Part 1:

Getting Started with PowerConnect

(IS800 edition)

Table of Contents

1 Introduction

1.1 Installing PowerConnect

1.1.1 Hard- & software requirements

PowerConnect is a 32-bit software program for the MS Windows operating system. Although it may be possible to run PowerConnect on previous versions of MS Windows (without any warranty from BuildSoft, however), it is highly recommended to use it on **MS Windows XP** or **MS Windows Vista**.

For a smooth operation of the software program, following requirements should be met:

- a minimum of 512 MB of RAM.
- A graphical card (by preference nVidia or ATI) with minimum 32MB RAM on-board, and supporting OpenGL

1.1.2 Installation procedure

The PowerConnect software can be installed from CD-ROM or over the internet. In this case, you should have a valid LOGIN and PASSWORD to access the “Customer Care” section of the BuildSoft web site http://www.buildsoft.eu. BuildSoft customers receive access to this protected section as part of their maintenance or lease service contract. Other people interested in evaluating PowerConnect receive valid access data for a 30-days period provided they register at the BuildSoft web site.

In case all defaults are accepted as proposed by the PowerConnect installation procedure, the software will be installed on the directory “C:\Program Files\Buildsoft\PowerConnect”.

1.1.3 Demo copies of the software

In case PowerConnect is installed on a MS Windows workstation, the user will have access to a demo version of the software when no USB license dongle is available. A valid license on a USB dongle is indeed required to have continued access to all PowerConnect functions. With a demo license, existing PowerConnect models can be opened, while new models can only be defined with a cross-section determined by the program itself.

1.2 Local installations

1.2.1 Administration rights during installation

A correct installation of PowerConnect requires you to log on with appropriate administration rights.

1.2.2 Installing from CD-ROM

Insert the BuildSoft CD-ROM in your computer's CD-drive. After a short while, the BuildSoft installation program will appear on the screen. Select **PowerConnect** from the list of available programs to launch the installation.

1.2.3 Where to install ?

During the installation process, you will be prompted to define the location on your hard drive where PowerConnect should be installed. By default, the installation program will propose the directory *'C : \Program Files\BuildSoft\PowerConnect'*. It is recommended to confirm the default settings, although you are of course free to choose another location if this would be more convenient.

During the remaining part of the installation procedure, the choices made during each step can be confirmed by means of the 'Next'-button.

1.2.4 Completing the installation

Upon completion of the installation process, you will be asked to restart your computer. After a first installation of **PowerConnect** on a particular computer or after re-installation, it is indeed required to shutdown the computer and reboot it to obtain the licenses which are required to use **PowerConnect**.

1.2.5 Activating your license

To start with, it is important to remember that the installation procedure has been completed successfully, taking into account all elements discussed in the previous section.

Your PowerConnect license is delivered on a hardware dongle (CodeMeter-Stick) to be installed on a USB-port. The dongle is shipped to you with this reference manual. Please verify that the dongle is correctly plugged in before PowerConnect is launched. In case the dongle is correctly recognized by the operating system and a valid license is available on the dongle, PowerConnect will function directly with full access to all licensed capabilities. In case the dongle is not recognized by the operating system or does not contain any valid license, PowerConnect will report at start-up that only a demo license is available.

1.3 Network installations

With a network installation, the PowerConnect licenses are administered centrally on the server system. The server system doesn’t actually need to be a server “stricto senso”, but can actually be any workstation within the network environment that is accessible to all users at all times.

The management of the BuildSoft licenses is based on the license information stored on the hardware dongle (CodeMeter-Stick) that is connected to a USB port of the server system. Apart from installing the CodeMeter Control Center, no extra software needs to be installed on the server system. Is is however required to specify that the dongle should function as a network device, which can be done on the configuration page of the CodeMeter WebAdmin application. This application is a tool which allows to read the contents of the CM-stick, and can be launched by means of the WebAdmin -button which is found at the lower left bottom corner of the CodeMeter Control Center window. The CodeMeter Control Center itself is launched through the icon at the bottom right corner of your MS Windows desktop.

Furthermore, it is required to install both the CodeMeter Control Center and PowerConnect locally on workstation as described in Local installations. In case PowerConnect is launched and no CodeMeter dongle is present locally on your workstation, PowerConnect will automatically scan the network for valid PowerConnect licenses and will acquire the necessary licenses (if available).

1.4 Why PowerConnect?

PowerConnect is an exceptionally easy to use software program. Connection design analyses that would require hours when done by hand, can be performed in a very limited time frame when PowerConnect is being used. At the same time, PowerConnect will offer a significantly higher results accuracy because of the more refined analysis methods that have been implemented.

PowerConnect’s user interface has been designed to enable the design engineer to define as easily as possible modifications to existing connection designs and to test in the shortest possible time frame the impact of various design changes on the connection strength & stiffness. As a consequence, optimal connection design becomes feasible. Throughout this process, the user will be supported by well-documented dialogue windows, thus easing the design task and minimising error risk.

Although the underlying design analysis methods are quite complex in nature, the user will not be hindered by this complexity during the design analysis process. As the PowerConnect analysis engine is quite fast, results will almost immediately be available so that the impact of various design modifications can truly be tested to gain more insight into the effect of various design parameters.

Each part of every connection can be documented in full detail. The graphics are an excellent aid to visually control all connection design analyses.

At the end of the process, a clear and concise analysis report can be produced. Drawings of connection elements (along with the appropriate dimensions) can directly be included in such a report and/or can be exported to various CAD programs for further exploitation.

1.5 PowerConnect benefits

The PowerConnect software allows for design analysis of various steel connection types, with or without a wide range of stiffening elements.

PowerConnect can be used as a stand-alone program, in which case all geometry and loads data are entered manually by the user. PowerConnect is also integrated within BuildSoft's **PowerFrame** program for 3D frame analysis. The PowerFrame Master license allows for an automated transfer of geometry and loads data from the 3D frame model to the PowerConnect environment for detailed steel connection analysis. During the transfer procedure, the user can apply filter criteria in order to automate the selection of relevant load cases.

1.5.1 Design analysis according to IS800

The IS800 standard (IS800 : 2007, section 10) covers the design analysis of structural joints connecting H- or I-sections. As PowerConnect currently supports a wider range of connection types than the ones which are actually specified in the IS800 design standard, PowerConnect will automatically switch to another design method for connection types not specified by IS800:

- EC3 for beam to column web connections
- EC3 (CEDICT) for hollow structural section joints.

2 PowerConnect tutorials – IS800

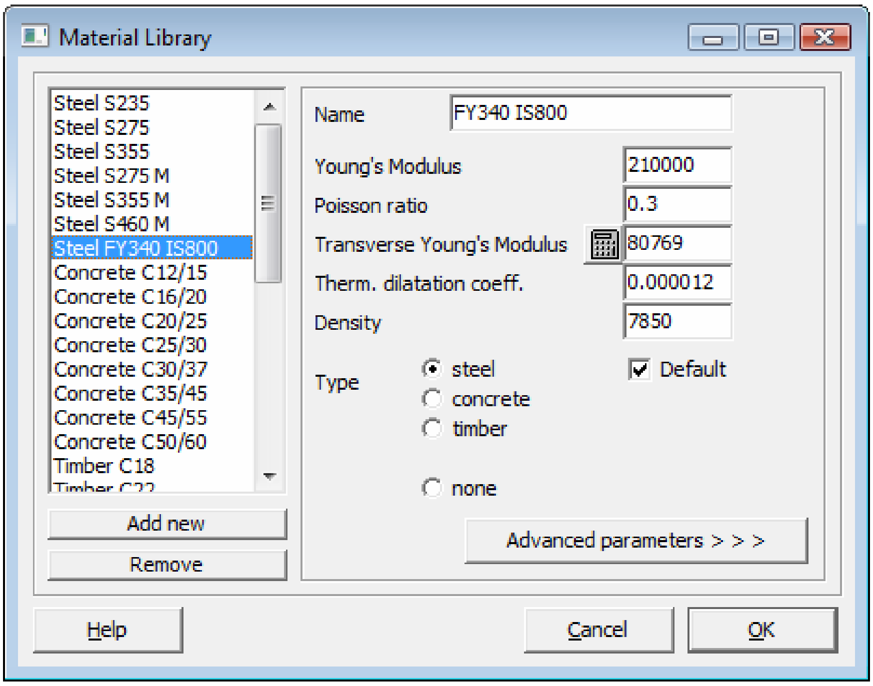
The best way to get acquainted with the PowerConnect software is to explore the product's functionality through a number of examples which highlight the various connection types supported by PowerConnect.

A range of examples based on the application of the IS800 design standard are covered in the tutorials below. The objective of the tutorials is not to provide a detailed and complete overview of the PowerConnect capabilities, but rather to concentrate on the information that is needed to get started with PowerConnect in a short time frame. The more detailed documentation of all product functions are covered in a separate reference manual.

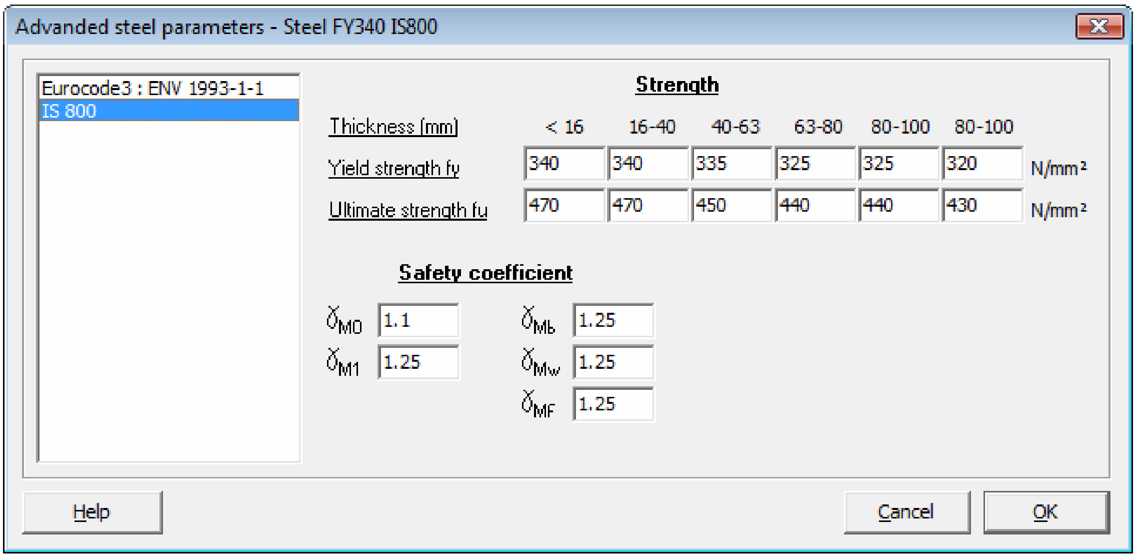
Following items should be checked in order to run smoothly through all tutorials which are covered in this manual:

- verify if the proper design standard has been selected using the menu entry **Analysis – Design Code – IS800,** to ensure that the IS800 design standard will effectively be used during all design analyses.

- define a steel grade FY340 in the PowerConnect material library, and declare it to be the default steel grade for newly created elements. This is done through the menu entry "Edit – Material library", which launches the following dialogue window:

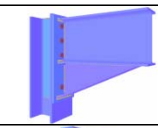
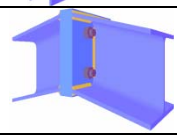
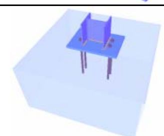
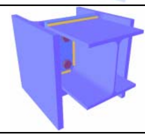
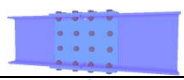
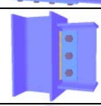
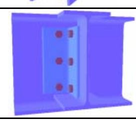


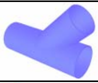
Enter a new material by using the button Add new, give a proper name to the material and make sure to enter the appropriate strength properties using the Advanced parameters > > > button:



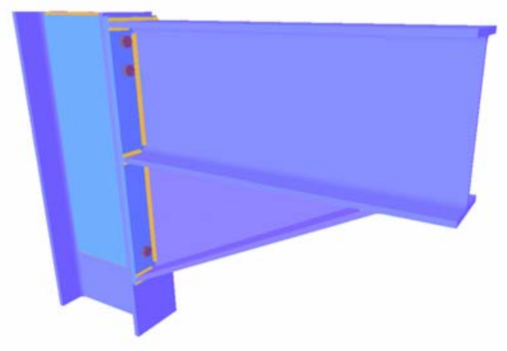
In the above dialogue window, make sure to select the IS800 design standard, and enter the appropriate value for f_y.

