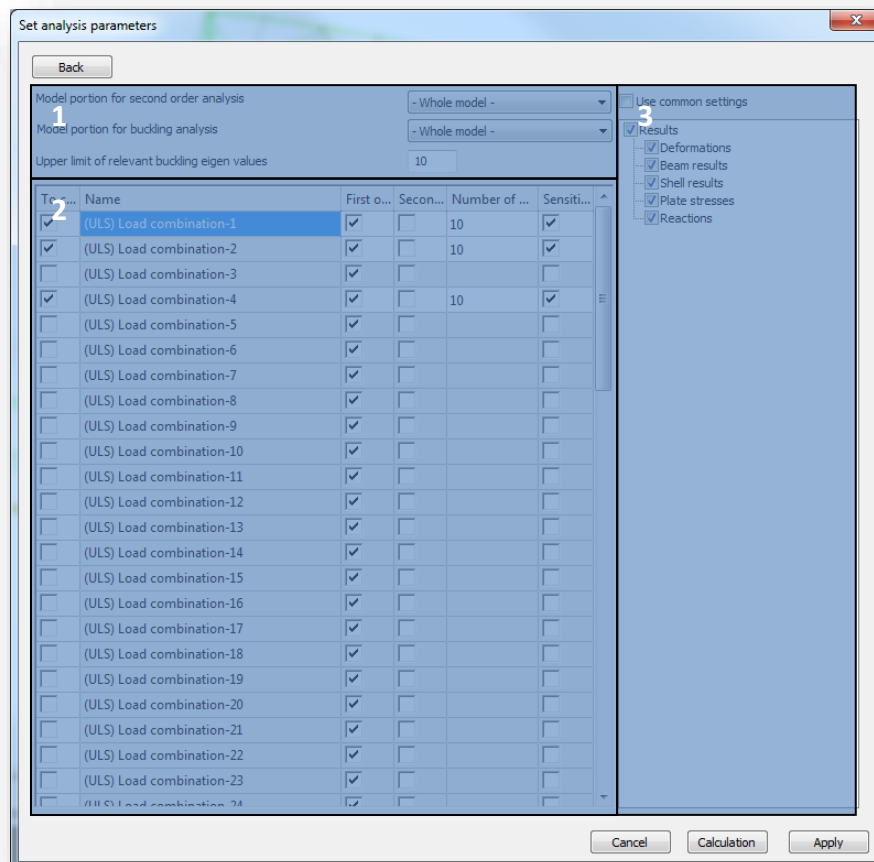
In this table, all of the loadcases are listed. With the checkboxes, it can be decided that which of the loadcases should be calculated during the analysis. Results for load cases will be calculated according to the settings in the result tree (#2)

► The result tree (#2)

In the result tree, it can be decided, that which result type should be calculated for the load cases. Calculated results can be a common setting for all of the load cases if the **USE COMMON SETTINGS** checkbox is clicked. If it is unclicked, calculated results can be set differently for each loadcases by clicking on the name of a loadcase and selecting the proper result types.



8.4.4 SUBPAGE OF LOAD COMBINATIONS



This subpage has three main parts:

► Portion and relevant buckling eigenvalues settings (#1)

In the dropdown menu previously created model portion or whole model can be selected for second order and buckling analysis. The analysis will be performed just for the selected portion. Here can be entered also the upper limit of the relevant buckling eigen values. All the eigen values which are higher than the limit will be skipped. Because of this the final number of the calculated eigenshapes could be less than required.

► The load combinations table (#2)

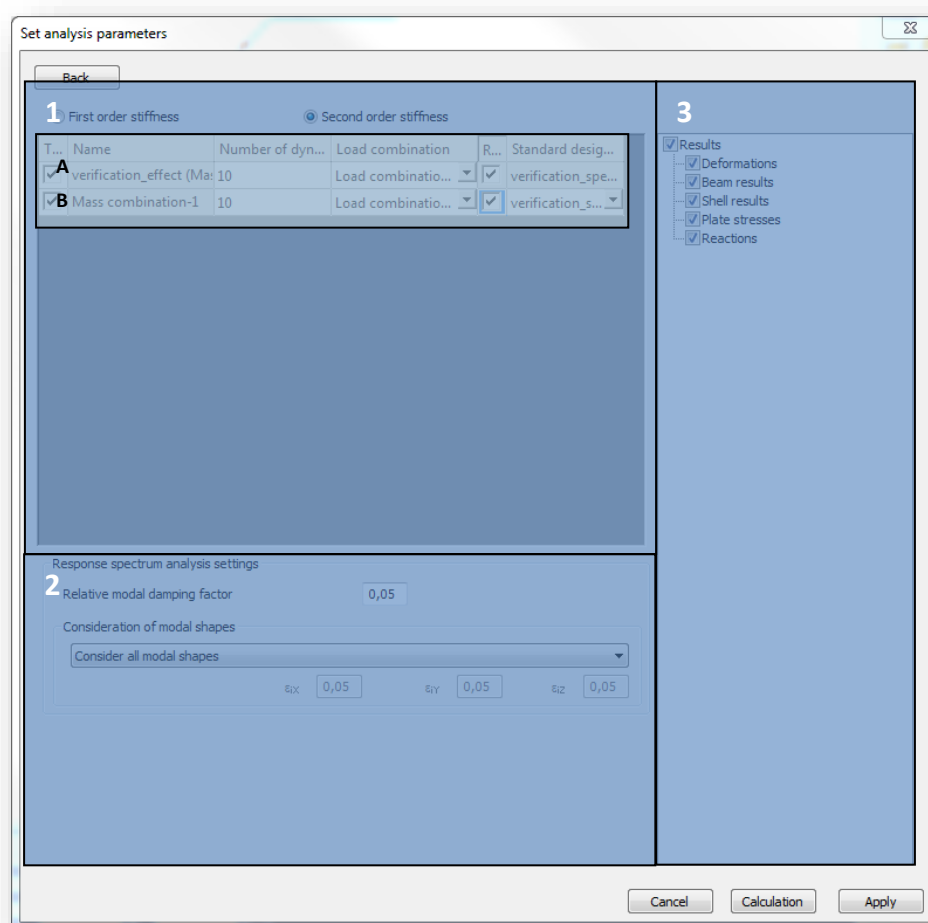
In this table, all of the loadcases are listed. With the checkboxes in the first column, it can be decided that which of the load combinations should be calculated during the analysis. First and second order analysis calculation can be turned on or off for each combination, as well as the calculation of buckling sensitivity. Number of calculated eigenshapes can be given for each combination individually Results for load cases will be calculated according to the settings in the result tree (#3)



► The result tree (#3)

In the result tree, it can be decided, that which result type should be calculated for the load combinations. Calculated results can be a common setting for all of the load combinations if the **USE COMMON SETTINGS** checkbox is clicked. If it is unclicked, calculated results can be set differently for each load combinations by clicking on the name of a load combination, and by selecting the proper result types.

8.4.5 SUBPAGE OF DYNAMIC ANALYSIS



This subpage has three main parts:

► The dynamic calculation settings table (#1)

Above the table, it can be decided, if first, or second order stiffness matrix should be used for the dynamic calculations. In case if the second order stiffness checkbox is checked, an additional Load combination column will appear in the table below, where it has to be decided that which load combination's second order stiffness should be used for each seismic or dynamic calculation.



In the table, the previously defined seismic effect, and all of the mass combinations are being listed as individual rows. Number of dynamic eigenshapes can be defined for each effect and mass combination, the default value is 10.

The rows of the table can be separated into two groups:

- A, Row for Modal Response Spectrum Analysis (MRSA)

For seismic MRSA calculation, it is necessary to have at least one **SEISMIC EFFECT** defined and assigned to the seismic load group in the model. For the possibilities of definition of seismic effects, please check out **CHAPTER 12 EARTHQUAKE ANALYSIS**.

- B, Rows for dynamic and response spectrum analysis

Each defined **MASS COMBINATION** is listed as an individual row in the table.

According to the settings on the analysis Overview page in chapter **8.4.1**, free vibration and response spectrum analysis can be performed.

In case if the check box of “To calculate” is turned on, and “Response spectrum analysis” is turned off for a mass combination, only a **FREE VIBRATION ANALYSIS** will be performed.

In case if bot of the “To calculate” and “Response spectrum analysis” checkboxes are turned on for a mass combination, **RESPONSE SPECTRUM ANALYSIS** will be added to the free vibration calculation. Predefined response spectrum is necessary to be defined previously in the model.

- ▶ The Response spectrum analysis settings (#2)

Covers the relative modal damping factor, what can be overwritten manually, and the consideration of modal shapes in each direction. By default, all of the modal shapes will be considered during the calculation, what can be changed using the dropdown menu.

- ▶ The result tree (#3)

In the result tree, it can be decided, that which result type should be calculated for the mass combinations. Calculated results can be a common setting for all of the mass combinations if the **USE COMMON SETTINGS** checkbox is clicked. If it is unclicked, calculated results can be set differently for each mass combinations by clicking on the name of a mass combination, and by selecting the proper result types.



8.5 ANALYSIS TYPES

8.5.1 ELASTIC ANALYSIS

8.5.1.1 FIRST ORDER

The first order analysis calculates the structural response considering the initial stiffness of the model. It is advisable to run a first order analysis in order to check the model performance before executing more costly calculations (for instance eigenvalue analysis). The steps of the first order analysis are the following:

1. Calculation of first order (initial) stiffness matrices (\mathbf{K}_s^{el}) of the finite elements in their local coordinate system
2. Compiling the global stiffness matrix (\mathbf{K}_s) and nodal force vector (\mathbf{P}) of the whole model by transforming the element stiffness matrices into the global coordinate system
3. Modifying the global stiffness matrix and nodal force vector considering the special boundary conditions (supports, continuity releases between the elements, prescribed displacements, temperature loads etc.)
4. Solution of the basic linear system of equations which writes the relationship between the applied nodal forces – known variables generated from the loads – and the nodal displacements – unknown variables (\mathbf{U}) – in the global coordinate system for the global model (see section **8.2 FINITE ELEMENTS** for the interpretation of nodal displacements and forces):

$$\mathbf{K}_s \mathbf{U} = \mathbf{P} \quad \rightarrow \quad \mathbf{U} = \mathbf{K}_s^{-1} \mathbf{P} \quad (1)$$

5. Calculation of the internal forces (and stresses) of the elements (\mathbf{f}^{el}) in their local coordinate system by transforming the global nodal displacements of the element into local system (\mathbf{u}^{el}) using their local stiffness matrices:

$$\mathbf{f}^{el} = \mathbf{K}_s^{el} \mathbf{u}^{el} \quad (2)$$

8.5.1.2 SECOND ORDER

The second order calculations take into account that the loaded and deformed structure can behave differently than the initial configuration. This effect can be considered as if the initial stiffness was changing during the loading history. The steps of the second order analysis are the following:

1. Performing the whole first order analysis as described in the previous section
2. Calculation of geometric stiffness matrices (\mathbf{K}_g^{el}) of the finite elements in their local coordinate system by the internal forces of the elements (\mathbf{f}^{el})



3. Compiling the second order global stiffness matrix ($\mathbf{K}_s + \mathbf{K}_g$) and nodal force vector (\mathbf{P}) of the whole model by transforming the element stiffness matrices into the global coordinate system
4. Modifying the second order global stiffness matrix and nodal force vector considering the special boundary conditions (supports, continuity releases between the elements, prescribed displacements, temperature loads etc.)
5. Solution of the basic linear system of equations which writes the relationship between the applied nodal forces – known variables generated from the loads – and the nodal displacements – unknown variables (\mathbf{U}) – in the global coordinate system for the loaded and deformed global model (see section **8.2 FINITE ELEMENTS** for the interpretation of nodal displacements and forces):

$$(\mathbf{K}_s + \mathbf{K}_g)\mathbf{U} = \mathbf{P} \quad \rightarrow \quad \mathbf{U} = (\mathbf{K}_s + \mathbf{K}_g)^{-1}\mathbf{P} \quad (3)$$

6. Calculation of the internal forces (and stresses) of the elements (\mathbf{f}^{el}) in their local coordinate system by transforming the global nodal displacements of the element into local system (\mathbf{u}^{el}) using their local stiffness matrices:

$$\mathbf{f}^{el} = \mathbf{K}_s^{el} \mathbf{u}^{el}$$

7. If the difference between the new nodal displacements and the ones obtained earlier exceeds a certain limit repeat the calculations from step 2

8.5.1.3 STATIC EIGENVALUE – BUCKLING ANALYSIS

In a mechanical interpretation the eigenvalue analysis approximates the elastic critical load levels where the structure is subjected to some modes of loss of stability. Mathematically it means that the second order equation of (3) has no unique solution because the second order stiffness matrix is singular. In *Consteel* linear eigenvalue analysis is performed considering one parameter, conservative loading and that the geometric stiffness matrix depends linearly on the load factor (λ):

$$\mathbf{K}_g(\lambda \mathbf{f}) = \lambda \mathbf{K}_g(\mathbf{f}) \quad (4)$$

In this case the eigenvalue analysis can be written in the following form:

$$(\mathbf{K}_s + \lambda \mathbf{K}_g)\mathbf{U} = 0 \quad (5)$$

The solutions are certain critical load factors (buckling loads factor λ_{cr}^i) which make the second order stiffness matrix singular and corresponding displacements (buckling shapes \mathbf{U}^i).

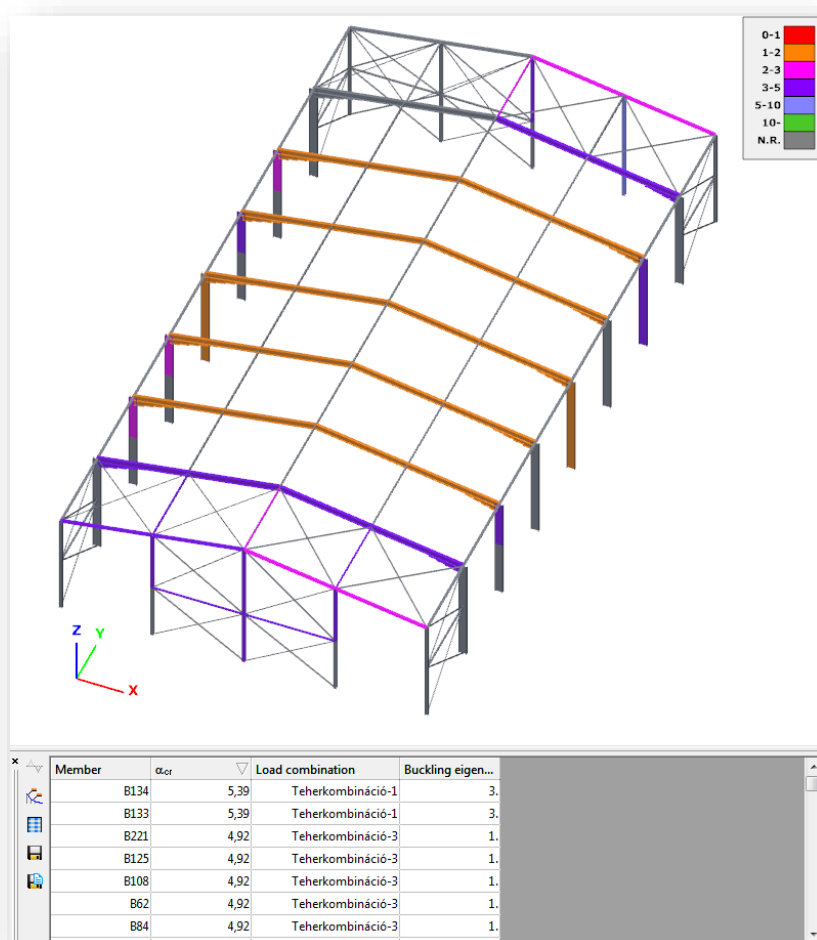
The possible buckling shapes which can be calculated by this eigenvalue analysis are basically influenced by the considered second order effects which are determined by the applied finite element. In case of beam-column structures the 7 DOF finite elements have the capability to



consider all modes of global buckling shapes: flexural buckling, torsional buckling, lateral-torsional buckling, and any interactions of these.

8.5.1.4 BUCKLING SENSITIVITY

Buckling sensitivity analysis is a very useful function to assist the global stability design. Buckling sensitivity gives a review about the eigen shapes of the structure and gives for every member the relevant eigen shape which is the best for the buckling analysis. Based on this analysis the software can automatically select the appropriate critical load factor for the global design. See 9.2.1 **GLOBAL CHECK**



8.5.1.5 IMPERFECTION SENSITIVITY

This analysis determines the critical member and critical section for each of the eigen shapes. With the help of this analysis the appropriate amplitude of the buckling shape-based imperfection can be calculated. The graph shows the stress-based utilization from the internal forces obtained by applying the eigen shape as an imperfection displacement load,



where the cross-section corresponding to the highest utilization is given the value 100%. See more in chapter 6.5.3.2.

8.5.1.6 DYNAMIC EIGENVALUE – VIBRATION ANALYSIS

In a mechanical interpretation the dynamic eigenvalue analysis approximates the eigenfrequencies where the structure is subjected to some modes of free vibration. In *Consteel* linear eigenvalue analysis is performed considering the second order stiffness matrix and consistent mass matrix (**M**)

$$((\mathbf{K}_s + \mathbf{K}_g) + \omega^2 \mathbf{M})\mathbf{U} = 0 \quad (6)$$

The solutions are certain eigenfrequencies (ω^j) and corresponding displacements (free vibration shapes \mathbf{U}^j).


The possible vibration shapes which can be calculated by this eigenvalue analysis are basically influenced by the considered stiffness and mass matrices which are determined by the applied finite element. In case of beam-column structures the 7 DOF finite elements have the capability to consider all modes of global vibration shapes: flexural, torsional, lateral-torsional vibration and any interactions of these.

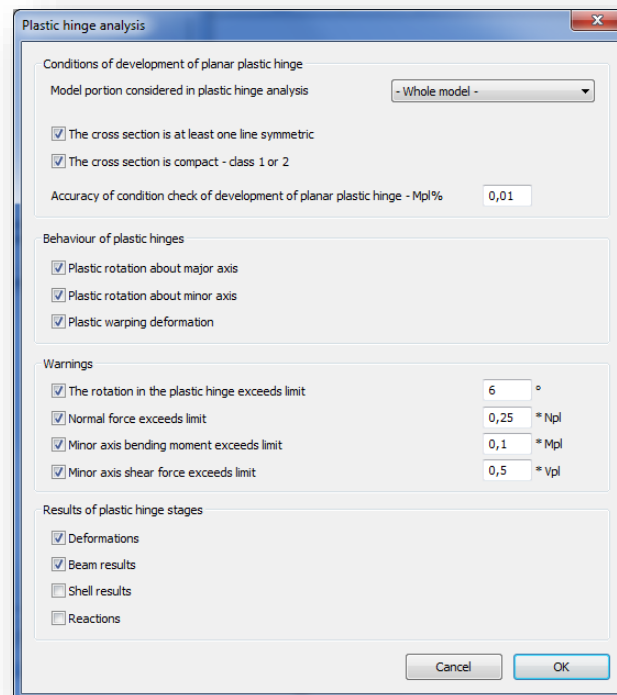
8.5.2 PLASTIC ANALYSIS

To start a plastic analysis, go to the **ANALYSIS SETTINGS** window of the **ANALYSIS** tab. This requires the selection of the **PLASTIC** option of the **CALCULATION TYPE** drop-down menu.



8.5.2.1 BASIC

When plastic analysis is selected a plastic hinge analysis is performed considering planar hinges which may develop about the local y axis of the cross sections due solely to the major axis bending moment (M_y) – no other effects (like shear, normal force or minor axis bending) influence the formation of the hinge. The basic settings for the plastic analysis are available by pressing the three dots () button next to the *Type of calculation* combo on the **SET ANALYSIS PARAMETERS** dialogue.



The first group of options controls the conditions for the development of the plastic hinge. The proper model portion can be selected where the hinges are searched. Two options are available for the cross section where hinges may develop: limited to at least singly symmetric (about the local 'z' axis) and to compact (AISC) or class 1 (EC) sections. According to the usual rules of design standards these last two restrictions are necessary for the plastic hinge analysis. The accuracy of the hinge calculation can also be set as the percentage of the plastic bending resistance (M_{pl}).

In the second group of options the mechanical behavior of the plastic hinges after formation. Since the planar hinges are part of a spatial model (the "planar" word refers only to the source of the hinge formation) the further mechanical behavior should be defined as a spatial hinge object (spatial release). Accordingly, the hinge can rotate about the major axis (in the original plane of source bending moment M_y), about the minor axis together with free warping deformation. The two latter options are realistic considering that a planar plastic hinge in an I-shaped section practically causes fully yielded flanges which obviously implies the minor axis rotation and warping hinge behavior. These options influence however only the out-of-plane behavior of the model (for instance buckling of members next to the hinge out-of-the-plane of the planar hinge).

The third group of options offers warning displays. These warnings are indicating if the plastic hinge is significantly influenced by other effects than the major axis bending moment (M_y) during the whole hinge history.



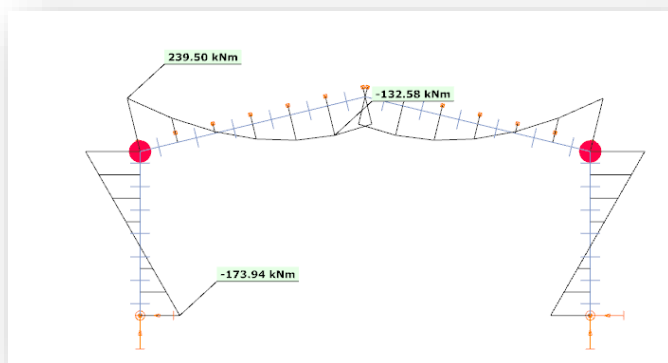
In the fourth group of options the important results can be selected which have to be saved and displayed for all the stages. In case of larger models and possibility for large number of hinges the amount of results can increase significantly so it is advisable to carefully choose the really important ones.

8.5.2.2 FIRST ORDER

Mathematically, it is done similarly to that described for elastic calculation, but with the big difference that it not only analyzes the specified load, but changes (increases or decreases) the specified load step by step until the structure becomes unstable due to the plastic hinges.

The solution process is as follows:

- 1: A first-order elastic analysis is performed according to the load combination specified by the user, and then the obtained bending moment values M_y about the strong axis are compared with the plastic moment resistance of the section of every finite element according to the criteria in the first group.
- 2a: If the stresses calculated at the load level specified by the user do not meet the conditions for the formation of the plastic hinge(s) at any point of the elements selected for plastic analysis, Consteel raises the load level in steps until the first plastic hinge is formed.
- 2b: If there is a point at the user-specified load level where the plastic hinge would form, Consteel reduces the load level in steps until the load level is found when the first plastic hinge is formed.
- 3: At the found load level $\alpha \cdot M_{y,Ed}$ Consteel places hinges on all current finite element points where the conditions for the formation of the plastic hinges are given according to the parameters of "Behavior of plastic hinges", which is used in the analysis for additional load steps. Due to the placement of the hinges, the global stiffness matrix of the structure is updated, and another level of calculation is started. The placed joints are showed on the structure and the next calculation step starts.



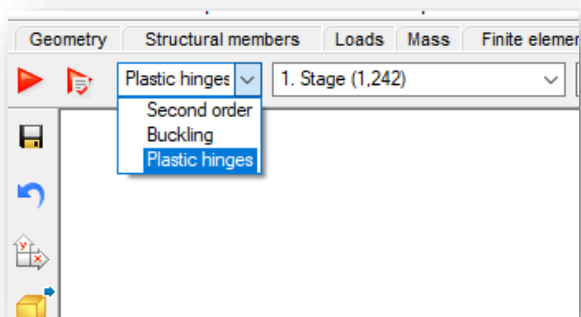
4: Consteel further increases the load through the α load factor using the changed stiffness matrix until the load level for the formation of the next plastic hinge is reached.

5: As in point 3, place joints on the newly found nodes, update the stiffness matrix, and continue the iteration according to point 4.

The plastic analysis ends when the resulting structure including the plastic hinges become unstable as a result. If the value of the final load factor thus obtained is less than 1.00, the structure is unstable, and the first-order calculation ends without result. A message alerts the user.

During the iteration, when the program reaches the load factor value of 1.00, the current internal force values are saved because the global design must be performed at this level, i.e. at the specified load level. These internal forces will be the basis for the buckling analysis to be performed in the next step.

You can view the history of each load level step, its associated load factors, and the plastic hinges formed during the steps by selecting the “Plastic Joints” option from the Analysis Types drop-down menu.



8.5.2.3 SECOND ORDER



Coming soon!

8.5.2.4 STATIC EIGENVALUE – BUCKLING ANALYSIS

The iteration described for the first-order analysis is performed up to a load factor of 1.00, which corresponds to the specified load level. Using the first-order K_s corresponding to the static model valid at this load level and the K_g matrices calculated for the corresponding internal force distribution, the calculation is performed as described in the elastic analysis.



8.6 ANALYSIS RESULTS

8.6.1 RESULT TYPES

For the two types of finite elements (line and surface elements) the following analysis results are available:

1. Line elements

Elastic and plastic analysis

- ▶ First and second order calculations:
 - ▶ Deformations – on the finite element nodes in the global coordinate system
 - XYZ – all components
 - X –displacements in the "X" direction
 - Y –displacements in the "Y" direction
 - Z –displacements in the "Z" direction
 - R_x –rotation around "X" axis
 - R_y –rotation around "Y" axis
 - R_z –rotation around "Z" axis
 - W –warping of the member [1/rad]
 - R_{xx} –rotation around the local "x" axis of the member [degree]
 - ▶ Internal forces – on the end nodes of each finite element in the local coordinate system
 - N – axial force
 - V_y – shear force in the local "y" direction
 - V_z – shear force in the local "z" direction
 - T – torsional moment
 - M_y – bending moment about the local "y" axis
 - M_z – bending moment about the local "z" axis
 - B – bimoment
 - ▶ Reactions – on the support nodes in the local coordinate system of the support
 - R – all the reaction forces and moments
 - R_R – all the reaction forces
 - R_{RR} – all the reaction moments
 - R_x – reaction force in the in the global "X" direction
 - R_y – reaction force in the in the global "Y" direction
 - R_z – reaction force in the in the global "Z" direction
 - R_{xx} – reaction moment about the global "X" direction
 - R_{yy} – reaction moment about the global "Y" direction
 - R_{zz} – reaction moment about the global "Z" direction



- ▶ Static eigenvalues and corresponding eigenshapes – on the finite element nodes in the global coordinate system

Only elastic analysis

- ▶ Dynamic eigenvalues and corresponding eigenshapes – on the finite element nodes in the global coordinate system

Only elastic analysis

- ▶ Plastic hinges – plastic hinge history with the positions of the plastic hinges on the proper finite element ends and the corresponding stages by load factors

2. Surface elements

- ▶ First and second order calculations:
 - ▶ Deformations – on the finite element nodes in the global coordinate system
 - XYZ – all components
 - X – only displacements in the "X" direction
 - Y – only displacements in the "Y" direction
 - Z – only displacements in the "Z" direction
 - R_x – only rotation around the local "x" axis of the member
 - R_y – only rotation around the local "y" axis of the member
 - R_z – only rotation around the local "z" axis of the member
 - W – only warping of the member [1/rad]
 - R_{xx} – only rotation of the member [degree]
 - ▶ Equilibrium – signed summation of the internal nodal force components and the appropriate external force and reaction components, all the values should be zero which means the model is in equilibrium in the calculated deformed state
 - ▶ Forces on surface – edge forces and moments per unit length on the end nodes of each finite element in the local coordinate system
 - m_x – bending moment on the section perpendicular to the local "x" axis
 - m_y – bending moment on the section perpendicular to the local "y" axis
 - m_{xy} – torsional moment
 - n_x – normal force in the local "x" direction
 - n_y – normal force in the local "y" direction
 - n_{xy} – membrane shear force
 - v_{xz} – plate shear force on the section perpendicular to the local "x" axis
 - v_{yz} – plate shear force on the section perpendicular to the local "y" axis
 - v_{Rz} – resultant plate shear force
 - α_n – principal directions of the membrane forces



$$\alpha_n = \frac{1}{2} \arctan\left(\frac{2n_{xy}}{n_x - n_y}\right) - 90^\circ < \alpha_n \leq +90^\circ$$

- α_m – principal directions of the plate moments

$$\alpha_m = \frac{1}{2} \arctan\left(\frac{2m_{xy}}{m_x - m_y}\right) - 90^\circ < \alpha_m \leq +90^\circ$$

- Stresses on surface – on upper, middle, and lower plane of the surface on the end nodes of each finite element in the local coordinate system

- σ_x – normal stress in the local “x” direction
- σ_y – normal stress in the local “y” direction
- σ_{xy} – shear stress
- σ_1 – maximum principal stress

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2}$$

- σ_2 – minimum principal stress

$$\sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \sigma_{xy}^2}$$

- σ_{HMH} – Huber-Mises-Hencky stress

$$\sigma_{HMH} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\sigma_{xy}^2}$$

- α_σ – principal directions of the stresses

$$\alpha_\sigma = \frac{1}{2} \arctan\left(\frac{2\sigma_{xy}}{\sigma_x - \sigma_y}\right) - 90^\circ < \alpha_\sigma \leq +90^\circ$$

- Reactions – on the support nodes in the global coordinate system

- R – all the reaction forces and moments
- R_R – all the reaction forces
- R_{RR} – all the reaction moments
- R_x – reaction force in the in the global “X” direction
- R_y – reaction force in the in the global “Y” direction
- R_z – reaction force in the in the global “Z” direction
- R_{xx} – reaction moment about the global “X” direction
- R_{yy} – reaction moment about the global “Y” direction
- R_{zz} – reaction moment about the global “Z” direction

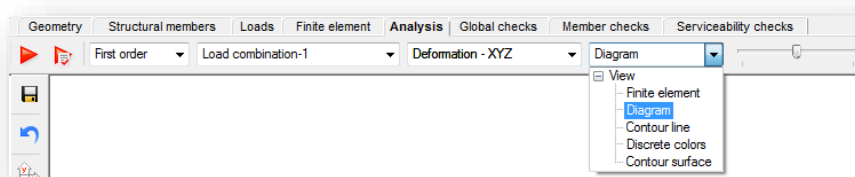
- Static eigenvalues and corresponding eigenshapes – on the finite element nodes in the global coordinate system

- Dynamic eigenvalues and corresponding eigenshapes – on the finite element nodes in the global coordinate system



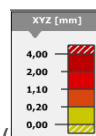
8.6.2 VISUALIZATION OPTIONS

The results of the performed analysis are usually a huge amount of data so the efficient handling of it has great importance. There should be opportunities for global overview and for obtaining accurate, detailed information about a certain part or problem. There are two main possibilities for the demonstration of the analysis results: the *graphical visualization* and the *result tables* (for the general functionality of tables used in *Consteel* see section **1.4 GENERAL FUNCTIONS FOR TABLES**). The two visualization options are obviously in strong connection and can be manipulated by the functions placed on the upper part of the **ANALYSIS** tab. The four combos contain the following selection options (from left to right):

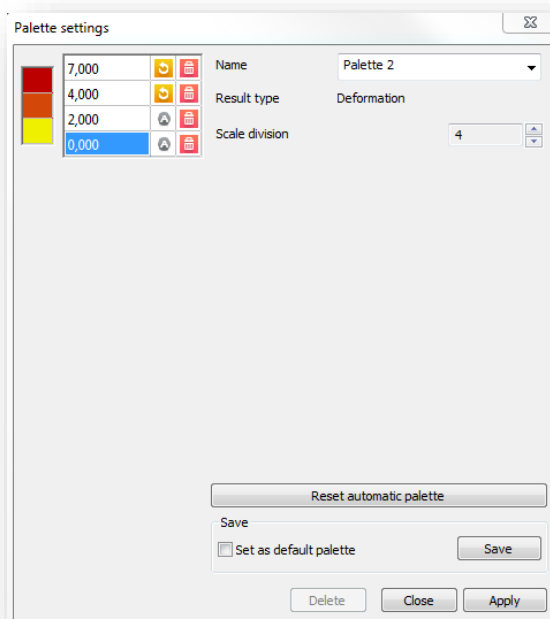





- ▶ selection of analysis type (discussed in section **8.5 ANALYSIS TYPES**)
- ▶ selection of load combination or load case or envelope figures
- ▶ selection of result type (discussed in section **8.6.1 RESULT TYPES**)
- ▶ selection of type of view (finite element/diagram/contour line/ discrete colors/contour surface)

If choosing the **DISCRETE COLORS** in the dropdown menu of the type of view, there is a possibility to modify the default settings of the color palette. To open up the **PALETTE**



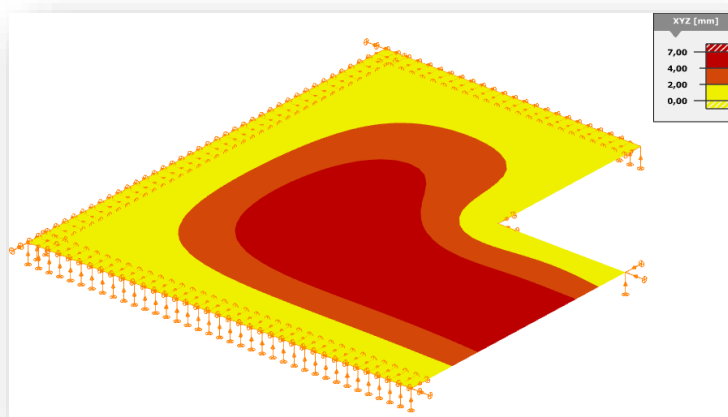
SETTINGS dialogue, a right click on the palette summary () is necessary.