Inventory of tutorials:

Page	Section	Tutorial contents	Design code	Connection
page 8	§ 2.1	Tutorial 1: bolted beam to column flange (IS800)	IS800	
page 23	§ 2.2	Tutorial 2 : bolted beam to beam with moment end plate (IS800)	IS800	
page 33	§ 2.3	Tutorial 3 : column base with extended end plate (IS800)	IS800	
page 41	§ 2.4	Tutorial 4 : bolted beam to column web (IS800)	~~(IS800)~~ EC3	
page 47	§ 2.5	Tutorial 5: bolted splice (IS800)	IS800	
page 52	§ 2.6	Tutorial 6 : shear connection – beam to column flange with fin plate (IS800)	IS800	
page 61	§ 2.7	Tutorial 7 : shear connection – beam to beam web with bolted angle cleats (IS800)	IS800	

page 66	§ 2.8	Tutorial 8 : HSS connection (circular members)	~~(IS800)~~ CEDICT	
page 69	§ 2.9	Tutorial 9 : HSS connections (rectangular members)	~~(IS800)~~ CEDICT	

2.1 Tutorial 1: bolted beam to column flange (IS800)



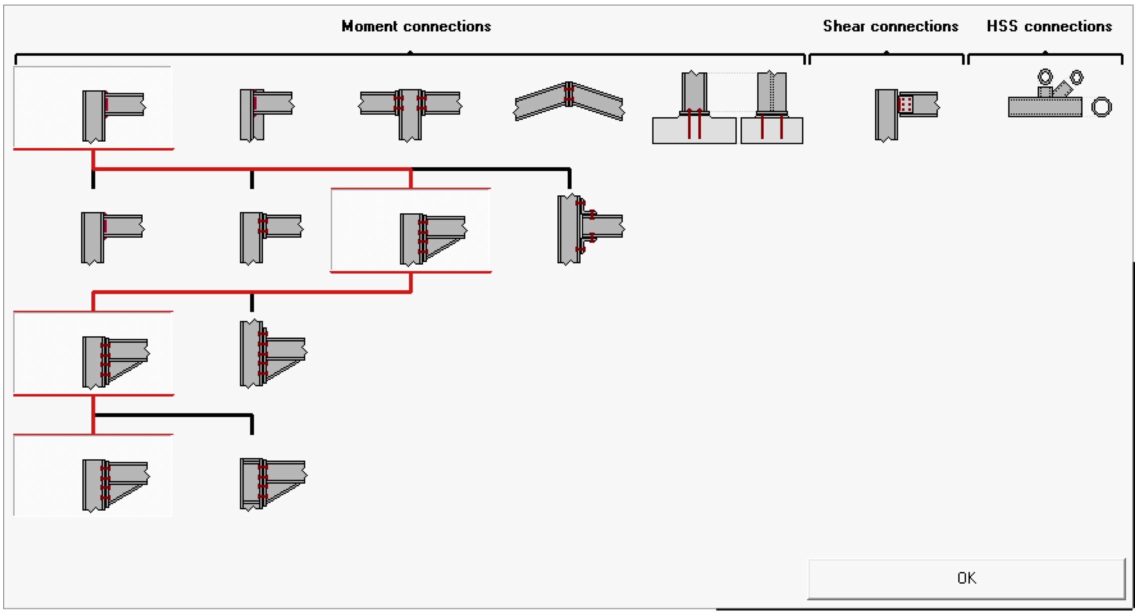
2.1.1 Setting up the model

Launch PowerConnect and use the "File – New" menu instruction or the icon. A window will appear (the so-called navigation window) in which you can select the type of connection that you want to design. Among the available moment connection types, choose the one labeled "Single-sided beam to column flange" (note: the labeling is done through the use of tooltips that appear when you move the mouse over the available icons). You will then initiate a tree structure through which you can navigate to select a specific connection type.

Choose the following entries

- haunched beam end plate
- flush moment end plate

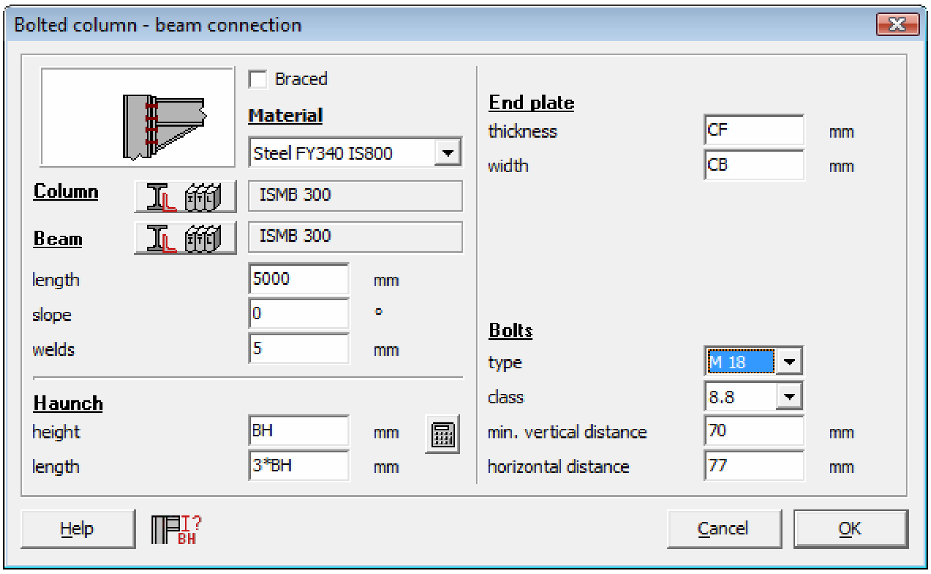
to define a haunched connection without any further stiffening elements. Confirm your final choice using the 'OK'-button. Please check that the navigation window appears as illustrated below.



By means of the dialogue window that appears next, the connection definition can quickly be completed. While the proposed default values for length, slope and steel grade of connected members will be accepted, beam and column sections are modified as follows:

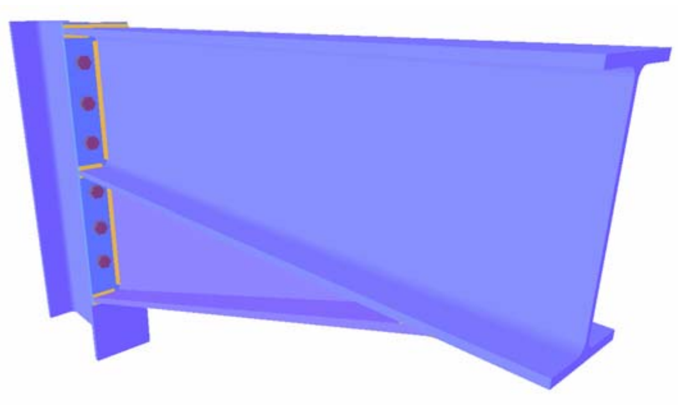
- ISMB 300 for the column member,
- ISMB 300 for the beam member.

Verify all other values as proposed by the program and change them, if needed, as shown in the dialogue window below. **In particular, choose bolts of type M18.** It should be realized that it remains possibly to modify them at any time through a straightforward interaction with the geometry model just by double-clicking on an element that needs modification.



***Remark**: it is possible that some of the input fields in the above dialogue contain parameters rather than numbers (or even arithmetic expressions, rather than parameters by themselves). In this case, the corresponding dimension is linked to the dimension of another element of the connection. The actual meaning of the parameters can be clarified by means of the icon button  in the dialogue window. For more information on this topic, consult the PowerConnect reference manual.*

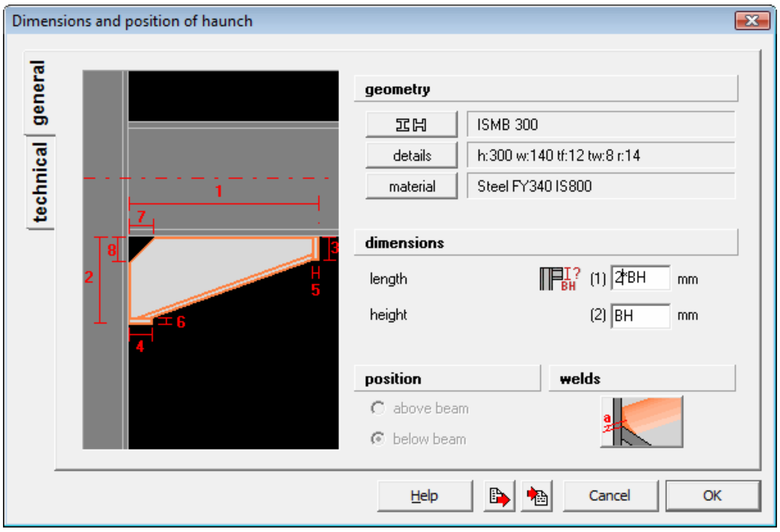
This definition is finally confirmed through the 'OK'-button, and as a consequence a 3D geometry model will be created and visualized on the screen.

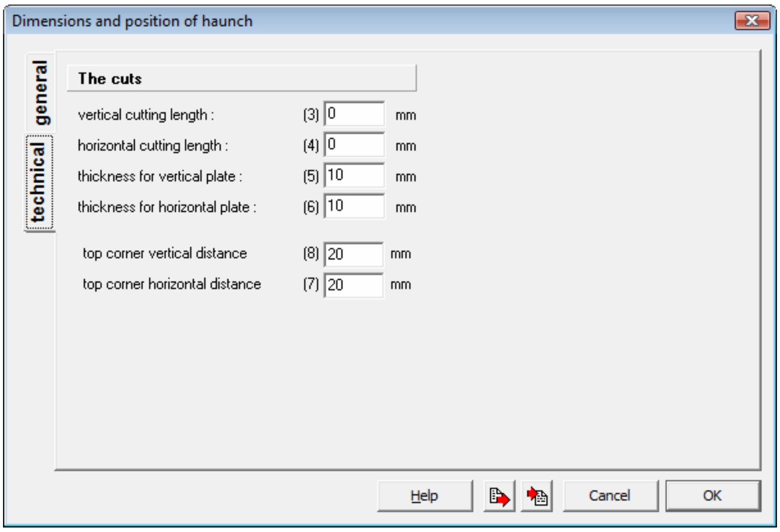


2.1.2 Completing the geometry model

The scale which is used for model representation can be modified using the 'Zoom in' () and 'Zoom out' () icons of the icon toolbar or by using the scrollbar of the mouse. The geometry model can furthermore be moved across the screen by holding down the left-hand mouse button while moving the mouse across the 'Geometry' window (take care not to position the mouse such that any of the connection elements is selected, it should really be positioned on the drawing canvas of the 'Geometry' window).

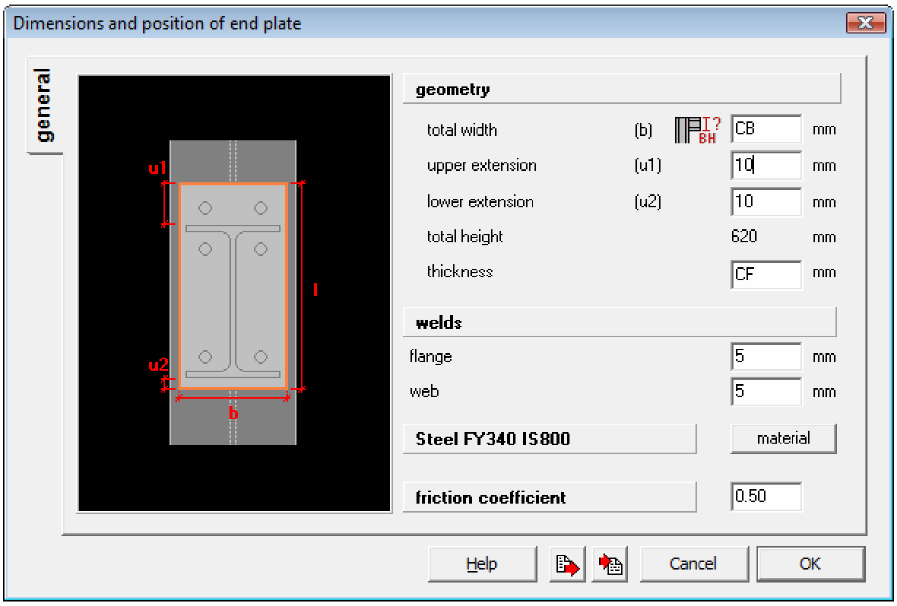
The dimensions of various elements of the connection that has just been created will now be further verified and modified, if needed. Double-click for instance with the left mouse button on the haunch and verify if the fields of the dialogue window are as shown below. In particular, **modify the length of the haunch such that it is twice the height of the beam element BH**.





It should be noted that by default, the haunch is based on a ISMB 300 section, which is the section used for the beam element. If needed, the haunch can be based on a different section defined through the icon on the 'general' tab sheet.

The dimensions and the position of the end plate should also be verified. Again, double click on the end plate in the 3D 'Geometry' window to open the dialogue window below and fill out the parameters as shown hereafter.

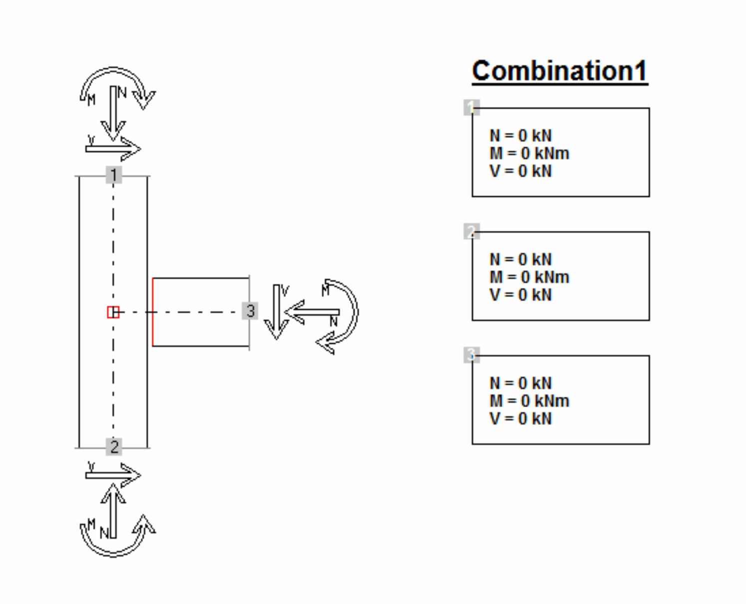


Each time a set of dimensions is confirmed for a selected element, PowerConnect will automatically verify the position and alignment of individual bolts. In case a problem is identified (either with respect to minimum distances imposed by standards or with respect to minimum distances specified by the user), PowerConnect will issue a warning on the matter.

2.1.3 Defining the loads

Now that the basic geometry definition has been completed, loads can be assigned to the connection. Switch to the "Loads" window by clicking on the -icon that is part of the 'Windows'-toolbar:

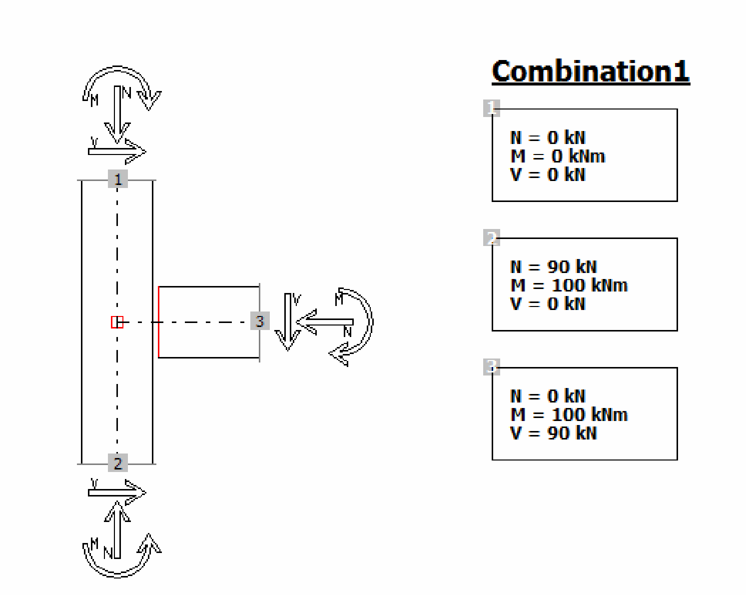
The following information will appear in the 'Loads'-window.



Following loads should be applied:

- at the lower end of the column, a bending moment of 100 kNm and a normal force of 90 kN. Activate the appropriate dialogue by clicking with the mouse on the label “2” at the lower end of the column and by filling out the values in the dialogue which pops up;
- at the right end of the beam, a bending moment of 100 kNm and a shear force of 90 kN. Activate the appropriate dialogue by clicking with the mouse on the label “3” at the right end of the beam and by filling out the values in the dialogue which pops up.

As a result, the information in the ‘Loads’-window should now appear as follows:

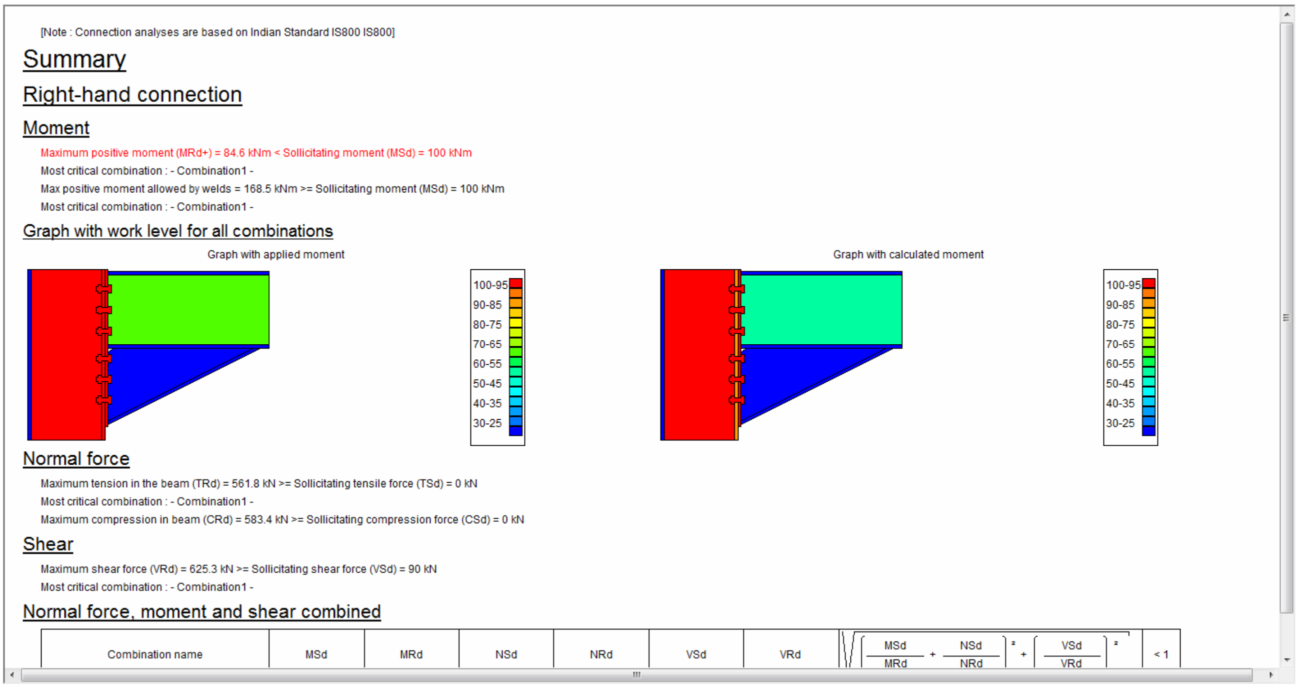


2.1.4 Running a first connection design analysis

The connection design analysis can be initiated in 3 different ways:

- through the menu command 'Analysis – Analysis',
- through the shortkey F9,
- through the  icon in the Analysis toolbar.

Prior to running the connection design analysis, verify whether IS800 is defined to be the active steel design code. This can be done through the menu entry 'Analysis – Steel Design Code'. The summary results of the subsequent design analysis are presented below.

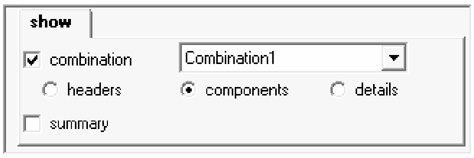


A more in-depth analysis of the above results already provides following feedback:

- the current connection design doesn't fulfill the imposed strength requirements, as the ratio of applied loading to resistance achieves a value of 1.19 (looking at the combination of **bending moment and normal force**),
- from the results available for **moments** only, it can be derived that the welds are OK
- from the **work level graph** valid for **moments** only, it shows that the column web, bolts and end plate are loaded up to their maximum capacity,
- from the results available for **shear** only, it can be concluded that the connection largely provides sufficient shear strength

For a more detailed interpretation of analysis results, it is possible to switch to a more advanced reporting lay-out. To this purpose, click with the mouse on the field ‘Results preferences” at the right-hand bottom of the PowerConnect window.

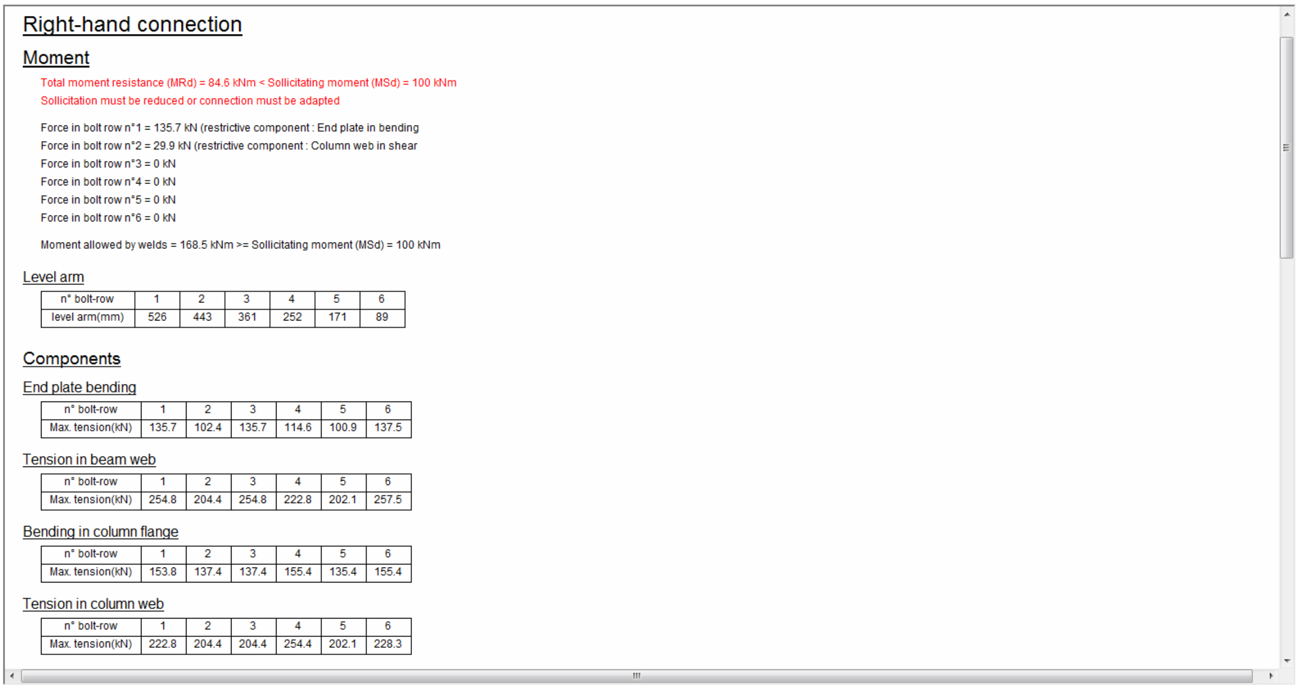
In the dialog which appears now, ask for the results related to Combination 1, rather than to look at summary results. For the time being, it is sufficient to ask for all components results without any further details (as shown below).



This will provide the information shown below (only the first part of the screen report is shown; the remaining information can be screened by using the scrollbar on the right hand side of the PowerConnect window), from which following conclusions can be drawn:

- only bolt rows 1 & 2 contribute to the connection’s resistance in bending
- the most critical components of the connection are the end plate (failure in bending) and the column web (shear failure)

This information, consistent with the information provided by the work level graphs shown before, allows to modify the connection to achieve the desired level of resistance.