On the palette settings dialogue, the division of the scale can be set with the up and down arrow buttons (). With the delete button () on the dialogue, division values can be deleted. Division values are calculated automatically by default between the minimum and maximum values of the results, but these values can be set manually at any time, with a manual input of a new division value. If a value is modified manually, a refresh button () will appear next to it, what can be used to recalculate it according to the division scale.

Modifications can be saved for further use by clicking on the save button. The settings will be saved to the UserConfig.xml, what can be found in the Documents/Consteel folder.

Also, the modified user palette can be set as a default palette.





All the model view options discussed in section **3.2 MODEL VIEWS** are applicable on the result graphics. Moving the slide beside the combos the scaling of the results can be adjusted on the graphics. In case of partial or submodel view the graphics and the tables show only the results of the actual model part. Three types of result tables can be viewed:



Extreme values by members: select the maximum and minimum values for each structural member



User defined values: show the values belonging to the markers defined by the user (discussed more deeply in section **8.6.3 RESULT MARKERS**)



All values.

The result tables arrange the values according to the current result type:

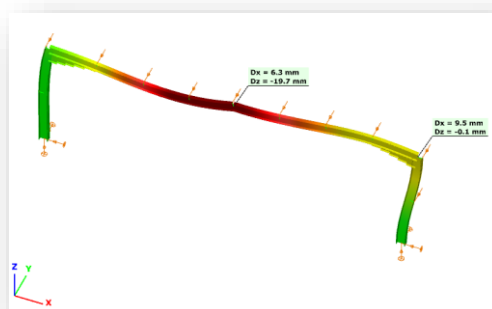
- ▶ displacement type results (first or second order deformations, static or dynamic eigenshapes): finite element node number, displacement components
- ▶ force type results (internal forces, forces, or stresses on surface): finite element node number, finite element number, force components
- ▶ reaction type results (reactions, equilibrium): finite element node number, reaction components.

8.6.3 RESULT MARKERS

On the graphical interpretation of the results markers can be placed in order to show certain significant values. When moving the mouse along the structural elements (or more correctly the finite elements) the result markers continuously appear showing the actual values. These markers can be fixed by clicking on the right mouse button and choosing the 'Marker' option.

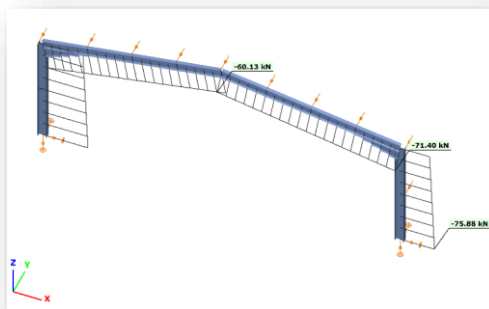
The fixed markers will appear on every result view where it has interpretable value:

- ▶ Deformation

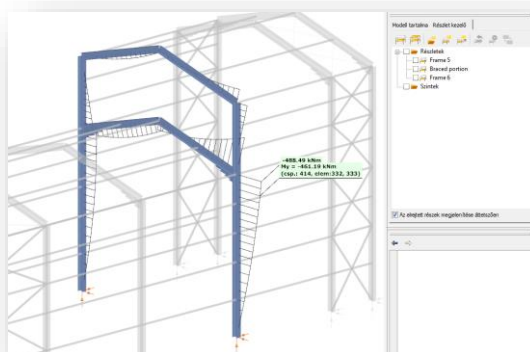
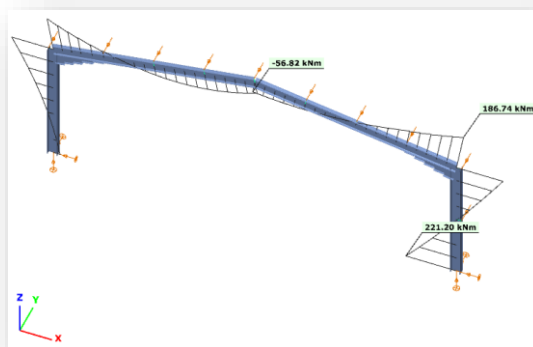




► Normal force



► Bending moment



When there are fixed markers on the model the 'User defined values' table contains the appropriate (view dependent) values of the marked points. In this table the markers can be switched to disabled by uncheck the proper row.



<input type="checkbox"/>	5	37	-60,130	0,000	4,900	0,000	-56,820	0,000	0,000
<input checked="" type="checkbox"/>	4	56	-71,400	0,000	52,980	0,000	186,740	0,000	0,000
<input checked="" type="checkbox"/>	3	9	-75,880	0,000	-78,680	0,000	221,200	0,000	0,000

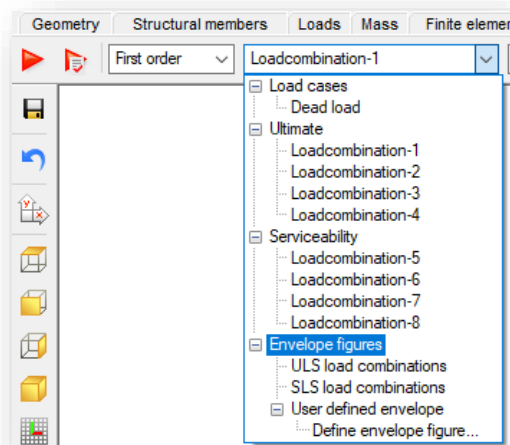
The markers can be deleted by:

- ▶ click on the proper row in the table by the right mouse button
- ▶ click on the marked point on the graphics by the right mouse button and chose 'Remove marker'

Extreme values can automatically be marked by the check boxes on the 'Extreme values' table rows.

8.6.4 ENVELOPE FIGURES

In Consteel, *min. max* and *min-max* envelope figures are available both for *bar members*, and *shell models* too. Envelope visualization of results can be accessed through the **LOAD COMBINATION** dropdown menu of the **ANALYSIS** tab, after a successful calculation. Envelope figures are available both for first, and second order results. By default, there are two envelope figures to choose from, one for all of the calculated ULS and one for all of the calculated SLS combinations. It is possible to create custom envelope figures, which is explained in detail in the next **CHAPTER 8.6.4.1**.

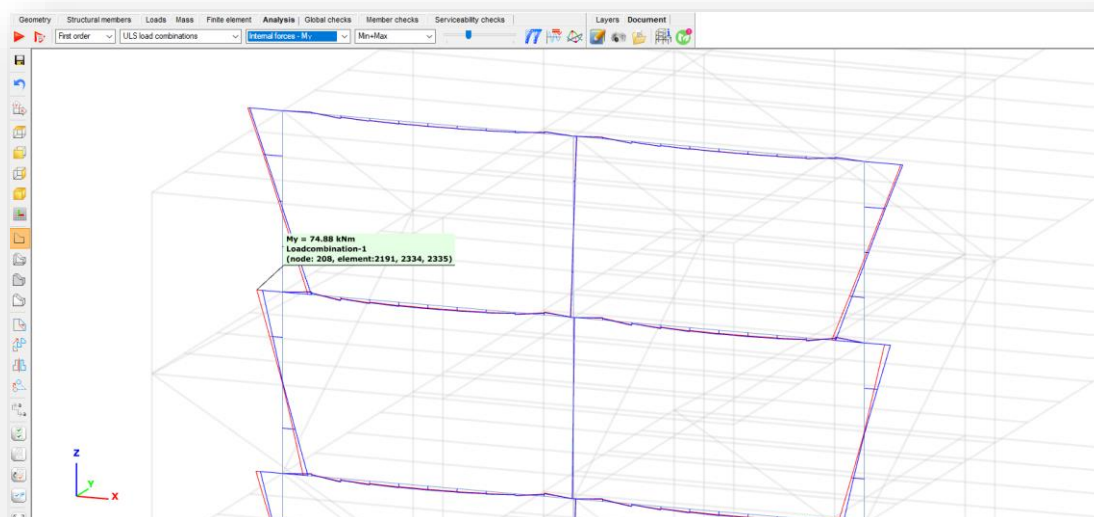


The following result types can be displayed through envelope figures (detailed explanation on **RESULT TYPES** can be found in **CHAPTER 8.6.1**):

- ▶ Internal forces for bar members
- ▶ Forces on shell
- ▶ Stresses on shell



There is a color scheme for the envelope figures. Minimal values represented with blue, while maximal values with a red diagram. When hovering the cursor above a point of an envelope, (either min or max), the value, and the load combination from which it is coming from, is displayed in a flag.

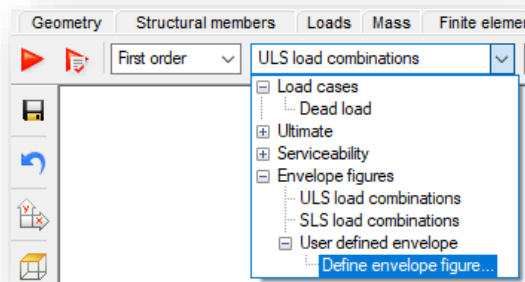


Placing flags on the envelope figures values is also possible. In this case, the table on the bottom of the main window will contain every envelope information about the flagged point.

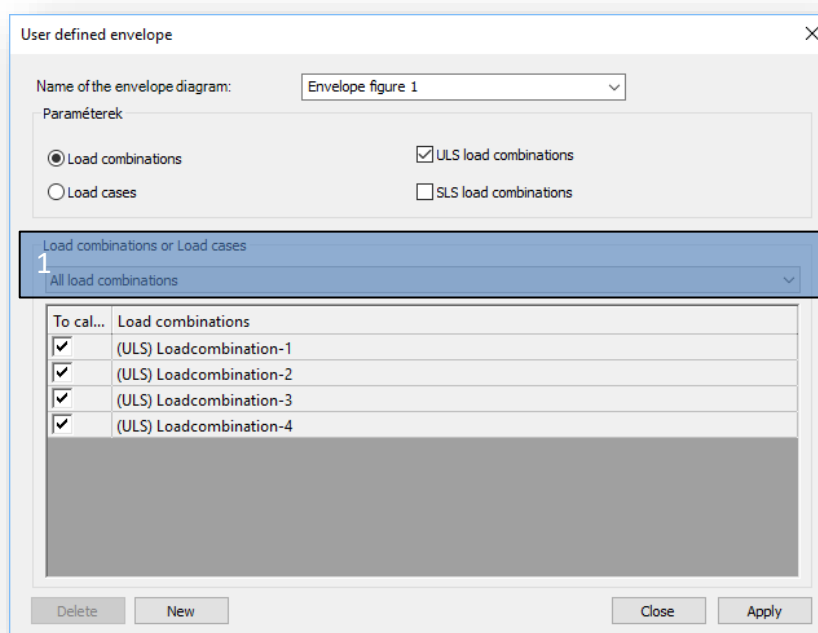
Min/Max My	Node	Element	Load combination	N [kN]	V _y [kN]	V _z [kN]	T [kNm]	M _y [kNm]	Δ	M _z [kNm]	B [kNm ²]
<input checked="" type="checkbox"/>	Minimal	199	2360 Loadcombination-1	-631,880	5,100	-50,560	0,011	-75,890		-7,350	-0,019
<input checked="" type="checkbox"/>	Minimal	208	2334 Loadcombination-3	-578,371	4,510	39,530	-0,010	58,240		-6,420	0,019
<input checked="" type="checkbox"/>	Maximal	208	2334 Loadcombination-1	-624,410	5,430	49,730	-0,012	74,880		-7,850	0,021

8.6.4.1 USER DEFINED ENVELOPE FIGURES

Besides the default, built in envelope options (all ULS and SLS combinations), it is possible to create user defined envelope figures. This means, that the results, from which the envelope function can build up the figure, can be specified, and saved as a new **USER DEFINED ENVELOPE FIGURE**. Definition can be initiated from the **LOAD COMBINATION** dropdown menu's **DEFINE ENVELOPE FIGURE...** option, after a successful first and/or second order analysis calculation.



After clicking on the function, the **USER DEFINED ENVELOPE** dialogue will appear. On this dialogue, any number of custom envelope figures can be created, using the **NEW** button.



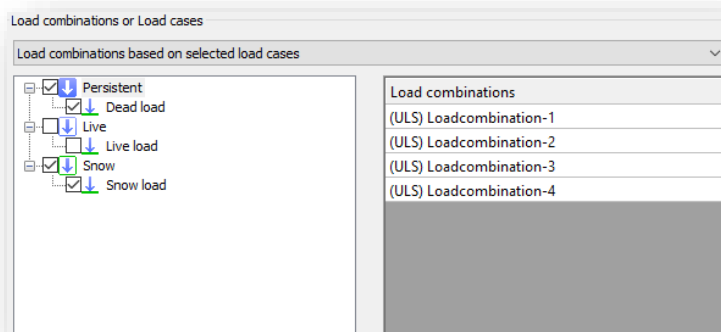
If the Load combinations is selected at the **PARAMETERS** part of the dialogue, the elements of the dropdown menu below **LOAD COMBINATIONS OR LOAD CASES**, and the table below will be different.

If the Load combinations is selected at the parameters, the options of the dropdown menu (#1) are:

- ▶ All load combinations: All of the calculated load combinations will be used for the envelope figure
- ▶ Selected load combinations: Calculated load combinations can be selected with checkboxes to be taken into account for the envelope figure



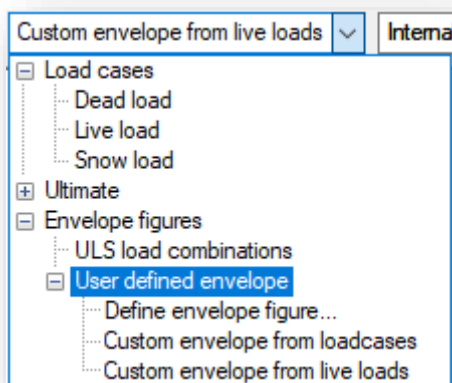
- Load combinations based on selected load cases: Only those load combinations will be taken into account, which are generated based on the selected loadcases, using the checkboxes




If the Load case is selected at the parameters, the options of the dropdown menu (#1) are:

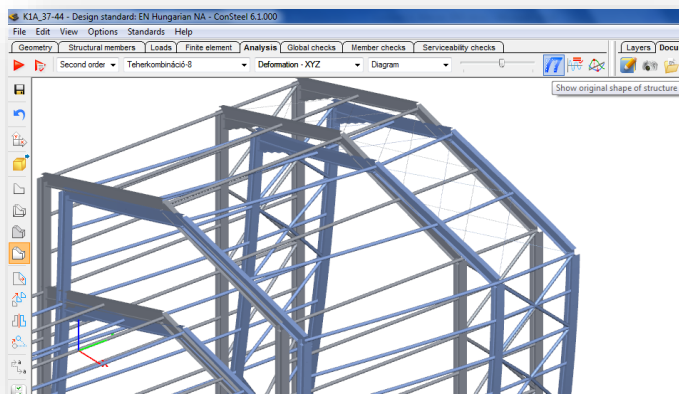
- All loadcases: All of the loadcases will be used for the envelope figure
- Selected loadcases: Only the selected loadcases will be used for the envelope figures

After the user defined envelopes are created, they will be listed at the **LOAD COMBINATIONS** dropdown menu of the **ANALYSIS TAB**, and will be listed at the **USER DEFINED ENVELOPE** part:



8.6.4 SHOW ORIGINAL SHAPE OF STRUCTURE

SHOW ORIGINAL SHAPE OF STRUCTURE function  will show the original shape of structure and the deformed structure at the same time:



8.6.5 TABLE OF DOMINANT VALUES



The last icon on the **ANALYSIS** tab activates the table of dominant values. The table is view sensitive which means that the dominant values are always selected from the current result type. Only the values at the ends of structural members are examined. The functionality of the table is as follows:

Dominant values

Settings

Limit state

Ultimate

Extreme values

Absolute Maximum

Sort

For bars

Bar end

A, B separately

☒ If the dominant value was 0, the table does NOT include it.
 ☐ Separate rows

Designation	Section	Dominant	N [kN]	V _y [kN]	V _z [kN]	M _x [kNm]	M _y [kNm]	M _z [kNm]	B [kNm ²]	Load combination
R648 A end	IPE 400	M _y	104,8	-0,1	27,7	0,1	-223,3	-0,4	0,2	Teherkombináció
R648 B end	IPE 400	M _y	-4,9	-0,1	156,3	0,1	505,5	0,4	0,0	Teherkombináció
R649 A end	IPE 400	M _y	23,6	0,2	-150,2	-0,1	329,4	0,6	-0,1	Teherkombináció
R649 B end	IPE 400	M _y	103,6	0,1	-31,8	-0,1	-223,3	-0,4	0,2	Teherkombináció
R650 A end	IPE 400	M _y	5,9	-0,4	26,8	0,1	-150,5	-0,2	0,1	Teherkombináció
R650 B end	IPE 400	M _y	-36,3	0,7	139,6	0,0	446,0	-0,7	-0,1	Teherkombináció
R651 A end	IPE 400	M _y	-29,7	-0,1	-135,5	-0,1	293,7	-0,3	-0,1	Teherkombináció
R651 B end	IPE 400	M _y	18,9	0,3	19,3	-0,1	-150,4	-0,2	0,1	Teherkombináció
R533 B end	HEA 300	M _y	-111,1	-0,4	36,1	0,0	131,8	0,1	-0,1	Teherkombináció
R786 A end	HEB 340	M _y	-90,5	0,3	-38,0	0,0	-226,7	0,2	0,0	Teherkombináció
R786 B end	HEB 340	M _y	-80,0	1,0	-0,9	0,0	-322,9	-2,3	-0,2	Teherkombináció
R788 A end	HEB 340	M _y	-280,3	0,4	-54,8	0,0	-274,1	0,6	0,0	Teherkombináció
R788 B end	HEB 340	M _y	-109,1	-0,3	-59,4	0,4	-238,3	-0,3	-0,3	Teherkombináció
R790 A end	HEB 300	M _y	-184,5	0,8	-38,7	0,0	-190,6	0,9	-0,1	Teherkombináció
R790 B end	HEB 300	M _y	-172,4	0,5	-21,9	-0,1	-337,4	-0,2	0,0	Teherkombináció
R792 A end	HEB 300	M _y	-171,9	-0,5	-22,1	-0,1	-336,8	-0,2	0,0	Teherkombináció
R792 B end	HEB 300	M _y	-168,1	-0,1	-8,4	0,2	-397,9	-0,4	-0,2	Teherkombináció
R534 B end	HEA 300	M _y	-124,4	-0,6	-46,0	0,0	-206,2	0,1	0,1	Teherkombináció
R535 B end	HEA 300	M _y	-239,4	-0,3	87,9	0,0	328,7	0,0	0,0	Teherkombináció
R636 B end	HEA 300	M _y	-730,7	-0,6	-81,1	0,0	-366,1	0,0	0,0	Teherkombináció

Close

Limit state: selection of appropriate load combinations belonging to resistance or serviceability limit states (the deformations are automatically appearing for the serviceability limit state, while the internal forces and reactions for the resistance limit state)



Extreme values: setting the type of extreme values

Sort: sorting the values for bars (structural members), bar groups or cross sections

Bar end: handle the ends of the members separately (A, B ends) or together (Both ends)

Single or multiple component selection is possible, the dominant values are always highlighted by colored cells, the 'Dominant' column contains the dominant components.


Settings

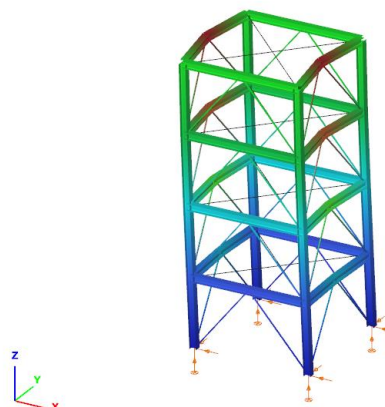
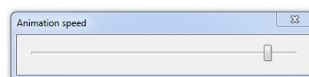
Limit state: Ultimate Extreme values: Minimum Sort: For bar sections Bar end: Both ends

☒ If the dominant value was 0, the table does NOT include it. ☐ Separate rows

Designation	Dominant	N [kN]	V _y [kN]	V _z [kN]	M _x [kNm]	M _y [kNm]	M _z [kNm]	B [kNm ²]	Load combination
CHS 114.3x3.6	V _z	0,2	0,0	-0,4	0,0	0,0	0,0	0,0	Teherkombináció
IPE 400	V _z	-152,4	-0,2	-205,3	0,0	304,7	0,0	0,0	Teherkombináció
IPE 400	M _y	-39,8	0,2	17,8	-0,1	-338,0	-0,5	0,2	Teherkombináció
KA_20	V _z	0,0	0,0	-0,1	0,0	0,0	0,0	0,0	Teherkombináció
HEA 300	V _z	-245,0	0,6	-93,3	0,0	0,0	0,0	0,0	Teherkombináció
HEA 300	M _y	-239,2	-0,6	-81,1	0,0	-366,1	0,0	0,0	Teherkombináció
HEB 340	V _z	-300,5	0,3	-94,2	0,0	0,0	0,0	0,0	Teherkombináció
HEB 340	M _y	-222,1	-0,2	-36,4	0,0	-530,2	0,1	0,1	Teherkombináció
HEB 300	V _z	-204,6	0,2	-53,3	0,1	0,0	0,0	0,0	Teherkombináció
HEB 300	M _y	-168,1	-0,1	-8,4	0,2	-397,9	-0,4	-0,2	Teherkombináció

8.6.6 ANIMATION OF DYNAMIC SHAPES

In case of vibration analysis, the animation of the dynamic shapes can be reached to click on the  icon. Animation speed can be increased and decreased with the slide bar.





9 STANDARD DESIGN

The design functionalities are placed on three tabs: the *GLOBAL CHECKS*, *MEMBER CHECKS* and *SERVICEABILITY CHECKS* tab.

9.1 BASICS

The required code checks of the different types of structural components – cross sections, members – can be conveniently evaluated based on the following standard:

Design of steel structures:

- ▶ EuroCode
 - EN 1993-1-1: General rules and rules for buildings
 - EN 1993-1-2: General rules. Structural fire design
 - EN 1993-1-3: General rules. Supplementary rules for cold-formed members and sheeting
 - EN 1993-1-5: Plated structural elements (particular)
- ▶ Spanish standards
 - Structural Steel Code (EAE)

Design of composite steel and concrete structures:

- ▶ EuroCode
 - EN 1994-1-1: General rules and rules for buildings

Design of concrete structures:

- ▶ EuroCode
 - EN 1992-1-1: General rules and rules for buildings

Several National Annexes are implemented, and user annex can also be defined and saved.

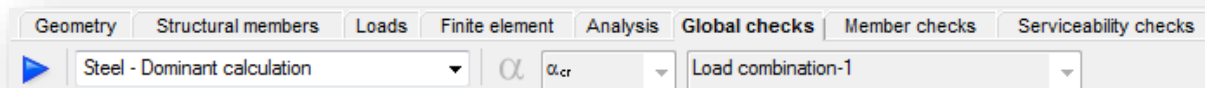


9.2 STEEL DESIGN

Steel ultimate state design related functions can be found on the **GLOBAL CHECKS** and the **MEMBER CHECKS** tabs.

9.2.1 GLOBAL CHECKS

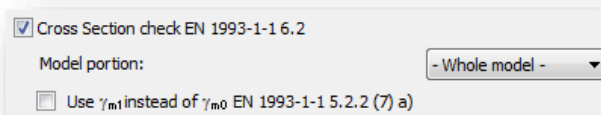
9.2.1.1 BASICS



Cross-section and global buckling checks (according to the Section 6.3.4 (General method) of EN 1993-1-1) which are independent of any specific member parameter can be fully automatically evaluated on the **GLOBAL CHECKS** tab.

As basic settings the analysis result type (first or second order) should be selected and the load combinations which should be evaluated.

9.2.1.2 CROSS SECTION CHECK

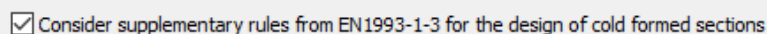


Cross-section check can be done according to the EN 1993-1-1 6.2 or EN 1993-1-2 4.2 (if the combination contains fire effect).

Check can be performed for the whole model or partial model.

Used safety factor can be selected. If it is necessary γ_{M1} can be used instead of γ_{M0} by clicking on the checkbox.

If the model also includes cold-formed sections, their cross-sectional dimensioning according to EN 1993-1-3 can be performed only, if the check box on the **SET DESIGN PARAMETERS** window is checked.





9.2.1.3 STABLE LENGTH CHECK

According to the Eurocode (1993-1-1 BB3), stable length check can be defined using the results of a plastic hinge analysis. During the calculation, the distance between the plastic hinge and the nearest lateral (L_{ub}) or torsional restraint (L_m , L_s) is being compared with the calculated stable length of the corresponding plastic segment. If the stable length of a plastic segment is bigger than the distance between the plastic hinge and the lateral/torsional restraint, lateral torsional buckling of the member can be neglected.

During the stable length check, the following checks are performed by Consteel:

1. Automatic recognition of the plastic hinges on the structure
2. Searching for the nearest supports of each plastic hinges
 - a. Lateral restraint
 - b. Torsional restraint
3. Defining the distance between the plastic hinge and the nearest supports
4. Calculating the stable length (depending on the type of the support) for the plastic segments, between the plastic hinge and the nearest supports

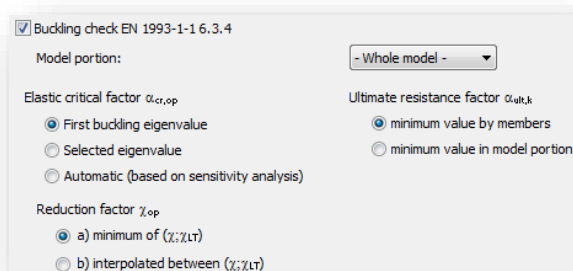
On the elastic segments global stability resistance will be evaluated according to the General method of Eurocode.

9.2.1.4 BUCKLING CHECK

Buckling check can be evaluated for steel structures according to the EN 1993-1-1 6.3.4.

$$\frac{\chi_{op} \alpha_{ult,k}}{\gamma_{M1}} \geq 1,0$$

To run the buckling check, it is required to have buckling analysis results.





For the buckling check the following parameters can be set:

- ▶ Elastic critical load factor $\alpha_{cr,op}$: eigenvalue of the buckling analysis. It can be the first or the selected eigenvalue according to the design situation or can be automatically selected for each member based on the results of the sensitivity analysis.

Eigenvalue can be selected on the **ANALYSIS** tab to click in the model area with right click.

- ▶ Ultimate resistance factor $\alpha_{ult,k}$: reciprocal of utilization calculated with characteristic resistances of axial force and strong axial bending dominant in terms of loss of stability. Value of the utilization can be considered by members or by the model portion.

$$\bar{\lambda}_{op} = \sqrt{\frac{\alpha_{ult,k}}{\alpha_{cr,op}}}$$

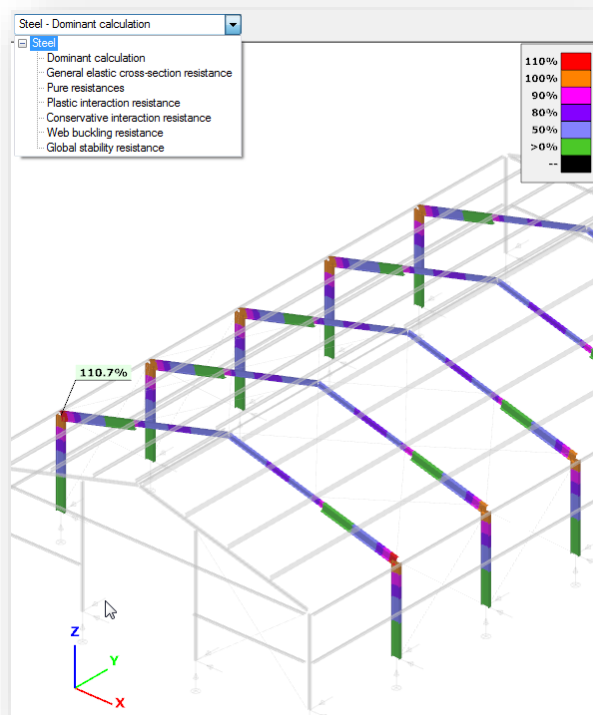
- ▶ Reduction factor χ_{op} : reduction factor for the λ_{op} slenderness. It can be determined from the minimum of (χ, χ_{LT}) or from the interpolated value of (χ, χ_{LT}) .

Check can be performed for the whole model or partial model.

9.2.1.5 RESULTS

The results of the performed checks are demonstrated with graphical visualization and result tables (for the general functionality of tables used in *Consteel* see section **1.4 GENERAL FUNCTIONS FOR TABLES**).

The shown results can be changed in the drop-down menu.

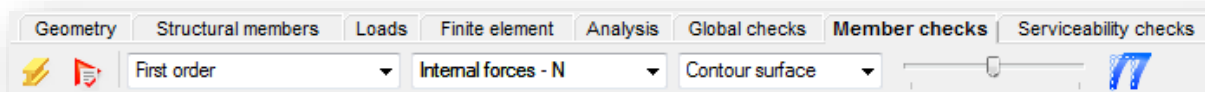


When moving the mouse along the structural elements the result markers continuously appear showing the actual utilization.

The detail of the results can be seen in the Section module (see section **10 SECTION MODULE**). Section module can be opened directly from the **GLOBAL CHECKS** tab to click on the proper cross section on the model area or in the result table with right click.

9.2.2 MEMBER CHECKS

9.2.2.1 BASICS



All steel member design related functions can be found on the **MEMBER DESIGN** tab.

The following parts of the Eurocode 3 (EN 1993-1-1) can be evaluated:

6.3.1 Uniform members in compression

6.3.2 Uniform members in bending



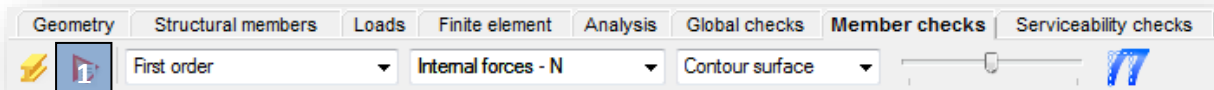
6.3.3 Uniform members in bending and axial compression

9.2.2.2 INDIVIDUAL MEMBER DESIGN

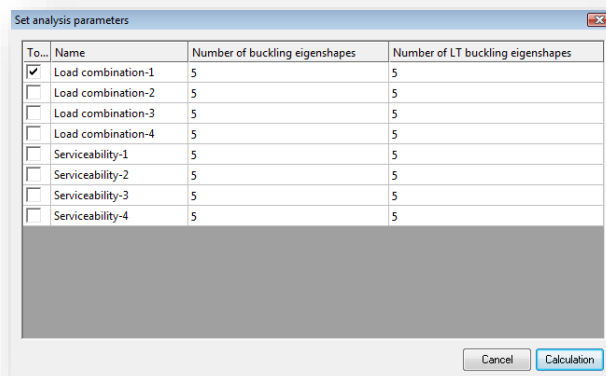
To run steel member design, go to **MEMBER CHECKS** tab and select **STEEL** tab in the table at the bottom of the screen. First the members have to be selected and then added to the list. It can be performed by clicking on the **ADD** button. After that one member has to be chosen and **SELECT** button is clicked.