Right-hand connection

Moment

Total moment resistance (MRd) = 84.6 kNm < Sollicitating moment (MSd) = 100 kNm
Sollicitation must be reduced or connection must be adapted

Force in bolt row n°1 = 135.7 kN (restrictive component : End plate in bending
Force in bolt row n°2 = 29.9 kN (restrictive component : Column web in shear
Force in bolt row n°3 = 0 kN
Force in bolt row n°4 = 0 kN
Force in bolt row n°5 = 0 kN
Force in bolt row n°6 = 0 kN

Moment allowed by welds = 168.5 kNm >= Sollicitating moment (MSd) = 100 kNm

Level arm

n° bolt-row	1	2	3	4	5	6
level arm(mm)	526	443	361	252	171	89

Components

End plate bending

n° bolt-row	1	2	3	4	5	6
Max. tension(kN)	135.7	102.4	135.7	114.6	100.9	137.5

Tension in beam web

n° bolt-row	1	2	3	4	5	6
Max. tension(kN)	254.8	204.4	254.8	222.8	202.1	257.5

Bending in column flange

n° bolt-row	1	2	3	4	5	6
Max. tension(kN)	153.8	137.4	137.4	155.4	135.4	155.4

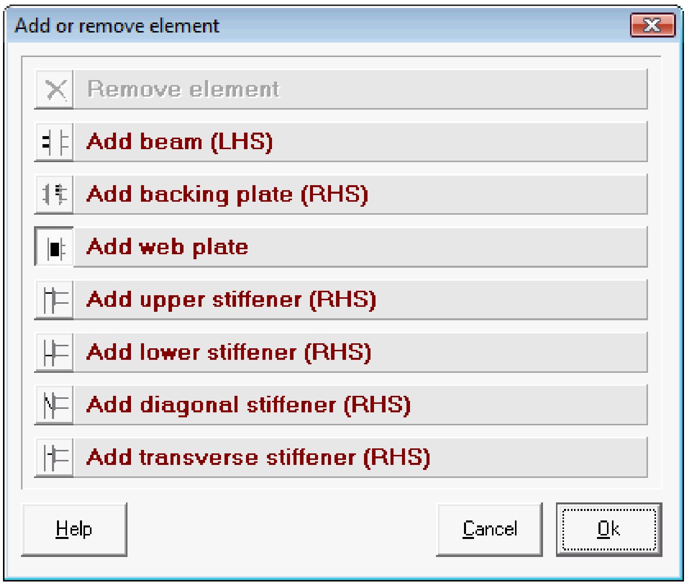
Tension in column web

n° bolt-row	1	2	3	4	5	6
Max. tension(kN)	222.8	204.4	204.4	254.4	202.1	228.3

2.1.5 Optimizing the connection design

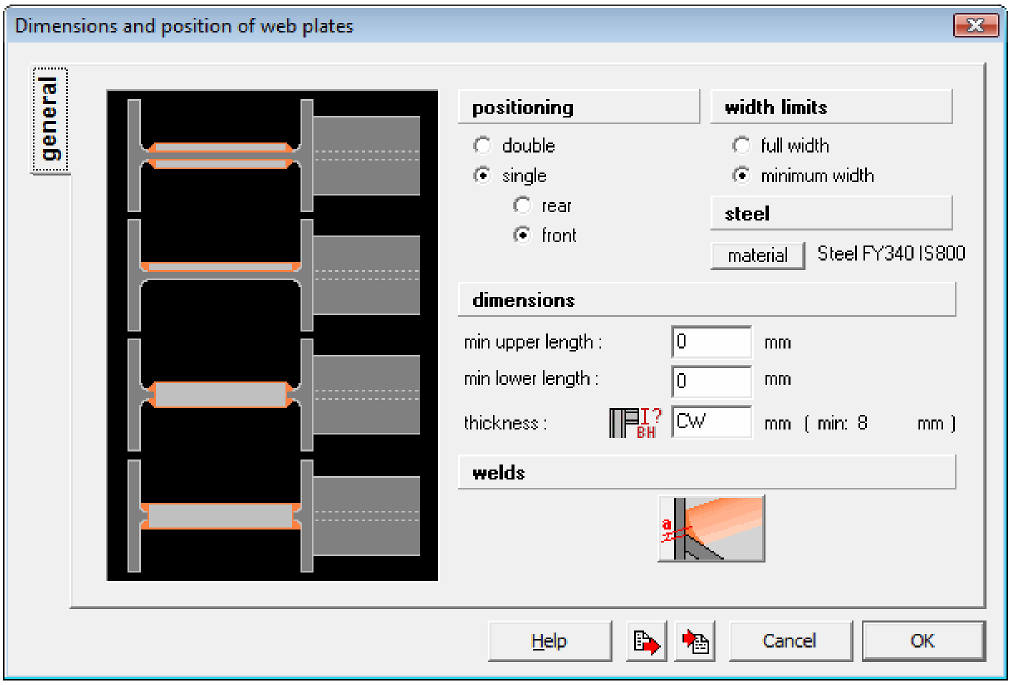
Based on the results provided by the first design analysis, a number of modifications will now be defined to the existing connection such that its resistance is increased by focusing on the most critical component information.

In a first step, it is decided to add a web plate to counteract the column web shear failure **to increase the contribution of the second bolt row to overall connection resistance**. Therefore, select the column web in the 'Geometry' window and click on the right-hand mouse button to make the following window appear on the screen.



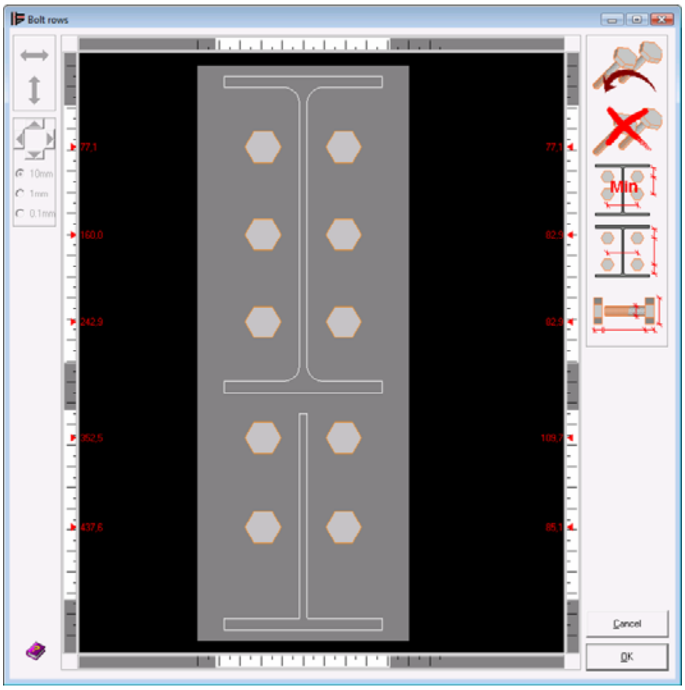
Choose the option "Add web plate", and confirm this choice by means of the 'OK'-button.

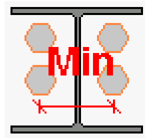
In order to verify and to possibly modify the web plate dimensions, double-click on the web plate that is now visible on the geometry model. A new window will appear providing full access to all geometry details of the web plate:



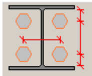
Make sure all parameters match with the ones presented above.

Finally, double-click on one of the bolts that is part of the 3D geometry model to have access to the definition of bolts & bolts lay-out. As only 2 bolt rows have an active contribution to the connection's bending resistance, a number of bolt rows will now be removed as follows:

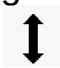
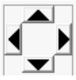


- select one of the bolts belonging to bolt row 3 and then use the icon  to remove this bolt row,
- out of the remaining 5 bolt rows, again select bolt row 3 to remove it using the same icon,
- out of the remaining 4 bolt rows, again select bolt row 3 to remove it using the same icon,
- then use the icon 'Minimum optimisation' 

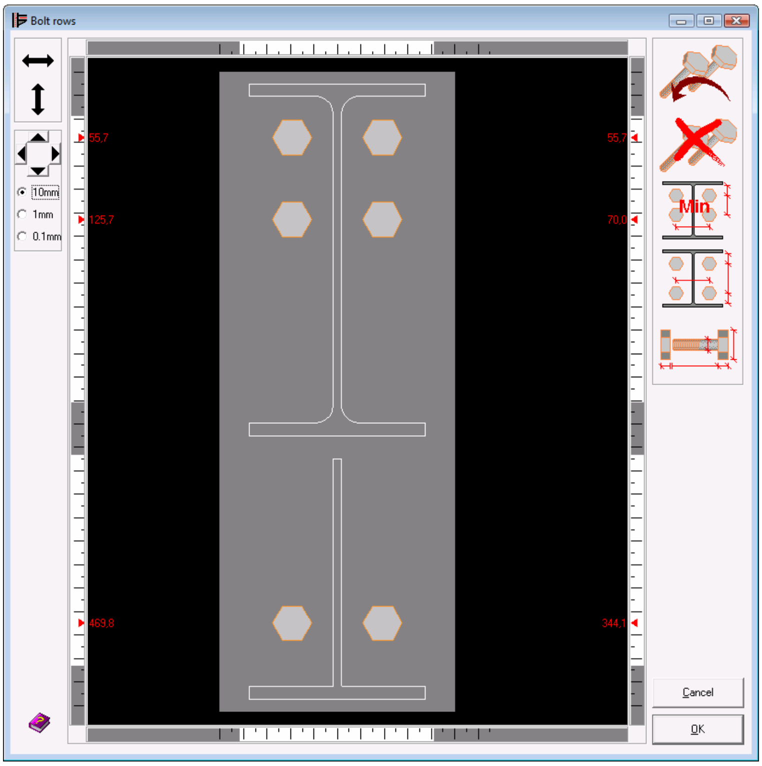
to

optimize bolt row positions with minimum intermediate distance (the other icon  will optimize bolt row positions with maximum intermediate distance)

In case the user wants to further fine-tune bolt row positions, this can be easily achieved as follows:

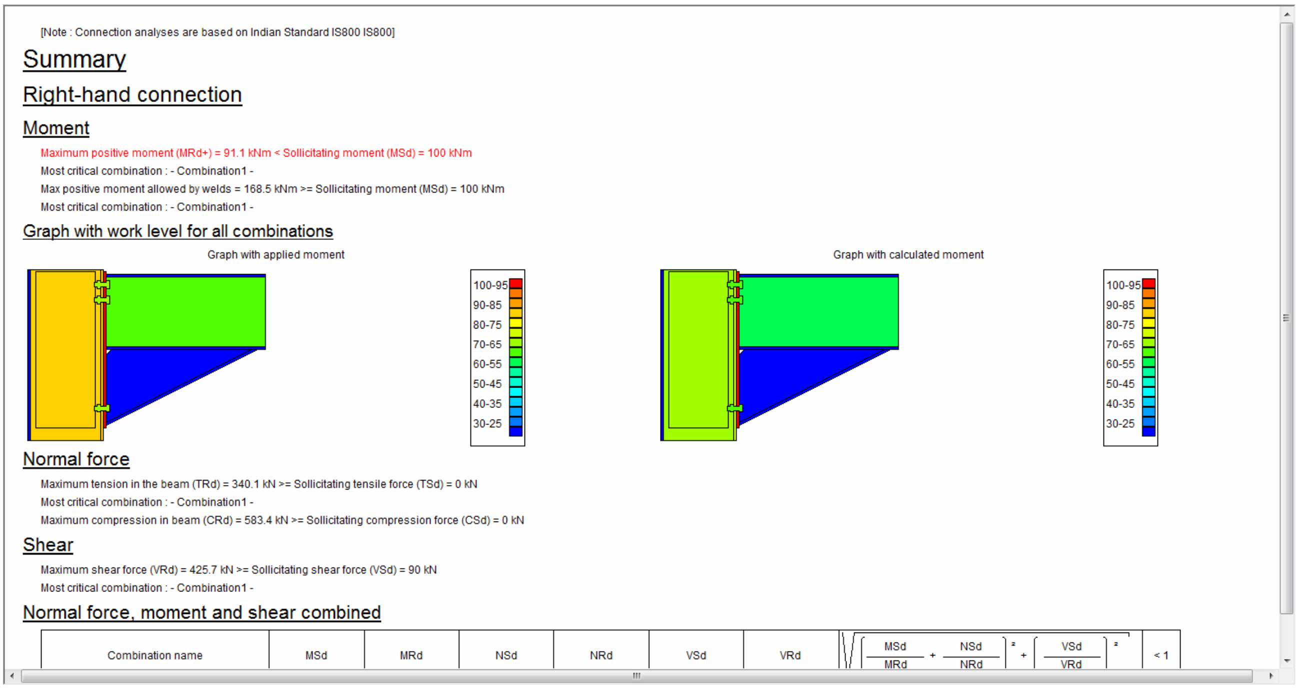
- select the bolt row which needs re-positioning
- activate the vertical displacement function  and move the selected bolt row as required
- alternatively, the arrows  can be used to move the selected bolt row according to the selected precision level;

Currently, it is assumed that no such modifications are implemented to the lay-out that was obtained using the minimum optimization function. The bolt row lay-out should thus look like