Name	Parameters	State	Validity
B1 (selected)	L=10000mm, IPE 600	Unexamined	No
B5	L=12000mm, IPE 330	Unexamined	No
B2	L=10000mm, IPE 600	Unexamined	No
B9	L=6000mm, IPE 330	Unexamined	No
B3	L=10000mm, IPE 600	Unexamined	No
B7	L=6000mm, IPE 330	Unexamined	No
B4	L=6000mm, IPE 330	Unexamined	No

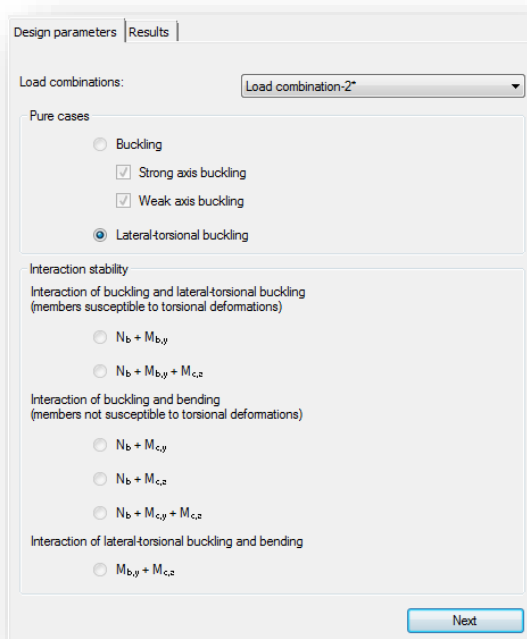
If a member is selected, the corresponding row highlighted with green and analysis results are automatically loaded. Member design can be run if there is analysis result (first and second order) and cross check for the member. Same like in the analysis the type of the result view can be set by three drop-down menus.



Special analysis can be run by clicking on the second icon (#1). Only one load combination can be selected at the same time. Buckling and lateral torsional buckling analysis is performed just for the selected member. If the normal force is negligible then no buckling analysis can be run. On the basis of these special analysis, *Consteel* can determine the factors (effective length factors, warping factor etc.) for the buckling and the lateral-torsion buckling design.

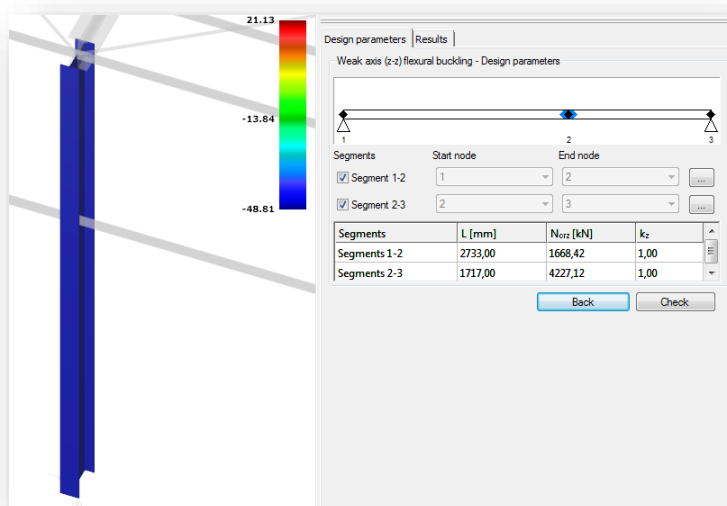


The next step is to choose the load combination and design type from the options: pure cases (strong axis buckling, weak axis buckling, lateral-torsional buckling) and interaction stability (interaction of buckling and lateral torsional buckling, interaction of buckling and bending, interaction of lateral-torsional buckling and bending). The dominant load combination is automatically selected and marked with a * symbol.

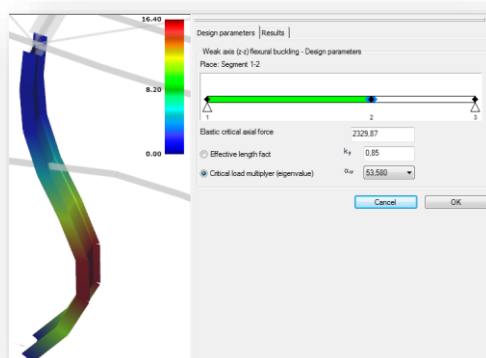


Depending on the member not all checks can be performed. If the normal force is negligible then strong or weak axis buckling design cannot be run.

If **strong or weak axis buckling option** is selected, then first the design parameters must be set. The program automatically identifies the supports which could have effect on the buckling check.



Among the supports the member is divided to segments. Segments can also be turned off in order not to calculate them during the analysis. The design parameters can be individually set for each segment by clicking on the three dots icon.



The actual segment is highlighted with green. There are two options to set the design parameters: set the effective length factor manually by typing in the appropriate value or by choosing the right critical load multiplier. The second option is possible if the special analysis has already been run. In both cases the elastic critical axial force is automatically calculated.

If all the design parameters have been properly set, then design check can be performed by clicking on the **CHECK** button. Results will be displayed.



Design parameters Results

Calculated problems

Member: R13

Load combination: Load combination-2

Buckling case: Case 1

Examined system length(s)

Weak axis buckling

Summary of results

Used capacity in lateral buckling:	4,5%
Place of the dominant cross section:	0 mm from the first node
Number of the dominant finite element:	1
Place of the dominant FE node:	1
Class of the dominant cross section for compression:	2
Used part of standard:	6.3.1(6.46-6.49) formula

Detailed calculation

N_{Ed}	43,5 kN
$N_{b,Rd}$	964,3 kN
N_{cr}	2329,9 kN
L	2733 mm
k	0,846
λ	0,737
α	0,340
Φ	0,863
χ	0,763
A	5381,2 mm ²
f_y	235,0 N/mm ²
γ_{M1}	1,0

There are three drop-down menus to view different results. The first one can be used to change member, the second one is to change load combinations and the third one is to change the buckling case. The corresponding case is highlighted with green in the image. A short explanation can be read in the bottom when any of the rows is selected.

Lateral torsional buckling design

is more or less the same as the buckling design in *Consteel* usage, there are only small differences. New cases can be defined, and unnecessary cases can be deleted. For each segment start and end node can be set.

By clicking on the three dots button the design parameters can be altered. The elastic critical bending moment can be calculated from the analytic formula or from the critical load multiplier. When the first method is used the factors can be typed in or a special automatic C factor calculator can be used by

Design parameters Results

Lateral-torsional buckling

New case Delete unchecked cases

Segments Start node End node

☒ Segment 1-2 1 2

☒ Segment 2-3 2 3

Segments	L [mm]	M_{cr} [kNm]	k_z	k_w	C_1	C_2	C_3	z_g
Segments 1-2	2733,00	548,96	1,00	1,00	1,88	1,00	0,94	0,00
Segments 2-3	1717,00	805,51	1,00	1,00	1,21	1,00	1,00	0,00

Back Check



clicking on the **AUTO C** button. The second option is to choose the corresponding critical load multiplier from the list.

Design parameters | Results |

Lateral-torsional buckling
Place: Segment 1-2

Elastic critical bending moment [kNm] 618,31

☒ Analytic formula

Effective length factor k_a 1,30

Warping factor k_w 0,84

C₁ factors C_1 2,44

C_2 1,00

C_3 0,21

AutoC

Eccentricity of load [mm] z_q 0,00

☐ Critical load multiplier (eigenvalue) α_{cr}

Cancel OK

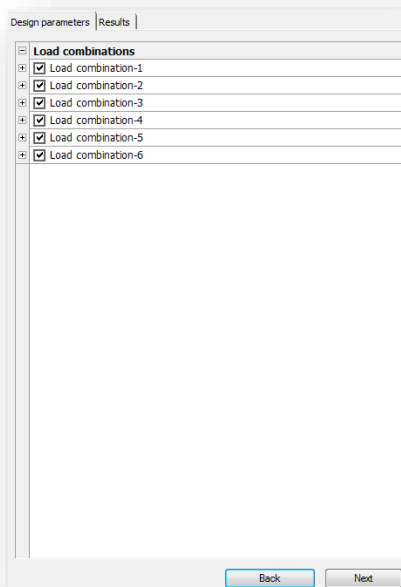
Interaction stability design goes through the steps of the pure cases.

After the check is made the state of the member in the list at the bottom changes to 'Examined' from 'Unexamined'.

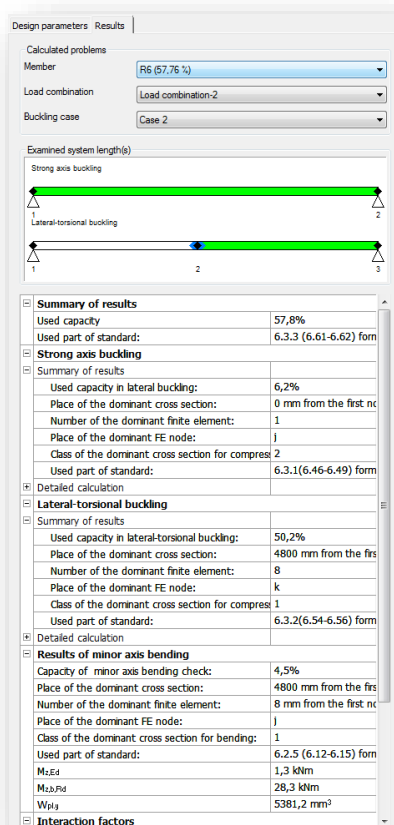
9.2.2.3 MEMBER GROUP DESIGN

By using the **SELECT (+)** button it is possible to select more members for the member design. **SELECT (-)** can be used for removing members from the selection. Member group design works nearly the same as individual member design there are just minor differences. No special analysis can be run in member group design therefore the critical load factor cannot be selected.

If the members are selected then the next step is to select the design type and set the design parameters, then click **CHECK** button similar to the individual member design.



For each load combination member design can be turned off. It is important to know that not all the design options can be run for all members in load combinations. It depends on the analysis result.



In the results tab the dominant member is automatically shown. The number next to the member number shows the capacity.



9.3 COMPOSITE DESIGN

Composite column design related functions can be found on the **GLOBAL CHECKS** tab, beam design related function can be found on the **MEMBER CHECKS** tab.

9.3.1 COMPOSITE COLUMN DESIGN

Cross-section of the composite columns can be evaluated on the **GLOBAL CHECKS** tab by clicking on the blue arrow. On the **DESIGN...** dialog the *Composite column design* settings has to be chosen by the check box. Checks can be performed according to the first or the second order analysis and for the whole or a previously created portion model.

Fully encased I section in concrete

Name: comp Fully encased I

Reinforcement

Diameter: 16 mm

Material: B 500 A

Upper bars: 4 pcs

Lower bars: 4 pcs

Left bars: 4 pcs

Right bars: 4 pcs

Cover - a: 20 mm

Concrete section

bc: 400 mm

hc: 400 mm

Material: C20/25 EN 1992-1-1:2010

Steel section

Name: HEA 200

Modulus of elasticity applied in structural analysis

☒ Secant modulus of elasticity $E_{cm} = 22(f_{cm}/10)^{1.3} = 29962,0$

☐ Design value of elastic modulus $E_{cd} = E_{cm}/\gamma_c = 19974,7$

☒ Special calculation of the effective flexural stiffness taking into consideration the shrinkage, creep and cracking

☐ Apply L/200 initial sway in Y direction

☐ Apply L/150 initial sway in Z direction

<< Previous Close Create

Diagram: A cross-section diagram of a fully encased I-section in concrete. The diagram shows the concrete section with dimensions b_c and h_c . The steel section is an I-beam with flange width a and web thickness a . Reinforcement bars are shown: Upper bars (top flange), Lower bars (bottom flange), Left bars (left flange), and Right bars (right flange). The Y and Z axes are indicated.

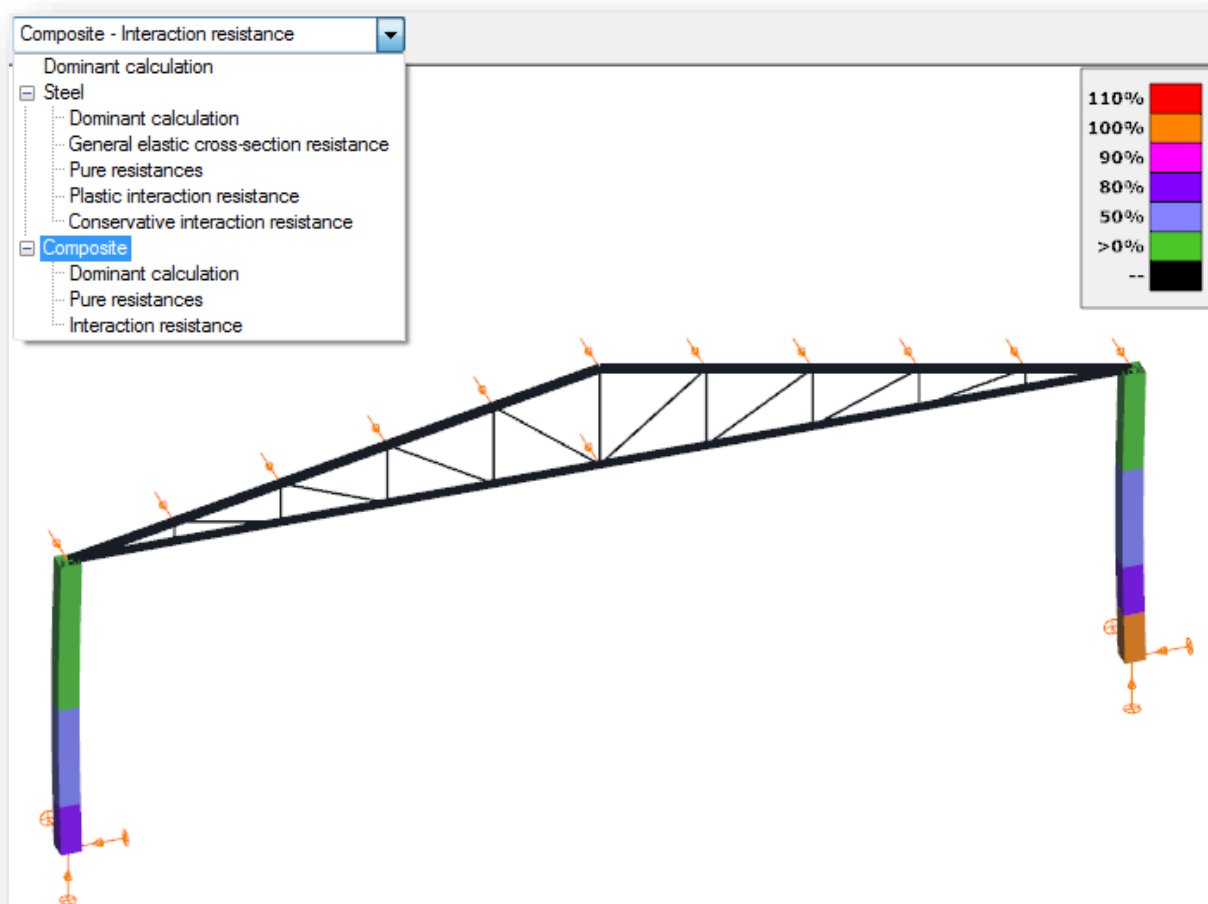
If the initial sways in the y and z directions were applied on the checked cross-section then the stability check of the composite columns can be neglected. Cross-section checks are enough.



9.3.1.1 RESULTS

The results of the performed checks are demonstrated with graphical visualization and result tables (for the general functionality of tables used in *Consteel* see section **1.4 GENERAL FUNCTIONS FOR TABLES**).

The shown results can be changed in the drop-down menu.



When moving the mouse along the structural elements the result markers continuously appear showing the actual utilization.

The detail of the results can be seen in the Section module (see **CHAPTER 10 SECTION MODULE**). Section module can be opened directly from the **GLOBAL CHECKS** tab to click on the proper cross section on the model area or in the result table with right click and select the **CALCULATE SECTION** menu.



9.3.2 COMPOSITE BEAM DESIGN

To run composite beam design, go to **MEMBER CHECKS** tab and select **COMPOSITE BEAM** tab in the table at the bottom of the screen. Then select the composite beams and click on **ADD** button. Now the selected beams are added to the table. Select the beam(s) from the list which you would like to design and click on **SELECT (SELECT+)** button. You can select which load combinations and first or second order results to use for the design. Then click on the **CHECK** button and the design will be performed.

Composite beam design in *Consteel* is carried out according to EN 1994-1-1:2010 standard.

The design bending resistance is determined using plastic theory according to 6.2.1.2 or 6.2.1.3 where the cross-section is in Class 1 or 2. The section class is determined acc. to 5.5.2. Class 3 and 4 cross-sections are not covered by *Consteel* composite beam design. The composite beam is checked for plastic bending, vertical shear, and shear buckling, crushing of the concrete flange and longitudinal shear at all the critical cross-sections. The critical cross sections are determined according to 6.1.1. (4). The following methods are not included in *Consteel*: non-linear resistance to bending (6.2.1.4.) and elastic resistance to bending (6.2.1.5.). The profiled steel decking is assumed not to contribute to the resistance.

9.3.2.1 ANALYSIS MODEL

In the **analysis model** the calculation of the effective width of concrete flange is based on the method defined in a previous chapter (in the dependence of the span and the distance between the shear studs in the cross section). Based on practice experiences, composite beams are usually created as two-pinned one span beams. *Consteel* can design composite beams with one span formation. In case of multi span beams, and where the tension is in the concrete flange, design cannot be performed.

In the **ANALYSIS** tab the analysis model is displayed.

9.3.2.2 DESIGN OF SHEAR STUDS

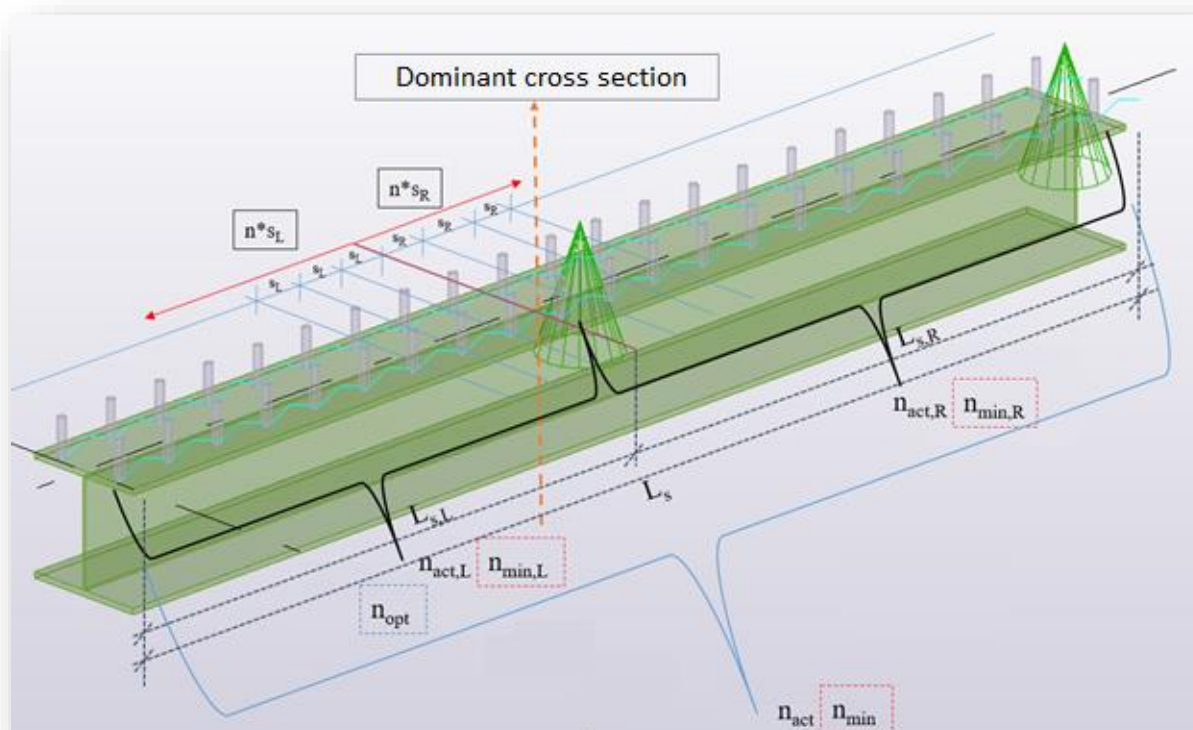
The allocation of the studs is plastic based, where the studs has to be distributed uniformly in both directions from the dominant cross section. The dominant cross section, where the bending is maximal, is located automatically.

If the number of shear studs is wanted to be calculated automatically, *Consteel* will calculate the bending resistance of the beam with the minimal required number of studs. *Consteel* will increase than the number of shear studs, until the bending resistance exceeds the acting bending on the beam.



The green section on the schematic figure below shows, where the optimal distribution of shear studs is calculated. The following parameters are evaluated for the examined part of the beam:

- n_{opt} : optimal number of shear stud positions along the dominant phase of the beam
- n_{act} : number of shear stud positions along the examined member
- s_L : shear stud distribution in the left direction from the dominant cross section [mm]
- $n_{act,L}$: number of shear stud positions in the left direction from the dominant cross section
- s_R : shear stud distribution in the right direction from the dominant cross section [mm]
- $n_{act,R}$: number of shear stud positions in the right direction from the dominant cross section



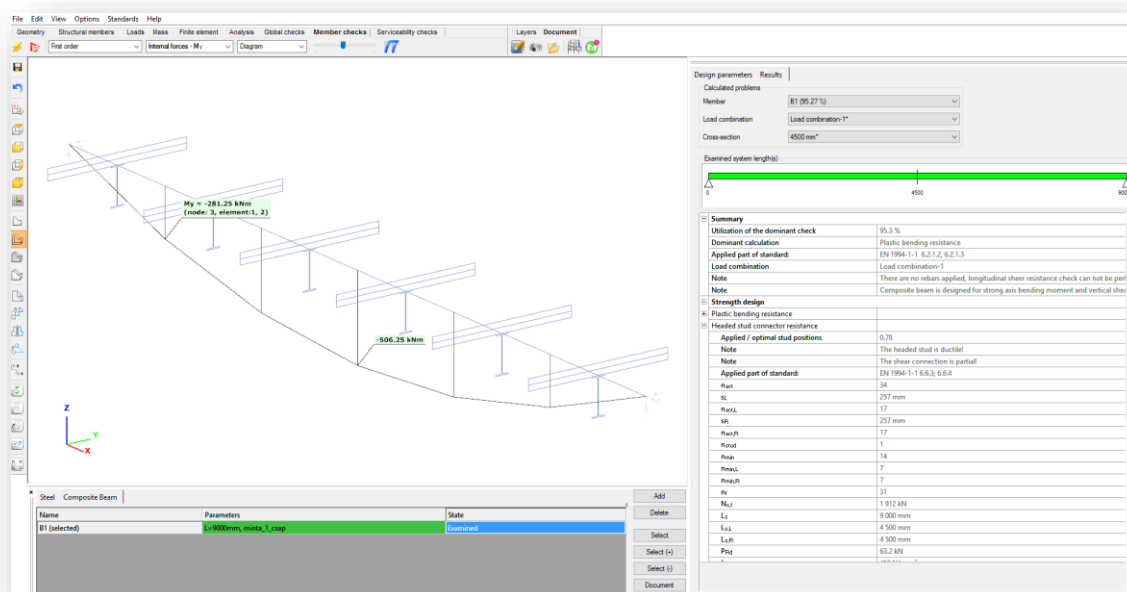
- n_{stud} : number of shear studs in one cross section

- n_{min} : minimum number of shear stud positions along the member
- $n_{min,L}$: minimal number of shear stud positions in the left direction from the dominant cross section
- $n_{min,R}$: minimal number of shear stud positions in the right direction from the dominant cross section

Instead of using the automatic evaluation of the number of the shear studs, manual definition of the number of studs is available too. In this case, the software checks, if the distribution fits

to the detailing rules, such as the minimal and the maximal distance between the studs. The number of the studs has to be given for the whole length of the beam. During the check of the beam, Consteel will uniformly distribute the studs along the member (In case of automatic evaluation of required shear stud numbers, non-uniform distribution is also possible).

Calculation of the utilizations of the shear studs are evaluated by the dividing the applied number of shear studs with the optimal number of shear studs (n_{act} / n_{opt})



9.3.2.3 SHEAR BUCKLING RESISTANCE OF COMPOSITE BEAMS

The shear buckling resistance of the web is determined in accordance with section 5 and Appendix A of EN 1993-1-5:2006. The shear resistance contribution of the flanges is ignored.

9.3.2.4 BENDING AND VERTICAL SHEAR RESISTANCE

The influence of vertical shear on the bending resistance is ignored if the vertical shear force is less than the half of the shear resistance.

For Class 1 or 2 cross-sections, if the vertical shear force exceeds the half of the shear resistance, the reduced design steel strength is used to calculate the bending strength of the member as defined in 6.2.2.4 (2)

9.3.2.5 LATERAL-TORSIONAL BUCKLING RESISTANCE OF COMPOSITE BEAMS

Lateral-torsional buckling of composite beams is not included.



9.3.2.6 SHEETING WITH RIBS PARALLEL TO THE SUPPORTING BEAM

The design shear resistance of studs is taken as the resistance of the studs in solid slab multiplied by the reduction factor as defined in 6.6.4.1 (2).


If the sheeting is discontinuous Consteel assumes that it is welded to the flange of the beam but the distance between two ribs ('a' parameter) can be set.

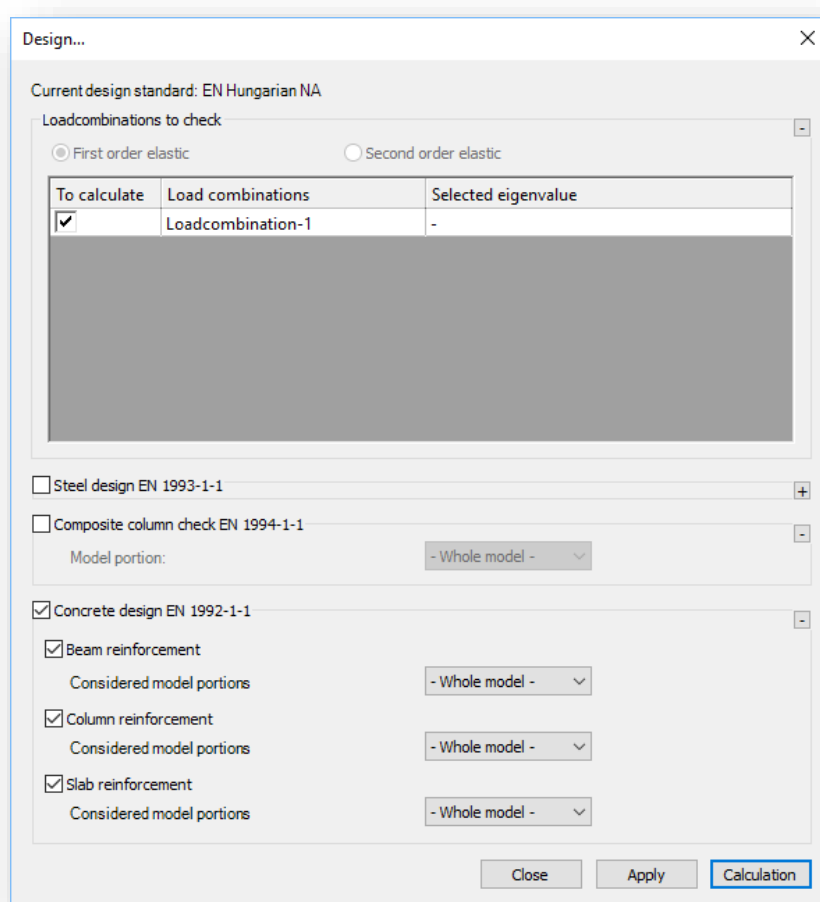
9.3.2.7 SHEETING WITH RIBS PERPENDICULAR TO THE SUPPORTING BEAM

The design shear resistance of studs is taken as the resistance of the stud in the solid slab multiplied by the reduction factor as defined in equation 6.23, limited to the maximum value as defined in Table 6.2. While calculating the resistance of studs in solid slabs the stud ultimate tensile strength is limited to 450 N/mm².



9.4 REINFORCED CONCRETE DESIGN

Design of concrete members are available at the **GLOBAL CHECKS** tab. By clicking on the  button, the **DESIGN...** dialogue will appear, where below the *Steel* and *Composite design*, the **CONCRETE DESIGN EN 1992-1-1** panel can be found. On the panel, **BEAM REINFORCEMENT**, **COLUMN REINFORCEMENT** and **SLAB REINFORCEMENT** calculations are available. If the necessary input parameters for these calculations are available (*cross sections, reinforcement data, design parameters and analysis results*) the checkboxes are active, and choosing the desired item, **CALCULATION** can be initiated to obtain utilizations.



Design...

Current design standard: EN Hungarian NA

Load combinations to check

☒ First order elastic ☐ Second order elastic

To calculate	Load combinations	Selected eigenvalue
<input checked="" type="checkbox"/>	Loadcombination-1	-

☐ Steel design EN 1993-1-1

☐ Composite column check EN 1994-1-1

Model portion: - Whole model -

☒ Concrete design EN 1992-1-1

☒ Beam reinforcement

Considered model portions: - Whole model -

☒ Column reinforcement

Considered model portions: - Whole model -

☒ Slab reinforcement

Considered model portions: - Whole model -

Close Apply Calculation

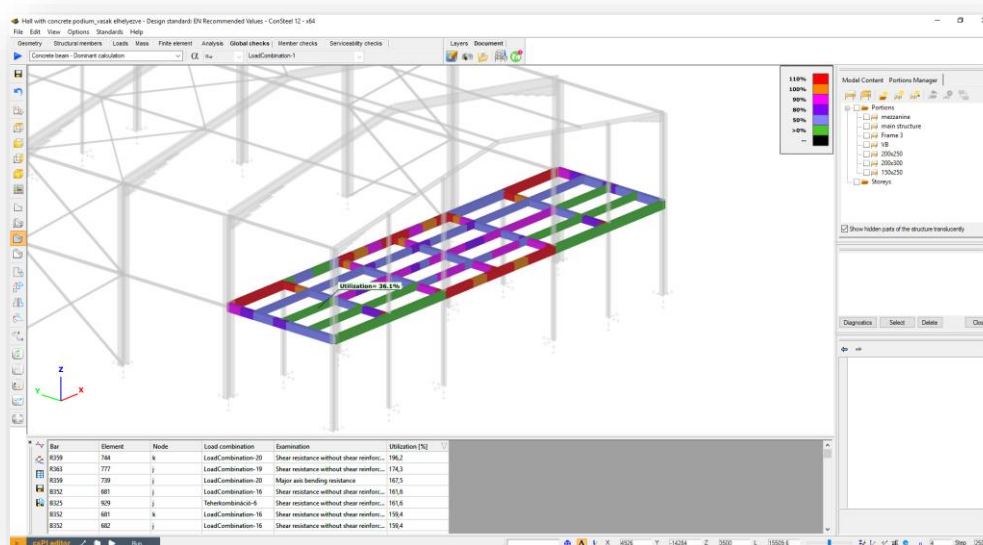
Required input parameters for concrete design are the following (see **CHAPTER 5.2.2 CONCRETE REINFORCED MEMBERS** for details):

- ▶ In case of concrete beams and columns
 - Reinforced concrete cross sections with design option (see **CHAPTER 5.2.2.1**)

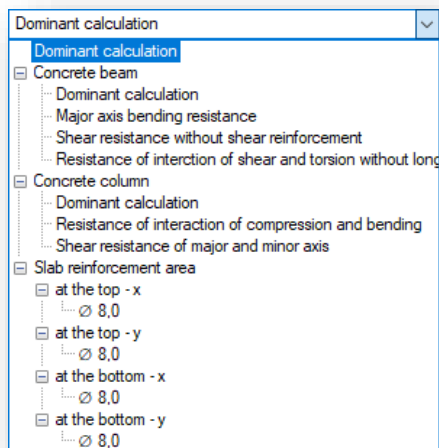


- Beam/column reinforcement object assigned to the concrete member (see **CHAPTER 5.2.2.1.1** and **5.2.2.1.2**)
- First or second order analysis results (see **CHAPTER 8.5.1.1** and **8.5.1.2**)
- ▶ In case of reinforced concrete slabs
 - Defined reinforcement schemes in the main directions (see **CHAPTER 5.3.1**)
 - First or second order shell results (see **CHAPTER 8.6.1**)

During the design, **CONSTEEL** will perform the available standard checks according to EN1992-1-1 for all of the cross sections automatically. Cross sections with their dominant utilizations will be collected into the results grid and will be shown using the color-coded visualization in the modelling area.