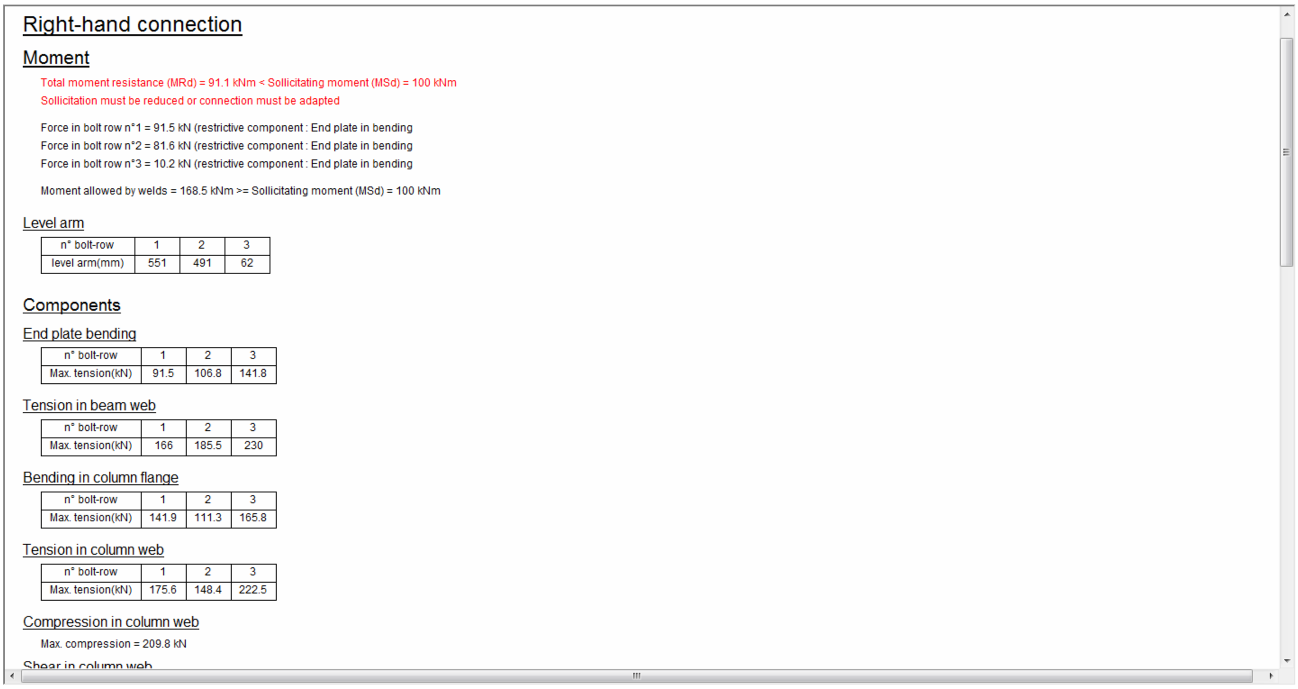
2.1.6 Re-running the connection design analysis on the optimized connection

Running the connection design analysis will now produce following summary results:



Those results confirm that not all strength requirements have been met yet by the connection, after the described changes have been introduced into the geometry model. Just like before, it remains possible to look at more detailed analysis results by clicking with the mouse on the field 'Results preferences" at the right-hand bottom of the PowerConnect window and by asking for the appropriate detail level for results reporting.

In the example below, detail is given on component level – and it can thus easily be deduced that the connection will now fail due to yielding of the end plate in bending. The most logical next step is therefore to increase end plate thickness.



Right-hand connection

Moment

Total moment resistance (MRd) = 91.1 kNm < Sollicitating moment (MSd) = 100 kNm
Sollicitation must be reduced or connection must be adapted

Force in bolt row n°1 = 91.5 kN (restrictive component : End plate in bending
Force in bolt row n°2 = 81.6 kN (restrictive component : End plate in bending
Force in bolt row n°3 = 10.2 kN (restrictive component : End plate in bending

Moment allowed by welds = 168.5 kNm >= Sollicitating moment (MSd) = 100 kNm

Level arm

n° bolt-row	1	2	3
level arm(mm)	551	491	62

Components

End plate bending

n° bolt-row	1	2	3
Max. tension(kN)	91.5	106.8	141.8

Tension in beam web

n° bolt-row	1	2	3
Max. tension(kN)	166	185.5	230

Bending in column flange

n° bolt-row	1	2	3
Max. tension(kN)	141.9	111.3	165.8

Tension in column web

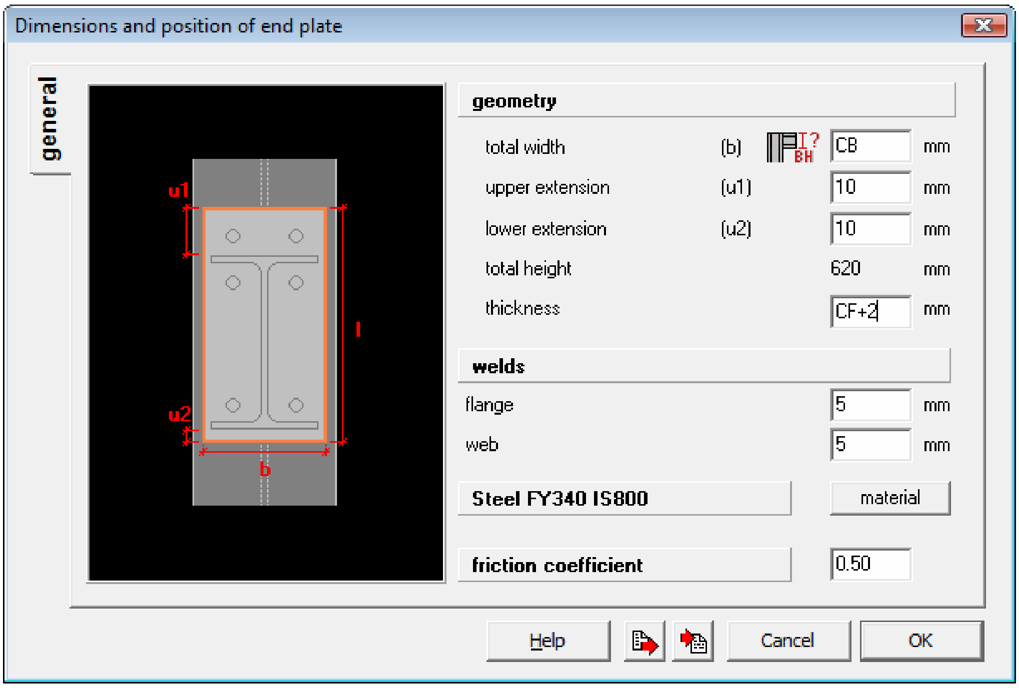
n° bolt-row	1	2	3
Max. tension(kN)	175.6	148.4	222.5

Compression in column web

Max. compression = 209.8 kN

Shear in column web

Increasing end plate thickness is most easily done by double-clicking on the end plate element in the 3D view of the connection to make the following dialogue window appear.



By default, end plate thickness is parametrically defined to be equal to column flange thickness CF. Define end plate thickness to be 2mm larger than column flange thickness CF and rerun the design analysis. As can be seen from the fully detailed results below, the connection now has sufficient strength to resist the applied loading.

Complete results for -Combination1-

Right-hand connection

Moment

Total moment resistance (MRd) = 111.1 kNm >= Sollicitating moment (MSd) = 100 kNm

Force in bolt row n°1 = 124.6 kN (restrictive component : End plate in bending
Force in bolt row n°2 = 86.4 kN (restrictive component : Column web in compression
Force in bolt row n°3 = 0 kN

Moment allowed by welds = 168.5 kNm >= Sollicitating moment (MSd) = 100 kNm

Level arm

n° bolt-row	1	2	3
level arm(mm)	551	491	62

Components

End plate bending

n° bolt-row	1	2	3
Max. tension(kN)	124.6	145.3	156.9
Mode 1 (End plate)(kN)	151	171.7	219.3
Mode 2 (End plate)(kN)	177.4	198.1	245.7
Mode 3 (End plate)(kN)	124.6	145.3	193
Mode 4 (Bolts)(kN)	221.2	221.2	221.2
Mode 5 (Bolts)(kN)	156.9	156.9	156.9
B eff(mm)	67	75	93

Tension in beam web

n° bolt-row	1	2	3
Max. tension(kN)	166	185.5	230

Bending in column flange

n° bolt-row	1	2	3
Max. tension(kN)	141.9	111.3	165.8

It is interesting to look a bit more closely in the design analysis results, in particular those for the end plate bending failure mechanism. It can indeed be seen that the maximum bolt row forces corresponding to bolt failure are significantly higher than those corresponding with an end plate yielding mechanism. As the connection is reported to fail through end plate yielding, this indicates that bolt size can still be reduced without any (or limited) negative impact on connection design strength.

For example, if bolts are changed from type M18 to type M16 (leaving the position of the 3 remaining bolt rows unaffected) then the overall moment resistance of the connection is not reduced (see below).

Complete results for -Combination1-

Right-hand connection

Moment

Total moment resistance (MRd) = 111.3 kNm >= Sollicitating moment (MSd) = 100 kNm

Force in bolt row n°1 = 128.3 kN (restrictive component : Bolts in tension on end plate
Force in bolt row n°2 = 82.7 kN (restrictive component : Column web in compression
Force in bolt row n°3 = 0 kN

Moment allowed by welds = 168.5 kNm >= Sollicitating moment (MSd) = 100 kNm

Level arm

n° bolt-row	1	2	3
level arm(mm)	551	491	62

Components

End plate bending

n° bolt-row	1	2	3
Max. tension(kN)	128.3	128.3	128.3
Mode 1 (End plate)(kN)	153.6	174.4	222
Mode 2 (End plate)(kN)	177.4	198.1	245.7
Mode 3 (End plate)(kN)	129.8	150.6	198.2
Mode 4 (Bolts)(kN)	180.9	180.9	180.9
Mode 5 (Bolts)(kN)	128.3	128.3	128.3
B eff(mm)	67	75	93

Tension in beam web

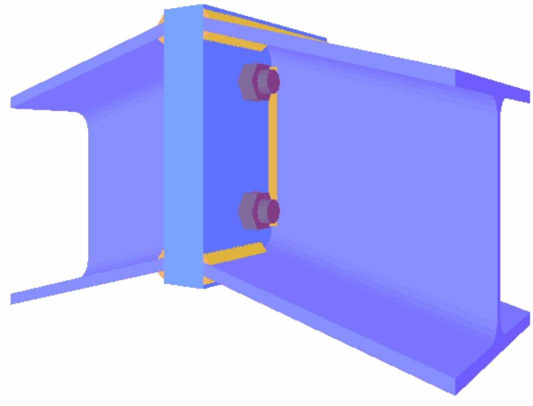
n° bolt-row	1	2	3
Max. tension(kN)	166	185.5	230

Bending in column flange

n° bolt-row	1	2	3
Max. tension(kN)	135.6	116.9	135.6

Of course, the actual failure mechanism that limit the moment capacity of the connection have changes as a result of bolt size reduction. The first bolt row will fail in tension – further reducing bolt size will therefore also reduce connection resistance.

2.2 Tutorial 2 : bolted beam to beam with moment end plate (IS800)

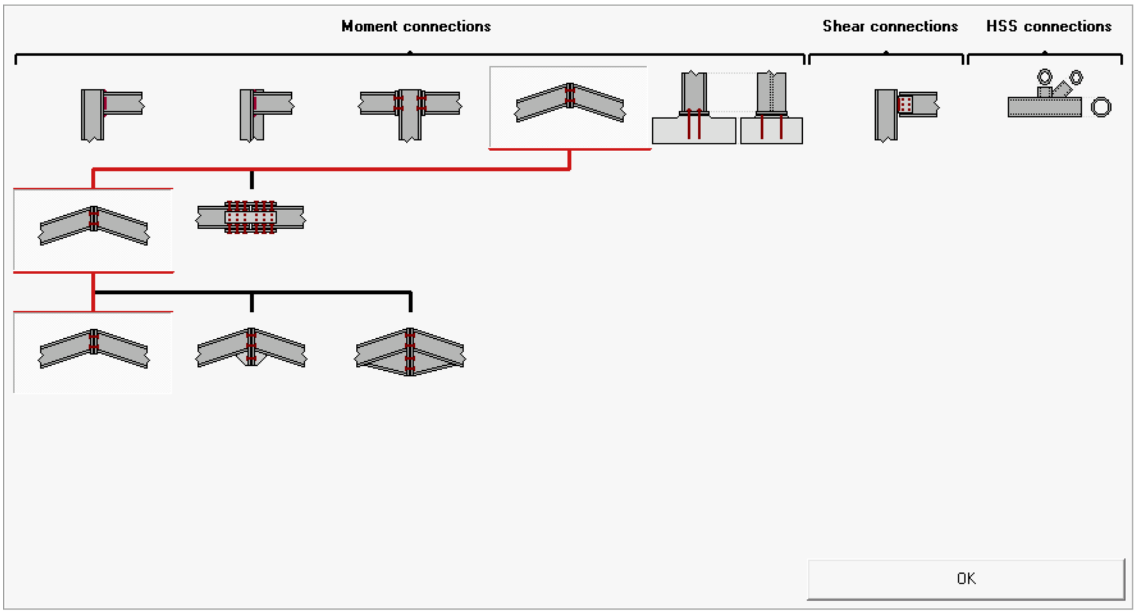


2.2.1 Setting up the model

To define the model for this second tutorial, click on the 'New' icon of the icon toolbar. Among the connection types which are available in the navigation window, select the one labeled "Beam to beam" (remember: the labeling is done through the use of tooltips that appear when you move the mouse over the available icons). Then further navigate through the tree structure by choosing the following entry

- bolted moment end plate

to finally select a beam to beam connection without any further stiffening elements. Confirm this final choice using the 'OK'-button, checking that the navigation window appears as illustrated below.

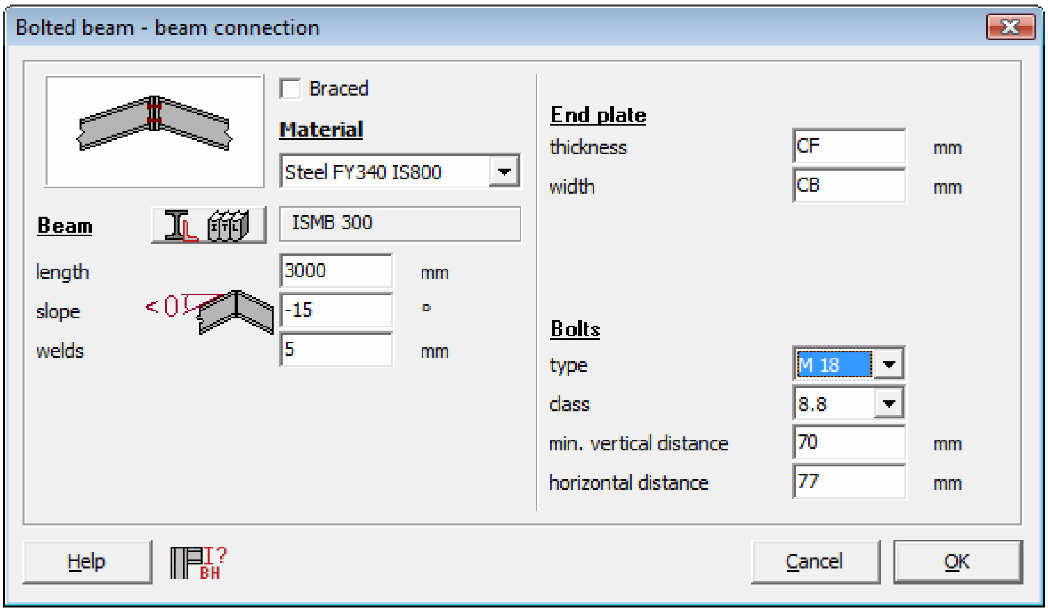


In the window that appears next, modify the data as follows:

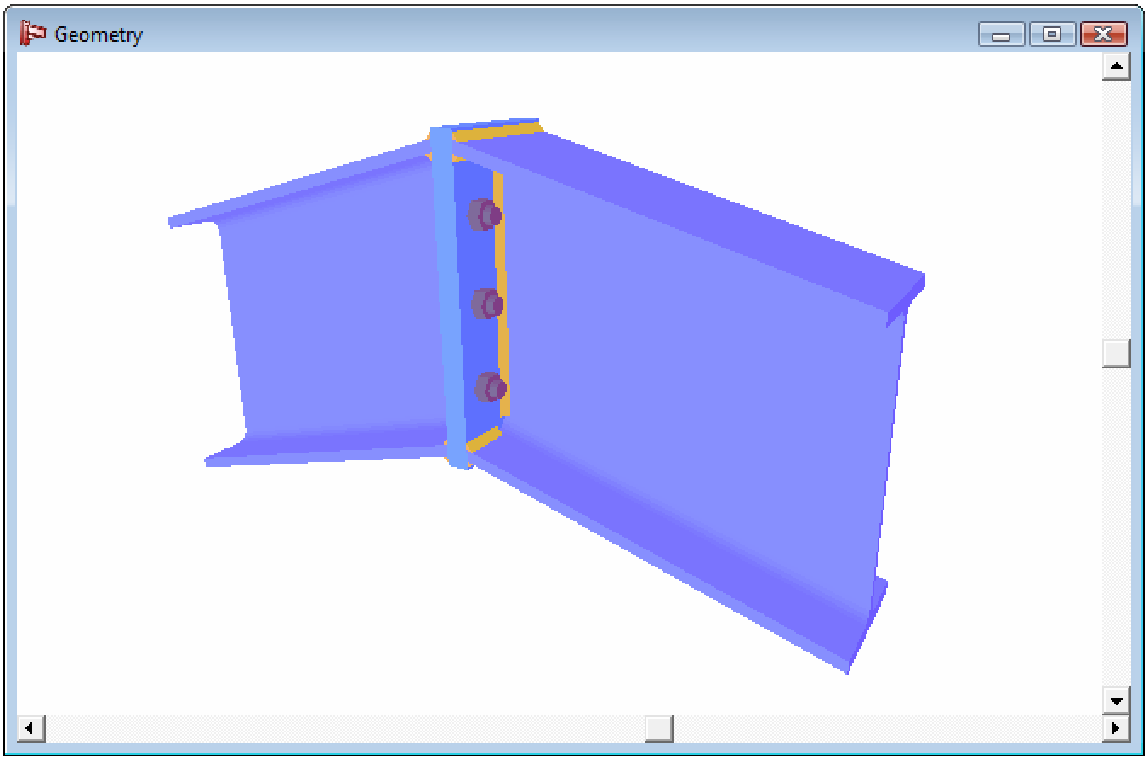
- beam section : ISMB 300
- beam length : 3000 mm

- slope of beam : -15°
- bolts M18, grade 8.8

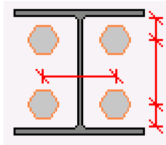
to arrive at the input data as shown below.

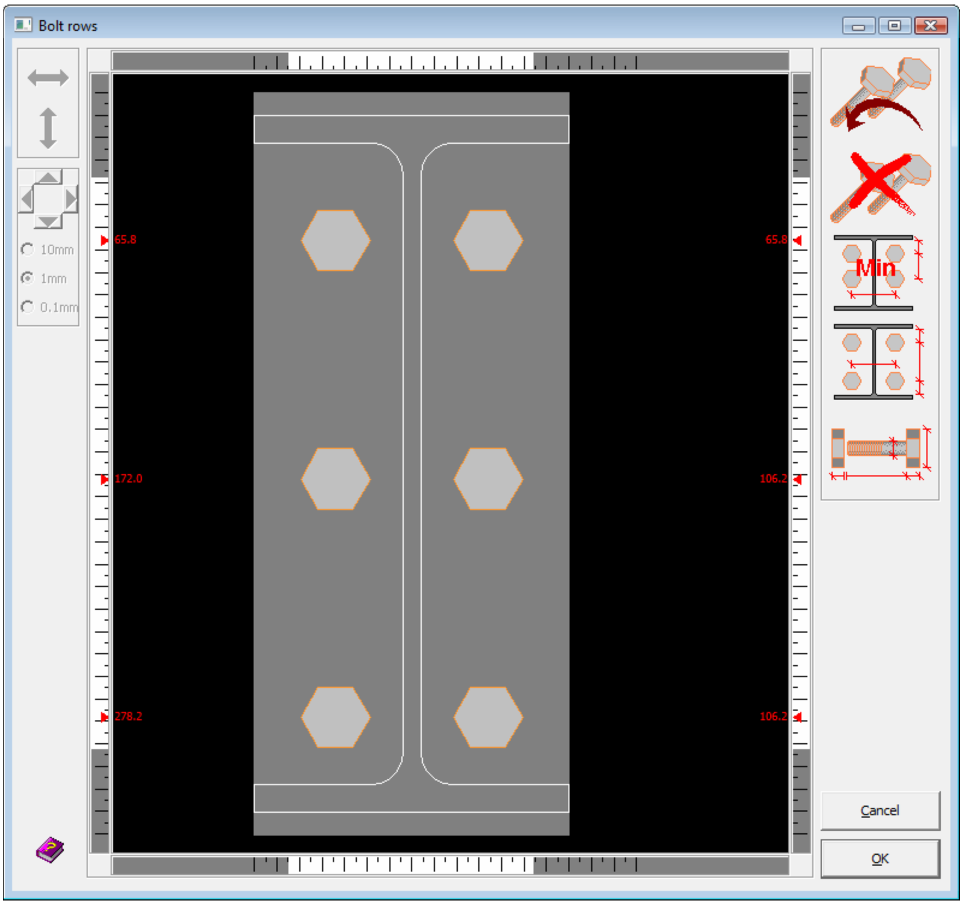


Confirm by means of the 'OK'-button to make following geometry model appear.

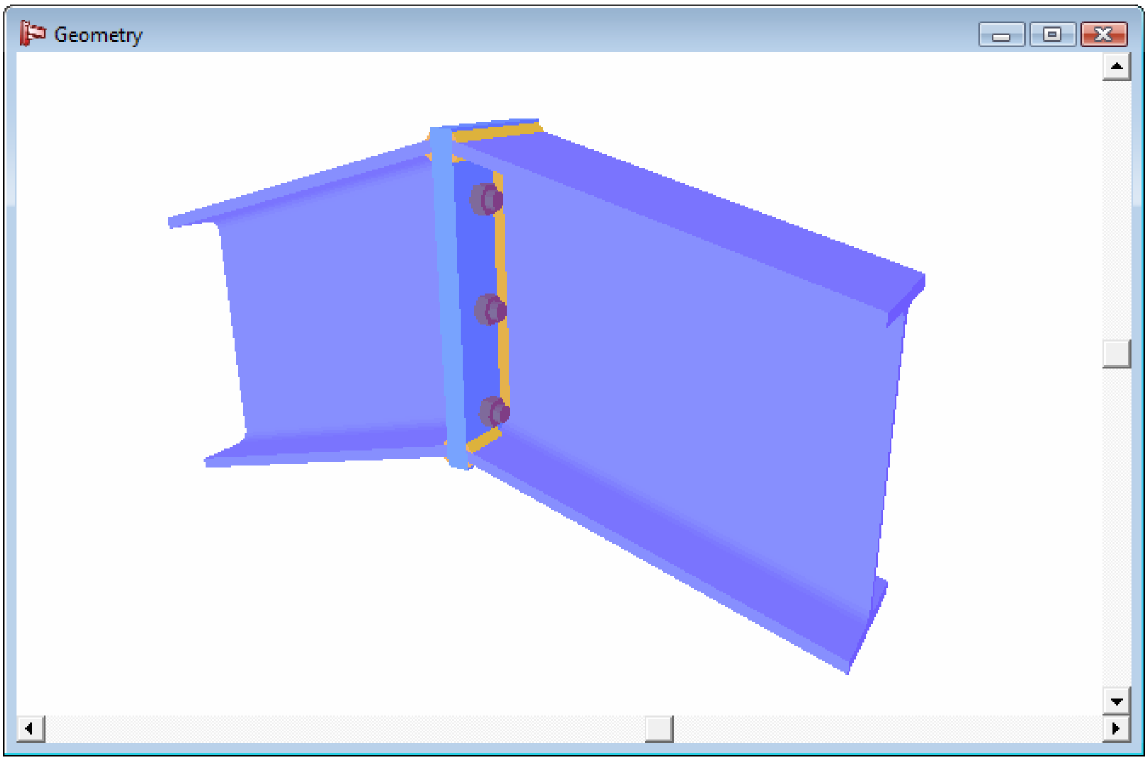


To re-align the bolt rows from the defaults proposed by PowerConnect, double-click on one of the bolts to make the bolt definition dialogue appear.