Results of the individual standard checks can also be obtained using the dropdown menu in the upper left corner of the design tab:



9.4.1 REINFORCED CONCRETE BEAM DESIGN

In case of concrete beam design, the following checks of **EN1992-1-1** will be performed:

- ▶ Longitudinal reinforcement
 - EN1992-1-1 9.2.1.1 (1) (9.1.n) formula - Minimum longitudinal reinforcement
 - EN1992-1-1 9.2.1.1 (3) formula - Maximum longitudinal reinforcement
 - EN1992-1-1 6.1 – Major axis bending
- ▶ Shear reinforcement
 - EN1992-1-1 9.2.2. (6) (9.6.N) formula – Maximum stirrup distance
 - EN1992-1-1 9.2.2 (5) (9.5.n) formula – Minimum percentage of reinforcement
 - EN1992-1-1 6.2.2. (1) (6.2.a) and (6.2.b) formula – Shear resistance without shear reinforcement
 - EN1992-1-1 6.2.3. (3) (6.8) and (6.9) formula – Shear resistance with shear reinforcement
- ▶ Interaction of shear and torsion
 - EN1992-1-1 6.3.2. (4) (6.29) formula – Resistance of inclined compression concrete bars
 - EN1992-1-1 6.3.2. (5) (6.31) formula – Required longitudinal torsion reinforcement
 - EN 1992-1-1 6.3.2. (3) (6.28) formula – Applied longitudinal torsion reinforcement

9.4.2 REINFORCED CONCRETE COLUMN DESIGN

In case of concrete column design, the following checks of **EN1992-1-1** will be performed:

► Longitudinal reinforcement

- EN1992-1-1 9.5.2 (1) formula – Minimum diameter of longitudinal reinforcement
- EN1992-1-1 9.5.2 (2) formula – Minimum longitudinal reinforcement
- EN1992-1-1 9.5.2 (3) formula – Maximum longitudinal reinforcement
- EN1992-1-1 5.8.3 and 5.8.8 – Biaxial bending

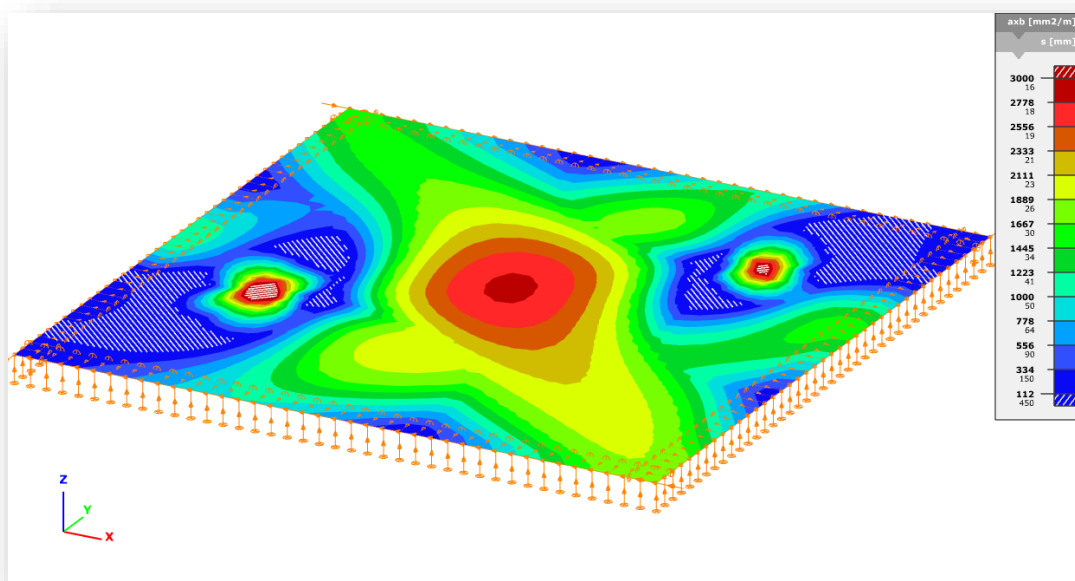
► Shear reinforcement

- EN1992-1-1 9.5.3 (1) formula – Minimum diameter of stirrup
- EN1992-1-1 9.5.3 (2) formula - Maximum distance of stirrups
- EN1992-1-1 6.2.2 (1) (6.2.a) and (6.2.b) formula – Shear resistance without shear reinforcement
- EN1992-1-1 6.2.3 (3) (6.8) and (6.9) formula – Shear resistance with shear reinforcement

9.4.3 REINFORCED CONCRETE SLAB DESIGN

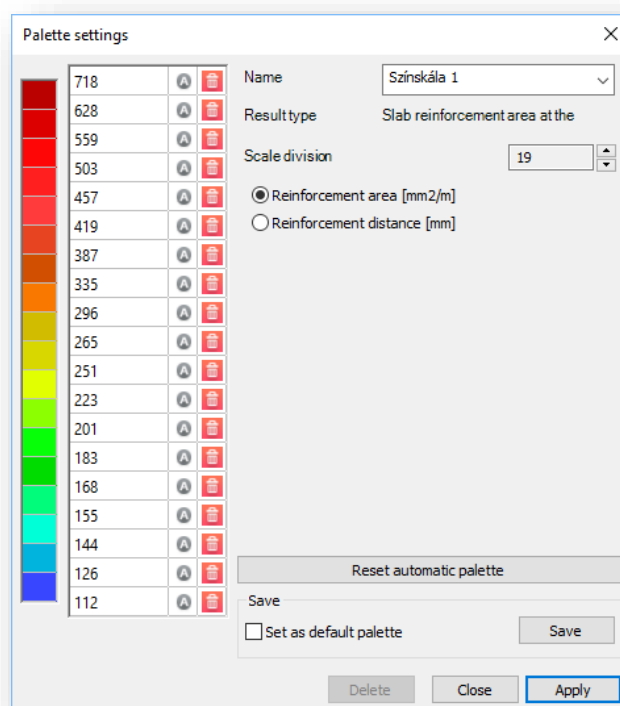
If there is a concrete slab placed in the model, with applied reinforcement in the main directions (see **CHAPTER 5.3**), the possibility for slab reinforcement calculation will be available in the **DESIGN...** dialogue.

Result of the calculation is the required area of reinforcement [mm²/m] in each of the main directions, both in upper and lower positions. Change between the visualization of the directions is possible with the dropdown menu in the upper left corner. Results are represented with contour surface visualization:





By clicking on the color palette with the right mouse button, properties (such as scale division, values of divisions) can be modified:



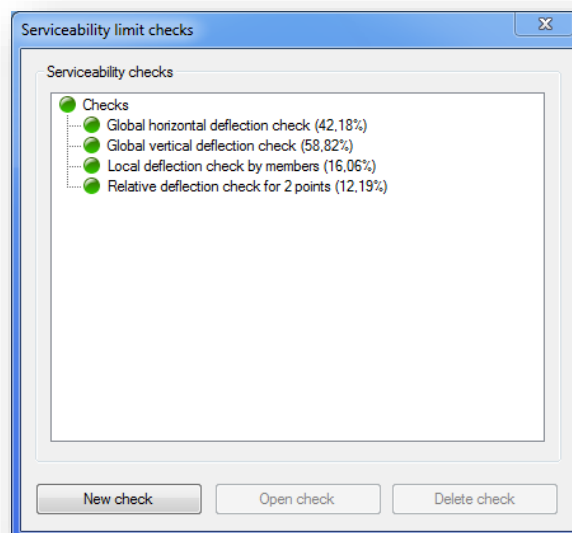
The result of the calculation, the contour surface with the color palette itself can be exported into dxf form from **FILE/EXPORT** menu (see **CHAPTER 2.6**).



9.5 SERVICEABILITY CHECKS

9.5.1 BASICS

All serviceability related functions can be found on the **SERVICEABILITY** tab. By clicking on the blue arrow icon, a new dialog appears. The previously defined serviceability checks can be found, and it is also possible to open or delete the selected checks.



To create a new serviceability, check **NEW CHECK** button is clicked. The following checks can be performed:

- ▶ Global horizontal deflection check
- ▶ Global vertical deflection check
- ▶ Local deflection check by members
- ▶ Relative deflection check for 2 points



9.5.2 GLOBAL HORIZONTAL DEFLECTION CHECK

Global horizontal deflection check can be used to check the biggest horizontal deflection in the model. First or Second order analysis can be selected just like the serviceability load combinations that need to be considered.

Reference height can be typed in or two points can be selected, and program calculates the height distance between them. Check is done after clicking the **CALCULATION** button. The dominant bar is automatically selected in the model to make the interpretation easier.

Global horizontal deflection check

Check name: Global horizontal deflection check

Type of design:
☒ First order analysis ☐ Second order analysis

To cal... Load combinations

<input checked="" type="checkbox"/>	Load combination-2
<input checked="" type="checkbox"/>	Load combination-3
<input checked="" type="checkbox"/>	Load combination-4
<input checked="" type="checkbox"/>	Load combination-5
<input checked="" type="checkbox"/>	Load combination-1

Parameters

Reference height H [mm]: 6000

First structural point: X: 0 Y: 0 Z: 6000

Second structural point: X: 0 Y: 0 Z: 0

Deflection limit: H / 100

Calculation

Results

Dominant load combination: Load combination-2

Bar name: B1

Finite element point: 2

Dominant horizontal deflection [mm]: 252,575

Deflection limit [mm]: 60

Capacity [%]: 420,958

Mégsé OK

9.5.3 GLOBAL VERTICAL DEFLECTION CHECK

Global vertical deflection check works similar to the global horizontal deflection check. There is just minor difference which is the following: reference length must be set instead of reference height. This can be set manually or by clicking two points on the model.

Global vertical deflection check

Check name: Global vertical deflection check

Type of design:
☐ First order analysis ☒ Second order analysis

To cal... Load combinations

<input checked="" type="checkbox"/>	Load combination-1
<input checked="" type="checkbox"/>	Load combination-2
<input checked="" type="checkbox"/>	Load combination-3
<input checked="" type="checkbox"/>	Load combination-4
<input checked="" type="checkbox"/>	Load combination-5

Parameters

Reference length L [mm]: 7000

First structural point: X: 0 Y: 0 Z: 6000

Second structural point: X: 7000 Y: 0 Z: 6000

Deflection limit: L / 100

Calculation

Results

Dominant load combination: Load combination-2

Bar name: B2

Finite element point: 3

Dominant vertical deflection [mm]: 291,489

Deflection limit [mm]: 70

Capacity [%]: 416,412

Mégsé OK



9.5.4 LOCAL DEFLECTION CHECK BY MEMBERS

Local deflection check by members goes through all the beams in the model, and checks the local deflection, and then selects the maximum. This check is suitable only for horizontal beams i.e. members in XY plane.

Local deflection check by members is not adequate for cantilever beams just for beams which are supported by two other beams or supports in both ends.

Local deflection check by members

Check name: Local deflection check by members

Type of design

☐ First order analysis ☒ Second order analysis

To cal...

	Load combinations
<input checked="" type="checkbox"/>	Load combination-2
<input checked="" type="checkbox"/>	Load combination-3
<input checked="" type="checkbox"/>	Load combination-4
<input checked="" type="checkbox"/>	Load combination-5
<input checked="" type="checkbox"/>	Load combination-1

Parameters

Model portion: Whole model

Deflection limit: L / 100

Calculation

Results

Dominant load combination: Load combination-1

Bar name: B2

Finite element point: 10

Dominant relative vertical deflection [mm]: 0,701502

Deflection limit [mm]: 50

Capacity [%]: 1,403

Mégse OK

9.5.5 RELATIVE DEFLECTION CHECK FOR 2 POINTS

Relative deflection check for 2 points can be used for two clicked points. Relative horizontal or vertical check can be selected and performed.

Relative deflection check for 2 points

Check name: Relative deflection check for 2 points

Type of design

☐ First order analysis ☒ Second order analysis

To cal...

	Load combinations
<input checked="" type="checkbox"/>	Load combination-2
<input type="checkbox"/>	Load combination-3
<input type="checkbox"/>	Load combination-4
<input type="checkbox"/>	Load combination-5
<input type="checkbox"/>	Load combination-1

Parameters

First structural point: X: 0 Y: 0 Z: 6000

Second structural point: X: 5000 Y: 0 Z: 6000

☐ Relative horizontal deflection

Deflection limit [mm]: 10

Dominant load combination: Load combinations

Dominant horizontal deflection [mm]: 0

Capacity [%]: 0

☒ Relative vertical deflection

Deflection limit [mm]: 100

Dominant load combination: Load combination-2

Dominant vertical deflection [mm]: 291,455

Capacity: 291,455

Calculation Mégse OK



10 SECTION MODULE

10.1 BASICS

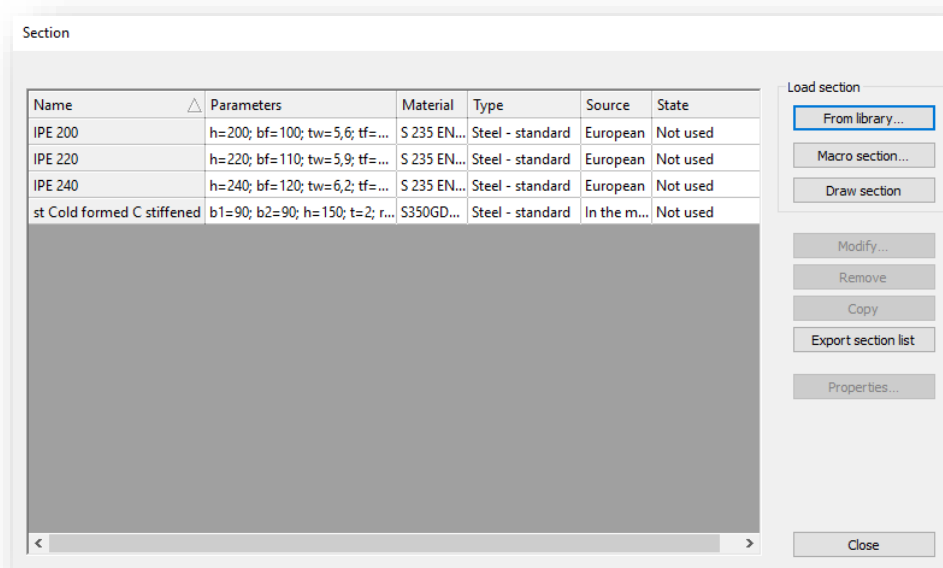
The wide functionality of the *Consteel* connected with cross-sections suggested detaching a separate module: Section Module (**CSSECTION**). This module collects all the tools relate to the creation, property calculation, stress analysis and standard design of a cross-section. Two parallel modelling possibilities exist: the *General Solid Section (GSS)* is an accurate finite element-based surface model for any kind of cross-sections; the *Elastic Plate Segment (EPS)* is a thin-walled model especially for steel profiles. The steel standard design formulas are easy to evaluate on the *EPS* model including the real effective section generation of class 4 cross-sections based on the sectional forces resulted from the structural analysis.



Section administration and Section module can be launched by clicking the icons shown above. These icons can be found in the **STRUCTURAL MEMBERS** tab.

10.2 SECTION ADMINISTRATION

Section must be loaded into the model database in order to use it in the model. This can be done in the section administration dialogue. Here you can see all the previously loaded sections and new sections can be loaded or created by clicking the buttons on the right.



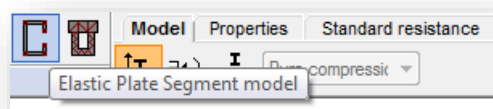


It is very important to know that the material grade of the member must be chosen when the section is loaded into the database.

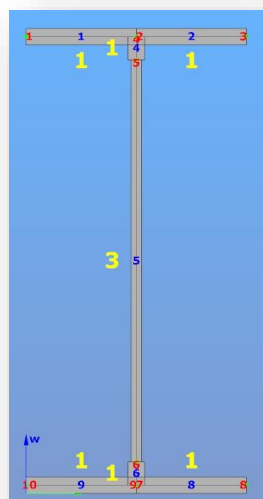
See Section 5.2 for details on loading and creating cross sections.

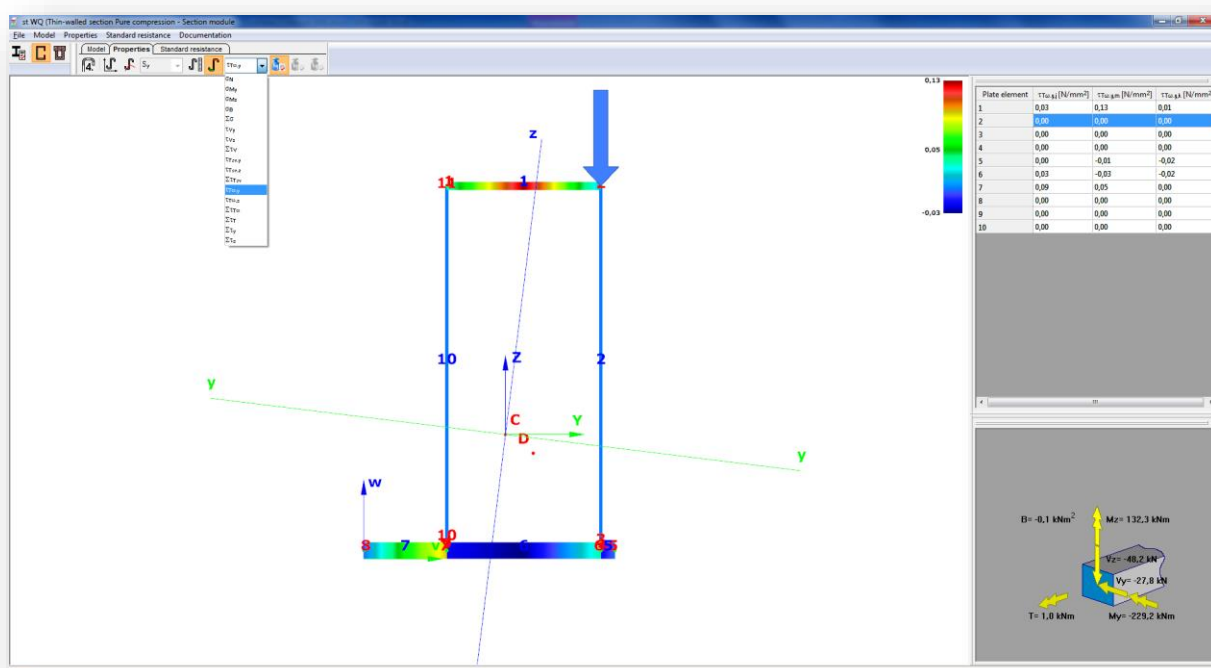
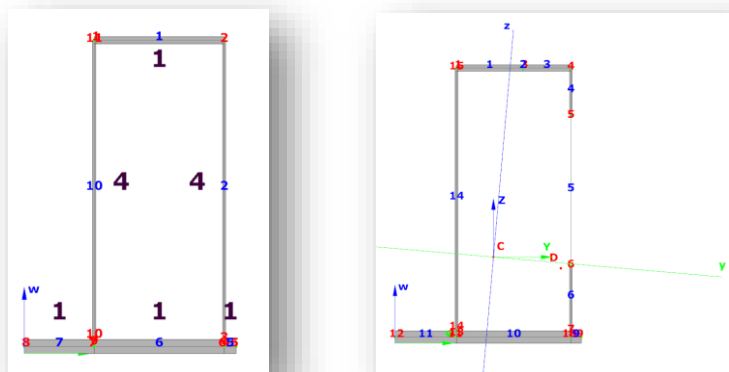
10.3 SECTION MODELLING

10.3.1 THE EPS MODEL

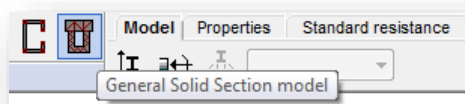


The *Elastic Plate Segment (EPS)* model is a thin-walled simplification of the usually steel profiles from welded, hot-rolled, or cold-formed sections. The model is very easy and fast to calculate and has accurate results for thin-walled sections compared with the GSS model, which can be used and run for the same section side by side. The model yields the same general, torsional and shear properties and stresses and moreover it calculates the static moments and sectional classes according to the EuroCode. The EPS model is also very suitable for the evaluation all of the standard design formulas in a very sophisticated way. In case of Class 4 profile the effective cross-section is automatically generated based on the proper sectional forces, and the standard procedures can be evaluated on this effective section. In Consteel version 13 it is new that the program automatically considers the effect of distortional buckling when calculating the effective cross-sections of cold-formed thin-wall sections.



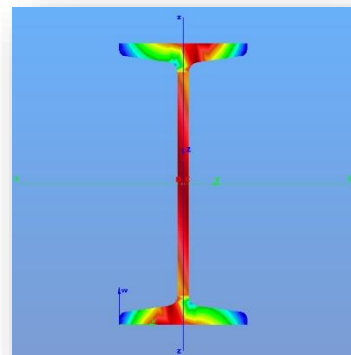


10.3.2 THE GSS (GENERAL SOLID SECTION) MODEL





The *General Solid Section (GSS)* was created to model any kind of cross sections as accurate as possible. The model dissolves the section with arbitrary shape into triangle elements and calculates the sectional properties by the finite element method. The section can be assembled with any number of different materials and the automatic finite element mesh generates separate triangles for the certain materials controlling the mesh size according to the elastic properties of the material. Beyond the usual properties (sectional area, second moment of inertia, etc.) the GSS model precisely calculates the torsional and shear properties like S_t , Venant and warping moment of inertia, shear areas and factors, etc., and these accurate properties are used in the global analysis. The elastic normal, torsional and shear stresses can be also calculated on this model using a spectacular colored view.



10.4 SECTION TOOLS

10.4.1 GEOMETRICAL CALCULATIONS

There are three coordinate systems in Section module: main axis system (y, z), section edit system (v, w) and the section edit system moved to the center (C) of the section (Y, Z). The point D is the center of rotation.

The section properties can be viewed according to these coordinate systems.

10.4.2 LOADS

If the section module is opened from the model, then all the load combination from the model are automatically imported into the section model. The relevant is chosen but any other can be selected and checked. It is also possible to add load combinations manually by clicking on

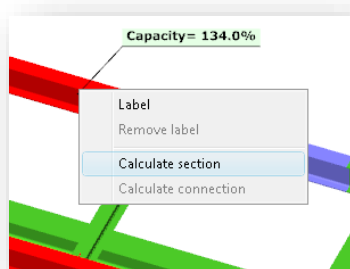
the **NEW LOAD COMBINATION** icon .

Lcomb.	Current	N_{Ed} [kN]	$M_{y,Ed}$ [kNm]	$M_{z,Ed}$ [kNm]	$V_{y,Ed}$ [kN]	$V_{z,Ed}$ [kN]	B_{Ed} [kNm ²]	$T_{t,Ed}$ [kNm]	$T_{w,Ed}$ [kNm]	T_{Ed} [kNm]	$\beta_{or,op}$ [-]	β_{ult} [-]
Load Combination 1 (first order)	<input type="checkbox"/>	0,0	-162,3	0,0	-0,0	93,8	-0,1	-0,1	0,1	0,0	1,370	0,937
Load Combination 1 (second order)	<input checked="" type="checkbox"/>	-0,5	-162,3	-0,0	-0,2	93,8	-0,1	-0,0	0,0	0,0	1,370	0,937

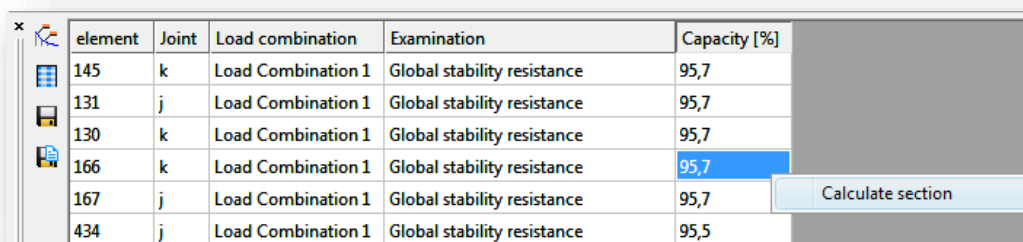
CSSECTION can be launched from the model if the **ANALYSIS** or **GLOBAL CHECK** tab is chosen and first or second order analysis or standard design had been run. There are two ways to



open **CSSECTION** directly for a selected section. First is to press right click over the section which needs to be analyzed and select **CALCULATE SECTION**.



The second way is to press right click over the element in the result sheet which can be found in the bottom of the screen and click on **CALCULATE SECTION**.




element	Joint	Load combination	Examination	Capacity [%]
145	k	Load Combination 1	Global stability resistance	95,7
131	j	Load Combination 1	Global stability resistance	95,7
130	k	Load Combination 1	Global stability resistance	95,7
166	k	Load Combination 1	Global stability resistance	95,7
167	j	Load Combination 1	Global stability resistance	95,7
434	j	Load Combination 1	Global stability resistance	95,5

Calculate section

10.4.3 STRESSES

Stresses can be checked by selecting the **PROPERTIES** tab and clicking on the **STRESSES**

icon . Stresses can be viewed both in the EPS and the GSS model.

The following stresses are calculated by **CSSECTION**:


Stress Symbol	Stress name
σ_N	Normal stress due to axial force
σ_{My}	Normal stress due strong axis bending
σ_{Mz}	Normal stress due to weak axis bending
σ_B	Normal stress due to bimoment
$\Sigma\sigma$	Resultant normal stress

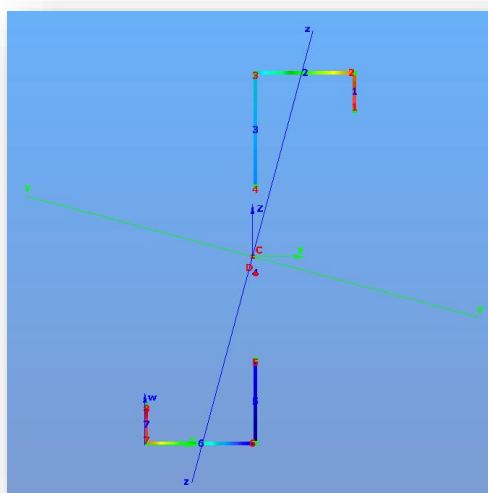


τ_{Vy}	Shear stress due to strong axis shear force
τ_{Vz}	Shear stress due to weak axis shear force
$\Sigma \tau_V$	Resultant shear stress due to shear forces
$\tau_{Tsv,y}$	Strong axis shear stress due to St. Venant torsion
$\tau_{Tsv,z}$	Weak axis shear stress due to St. Venant torsion
$\Sigma \tau_{Tsv}$	Resultant shear stress due to St. Venant torsion
$\tau_{Tw,y}$	Strong axis shear stress due to warping torsion
$\tau_{Tw,z}$	Weak axis shear stress due to warping torsion
$\Sigma \tau_{Tw}$	Resultant shear stress due to warping torsion
$\Sigma \tau_T$	Resultant shear stress due to torsion
$\Sigma \tau_y$	Strong axis resultant shear stress
$\Sigma \tau_z$	Weak axis resultant shear stress

10.4.4 EFFECTIVE CROSS SECTION



If the first icon  is clicked and EPS model is selected, then effective section takes into consideration.





10.4.5 STANDARD RESISTANCE CALCULATIONS



For the given loading case the module determines the necessary and possible checks, performs all the standard calculations, and evaluates the dominant case.

10.4.5.1 STEEL CROSS SECTIONS

The standard design procedures performed on the *EPS* model cover the major part of steel design methods in the Eurocode (the whole EN 1993-1-1 and parts of EN 1993-1-5) including the calculations of general elastic resistance, examination of pure cases, plastic and conservative interaction resistances of certain section types, web buckling analysis.

The following design checks are calculated by *CSSECTION*:

Verification type	Section class				Shape type					
	1	2	3	4	I	U	O	□	■	Other
Pure forces										
6.2.3	•	•	•	•	•	•	•	•	•	•
6.2.4	•	•	•	•	•	•	•	•	•	•
6.2.5	•	•	•	•	•	•	•	•	•	•
6.2.6(2-3)	•	•			•	•	•	•	•	•
6.2.6(4-5)			•	•	•	•	•	•	•	•
6.2.7	•	•	•	•	•	•	•	•	•	•
EN 1993-1-5	•	•	•	•	•	•		•		
Interactions – plastic										
V + T										
6.2.7(6.26)	•	•			•					
6.2.7(6.27)	•	•				•				
6.2.7(6.28)	•	•					•	•		

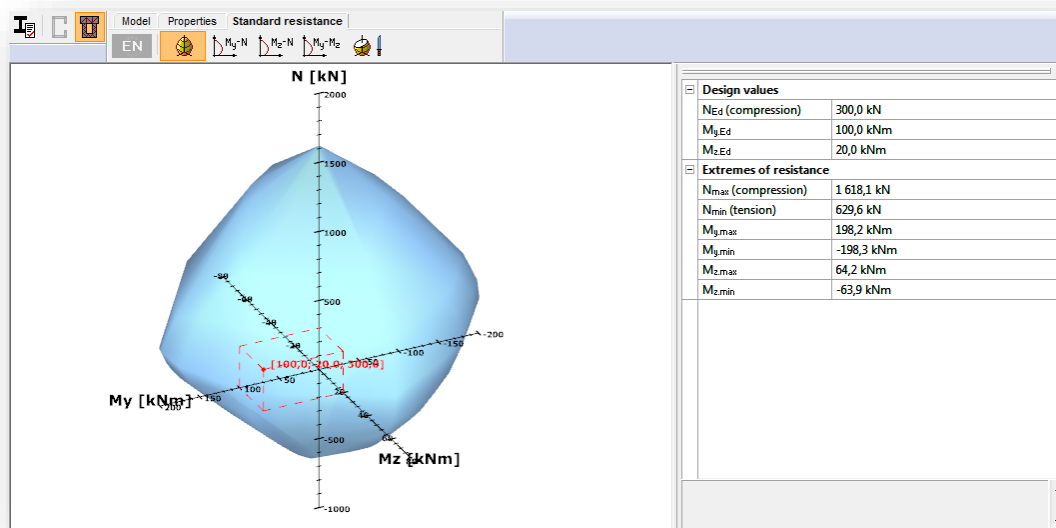


M + V (+ T)										
6.2.8	•	•			•	•	•	•	•	•
My + N (+ V + T)										
6.2.9(6.32)	•	•							•	
6.2.9(6.33 - 6.34, 6.36)	•	•			•					
6.2.9(6.39)	•	•						•		
ENV 1993-1-1:1995 (E) 5.4.8.1(5.34)	•	•					•			
Mz + N (+ V + T)										
6.2.9(6.32)	•	•							•	
6.2.9(6.35, 6.37 - 6.38)	•	•			•					
6.2.9(6.40)	•	•						•		
ENV 1993-1-1:1995 (E) 5.4.8.1(5.34)	•	•					•			
My + Mz + N (+ V + T)										
6.2.9(6.41)	•	•			•		•	•		
Interaction – General										
My + Mz + N (+ V + T)										
6.2.1 (6.2)	•	•	•		•	•	•	•	•	•
6.2.9.3(6.44)				•	•	•	•	•	•	•
Verification based on elastic stresses										
My + Mz + N (+ V + T)										
6.2.1 (6.1)	•	•	•	•	•	•	•	•	•	•
Lateral and lateral torsional buckling										
6.3.4	•	•	•	•	•	•	•	•	•	•








10.4.5.2 COMPOSITE AND REINFORCED CONCRETE CROSS SECTIONS

In case of reinforced concrete section, the **CSSECTION** module can perform just the resistance surface of the section. It is also possible to view the resistance line along three different axes and the arbitrary section.



For the composite sections the resistance surface and the part of the EC 4 are performed.

The following design checks are calculated by **CSSECTION** for the composite sections:

Verification type	Shape type				
					
Pure forces					
6.7	•	•	•	•	•
6.7.3.2 (6.30)	•	•	•	•	•
6.7.3.2 (figure 6.19), 6.7.3.4	•	•	•	•	•
6.7.1 (9), table 6.3		•	•	•	•
Interactions	•	•	•	•	•
6.7.3.6 (6.45)	•	•	•	•	•
6.7.3.7 (6.46-6.47)	•	•	•	•	•

10.4.5.3 RESULTS



There is a short summary about the calculations on the right and the name of the dominant case, formula and load combination can be found there.

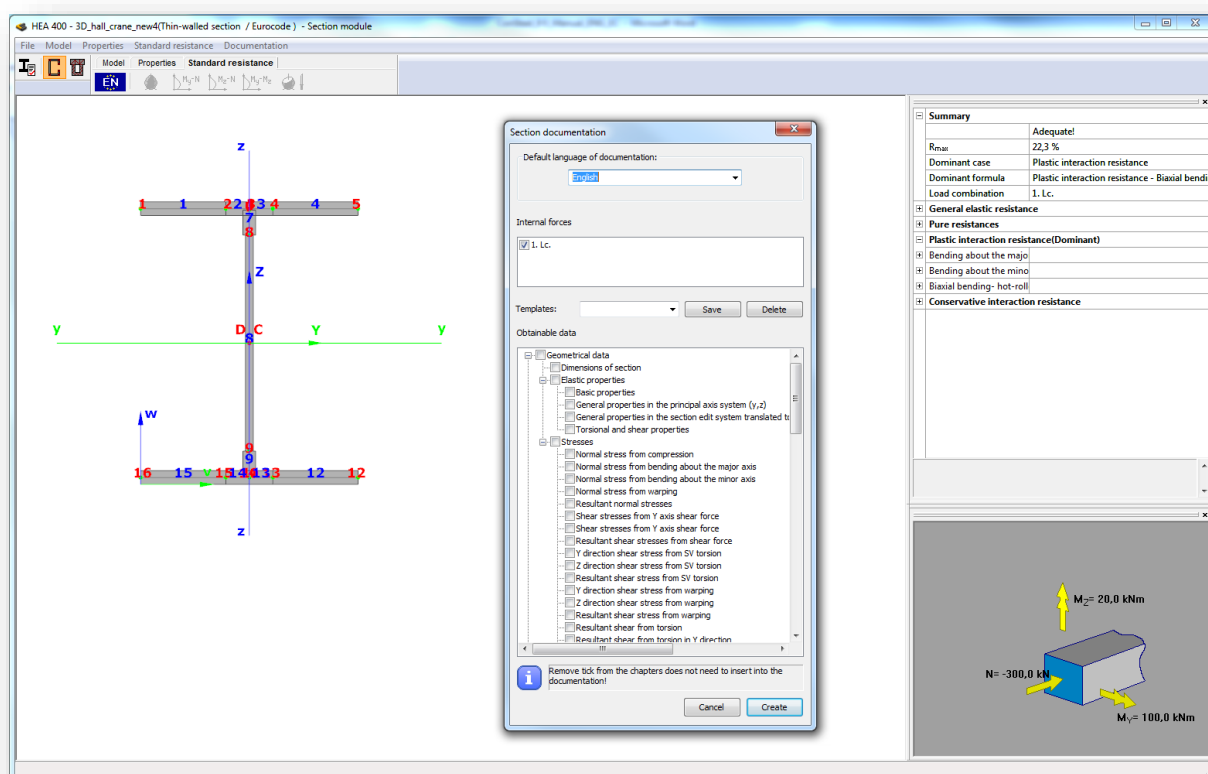
Summary	
	Adequate!
R_{max}	81,1 %
Dominant case	Interaction check
Dominant formula	Compression + Bending about the major axis
Load combination	1. Lc.
Pure resistances	
Compression	
Bending about the major axis	
Utilization	89,3 %
Applied part of standard	EN 1994-1-1 6.7.3.2 6.19 figure 6.7.3.5
$M_{y,Ed}$	200,0 kNm
$I_{eff,y}$	2 561 406 630,0 mm ²
$M_{pl,y,Rd}$	224,1 kNm
Interaction check	
Compression + Bending	
Utilization	81,1 %
Applied part of standard	EN 1994-1-1 6.7.3.6 (6.45) formula
N_{Ed}	1 000,0 kN
$M_{y,Ed}$	200,0 kNm
$M_{pl,y,Rd}$	224,1 kNm
$M_{pl,y,N,Rd}$	274,1 kNm
μ_{dy}	1,22
α_{My}	0,90
$M_{pl,y,Rd}$ Design resistance	



10.5 DOCUMENTATION

Each analyzed cross-section can be separately documented in detail for both section design including the shape parameters, geometrical, mechanical and design results, and the generated documents can be attached to the main documentation of the global structure.

After clicking the **Documentation** option on the menu bar, the way for creating documentation is the same as in *Consteel* main module (see **CHAPTER 13 DOCUMENTATION** for more detailed instructions).





11 FIRE DESIGN

The Fire design process is an integrated part of the *Consteel* automated and efficient design process. In case of fire design situation *Consteel* automatically uses and applies proper formulas of EuroCode for steel elements. General information about the design functionalities can be found in the **CHAPTER 9**.

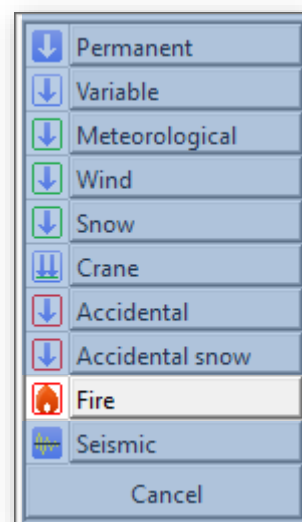
This chapter describes the workflow of the Fire design in *Consteel* and highlights the differences compared to the general rules. Depending on the designed fire protection solution, the structure can be unprotected or protected, in the latter case the fire protection can be passive (insulation) or reactive (intumescent painting). The calculation can be performed with material properties at elevated or room temperature. In the case of elevated temperature analysis, the indirect effects of thermal expansion can also be considered separately.

The required code checks of the different types of steel structural components – cross sections, members – can be conveniently evaluated based on the following standard:

- EN 1993-1-2: General rules. Structural fire design

11.1 FIRE LOAD GROUP

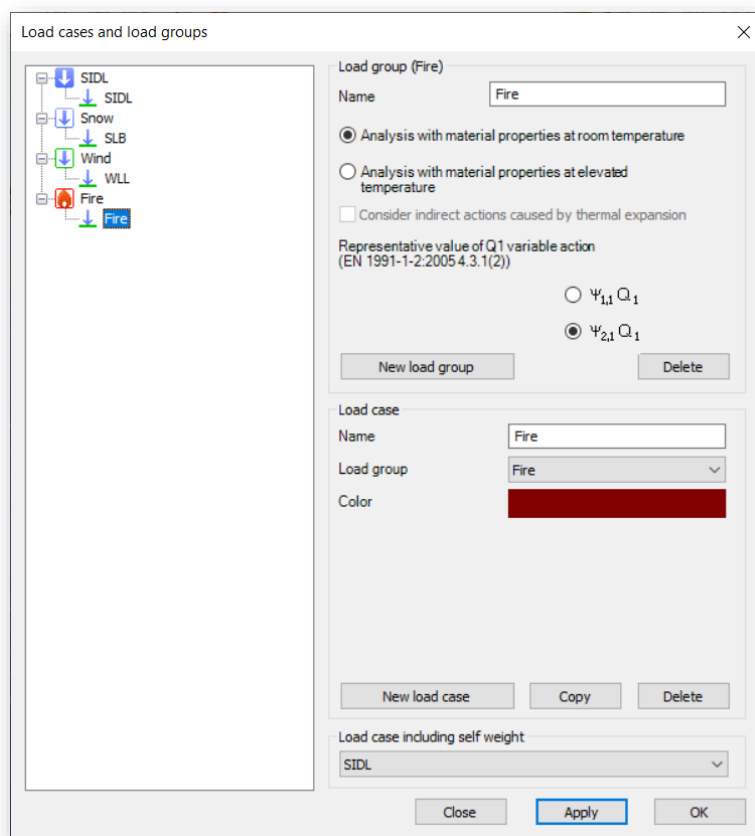
For fire design situation, a dedicated *Fire load* group was created that handles the specialties of fire effect. Before specifying the fire effect, a fire load group and at least one fire load case must be defined.





Fire load group has more options:


- ▶ Analysis with room temperature material properties - this calculation method must be chosen to check the structure with reactive protection (intumescent paint).
- ▶ Analysis with elevated temperature material properties - for the check of structures with passive protection (e.g. gypsum insulation) or without any protection. The stresses and displacements are determined based on the required fire resistance time.
 - Consider indirect actions caused by thermal expansion: By default, Consteel neglect the effect of thermal expansion during the analysis, but by clicking on the checkbox there is the possibility to take it into account.
- ▶ Value of variable factor for main variable load:
By default, Consteel applies the $\Psi_{2,1}$ but switching the radio button $\Psi_{1,1}$ also can be used for load combination generation.

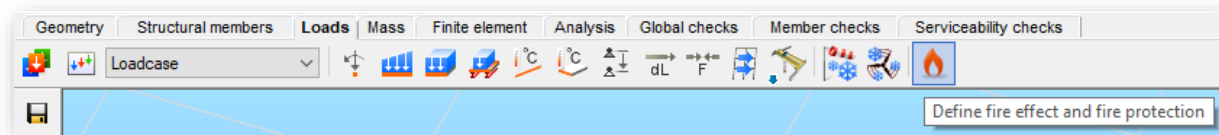


At least one load case must be added to the fire load group to place the fire effect on the model.



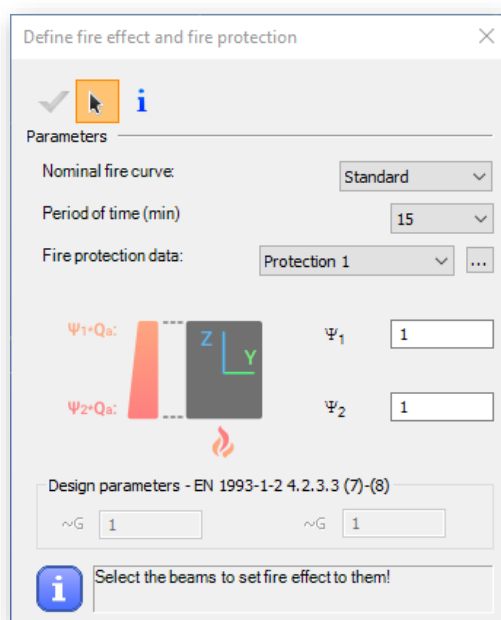
11.2 FIRE EFFECT AND PROTECTION

The fire effect and protection can be defined by clicking the **DEFINE FIRE EFFECT AND FIRE PROTECTION** () icon on the **LOADS** tab.



The first option is to set the nominal fire curve. Three EuroCode defined fire curves are implemented and can be used to define fire effect: Standard, External and Hydrocarbon.

The second one is to set the fire resistance time that can be varied between 15-200 min.



By clicking on the three-dot button next the *Fire protection data* label, different fire protection can be created.

Fire protection can be *Unprotected* and *Protected*. If Protected is chosen, the protection can be passive or reactive.

- **Passive protection:** the insulation material and the thickness must be specified. From the dropdown menu, the section grading for fire effect, according to EN 1993-1-2-4.5. chapter also must be selected.



- **Reactive protection:** this should be selected if the fire protection of the given structure (part) will be provided by an intumescent paint coating and the critical temperature calculation is required to select the paint.



ATTENTION! CRITICAL TEMPERATURE CALCULATION CAN ONLY BE REQUESTED FOR MEMBERS THAT HAVE REACTIVE PROTECTION!

Finally, in the lowest drop-down menu of the dialog box, for any protected or unprotected type, the section grading of the structural element acc. to EN 1993-1-2 - 4.2.5. / 4.2 and 4.3. should be specified.

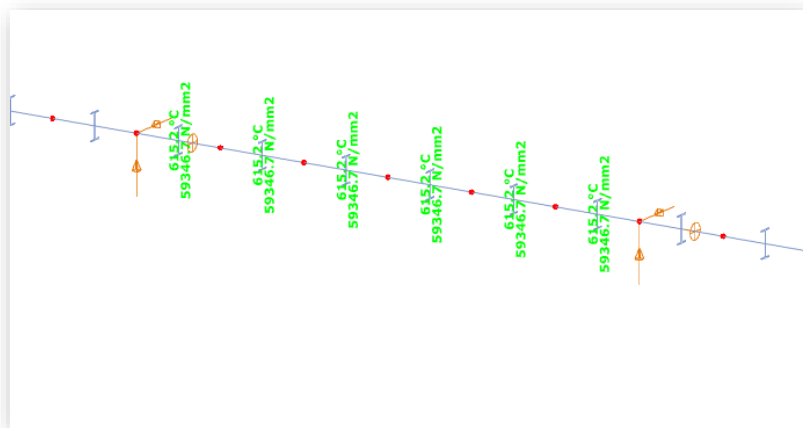
By clicking on the **APPLY** button, fire protection will be saved. With the **NEW** button, several other protections can be created. With **DELETE** button, the selected and created protection can be removed.

The fire effect can be set to a different intensity at the top and the bottom of the member by modifying Ψ_1 and Ψ_2 multiplication factors. In case of varying intensity, the design parameters acc. to the EN 1993-1-2 4.2.3.3 (7)-(8) also can be set.

Created fire effect can be placed on the members with a simple click on the model. It is possible to apply fire effect to more members at the same time. This case the members should be selected before clicking the fire icon.

11.3 ANALYSIS

During the finite element generation *Consteel* calculates the steel temperature and the reduced modulus of elasticity. These values can be viewed in the **FINITE ELEMENT** tab by selecting the appropriate load case.



The analysis for the fire load combinations are performed in global level. Therefore, the calculated deformations and internal forces possibly include the effect of the expansion and decreased elasticity modulus of those members which are subjected to fire.

11.4 DESIGN

11.4.1 FIRE DESIGN ON ELEVATED TEMPERATURE

Consteel performs cross section resistance and buckling checks for all steel members which are subjected to fire effect by using the adequate formulas from the EuroCode 3 standard.

Classification of cross-section (EN 1993-1-2 4.2.2)

Cross-sections are classified as for normal temperature (EN 1993-1-1) but using the reduced value for ε .

$$\varepsilon = 0,85 \cdot \left[\frac{235}{f_y} \right]^{0,5}$$

Tension (EN 1993-1-2 4.2.3.1)

Permanent temperature ((1))

$$N_{t,fi,\theta,Rd} = k_{y,\theta} \cdot \frac{\gamma_{M,\theta}}{\gamma_{M,fi}} \cdot N_{pl,Rd} \quad (\text{Class 1-4})$$

where

$k_{y,\theta}$ value based on a function according to Table 3.1

$N_{pl,Rd}$ based on normal case

Varying temperature ((2))



$$N_{t,fi,t,Rd} = A_{non,t} \cdot \frac{f_y}{\gamma_{M,fi}} \quad (\text{Class 1-4})$$

Compression (Class 1-3: EN 1993-1-2 4.2.3.2, Class 4: + Annex E.2)

Permanent temperature ((1))

$$N_{c,ft,t,Rd} = A \cdot \frac{k_{y,\theta} \cdot f_y}{\gamma_{M,fi}} \quad (\text{Class 1-3})$$

$$N_{c,fi,t,Rd} = A_{eff} \cdot \frac{k_{p0.2,\theta} \cdot f_y}{\gamma_{M,fi}} \quad (\text{Class 4})$$

where

$k_{p0.2,\theta}$ value based on a function according to Table 3.1

Varying temperature ((6))

Conservative way, case (1) where $\theta_a = \theta_{a,max}$

Bending (EN 1993-1-2 Class 1-2: 4.2.3.3; Class 3: 4.2.3.4; Class 4: + Annex E.2)

Permanent temperature ((1))

$$M_{fi,\theta,Rd} = k_{y,\theta} \cdot \frac{\gamma_{M,\theta}}{\gamma_{M,fi}} \cdot M_{Rd}$$

where $M_{Rd} = M_{pl,Rd}$ or in case of shear $M_{Rd} = M_{V,Rd}$ (Class 1-2)

$M_{Rd} = M_{el,Rd}$ or in case of shear $M_{Rd} = M_{V,Rd}$ (Class 3)

$M_{Rd} = M_{eff,Rd}$ (Class 4)

$k_{y,\theta}$ value based on a function according to Table 3.1

Varying temperature ((2))

$$M_{fi,t,Rd} = W_{pl,non,t} \cdot \frac{f_y}{\gamma_{M,fi}} \quad (\text{Class 1-2})$$

$$M_{fi,t,Rd} = k_{y,\theta,max} \cdot \frac{\gamma_{M,\theta}}{\gamma_{M,fi}} \cdot \frac{I}{\kappa_1 \cdot \kappa_2} M_{el,Rd} \quad (\text{Class 3})$$

where $\kappa_1 = 0,7$ if protection=1 and m_factor_section=2,3 or 10

$\kappa_1 = 0,85$ if protection=2 and m_factor_section=3 or 4

$\kappa_1 = 1,0$ in other cases

$\kappa_2 = 1,0$ conservative

$$M_{fi,t,Rd} = k_{p0.2,\theta,max} \cdot \frac{\gamma_{M,\theta}}{\gamma_{M,fi}} \cdot \frac{I}{\kappa_1 \cdot \kappa_2} M_{eff,Rd} \quad (\text{Class 4})$$



Shear (EN 1993-1-2 Class 1-2: 4.2.3.3(6); Class 3: 4.2.3.4(4); Class 4: + Annex E.2)

Permanent temperature

$$V_{fi,t,Rd} = k_{y,\theta,web} \cdot \frac{\gamma_{M,\theta}}{\gamma_{M,fi}} \cdot V_{Rd} \quad (\text{Class 1-4})$$

Varying temperature

$k_{y,\theta,web}$ the hottest point in the web

In case of complex internal forces *Consteel* uses the conservative interaction formula neglecting the effect of shear:

$$\frac{N_{fi,Ed}}{N_{fi,\theta,Rd}} + \frac{M_{y,fi,Ed}}{M_{y,fi,\theta,Rd}} + \frac{M_{z,fi,Ed}}{M_{z,fi,\theta,Rd}} \leq 1$$

Global stability resistance

To calculate the global stability resistance for fire design situation, *Consteel* uses EuroCode General method (EN 1993-1-1 6.3.4) as for normal temperature but using the proper buckling curves:

For compression

$$\chi_{fi} = \frac{1}{\varphi_{\theta} + \sqrt{\varphi_{\theta}^2 - \bar{\lambda}_{\theta}^2}}$$

For bending

$$\chi_{LT,fi} = \frac{1}{\phi_{LT,\theta,com} + \sqrt{\phi_{LT,\theta,com}^2 - \bar{\lambda}_{LT,\theta,com}^2}}$$

11.4.2 CRITICAL TEMPERATURE CALCULATION

The critical temperature calculation can be activated in the design settings window. This option is only active if the following conditions are met

- ▶ at least one member with passive fire protection
- ▶ at least one fire load case set to room temperature analysis
- ▶ at least one load combination with fire load case is selected for global design



Elastic stability check EN 1993-1-1 6.3.4

Elastic critical factor $\alpha_{cr,op}$

☐ First buckling eigenvalue

☐ Selected eigenvalue

☒ Automatic (based on sensitivity analysis of structural members)

Ultimate resistance factor $\alpha_{ult,k}$

☒ minimum value by members

☐ minimum value in model portion

Reduction factor χ_{op}

☐ a) minimum of $(\chi; \chi_{LT})$

☒ b) interpolated between $(\chi; \chi_{LT})$

Plastic stability check EN 1993-1-1 B83

☒ Consider the point of contraflexure as torsional restraint

☒ Critical temperature

Model portion: - Whole model -

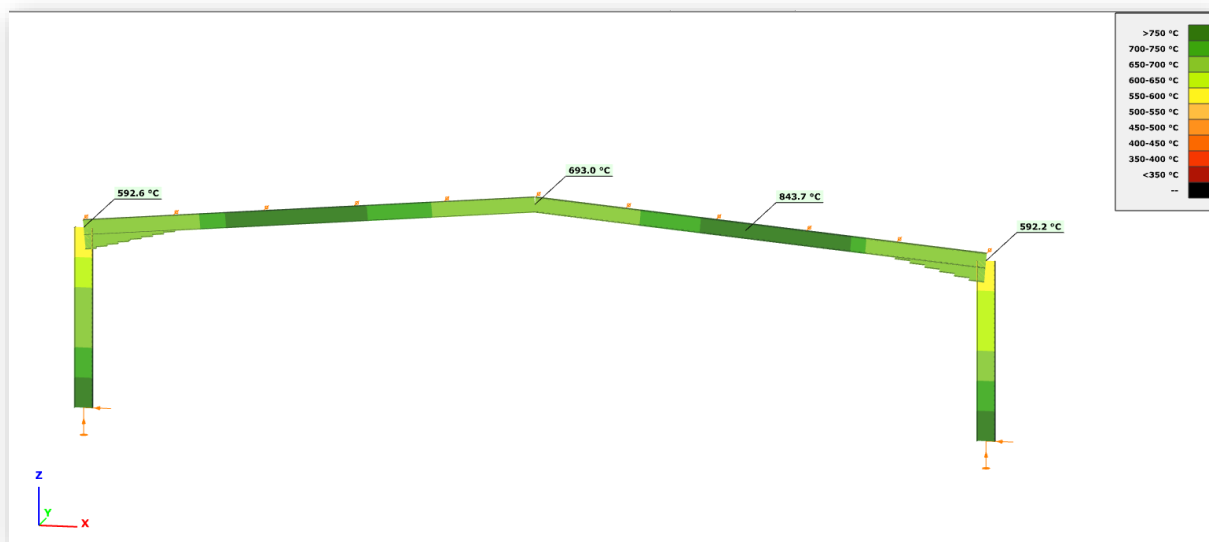
☐ Consider supplementary rules from EN1993-1-3 for the design of cold formed sections

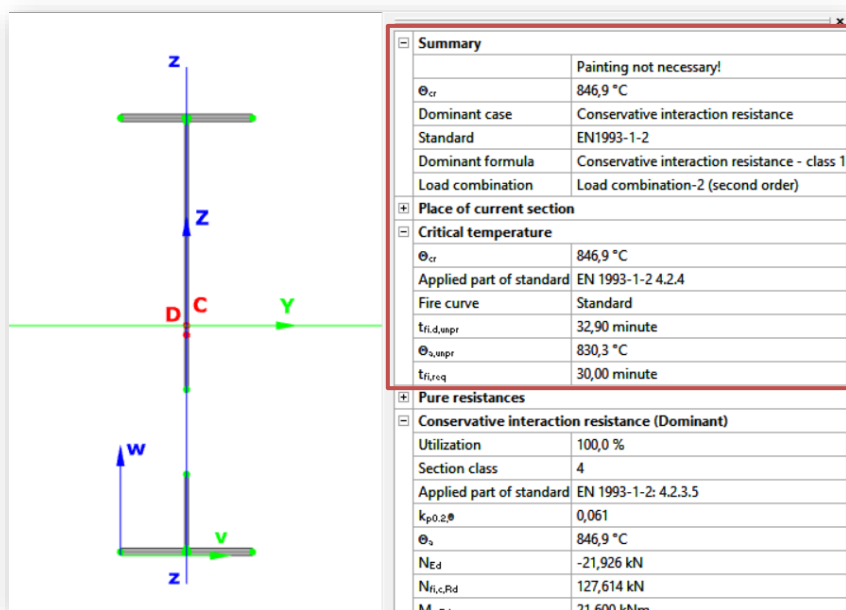
☐ Composite column check EN 1994-1-1

☐ Concrete design EN 1992-1-1

Close Apply Calculation

The results of the calculation can be queried in the Design Parameters drop-down menu. The results are displayed in a colored graphic. You can also open the **SECTION MODULE** from here by right-clicking on a given section, where the details of the critical temperature calculation can be found. The first line of the summary reads whether the profile should be protected or not, and the critical temperature field contains the relevant part of EC, the applied fire curve, the unprotected fire resistance time and temperature reached of the profile and the required fire resistance time.







12 EARTHQUAKE ANALYSIS

12.1 BASICS

Consteel can perform earthquake analysis is based on *Modal response spectrum analysis* (MRSA), and it supports three different analysis types:

- All modal shapes, CQC summation:
Consteel calculates the modal loads for all dynamic shapes, for all directions, and calculates the analysis results (displacements, internal forces) for each dynamic shape using first order analysis. After this, it summarizes them with Eurocode's CQC method. CQC summation method can give the highest expectable deformations and internal forces, based on a statistical method. Envelope diagrams of deformation and internal forces without signs are the result of the CQC summation
- Single dominant mode:
From the calculated dynamic shapes, Consteel chooses the dominant one for each direction, and performs the calculation for one dominant shape for each direction. Modal loads for each direction are the results of the method.
- Selected modes, linear summation:
With the modal shapes, chosen by the user, and with the combination factors for each shapes Consteel creates a linear combination of vibration shapes, and gives the results for all directions using the combined shapes. Modal loads for each direction are the results of the method.

Comparison of the three methods:

	All modal shapes, CQC summation	Single dominant mode	Selected modes, linear summation
Dynamic calculation	Required	Required	Required
Second order analysis	Not possible	Yes	Yes
Stability calculations	Not possible	Yes	Yes
Global check – Cross section check	Yes	Yes	Yes
Global check – Stability check	Not possible	Yes	Yes



Member check	Not possible	Yes	Yes
Masses taken into consideration	Masses corresponding for each vibration shapes for all directions	Masses for the chosen vibration shapes with the consideration of the combination factors in all <i>directions</i>	100% of the masses in all directions
Automation	Yes	Manual input required	Yes
Second order sensitivity	Yes	Yes	Yes

Results of the modal response spectrum analysis with the 100% „+” 30% rule are combined with the other effects acting in seismic situation, by Consteel.

$$\text{a) } E_{\text{Edx}} "+" 0,30 E_{\text{Edy}} "+" 0,30 E_{\text{Edz}}$$

$$\text{b) } 0,30 E_{\text{Edx}} "+" E_{\text{Edy}} "+" 0,30 E_{\text{Edz}}$$

$$\text{c) } 0,30 E_{\text{Edx}} "+" 0,30 E_{\text{Edy}} "+" E_{\text{Edz}}$$

12.2 STEPS OF THE SEISMIC ANALYSIS


Modal response spectrum based seismic analysis can be performed with the following steps in Consteel:

1. Definition of modal loads/Mass tab
 - Definition of mass cases and mass groups
 - Mass definition manually on the structure, or by converting existing load cases
 - Mass combination definitions
2. Seismic effect definition/Masses tab
 - Definition of Standard or User defined response spectrum
 - Definition of Seismic effect
 - Setting the analysis method
3. Seismic load group and load combination definition / Loads tab
 - Seismic load group and loadcase creation
 - Assignment of seismic effect to seismic loadcase



- Definition of considered shapes for the analysis – Only in the case of *Selected modes, linear summation* analysis method!
- 4. Analysis / Analysis tab
 - Setting the statical calculation parameters; For the comparison of available analysis types, please check *chapter 13.1*
 - Setting the parameters for Dynamic calculations
- 5. Design / Global checks and Member checks tab
 - For the available design checks, please go to the comparison of different analysis types at *chapter 13.1*

12.3 SEISMIC EFFECT

Seismic effects can be created with the **SEISMIC EFFECT** () function which can be found on the **MASS** tab. On the Seismic effect dialogue, all parameters can be set, which are required for the seismic analysis.

For the seismic effect creation, existence of pre-created mass combination and response spectrum is required. To see how to define these, please go to **CHAPTER 7 MASSES!**

New seismic effect can be created by pressing the **NEW** button. More seismic effects can be created and saved. Change between different saved seismic effects is possible with the *Name* dropdown menu.

Options of the **SEISMIC EFFECT** dialogue has been separated into two tabs:

- Seismic settings
- Additional effects

12.3.1. SEISMIC SETTINGS

In the *Settings* (#1) panel, main parameters of the seismic analysis can be set

- *Mass combination*: Choice of the used mass combination for the dynamic shape evaluation during the modal response spectrum analysis must be done. The dropdown menu is automatically filled up with the pre-defined mass combinations. Seismic analysis will only be performed for the mass combination which is selected here!
- *Calculation method*: Choice of the calculation method to be used for the seismic analysis. To see the differences between each calculation methods, please see *chapter 12.1*



- *Main direction of the structure from X:* The main direction of the structure can be set using the black arrow () tool, by clicking the start and end point of a vector in the modelling area. The other option is to set the angle between the main direction and the X axis manually in the edit box with direct input. The direction, which is given will be the „1” direction, perpendicularly to this will be the „2” direction of the effect. The q_1 and q_2 factors corresponds with these directions too.

On the response spectrums panel (#2), the response spectrum can be selected which will be used for the seismic analysis.



Handling of the response spectrums in ultimate and serviceability limit states can be the following:

- ULS response spectrum, and use of q_d factors
In this case choice of response spectrum (standard or user defined) is possible only for the ULS checks. Deformations, which are necessary for the SLS checks are evaluated from the ULS results, using the q_d displacement behavior factors
- response spectrum for ULS and SLS limit states
Choosing the *Elastic response spectrum for SLS* option, different response spectrum can be set for ULS and SLS limit states. For ULS limit state, only standard or user defined design spectrum, while for SLS limit state only standard or user defined elastic response spectrum can be chosen from the dropdown menu

Clicking on the (...) button will bring up the spectrum definition dialogue, where parameters of a spectrum can be checked, or even new ones can be created (see **CHAPTER 7.6 CREATING RESPONSE SPECTRUMS**)

At the *Behavior factors (#3)* panel, behavior and displacement behavior factors can be set for the main directions (1,2,z).

Number of adjustable behavior factors are depending of the type of the applied response spectrum(s):

	Behavior factor (q)	Displacement behavior factor (q_d)
ULS design spectrum and q_d factors for SLS	Adjustable in case of standard response spectrum In case of user defined spectrum, the spectrum itself contains it, cannot be adjusted	Adjustable

**Different response****spectrum for ULS and SLS
limit states**Adjustable in case of
standard response spectrumIn case of user defined
spectrum, the spectrum
itself contains it, cannot be
adjusted

Cannot be adjusted

Behavior factors besides the type of the spectrum, are dependent on the following options:

- *Consider vertical seismic effect:* If the option is turned on, vertical behavior factors can be set, and vertical seismic effects will be taken into consideration for the seismic analysis
- *Same behavior in Horizontal XY directions:* If the option is turned on, it is enough to define only one behavior parameter, it will be applied for both X and Y directions

At the bottom of the dialogue, in the Shown response spectrum panel (#4) the selected response spectrum –*design or elastic*– of the dropdown menu can be seen. By hovering the mouse over the points of the graph, its value will be displayed graphically.

12.3.2. ADDITIONAL EFFECTS

On the **ADDITIONAL EFFECTS** tab of the **SEISMIC EFFECT** dialogue, the following settings can be adjusted:

- **Accidental torsional effects:** In case of spatial 3D models, effects of the uncertainties of load placements causing torsional effects and must be considered. Consteeel calculates the effect automatically. For the calculation, storeys have to be defined, where torsion effect is acting, and eccentricity value, with which the mass points will be shifted.
- **Second order effect:** Second order effects must be taken into account, if the coefficient of the shift difference (θ) between the storeys is greater than 0,1. Consteeel automatically calculates it and takes it into account. Storeys has to be pre-defined.

Considered storeys has to be chosen in the *Considered storeys for accidental torsional and second order effects (#1)* panel. If there are storeys defined in the model (see **CHAPTER 3.4 PORTION MANAGER**), they will be automatically loaded into the table. If the checkbox is turned on next to a storey, it will be taken into consideration during the seismic analysis.



WHEN SPECIFYING THE LEVELS, IT IS IMPORTANT TO KNOW THAT CONSTEEL TAKES THE WEIGHTS OF THE STRUCTURE BELOW THE LOWEST LEVEL ALL OF THEM TO THE LOWEST LEVEL BY THE TORSIONAL AND SECOND ORDER EFFECTS. THIS CAN BE AVOIDED BY ESTABLISHING A LEVEL 0 IN THE PLANE OF THE SUPPORTS, SO THE WEIGHT DISTRIBUTION BETWEEN THE SUPPORT AND THE FIRST LEVEL WILL ALSO BE PERFORMED.

Seismic effect

Name
Seismic 1

Seismic settings Additional effects

Considered storeys for accidental torsional and second order effects

1 Storeys

☐ Level (+5000)

☐ Level (+3000)

☐ Level (+0)

Accidental torsional effects

2 Neglect

Accidental eccentricity [%] 5

New Delete Close Apply

At the *Accidental torsional effects* (#2), consideration of the effect can be turned on or off. The following combinations can be chosen for the shift of the mass points:

- $+e_{aX}+e_{aY}, -e_{aX}-e_{aY}$: Mass points will be shifted both for positive and negative directions in the global X and Y directions with the given value, but not mixed. It is a simplification, and it is reducing the number of seismic combinations
- $+e_{aX}+e_{aY}, +e_{aX}-e_{aY}, -e_{aX}+e_{aY}, -e_{aX}-e_{aY}$: Mass points will be shifted both for positive and negative directions in the global X and Y directions, including mixed signs too, with the given value. It is the recommended way by Eurocode, but it increases the number of seismic combinations.