Optimize bolt row lay-out by means of the ‘Optimization’ icon , such that the following lay-out is obtained:



As a result, the 3D geometry model will look as follows in the ‘Geometry’-window:

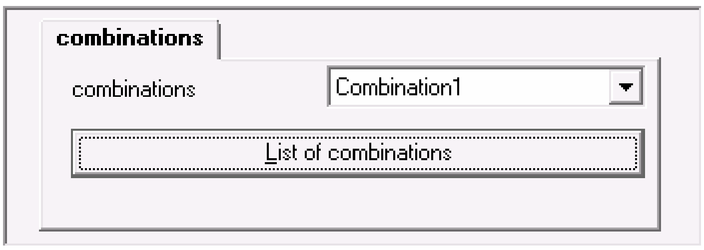


2.2.2 Defining the loads

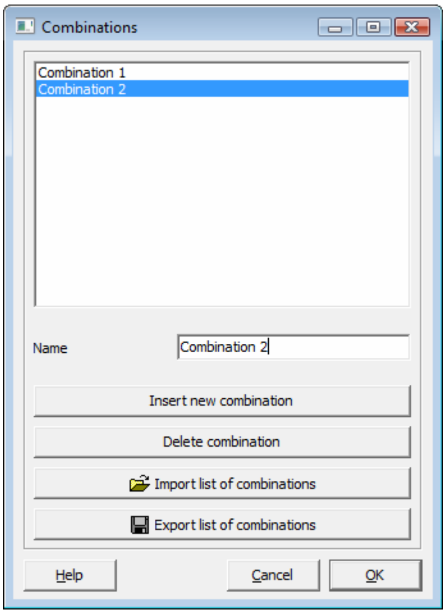
Now switch to the 'Loads'-window by means of the  icon. 2 loads combinations will be defined:

- in a first combination, a bending moment of 120 kNm will be applied at both sides of the connection
- in the second combination, a bending moment of 90 kNm and a compressive force of 150 kN will be applied at both sides of the connection

By default, PowerConnect presents only 1 loads combination. Before the values for this first combination will actually be filled out, the second combination that is needed with this model will first be created. To do so, click on the label 'Loads preferences" at the right hand bottom of the 'Loads'-window. Then use the button "List of combinations" to open the appropriate definition dialogue.

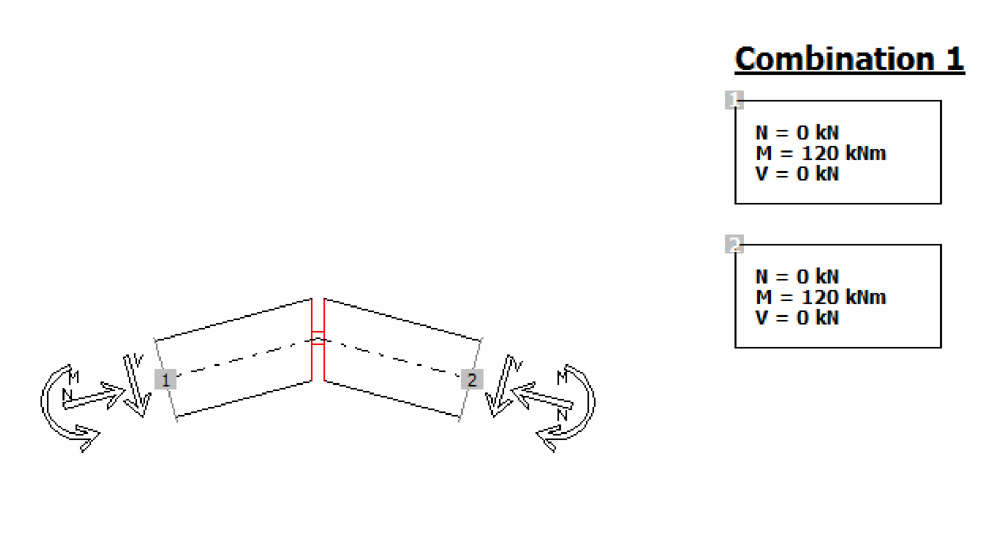


Use the ‘Insert new combination’-button and specify the name “Combination2” for the new combination that has just been created. Now click ‘OK’ to confirm those definitions and to quit the window

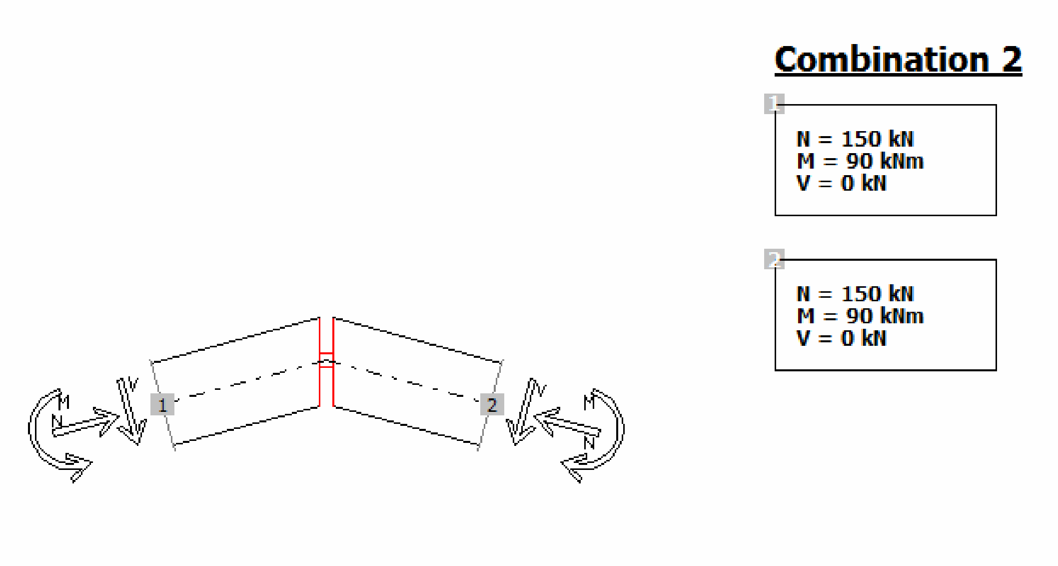


Make sure to leave the combination list visible at the right hand bottom of the ‘Loads’-window and check if ‘Combination1’ is the active combination. Then enter the appropriate load values for this combination, by clicking on the small labeled numbers which are visible on the geometry representation in the ‘Loads’-window.

This should deliver the following result :

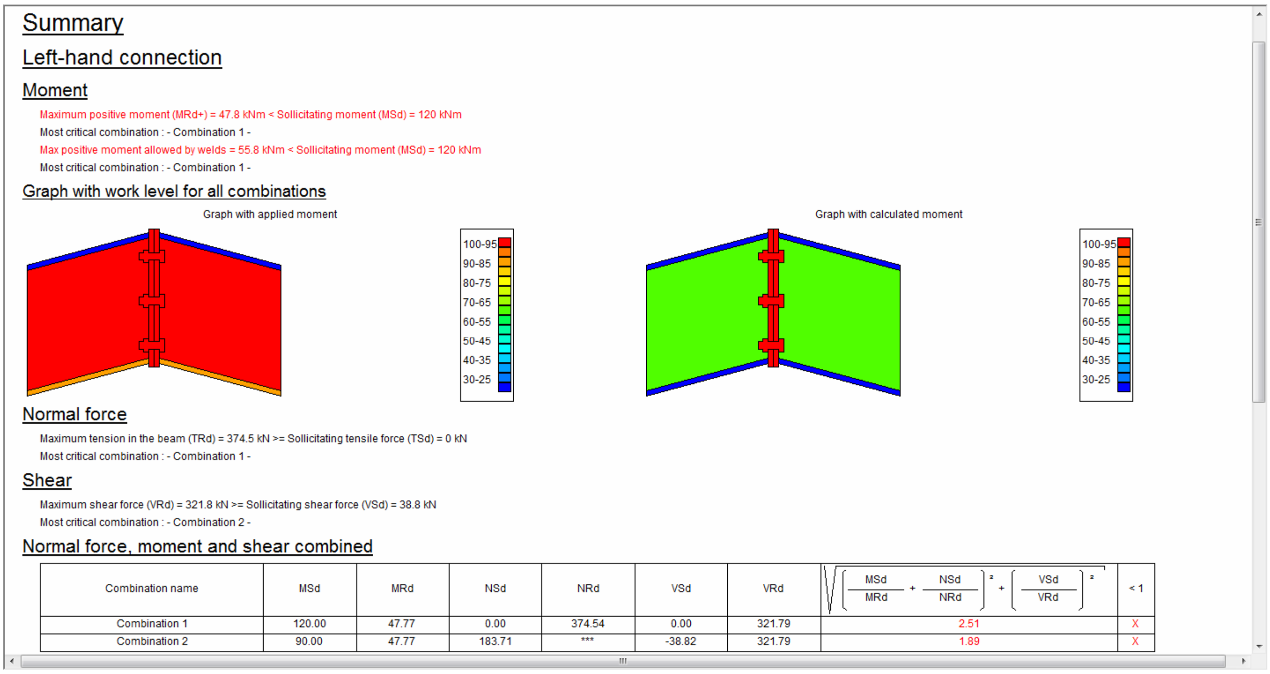


Now make sure ‘Combination2’ becomes the active loads combination (combination list at the right hand bottom of the ‘Loads’-window !) and enter the loads data as follows:



2.2.3 Running a first connection design analysis

As the connection is perfectly symmetric, it is of course sufficient to inspect the analysis results only for one side of the connection. For the time being, this inspection will be limited to the results summary (so the option "Summary" should be active when opening the window by clicking on the "Results preferences" label at the right hand bottom of the 'Results' window).


Summary

Left-hand connection

Moment

Maximum positive moment (MRd+) = 47.8 kNm < Sollicitating moment (MSd) = 120 kNm
Most critical combination : - Combination 1 -
Max positive moment allowed by welds = 55.8 kNm < Sollicitating moment (MSd) = 120 kNm
Most critical combination : - Combination 1 -

Graph with work level for all combinations

Normal force

Maximum tension in the beam (TRd) = 374.5 kN >= Sollicitating tensile force (TSd) = 0 kN
Most critical combination : - Combination 1 -

Shear

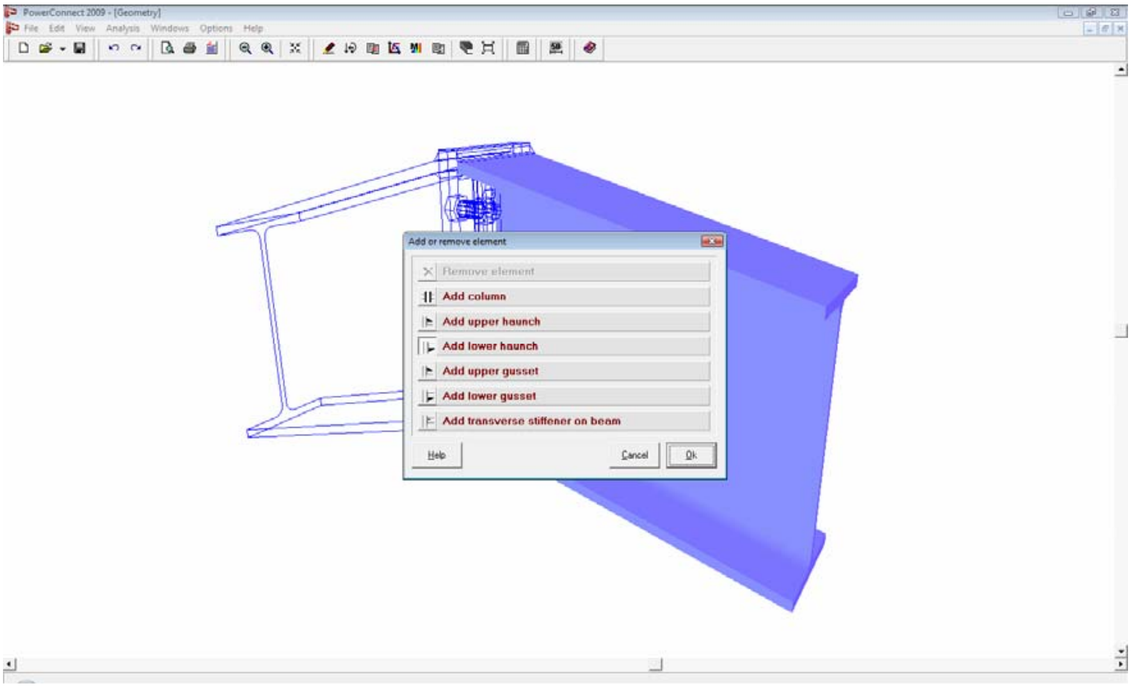
Maximum shear force (VRd) = 321.8 kN >= Sollicitating shear force (VSd) = 38.8 kN
Most critical combination : - Combination 2 -

Normal force, moment and shear combined

Combination name	MSd	MRd	NSd	NRd	VSd	VRd	$\sqrt{\left(\frac{MSd}{MRd}+\frac{NSd}{NRd}\right)^2+\left(\frac{VSd}{VRd}\right)^2}$	< 1
Combination 1	120.00	47.77	0.00	374.54	0.00	321.79	2.51	X
Combination 2	90.00	47.77	183.71	***	-38.82	321.79	1.89	X