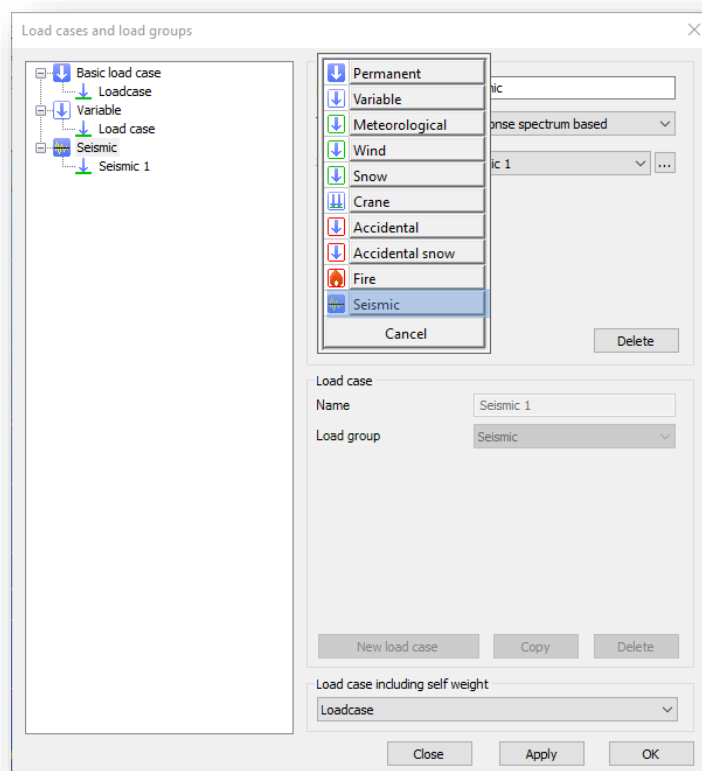
The value of the shift of the mass points can be given in the edit box with a percentage.



12.4 SEISMIC LOADCASES AND LOAD COMBINATIONS

12.4.1. SEISMIC LOAD GROUP AND LOADCASE

Going back to the **LOAD CASES AND LOAD GROUPS** dialogue, a new type of **SEISMIC LOAD GROUP** has to be defined. After creating a seismic load group, the pre-defined seismic loadcase will automatically assigned to the group as a seismic loadcase.



If the calculation method for the seismic effect is set to **SELECTED MODES, LINEAR SUMMATION**, an additional button will appear on the **LOAD CASES AND LOAD GROUPS** dialogue when the seismic loadcase is selected in the tree control. The **LINEAR COMBINATION OF MODAL EFFECTS (#1)** button stands for the option to set the combination factors for the calculated vibration shapes. After clicking on the button, a new dialogue will pop-up, which contains all the calculated vibration shapes, with the corresponding mass participation for each one, in all (1,2,z) main directions. By setting the combination factors, mass participation can be adjusted for each vibration modes, 1 which will be considered during the next seismic analysis.

If all the combination factor cells of the table are empty, Consteeel will perform seismic analysis with **SINGLE DOMINANT MODE** calculation method.



Load cases and load groups

Basic load case
Loadcase
Earthquake
Load case

Load group (Seismic)
Name: Earthquake
Type: Response spectrum based
Seismic: Earthquake

New load group Delete

Load case
Name: Load case
Load group: Earthquake

Free vibration analysis is required

1 Linear combination of modal effects

New load case Copy Delete

Load case including self weight
None

Close Apply OK

Linear combination of modal effects

Mass participation factors and consideration ratio of modal shapes

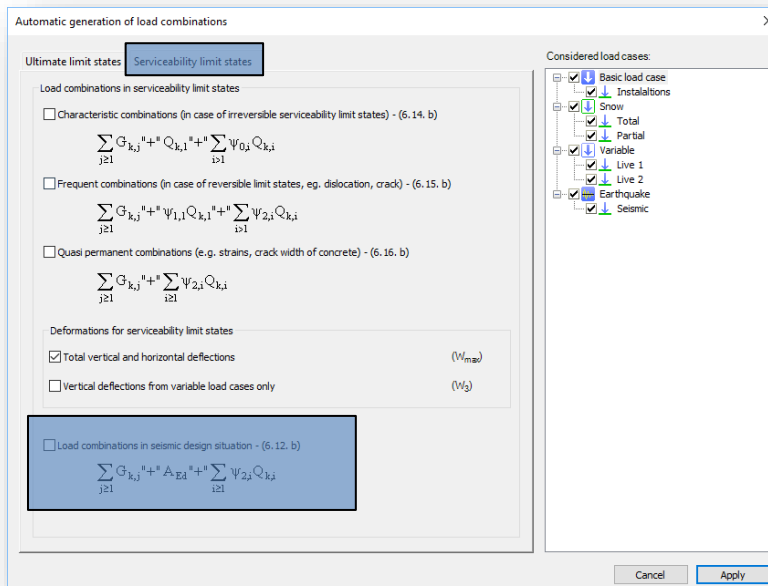
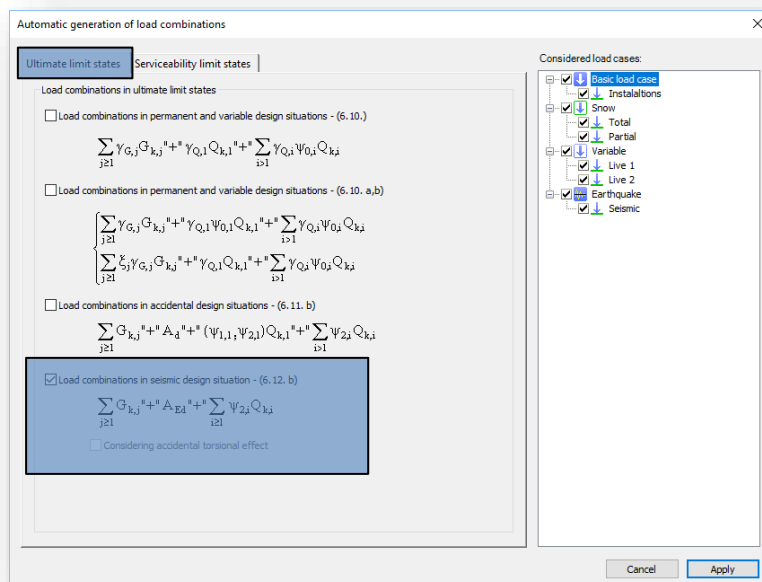
Modal shapes (Time [s])	1		2		Z	
	Mass p.	Comb f.	Mass p.	Comb f.	Mass p.	Comb f.
(1.) 0,692	0,92	1	0,00		0,00	
(2.) 0,257	0,00		0,00		0,01	
(3.) 0,248	0,08		0,00		0,00	
(4.) 0,236	0,00		0,00		0,99	
(5.) 0,000	0,00		0,54		0,00	
(6.) 0,000	0,00		0,46		0,00	

Cancel OK



12.4.2. LOAD COMBINATIONS IN SEISMIC DESIGN SITUATIONS

On the **AUTOMATIC GENERATION OF LOAD COMBINATIONS** dialogue, all combinations can be automatically generated for seismic situations too, including ultimate and serviceability limit states.





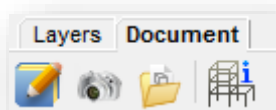
13 DOCUMENTATION

13.1 BASICS

In *Consteel* there is a powerful and easy-to-use documentation engine to create precise, easily editable static documents that meet the requirements of the structural engineers.

The static documentation contains the full description of the model and the results of the analysis and design.

13.2 THE DOCUMENT TAB



13.2.1 START DOCUMENTATION

All icons which related to the documentation are placed in the **DOCUMENT** tab. The documentation can be generated if first icon is clicked. The documentation wizard guides you through the documentation generating process. On the first window the name of the documentation can be set. The name appears on every page of the documentation. Other fields like the name of the project, the name of the engineers and the date of the creation can also be set but would appear only on the front page.

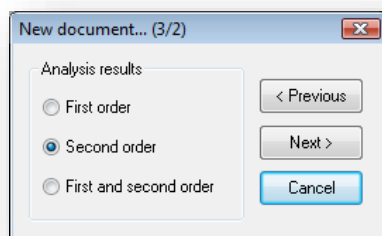
Name of document:	Document 1
Name of project:	
Names of engineers:	
Date of creation:	2008.11.10.
Default language of documentation:	English

i Click into required field to define property
Adding name of document is compulsory! The names of engineers should be separated by semicolon.

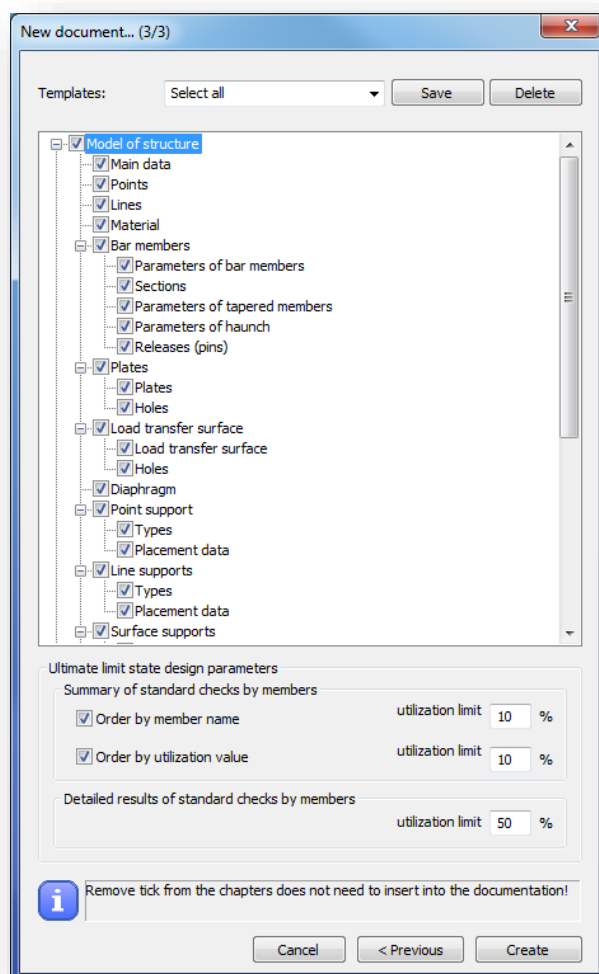
Next > Cancel



The header and the footer pictures of the document can be customized so your own company logo can be added. To do so the default header and footer images need to be replaced. These files can be found in the software's installation directory; the default path is the following: C:\Program Files\ConSteelversion\Pic. The "Header_pic.png" and the "Footer_pic.png" need to be replaced by your own images.



The second step is to choose which of the analysis results need to be included in the documentation. Any of the analysis results can be chosen if had been calculated previously.





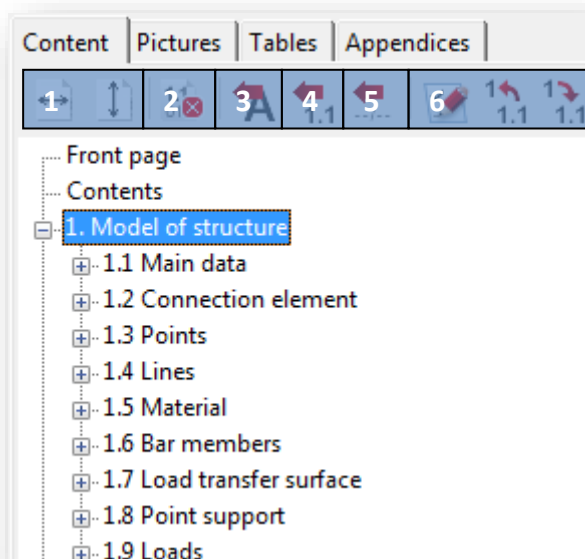
The third window of the wizard includes the name of the chapters which can be added to or can be removed from the documentation.

For the ULS design documentation utilization limit can be set at the bottom of the dialog. All the members will be included the generated documentation that are equal or higher than the set limits. Separate limits can be set for the summary and for the detailed documentations.

Documentation templates can be saved with the **SAVE** button. Most used documentation structures can be saved as templates. Based on the templates, documentation can be created with one click.

If you click on the **CREATE** button the program will generate the documentation.

13.2.1.1 DOCUMENTATION MODULE




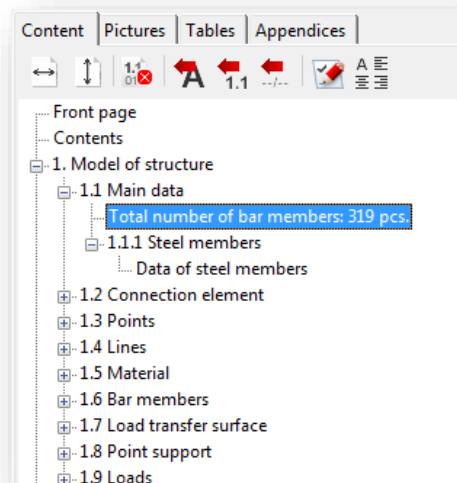
After creating the documentation, it will be opened in a new window. At the top right of the window the chapters can be seen. The chapters can be moved up or down by drag-and-drop function. It is also possible to delete content from document by clicking the third icon (#2).



Text can be inserted anywhere in the document if you click on the fourth icon (#3) and type in the desired text into the window. It is also possible to insert headings by clicking on the fifth icon (#4).

You can also insert page break anywhere in the document using the sixth icon (#5). The last three icons can be used for the following purposes: Edit heading and increase or decrease level of heading.

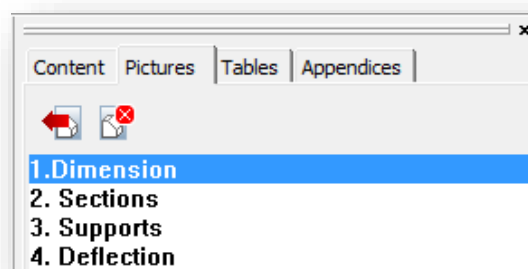



The last two icons on the right are different if you click on a chapter or in a paragraph. If you click on a chapter, then the icons are as described above. If a paragraph is clicked where there is a table, the last icon  can be used to delete any column from the table. If you click on a paragraph which contains text, then the last two icons on the right can be used to edit the paragraph content and the alignment.



With the first two icons (#1) the fitting of the pages can be set. Pages can be fit with width () or with height ()

By clicking the **Pictures** tab, the image handling icons can be seen. Any of the taken snapshots can be inserted into the documentation or can be deleted. The image will be inserted below the selected paragraph.



The third tab is the **Tables**. There are lot of possibilities in *Consteel* where tables can be saved. If you see the  icon during analysis and design process where the results appear in a table,



then that table is saveable. Any previously saved tables can be inserted to the documentation or can be deleted from the model database. The table will be inserted below the selected paragraph.

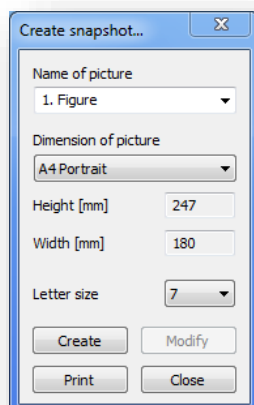
The last tab is the **Appendices**. If any joint or section documentation had been generated previously, these can be found here and can be added to the end of the documentation. The appendices can also be deleted from the database.



IT SHOULD BE BEAR IN MIND THAT THE DOCUMENTATION NEED TO BE REGENERATED TO BE UP TO DATE AFTER ANY CHANGES HAS BEEN MADE ON THE MODEL. IF THERE ARE SNAPSHOTS IN THE DOCUMENTATION THESE SNAPSHOTS SHOULD BE TAKEN AGAIN AND NEED TO BE ADDED TO THE DOCUMENTATION.

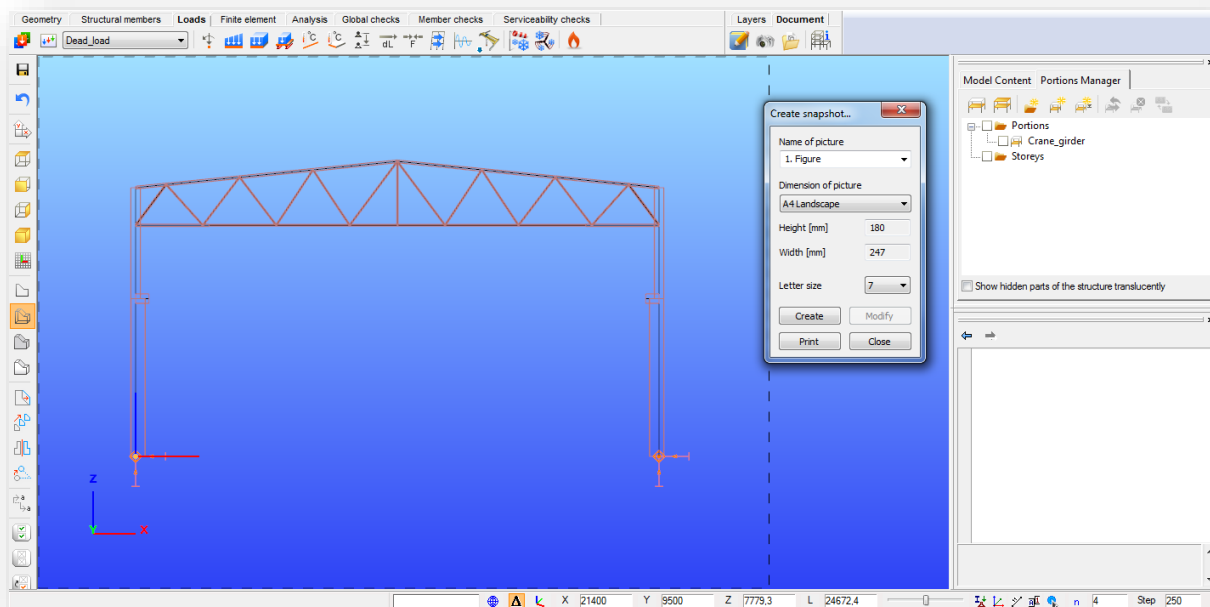
13.2.2 CREATING SNAPSHOTS

The second icon on the **DOCUMENT** tab can be used to take a snapshot of the model. The snapshots can be easily added to the desired part of the documentation (see 11.2.1.1 chapter for detailed information).




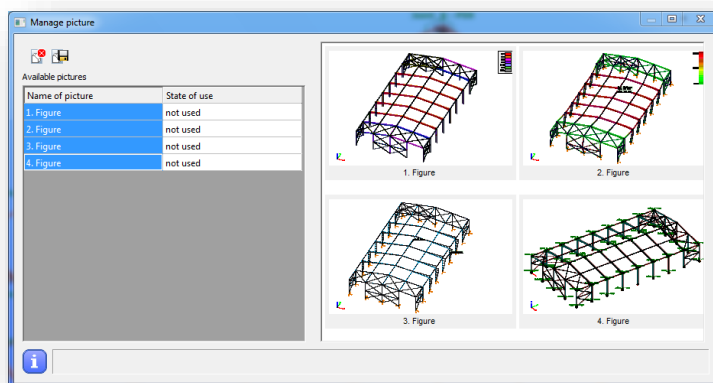
The size of the snapshot can be set, and a dashed rectangle shows which part of the model would appear on the picture. The model can be moved or rotated to fit into the dashed rectangle.

With the **PRINT** button the actual view of the model can be printed directly from the dialog.



13.2.3 SNAPSHOT MANAGER

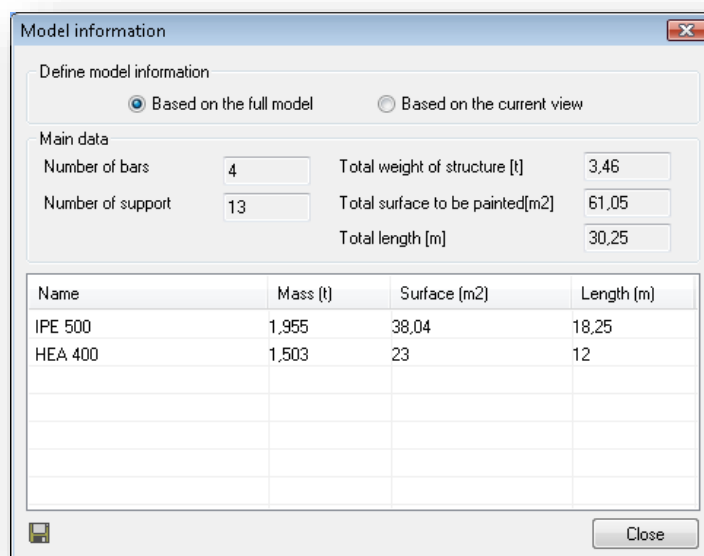
The third icon on the documentation tab is the Snapshot manager  where the taken snapshots can be exported to a file or can be deleted from the model (except if the picture was inserted into the documentation) in order to reduce model file size. Multiple selected pictures can be saved and deleted at the same time. The name of the images can also be edited by double clicking the name of the image.





13.2.4 MODEL INFORMATION

With using the fourth icon on the **DOCUMENT** tab the model information can be viewed or can be exported to a file. The model information window shows the most important features of the model like Number of bars, Number of supports, Total weight of the structure, etc. The mass, surface and the length can be viewed for each section in the model. The model information can be shown based on the full model or on the current view if the model view shows only a part of the full model using the sub model view.

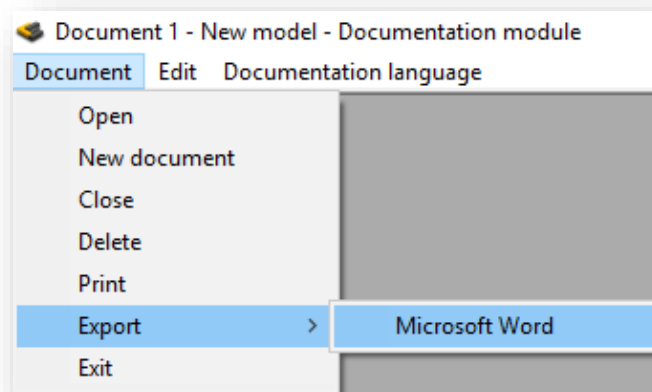


The dialog box titled "Model information" contains a section "Define model information" with two radio buttons: "Based on the full model" (selected) and "Based on the current view". Below this is a "Main data" section with four input fields: "Number of bars" (4), "Number of support" (13), "Total weight of structure [t]" (3,46), and "Total surface to be painted[m2]" (61,05). There is also a "Total length [m]" field with the value 30,25. At the bottom is a table with 4 columns: Name, Mass (t), Surface (m2), and Length (m). The table contains two rows of data: IPE 500 and HEA 400. A "Close" button is located at the bottom right.

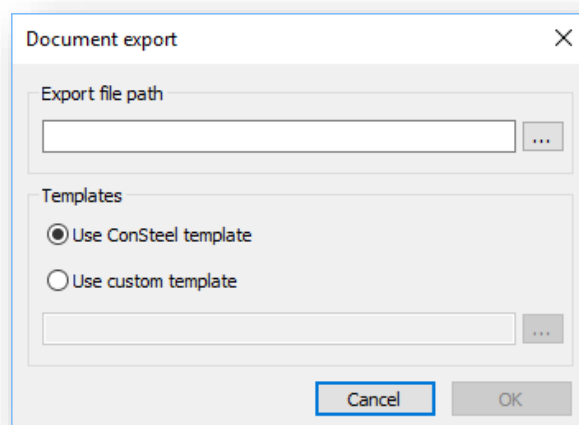
Name	Mass (t)	Surface (m2)	Length (m)
IPE 500	1,955	38,04	18,25
HEA 400	1,503	23	12

13.3 MS WORD EXPORT OF THE DOCUMENTATION

Documentations can be exported into an editable .docx format Word file. The export itself is a complete process, which means every table, picture and appendices will be exported. The **MICROSOFT WORD** export function can be found in the documentation module's **DOCUMENT** menu, under the **EXPORT** submenu.

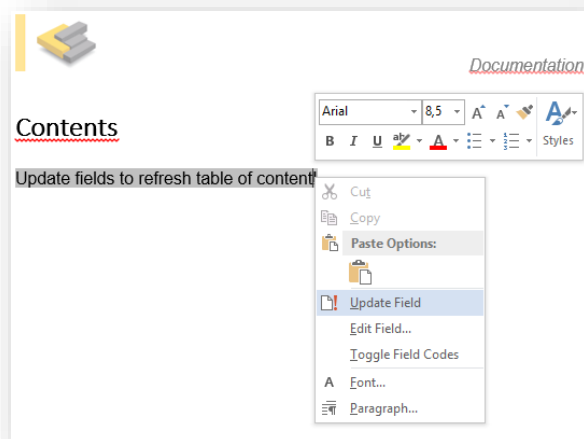


After pressing the **MICROSOFT WORD** button, the Documentation export dialogue will appear:



On the dialogue the path of the exported file must be given, by browsing it with the (...) button. It is available (and required) to choose a **TEMPLATE** for the exported document. Templates are a collection of styling settings, which will be applied on the exported Word file. By default, a Consteel template is provided in the installation package, and it contains the same styling settings as the main Consteel documentation. By selecting the **USE CONSTEEL TEMPLATE**, and pressing the **OK** button, Consteel will generate a Word file of your documentation, which is the same in content, and is as close as it can be in styling as the original one. Custom templates can also be used, please check **CHAPTER 13.3.1** to know more!

When opening an exported documentation in Word for the first time, the table of content has to be refreshed, by right clicking on the heading of the table and pressing the refresh button:

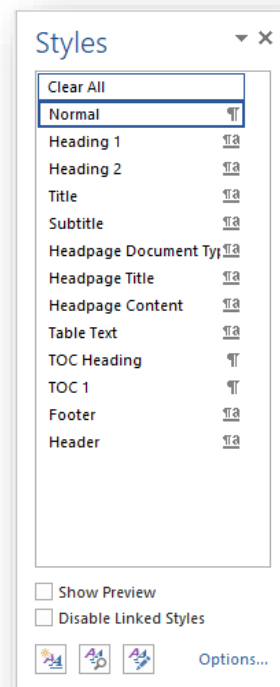


13.3.1 CREATING CUSTOM TEMPLATES FOR MS WORD EXPORT

As it was mentioned in the previous chapter, the installation package of Consteel contains a default template, which is filled up with the same styling settings, as the main documentation. This template can be found in the installation folder of Consteel, which is “C:\Program Files\Consteel 13\Data\Export\Consteel.dotx” by default.

If a new template, with customized styling settings is desired to be created, the **Consteel.dotx** file should be copied first. After opening the copied file, the change in stylings can be performed in the **STYLES** dialogue of MS Word:

After the settings are made, the file should be saved in **.dotx** format (as the original was), and it can be used for word exports in the future.





14 JOINT MODULE

14.1 BASICS

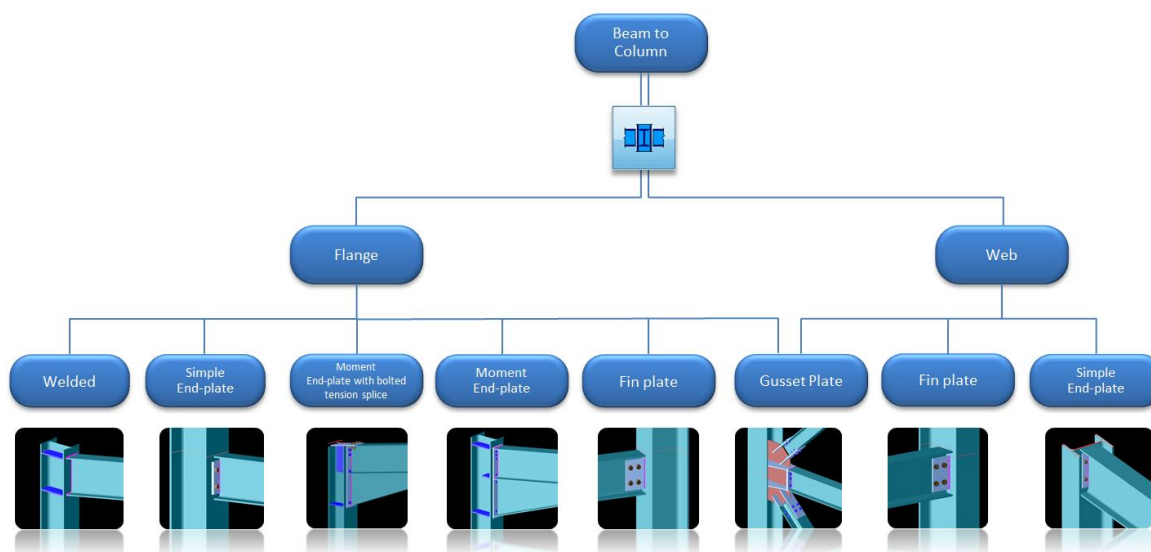
In the *Consteel* design approach great emphasis is placed on the integrated modelling and calculation of the global structure and its connections therefore a powerful joint analysis engine is developed as a separate module: *csJoint*. A great range of different joint types can be created easily applying several special connection elements, the design tools covers practically the whole joint standard Eurocode 3 Part 1-8. A joint can be defined alone or based on the global model by the automatic joint identification tool. A prepared joint can be placed several different places in the global model to make the joint integral part of it. A placed joint is always automatically rechecked based on the current analysis results, and the connection stiffness is also updated modifying the global model consequently.

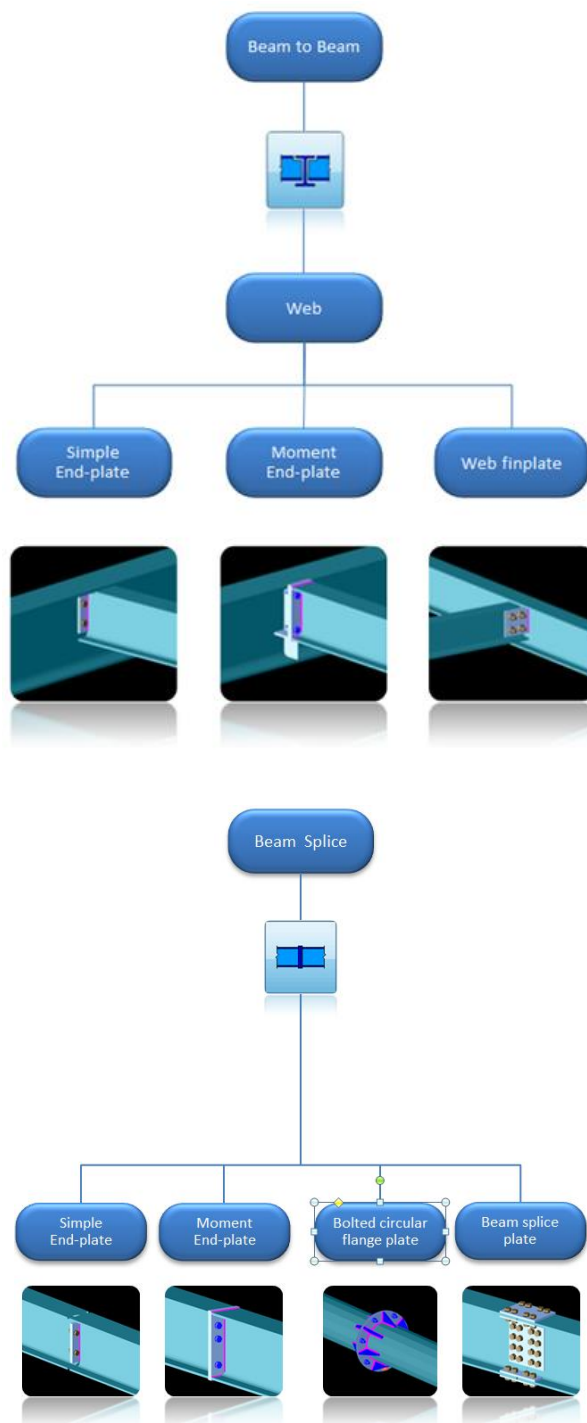


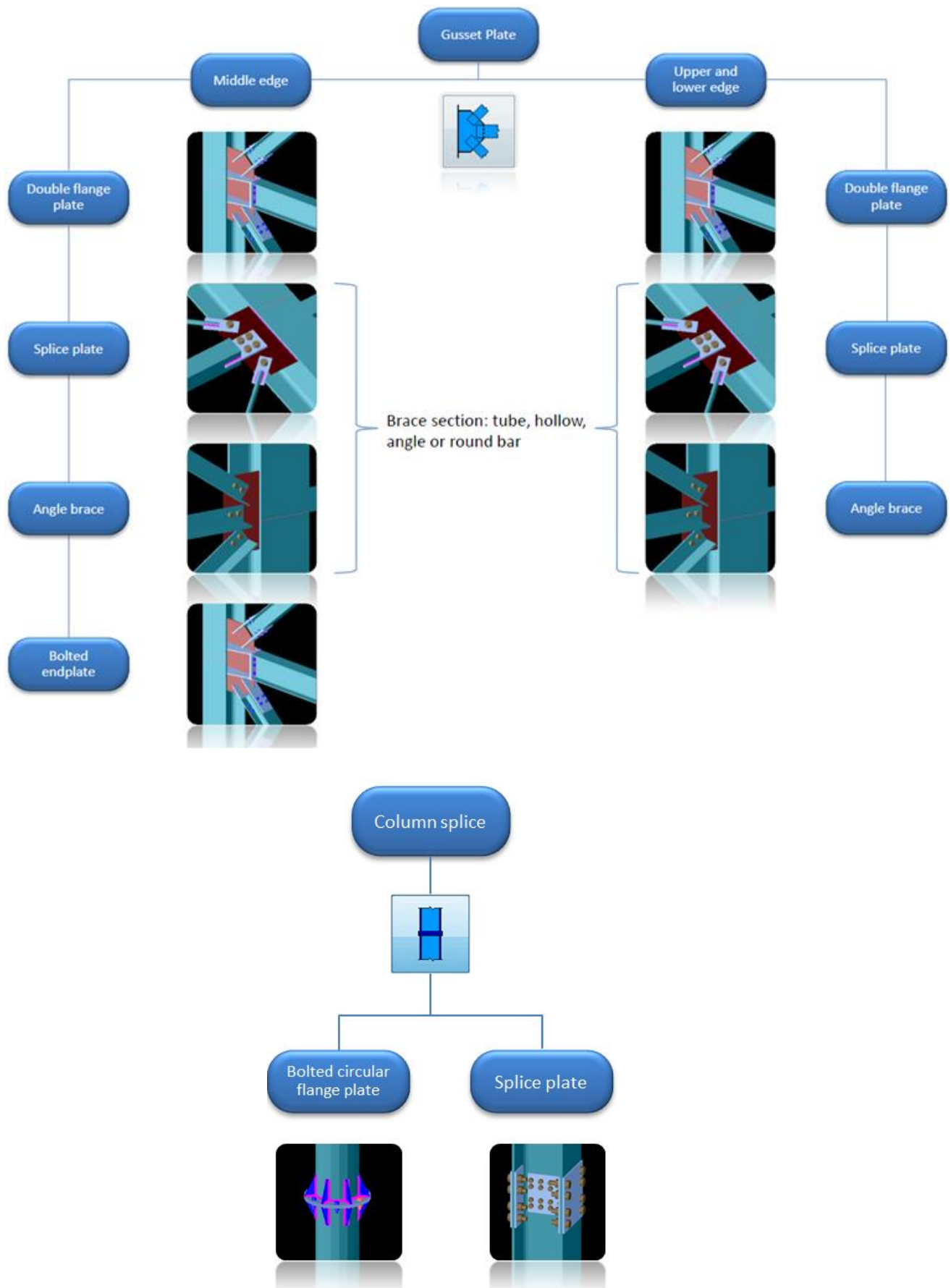
All the joint related commands can be found on the **STRUCTURAL MEMBERS** tab. These are the followings: Edit joint, Create joint by model, Place joint.

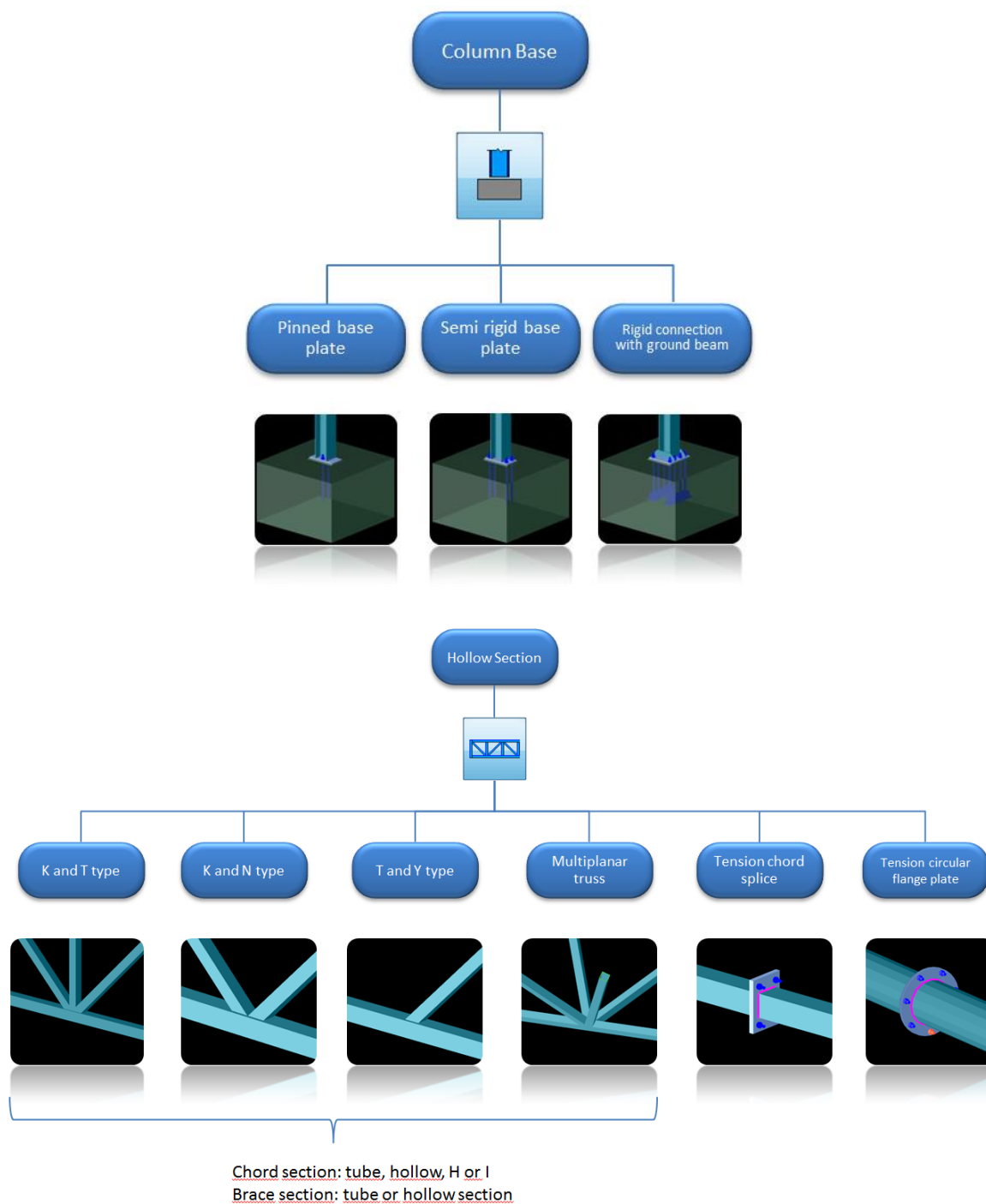
14.2 JOINT TYPES

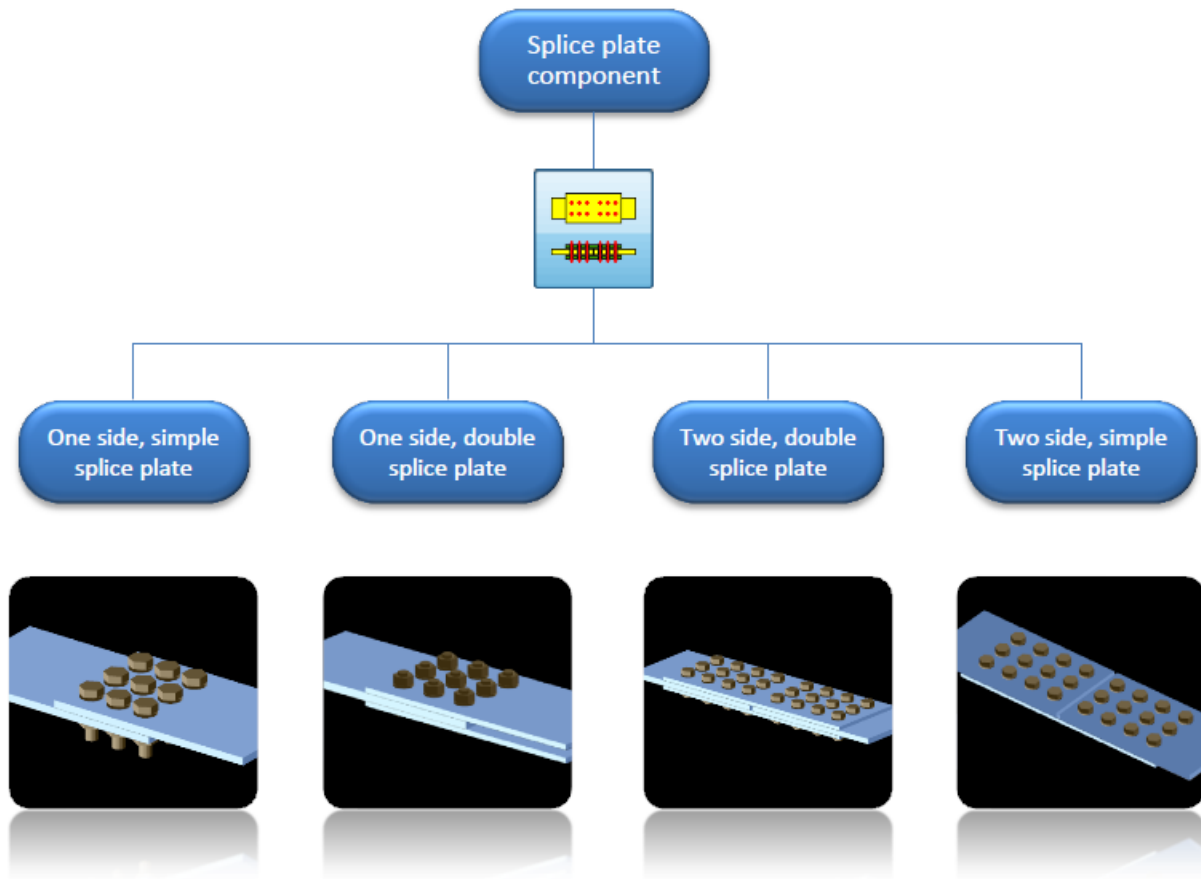
The number of the joint types is one of the most dynamically developing parts of the software, usually considering the claims of the users. The module offers a number of strengthening possibilities such as: lower or/and upper haunch with or without flange, transverse web stiffeners, flange stiffeners and flange backing plates, shear stiffeners (supplementary web plate, Morrison stiffener, single or double skew plate stiffener) etc. At the moment the *csJOINT* module has the following joint and connection types:







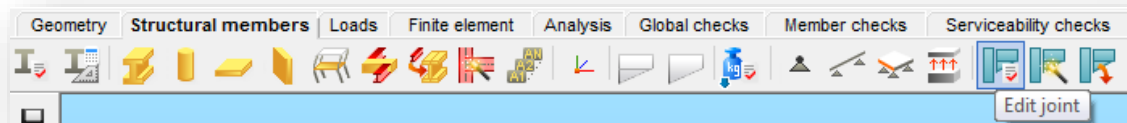




14.3 CREATE JOINT


14.3.1 CREATE JOINT WITHOUT MODEL

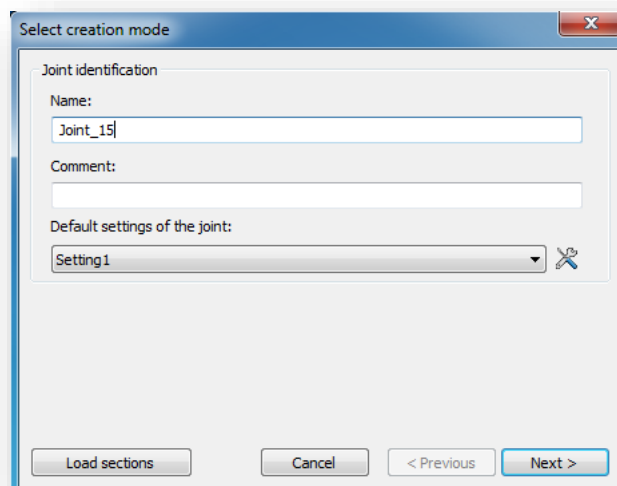
Joint models can be created without global model by clicking on the **EDIT JOINT** icon on the **STRUCTURAL MEMBERS** tab.



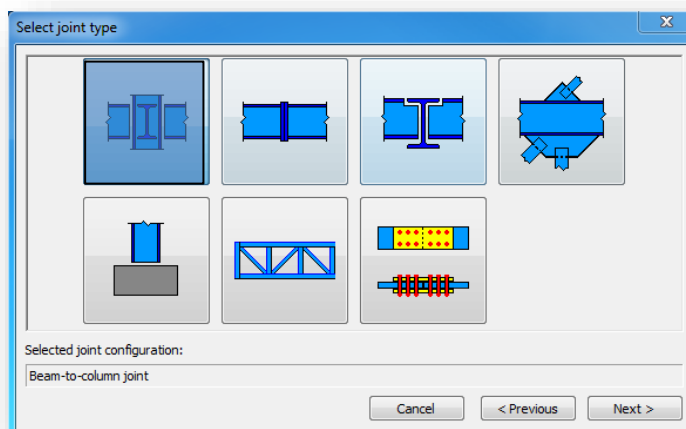
In this case the joint type, geometry and the loads need to be set manually. One of the advantages of *Consteel*, that in *csJoint* it is possible to handle several connections inside of a joint. By this, a large scale of customized joints can be designed. In the following, a creation of a beam-to-column joint will be demonstrated.

**► Step 1 - Joint identification**

After clicking on the **CREATE** button () on the top left corner the name of the joint must be given. Comment for the joint can be optionally given, and *Default settings* of the joint can be modified (see later in **CHAPTER 14.3.5 DEFAULT JOINT SETTINGS**).

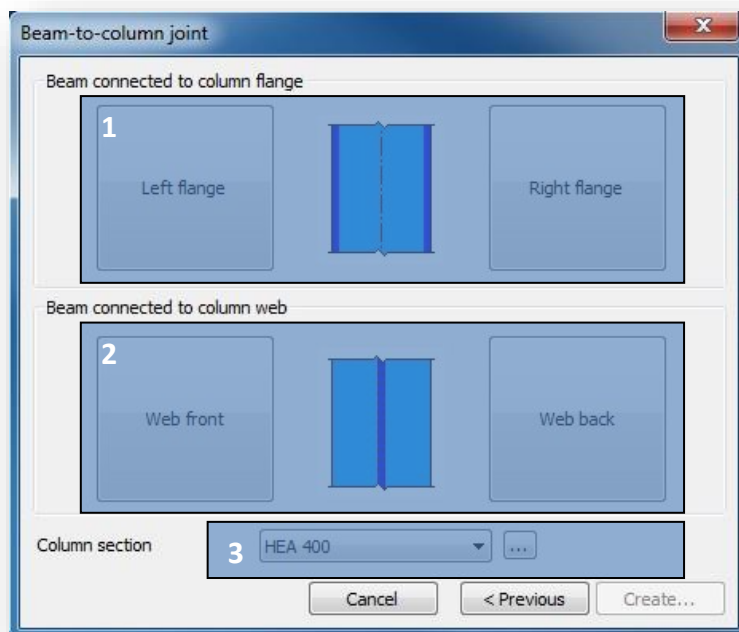
**► Step 2 – Joint configuration**

The type of the joint has to be defined on the next dialog. *csJoint* can handle great variety of joint types, which covers nearly the whole joint standard Eurocode 3 Part 1-8. (see joint types in **CHAPTER 14.2**)

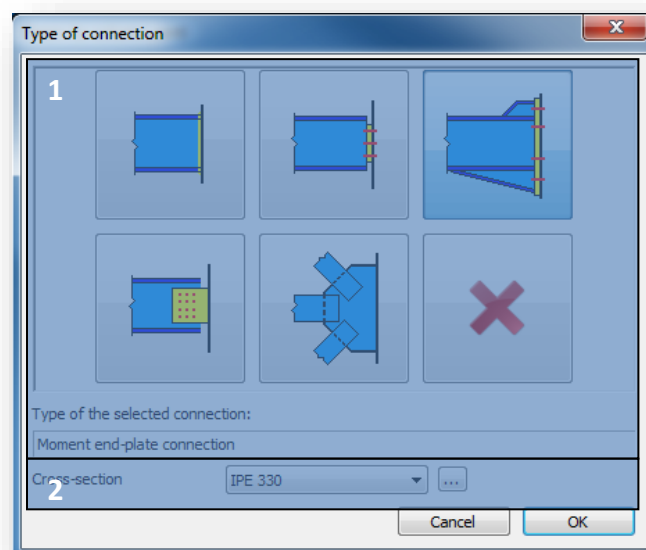




► Step 3 – Connections configuration



Here (picture above) it is possible to set connections both to the flanges (#1) and the web (#2). For eligible list of connections, please see **CHAPTER 14.2**. In this dialog, the section of the column is also has to be set. It can be chosen from the drop-down menu or loaded from the section administrator by clicking the three-dot button (...).

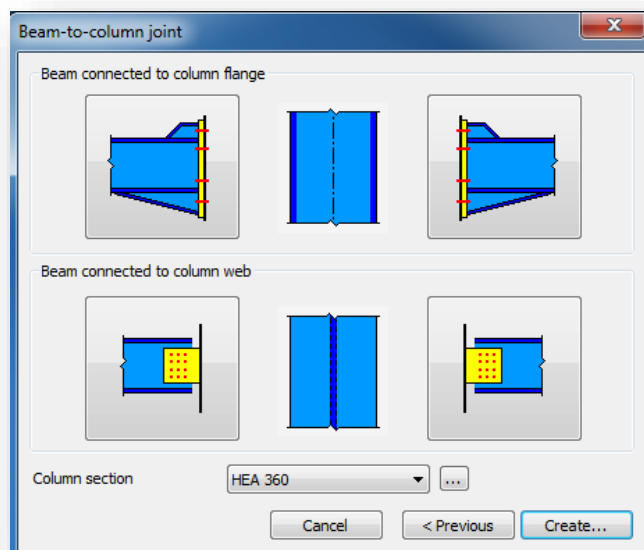


When setting a connection (picture above), the type (#1) and the cross section of the connected element (#2) has to be set. It can be chosen from the drop-down menu or loaded

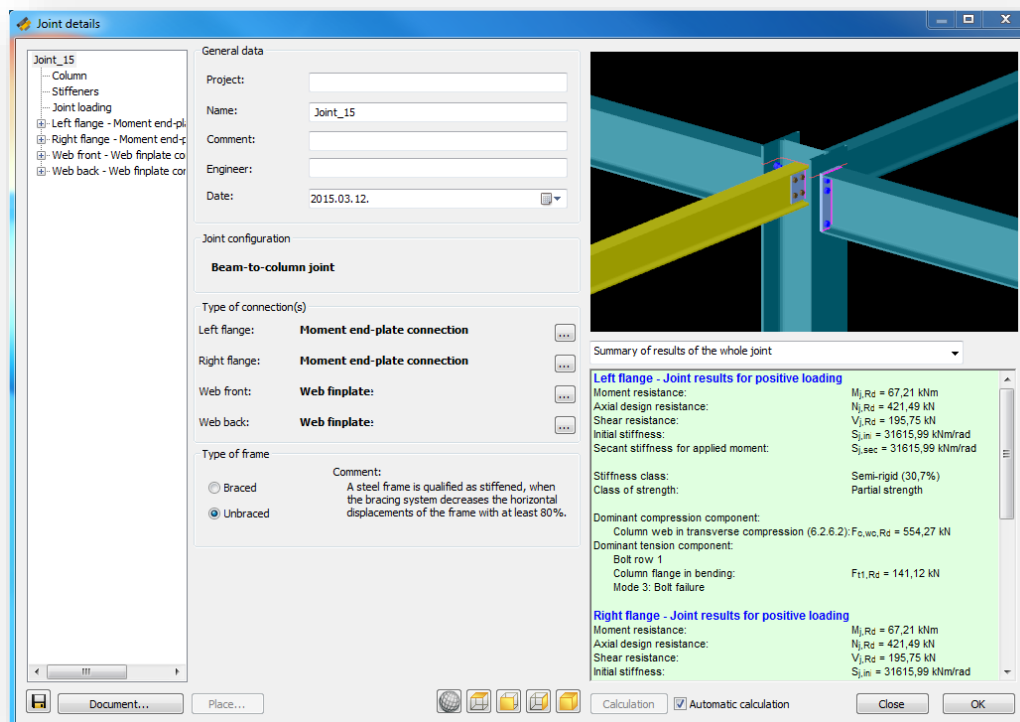


from the section administrator by clicking the three-dot button (⋮). For eligible list of connections, please see **CHAPTER 14.2**.

After the desired connections have been set (picture below), by clicking the **CREATE** button the joint will be created.



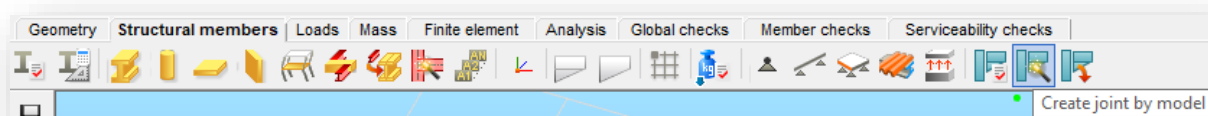
Joint loads can be given manually, and the manipulations of the connection elements can be made as a last step.



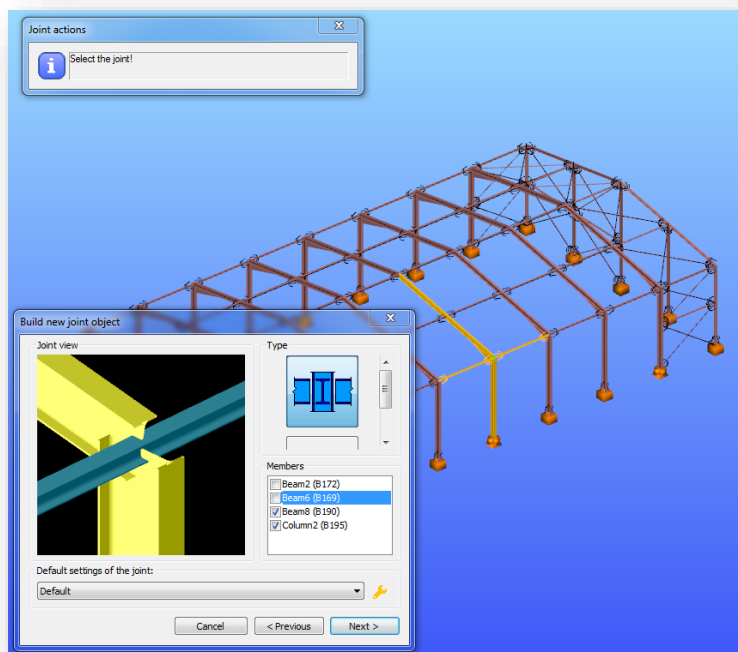
For complete information about manipulating the connection, please see **CHAPTER 14.3.4 MANIPULATING CONNECTIONS**.

14.3.2 CREATE JOINT BY MODEL

Creating joint by the model is simple and easy. Just click on the **CREATE JOINT BY MODEL** button and select the joint.



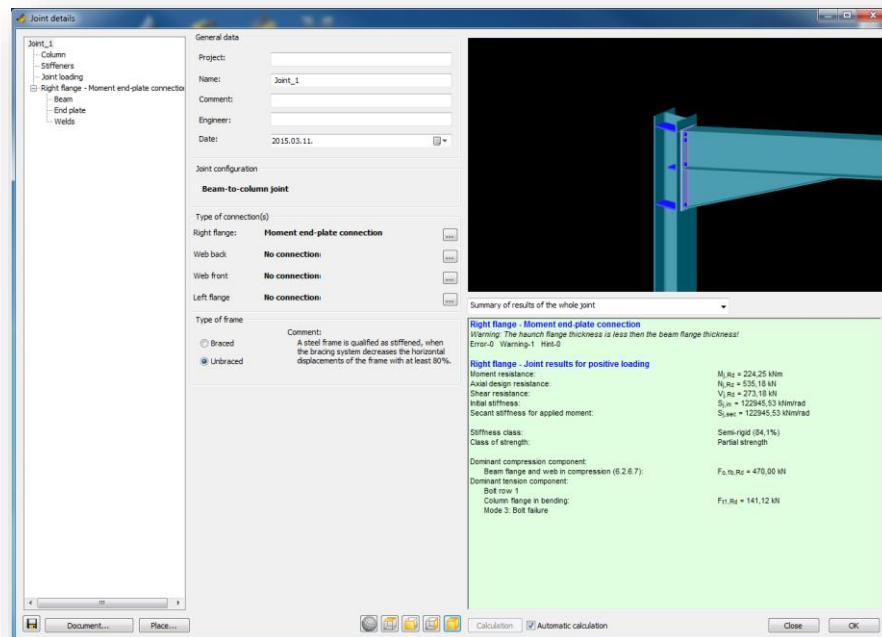
The members will be automatically identified, and the possible connection types are offered. Here is possibility to remove some members from the identified connection by removing the appropriate tick.



14.3.3 PLACE JOINT IN THE GLOBAL MODEL

After creating the joint it is advisable to place it in the global model. There are two options to do this:

The fastest way of placing a joint, is to place it from the **JOINT DETAILS** dialog directly, right after when it is been created. **PLACE...** button can be found at the bottom left corner of **JOINT DETAILS** dialog (see picture below). By choosing it, it is possible to place the joint to several places by single clicks on the 3D structural model where the same geometry exists. By clicking **END JOINT PLACEMENT** button (see picture below), loads will automatically be imported from the model if analysis results are available.




The other way of placing a joint, is to use **PLACE JOINT** function, which can be found on the **STRUCTURAL MEMBERS** tab. This function is useful when more previously created joints have to be placed. One joint can be placed to several places in the model where the same geometry exists. After the joint is placed, *csJoint* automatically import the loads from the global model if analysis results are available.

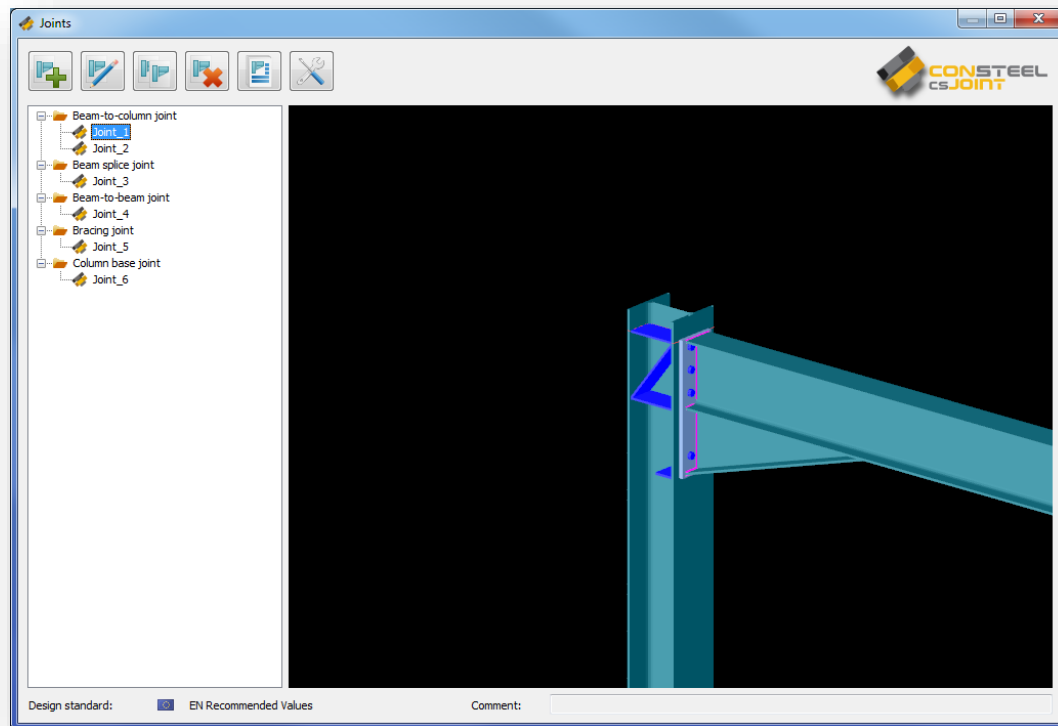


IT SHOULD BE BEAR IN MIND THAT THE SETTINGS IN THE *csJOINT* MODULE (PROFILES SIZES, MATERIAL GRADES, ETC.) WILL NOT AFFECT THE 3D MODEL. THE CHANGED VALUES WILL BE CONSIDERED IN THE JOINT CALCULATION ONLY! THE USER HAS TO WAY TO KEEP THE MODEL CONSISTENT: 1. AFTER MODIFYING THE CONNECTION THE 3D MODEL HAS TO BE CHANGED ACCORDINGLY, 2. CHANGE THE 3D MODEL FIRST RUN THE ANALYSIS, REDEFINE THE CONNECTION.

14.3.4 MANIPULATING JOINTS

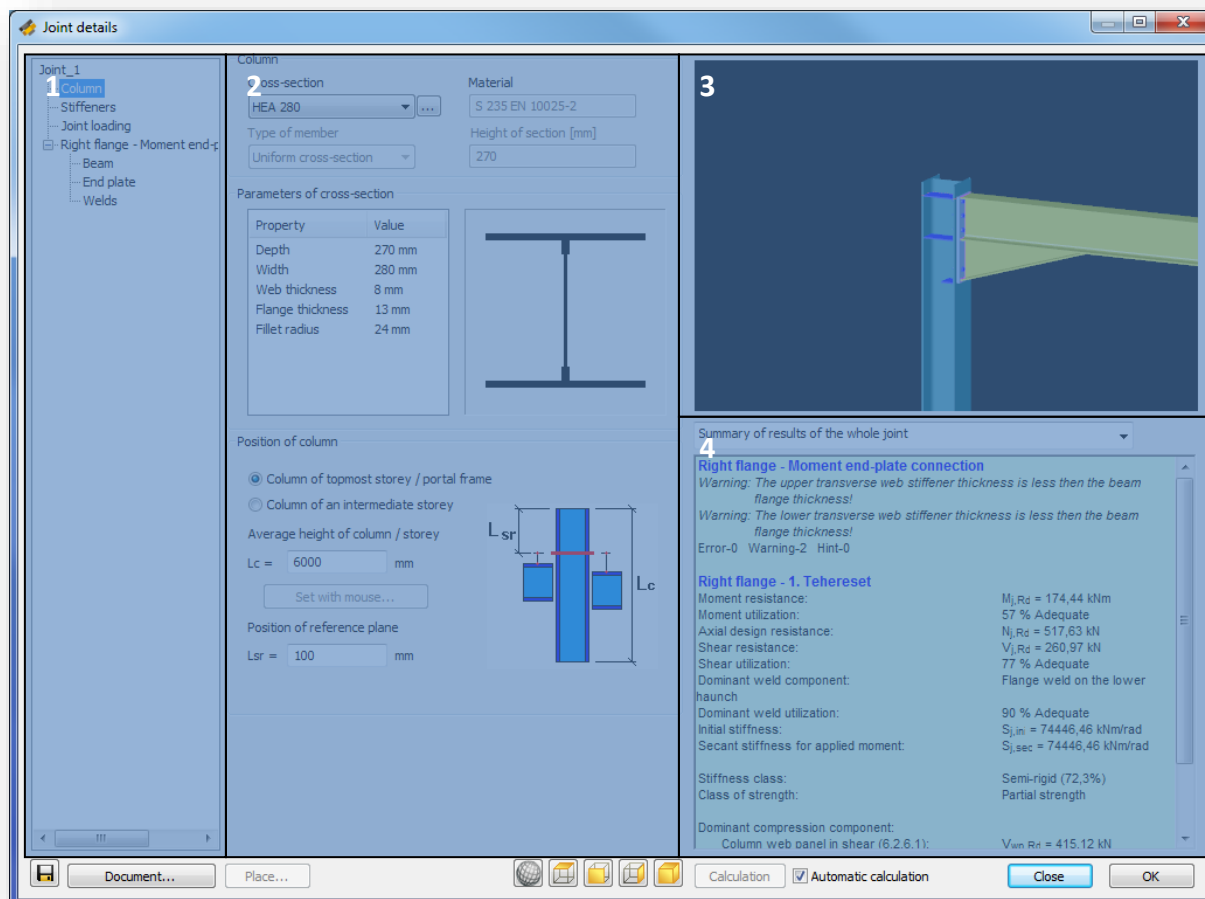
No matter if a joint is created with or without model manipulating the joint is the same. Joint details appear in a new window where numerous settings can be made. In the following pages we would like to give an overview of the *csJoint* module using a beam-to-column connection as an example.


Select the joint from the tree structure on the **JOINT** dialog, and press **DETAILS** () button, or double click on the name of the joint.



14.3.4.1 JOINT DETAILS DIALOG

After the creation of a new joint, or opening an existing one for modification, the **JOINT DETAILS** dialog appears, which can be separated into four parts. The window contains the general information about the joint: Joint name, project, engineer, date, etc. These properties will appear in the joint documentation and also useful to distinguish joints from each other.



- (#1) The first part shows the tree structure about the joint: all components of the connection can be seen and selected.
- (#2) On the second part, the selected component related information / properties can be seen and set: Joint name, project, engineer, date, etc. These properties will appear in the joint documentation and also useful to distinguish joints from each other.
- (#3) The third part is the graphical window. Predefined views of the joint can be selected with the view tools: 
- (#4) The fourth part shows the results of the joint calculation. Calculation is automatically run when any changes take place and the **AUTOMATIC CALCULATION** checkbox is clicked. If the checkbox is unchecked the calculation can be run with the **CALCULATION** button. In the pull-down menu the type of the result visualization can be set to three different types:
 - Summary for the whole joint
 - Summary for the selected connection
 - Detailed results of the selected connection

In the last two cases a connection must be chosen in the connection tree.

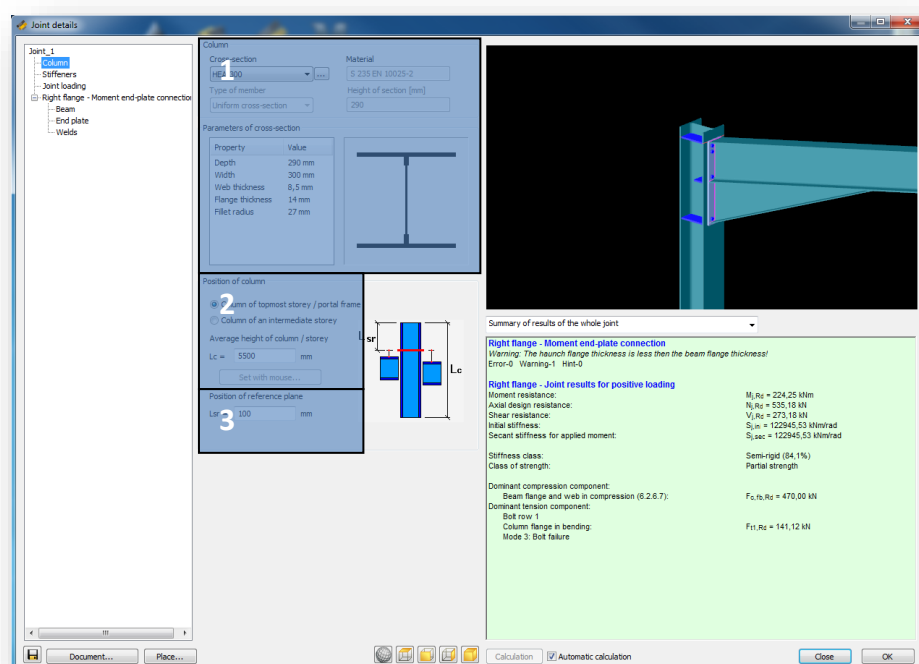


Documentation of the Joint can be started with the **DOCUMENT...** button on the bottom left corner of the dialog.

14.3.4.2 MANIPULATING JOIN

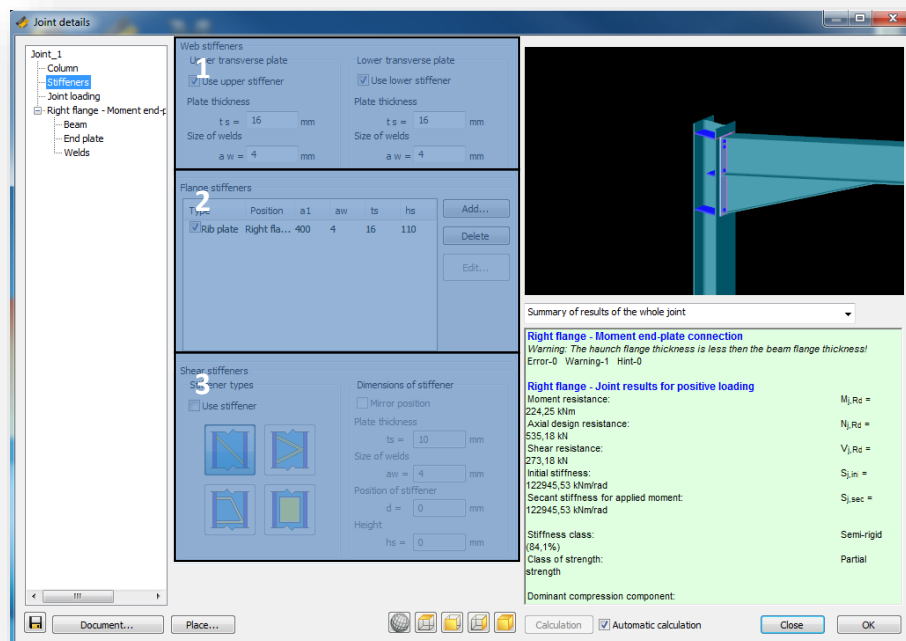
Column

If the *Column* is selected in the connection tree, then column related properties of the connection can be set like the section size and material grade (#1). Setting the position of the column is also very important (#2). Furthermore, the position of the reference plane is essential for the joint calculation. The image on the right gives a visual help about the meaning of ' L_{sr} ' and ' L_c ' variables.



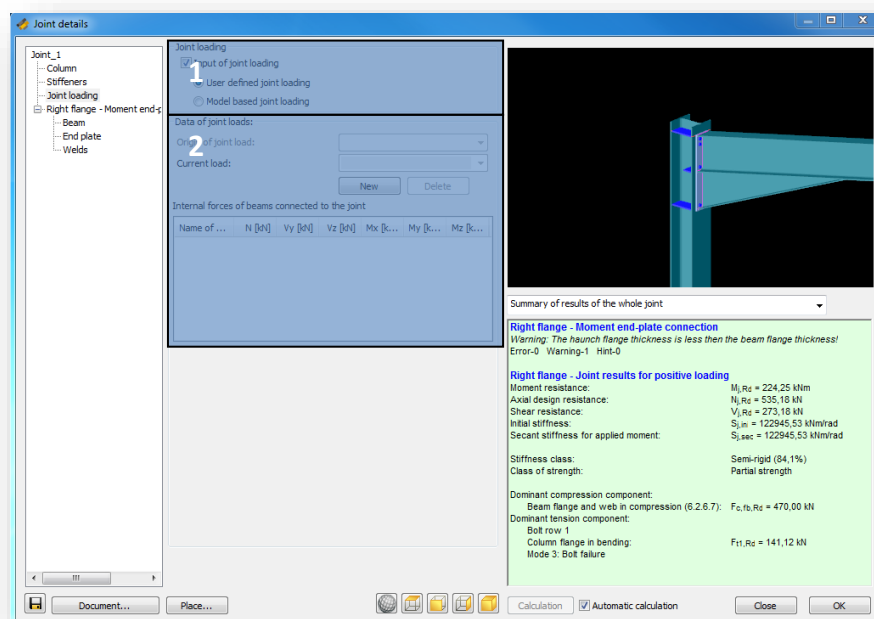
Stiffeners

Stiffeners can be added if *Stiffeners* is clicked in the connection tree. Upper and lower stiffener plate properties can be seen in the #1 part of the image below. Additional web and flange stiffeners can also be defined (#2). In order to place shear stiffener in the joint click on 'Use stiffener' check box (#3). Bear in mind that the position of the stiffeners are measured from the reference plane of the beam, which can be set if the *Beam* is clicked in the joint tree (see below!).



Joint loading

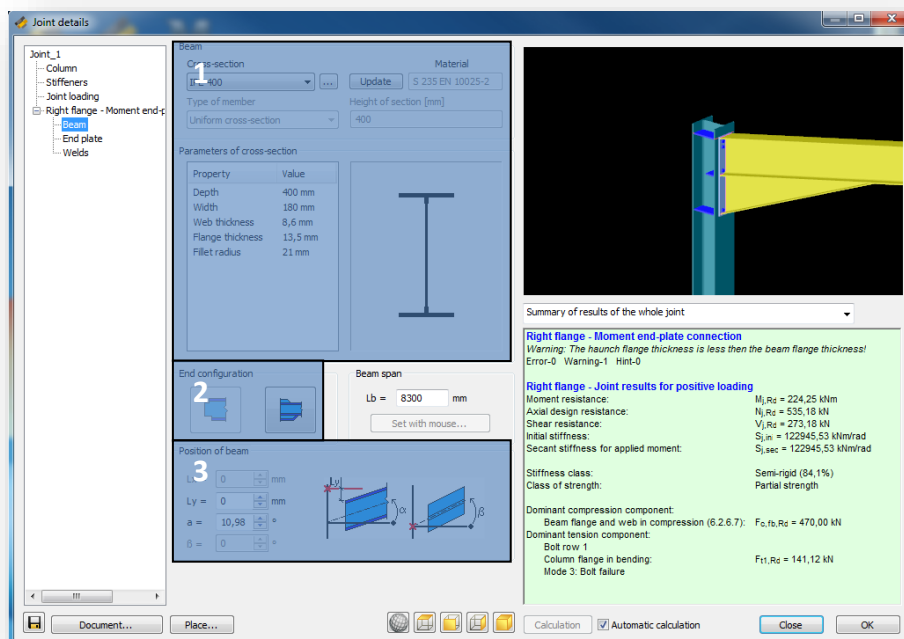
If *Joint loading* is selected, it is possible to choose from two options (#1). When “User defined joint loading” is selected, joint loads can be given manually by defining load cases, and internal forces (#2). If “Model based joint loading” is selected, *csJoint* automatically imports the internal forces from all of the combinations after the joint is placed in the modelling area.





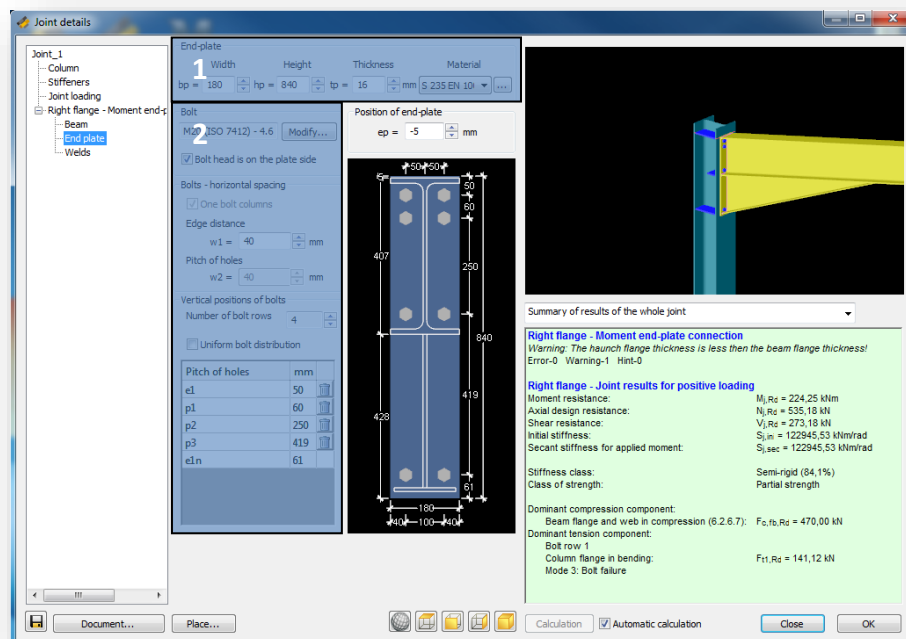
Beam

If the *Beam* is selected in the connection tree, then beam related properties of the connection can be set like the section size and material grade (#1). Beam end configuration can be set such as haunch (#2). Furthermore, the beam span and position of the beam are essential for the joint calculation (#3).



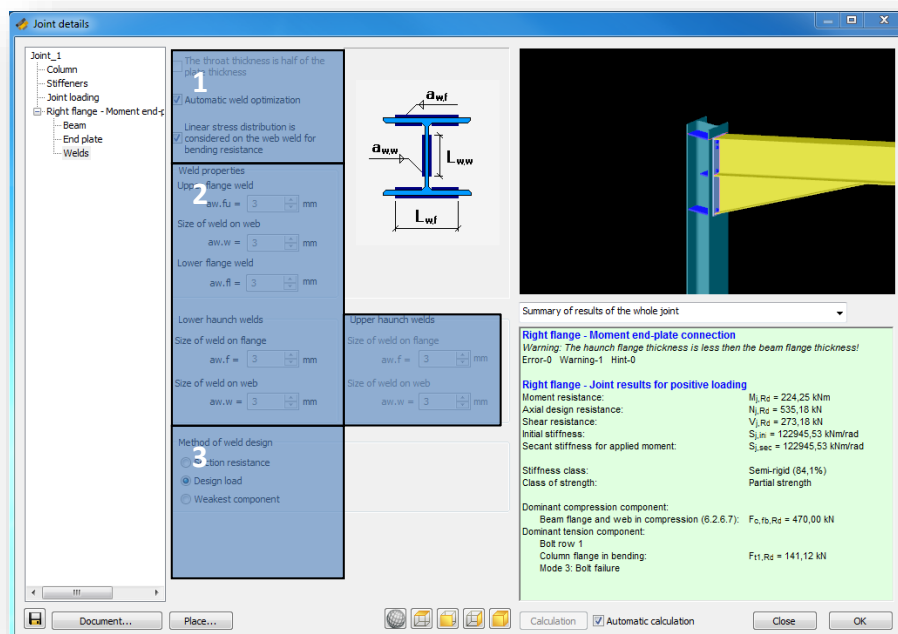
End plate

End plate properties (geometry, material) can be edited in the #1 part of the image below. Bolt properties can be seen on #2 part.



Welds

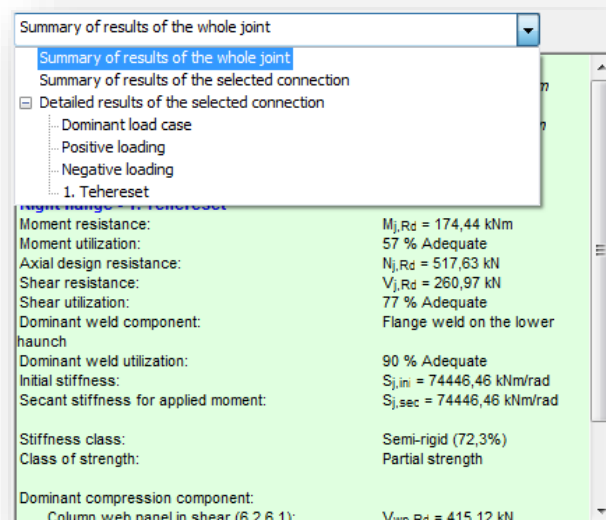
At *Welds*, it is possible to choose if welds should be optimized automatically or not (#1). If not, weld properties can be set manually (#2). Method of weld design also can be set in this window (#3)





Any changes made on the joint will take place either when pressing **ENTER** or by clicking to another editable field on the window. If *Automatic calculation* is turned on and any changes take place, then the calculation of the joint is automatically rerun. It can be turned off. In that case click on the **CALCULATION** button to run the calculation.

In the pull-down menu the type of the result visualization can be set to three different types: Summary for the whole joint, Summary for the selected connection, Detailed results of the selected connection. In the last two cases a connection must be chosen in the connection tree.



The result of the joint calculation can be seen in the highlighted part of the window. If the detailed result is selected, then all the results of the necessary calculations can be seen according to the selected load combination or according to the dominant load case.

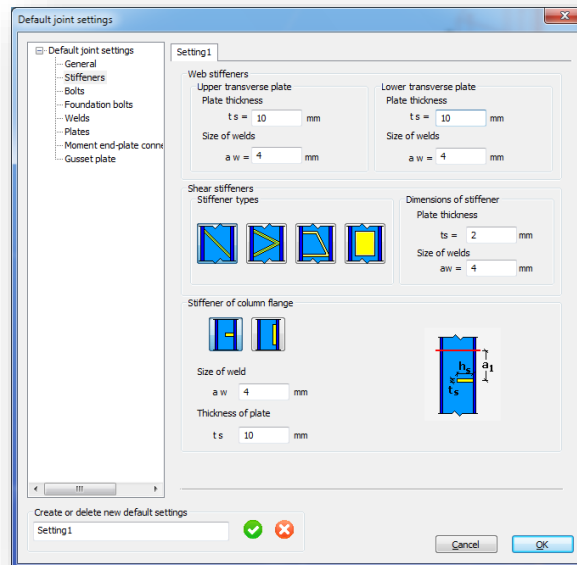
12.3.5 DEFAULT JOINT SETTINGS

The default joint setting like weld sizes, bolt diameter, etc. can be changed and saved.

Default joint settings can be changed and saved by clicking the **DEFAULT JOINT SETTINGS** (



) icon on the **JOINTS** dialog.



The default joint configuration file is saved to the Documents\Consteel folder as UserConfig.xml.

14.4 ANALYSIS OF CONNECTIONS

All the analysis in *CSJOINT* module is based on the standard procedures of Eurocode 3 Part 1-8, these procedures are almost entirely covered by the module. For the different types of connections, the following analyses are performed:

► Moment connections:

- Moment resistance based on the plastic tension components of the individual or grouped bolt rows and compression components including the effect of axial load
- Shear resistance of the bolts in combined shear and tension
- Bearing resistance of plates
- Web and flange weld resistance and capacity to the applied load, the section strength or the appropriate component
- Initial and secant stiffness based on the tension and compression components and applied moment

► Shear connections:

- Shear resistance of bolts and plates
- Bearing resistance of plates



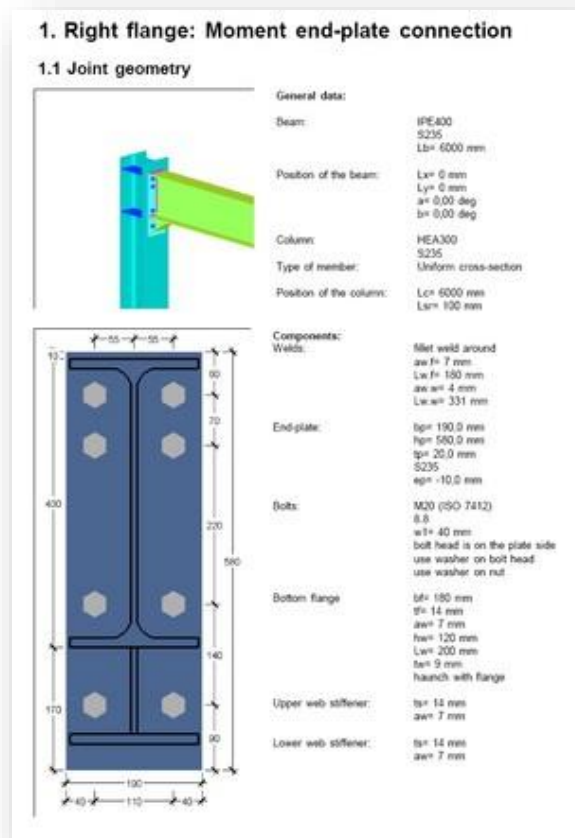
- Block tearing resistance of plates
- Weld resistance and capacity to the applied load or section strength

► Hollow section connections:

- Chord face failure, web failure, shear failure and punching shear failure
- Brace failure
- Local buckling of the members

14.5 RESULTS AND DOCUMENTATION


The analysis results are displayed in two main forms: a summarized view containing the main resistances, stiffness and capacities; and a detailed view showing the components of the main results which is comprehensive enough to see what are the weakest point of the connections and what type of strengthening would be the most efficient to apply. A joint is calculated for all the loads coming from different places or different combinations, and the dominant place and combination is automatically highlighted. The spectacular documentation shows the detailed geometry of the joint with its connections, and the summarized and detailed results for all cases can be flexibly documented.



The way for creating documentation is the same as in *Consteel* main module (see Chapter 11 for more detailed instructions).

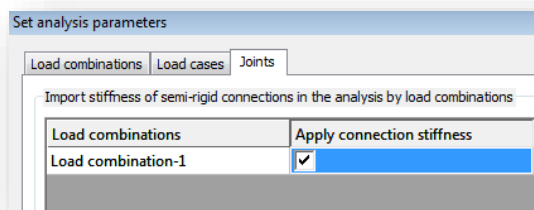
14.6 STRUCTURE-JOINT INTERACTION

The most up-to-date structural design procedures take into account the mechanical interaction between the global structural model and its connections (rigid, semi-rigid or pinned) which generally makes the results more economic and realistic. However, this approach requires a more complicated relationship between the joints and the structure and accordingly more serious modelling effort from the engineer. In the *Consteel* all the joint types can be defined freely or based on the global model geometry using the automatic identification tool, which examines the position of the connected members and the proper cross-sections and offer the possible joint types. After defining the joint it can place back to the global model and the appropriate connection stiffness can be automatically used in the global analysis, and a placed joint is always rechecked based on the current analysis results.

In order to place a joint to the global model click on the **PLACE JOINT** () icon on the **STRUCTURAL MEMBERS** tab. One joint can be placed to several places in the model if these meet the geometrical requirements. The stiffness of the connection can also be taking into

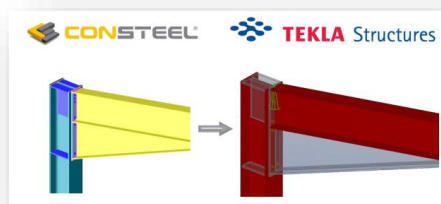


account during the analysis if desired. In order to do so click on the analysis parameters and put a tick to **APPLY CONNECTION STIFFNESS**. Rerun the analysis to the changes take place.



14.7 JOINT EXPORT

All joints can be exported to *TEKLA Structures* steel detailing software. See chapter 2.4 for more detailed information.





15 csPI – CONSTEEL PROGRAMMING INTERFACE

15.1 WHAT IS CSPI?

csPI is a new, sophisticated tool, a programming interface introduced in **CONSTEEL 11**, with which code based parametric models can be built easily and run at any time.

By writing the commands of **csPI**'s own "easy-to-read", very straightforward code language, any kind of Consteel objects (members, plates, support, loads etc.) can be created. Basic tools of programming are also included in csPI, like the usage of **VARIABLES**, **FOR LOOPS** and **IF-ELSE STATEMENTS** to make parametric structure building more effective.

For complete documentation of **csPI**, with detailed **command descriptions**, **copy&paste sample codes**, downloadable **csPI scripts** visit our wiki page:

http://wiki.consteelsoftware.com/index.php/Main_Page

15.2 FUNCTIONALITIES OF THE CSPI PANEL

csPI panel can be used in 2 sizes, minimized and maximized size. When Consteel is started, by default csPI panel appears on the bottom left part of your window in "minimized" size and it can be maximized at any time.

15.2.1 MINIMIZED PANEL SIZE

In minimized state of the panel, code cannot be written, only the following functionalities are available:



1. The size of the **csPI** panel can be "maximized or minimized" with the **OPEN/CLOSE** button, and model writing can be started
2. Existing **csPI** file (.cspi) can be imported by clicking on the **LOAD** button of the panel.
3. Loaded **csPI** files can be executed with the **RUN** button



15.2.2 MAXIMIZED PANEL SIZE

After the **CSPI** panel size is maximized with the **OPEN/CLOSE BUTTON**, further functionalities become available, and code writing can be started:

```
37 // 1.1) Loading the sections
38 MACRO_SECTION "id" "WeldedIorH_101" "WeldedColumn" "S 235 EN 10025-2" 250 10 300 8 250 10
39 MACRO_SECTION "id" "WeldedIorH_101" "WeldedBeam" "S 235 EN 10025-2" 200 10 400 8 200 10
40 LOAD_SECTION "Z 120x41x47 x 2.5"
41
42 //1.2) Building up the frames
43 for $n 0...$t
44 //Left columns
45 $l=$o-$i/2
46
47 create "id1" structural_member "WeldedColumn"
48 $l $k 0
49 $l $k $v
50 Name "R1"
51 ReleaseID_A "Continuous"
52 ReleaseID_B "Continuous"
+ create "id" support_point "id1" "Fixed"
```

1. The **CODE INPUT AREA** is the main part of the panel. This is where variables, cycles, commands can be defined, and will be executed line-by-line after the Run button is clicked. It has more features, like:
 - a. Automatic coloring of commands, variables comments, cycles etc.
 - b. Right click on the panel will bring up the **INSERT** possibility, with which sample codes can be imported automatically
 - c. Right click on the panel will bring up the **HELP** possibility, which will direct you to the wiki. If right click is performed on a command, it directs you to the clicked command in the wiki.
2. The **NUMBER OF LINES** has two main functions. It helps to **navigate** in the code and helps to **locate errors** in the code. If the code cannot be executed with the run button because of any kind of mistake (*syntax error for instance*), a **dialogue which locates the exact line where the problem is, will appear**.
3. The **UNDO/REDO BUTTON** does what is expected
4. The **SAVE BUTTON** can be used to save the script of the Code input area into a **.cspi** file, which can be opened later in **CONSTEEL**
5. Docking the **CSPI** panel is also possible, which can be useful if for example a secondary monitor is available to use. To dock the **CSPI** panel, **CLICK&HOLD** on the heading of the panel in maximized size, and **DRAG&DROP** to a place where the panel is desired to be moved.



15.3 BASIC TOOLS OF CSPI

15.3.1 VARIABLES

VARIABLES in a computer program are analogous to "Buckets" or "Envelopes" where information can be maintained and referenced. On the outside of the bucket is a name. When referring to the bucket, we use the name of the bucket, not the data stored in the bucket.

When creating or modifying objects with different kind of **COMMANDS**, they will require different input parameters (*such as start-end coordinates of a member, combination factors, ID's etc....*). These parameters can be defined locally as numerical values, or as a variable.

In **csPI**, definition of a variable starts with a "\$" sign, followed by the name of the variable, and after an equal sign, the value assignment:
\$x=1000

Value of a variable can be:

- ▶ numerical
- ▶ text variable (string of characters) [SOON]

If **VARIABLES** are defined, they are free to use them in the following lines of the code. They can either used as command attributes, and object attributes too.

15.3.1 MATHEMATICAL OPERATORS

MATHEMATICAL OPERATORS can be used with numerical values and variables too. They can also be used inside of a command in object attributes

The following mathematical operations are implemented in csPI:

+	→	Summation
-	→	Subtraction
*	→	Multiplication
/	→	Division
%	→	Modulo
^	→	Exponent
sin	→	Sine
cos	→	Cosine



tan	→	Tangent
log	→	Logarithm (base 10)
round	→	Rounding
floor	→	Rounding down
ceil	→	Rounding up
nint	→	Nearest integer
sqrt	→	Square root

15.3.2 CYCLES, FOR LOOPS

CYCLE is the basic tool to perform repeating (same or similar) operations. csPi handles the for cycle, for which the parameters are the:

- ▶ Definition of the running parameter
- ▶ Start value of the running parameter
- ▶ End value of the running parameter

15.3.3 IF ELSE STATEMENTS

An **IF-ELSE STATEMENT** in programming is a conditional statement that runs a different set of statements depending on whether an expression is true or false.

csPi supports **one-way** (*if-endif*) and **two-way** (*if-else-endif*) if selections also.

- ▶ One-way if selection:

```
if [expression]  
statement  
endif
```

- if and endif is reserved word
- expression must evaluate to true or false
- statement1 executed if value of expression is true

- ▶ Two-way if selection:

```
if [expression]  
statement1
```



else
statement2
endif

- if and endif is reserved word
- expression must evaluate to true or false
- statement1 executed if value of expression is true
- statement2 executed if value of expression is false

In the expression, after the if command, the following operators can be used:

==	→	equals
!=	→	Not equal
<	→	Less than
<=	→	Less equal
>	→	Greater than
>=	→	Greater equal

15.3.4 AVAILABLE COMMANDS OF CSPI

In this chapter, only the list of commands are collected. For a complete documentation of **csPI**, with detailed **command descriptions**, **copy&paste sample codes**, downloadable **csPI scripts** visit our wiki page:

http://wiki.consteelsoftware.com/index.php/Main_Page

► Load Section

With the LOAD_SECTION command, sections can be loaded from the standard library

► Macro Section

With the MACRO_SECTION command, different macro sections can be created and loaded into the model

► Create

With the CREATE command, the following list of *-so called-* conventional and unconventional objects can be created.

- LoadGroup
- LoadCase



- LoadTransferSurface
- Structural_Member
- Structural_Plate
- Tapered_Member
- Link
- Support_Point
- NodeForce
- MemberForce
- PlateForce

► Set

With the SET command previously created –*so called*- conventional or unconventional object attributes can be set, OR modified.

- LoadGroup
- LoadCase
- Structural_Member
- Structural_Plate
- Tapered_Member
- Link
- Support_Point
- NodeForce
- MemberForce
- PlateForce

► Get Release Name

With the GET_RELEASE_NAME command, end-releases can be found, and its settings can be stored in a variable. If the release to be found does not exists, a new release type will be created, and also stored in a variable.

► Get Support Name

With the GET_SUPPORT_NAME command, supports can be found by support conditions, and its settings can be stored in a variable. If the support type to be found does not exists, a new one will be created, and also stored in a variable.

► Select

With the select command, previously created objects can be selected, which objects can be used and modified in further commands



- Select all/Deselect all
- Select by_ID/Deselect by_ID
- Select by_Type/Deselect by_Type
- Select by_Attribute/Deselect by_Attribute
- Select by_User
- Select invert

► **Move & Copy**

With the mirror and copy commands, previously created and selected objects can be moved or copied with the commands below.

- Move_selected_point_or_edge
- Move_selected
- Copy_selected

► **Rotate**

With the rotate commands, previously created and selected objects can be rotated with the command options below:

- Rotate_selected
- Rotate_copy_selected

► **Mirror**

With the mirror commands, previously created and selected objects can be mirrored with the command options below:

- Mirror_selected
- Mirror_copy_selected

► **Get user input**

With the Get_user_input commands, input of variables can be performed through custom defined dynamic dialogues. On the custom dialogues, different kind of controls can be placed to obtain data in a dynamic way from the user, during the execution of the code:

- TEXT – Place an edit box on the dialogue, which will accept letters as input parameter
- NUMBER – Place an edit box on the dialogue, which will accept numbers as input parameter
- BOOL – Place a checkbox on the dialogue, which will have a value of 1 if checked, or a value of 0 if unchecked
- OPTION – Place a dropdown menu on the dialogue filled up with predefined values



- POINT – Place a selection button on the dialogue, with which a selected points coordinates can be obtained
- OBJECT – Place a selection button on the dialogue, with which the IDs of the selected objects can be obtained and stored

► Excel command package

The excel command package covers the commands below, with which data of an excel file can be accessed from csPI, so it can be read stored and used in the script:

- EXCEL_OPEN – Opens the Excel file found on the specified path in its command attribute
- EXCEL_CLOSE – Closes the lastly opened Excel file
- EXCEL_READ_CELL – Reads a value from a specified cell of a specified Excel worksheet, and stores its value in a csPI variable
- EXCEL_COUNT_FILLED_ROWS – Counts the filled rows in a specified column of a specified Excel worksheet, and stores its value in a csPI variable

15.4 TROUBLESHOOTING AND DEBUG FUNCTIONS OF CSPI

Debug function can be used to bug fix csPI codes or follow how the code is working.

Debug function has two parallel function:

- Automatic code check: code check is automatically and continuously running and evaluate the written code.

Code check has two signs:

1. Warning subjected line is yellow highlighted and after the code, a warning message appears. Warning sign does not block the code running
2. Error: subjected line is red highlighted and after the code, an error message appears. Error sign blocks the code running

12 LOAD_SECTION "HEA 200" Warning: Section was not loaded. There is a section with the same name already loaded into the model database


16 LOAD_SECTION "IPE 500" Error: Unknown command: LOAD_SECIION

- Debugging function: debugging function is a very useful function to step-by-step evaluate and follow the wrote code.

Debug functions can be found on the top line of the csPI editor





Add debug point: debug points stop the code during the debugging. Several debug points can be placed. To place a debug point, step to the line with the cursor and push the button. Place debug point highlights the number of the raw ().



Delete debug point: if the cursor is standing on a line where a debug point is, then the Add debug button is switched to Delete debug point button.



Delete all debug point: with a simple click, all the placed debug points can be deleted



Turn debug ON: by clicking on the button, debugging will be started and the running will stop at the first debug point. In case of switched ON debug function, there are some extra debugging option:



Go to next row: by pushing, debugging steps line-to-line



Go to next debug point: by pushing, debugging jumps to the next debug point



Run till end: by pushing, debugging neglects the following debug point(s), and run till end of the code



Turn debug OFF: by clicking on the button, debugging will be finished

Watch window: Watch window shows the actual value of the variables over the actual debugging position