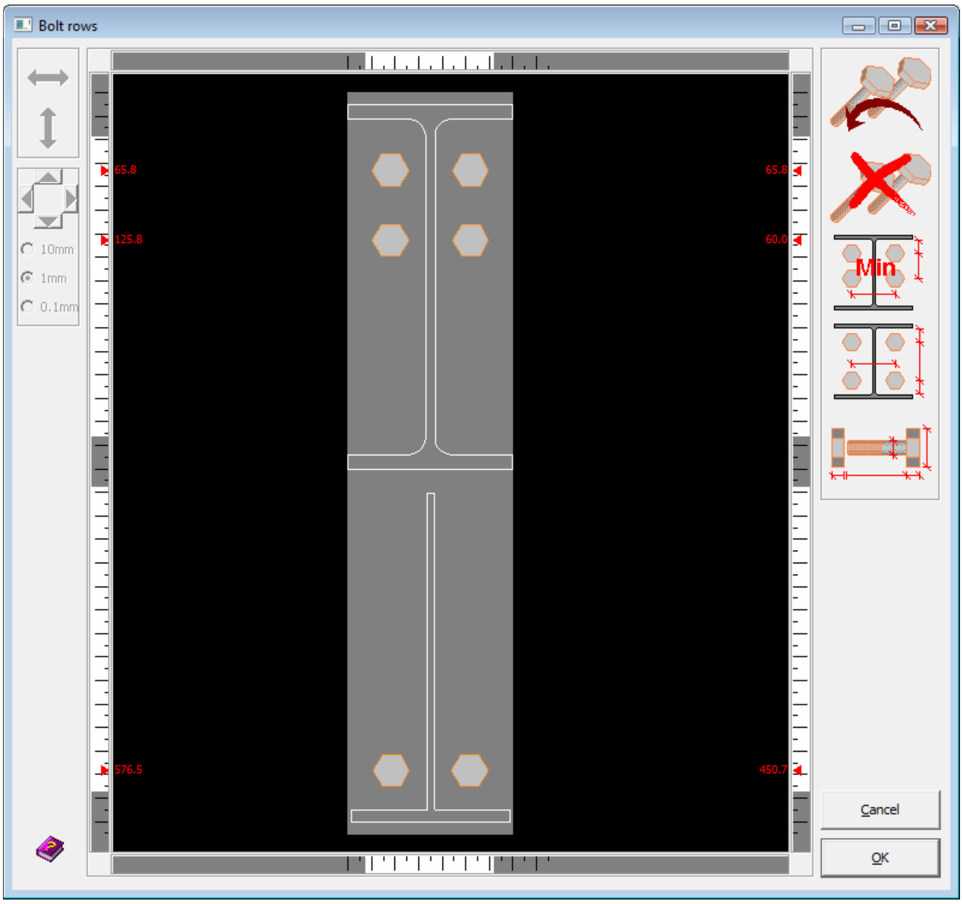
2.2.4 Improving the connection design

From the results summary, it is clear that the applied bending moment is too high as compared to the connection's moment resistance (for both loads combinations). To solve such type of problem, a haunch can for instance be added below the connected beams. To do this, select one of the beams in the ‘Geometry’-window and make the “Add or remove element” dialogue appear by pressing the right-hand button of the mouse. Select the “Add lower haunch” option.



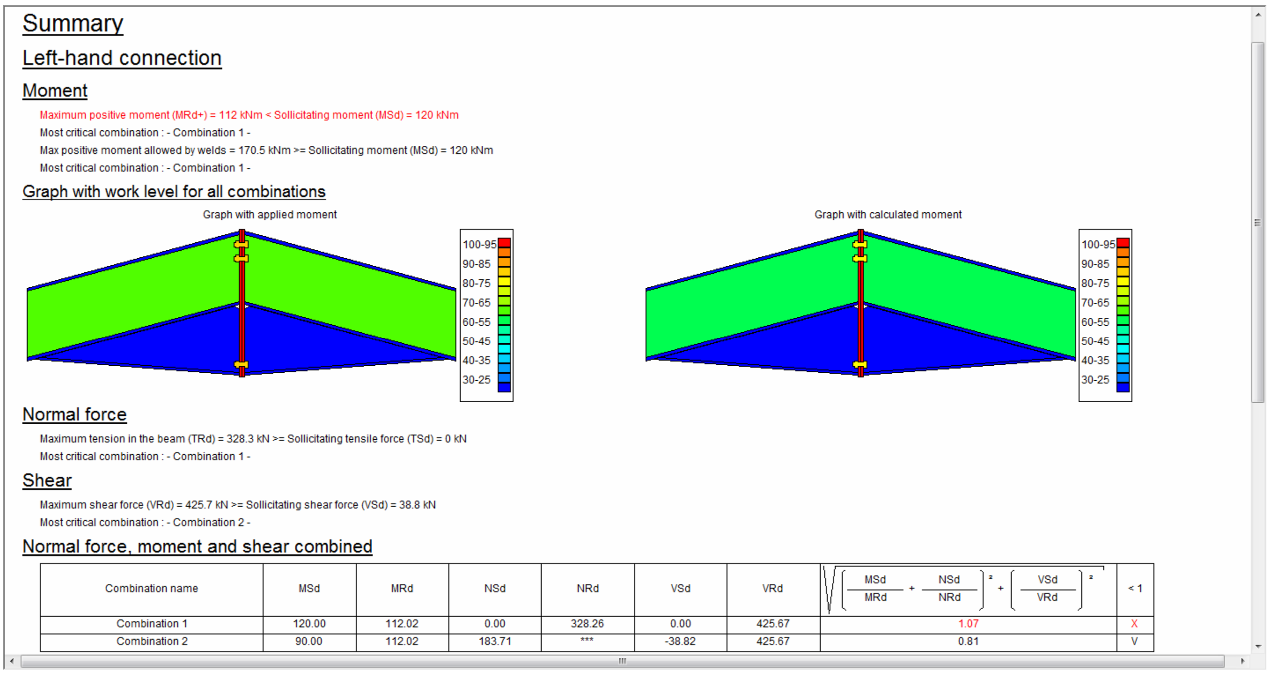
Now repeat this step for the other beam elements to create a symmetrically haunched connection.

Double-click on of the bolts to enter into the dialogue window to optimize the bolt lay-out taking into account the presence of the haunch (same procedure as before, but now use the MIN option to align bolt rows as close to the outer flanges as possible).



2.2.5 Re-running the connection design analysis on the modified connection

Running the connection design analysis again will now produce following summary results:



Summary

Left-hand connection

Moment

Maximum positive moment (MRd+) = 112 kNm < Sollicitating moment (MSd) = 120 kNm
Most critical combination : - Combination 1 -
Max positive moment allowed by welds = 170.5 kNm >= Sollicitating moment (MSd) = 120 kNm
Most critical combination : - Combination 1 -

Graph with work level for all combinations

Normal force

Maximum tension in the beam (TRd) = 328.3 kN >= Sollicitating tensile force (TSd) = 0 kN
Most critical combination : - Combination 1 -

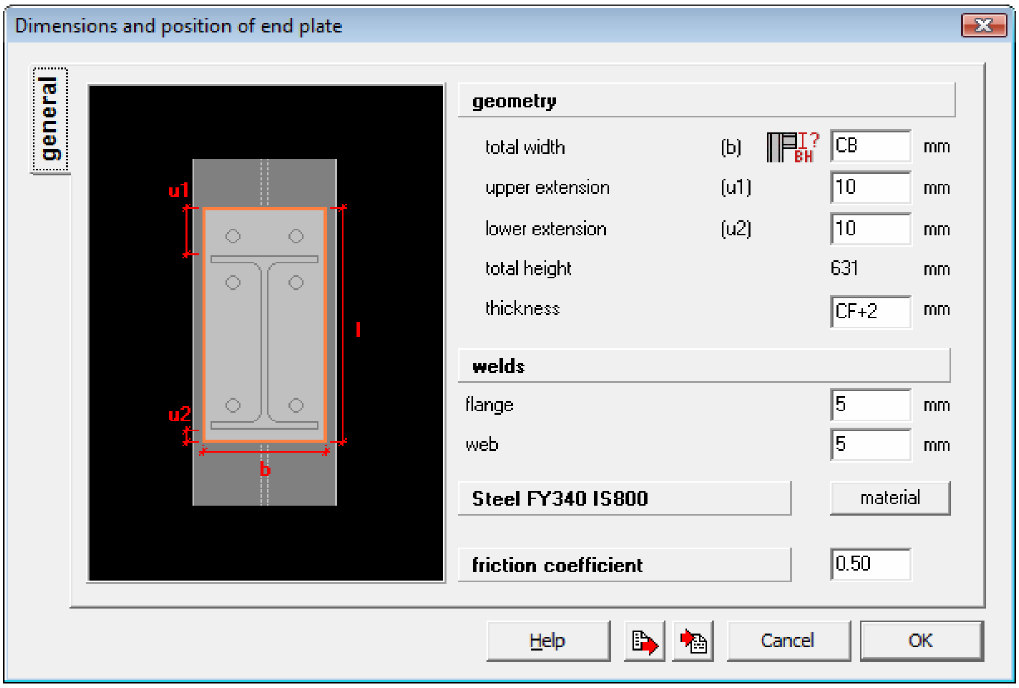
Shear

Maximum shear force (VRd) = 425.7 kN >= Sollicitating shear force (VSd) = 38.8 kN
Most critical combination : - Combination 2 -

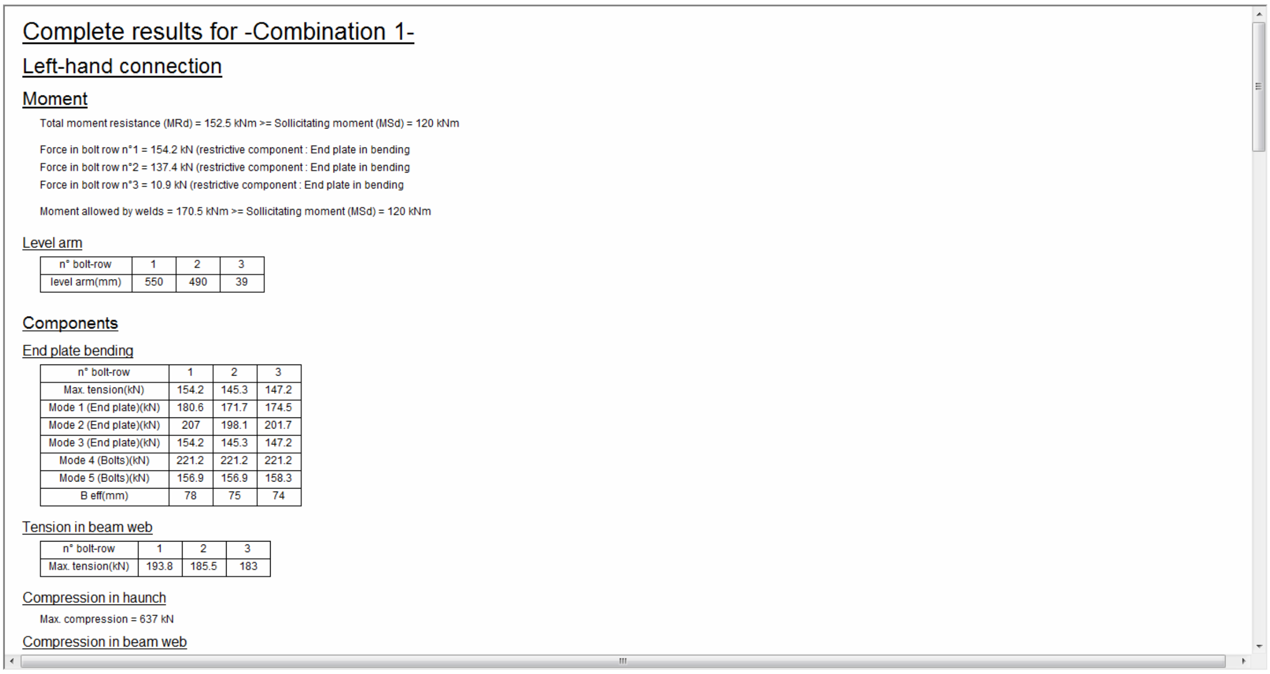
Normal force, moment and shear combined

Combination name	MSd	MRd	NSd	NRd	VSd	VRd	$\sqrt{\left(\frac{MSd}{MRd}+\frac{NSd}{NRd}\right)^2+\left(\frac{VSd}{VRd}\right)^2}$	< 1
Combination 1	120.00	112.02	0.00	328.26	0.00	425.67	1.07	X
Combination 2	90.00	112.02	183.71	***	-38.82	425.67	0.81	V

As can be seen from the results summary, the connection still has insufficient strength with respect to the applied loads combinations. Failure will occur due yielding of the end plate, which brings us to increasing the thickness of both end plates from CF (= 8mm) to CF+2 (= 10mm) in the dialogue window which is obtained by double-clicking on the end plates.



After rerunning the analysis, it will be seen that the connection now has sufficient strength.



Complete results for -Combination 1-

Left-hand connection

Moment

Total moment resistance (MRd) = 152.5 kNm >= Sollicitating moment (MSd) = 120 kNm

Force in bolt row n°1 = 154.2 kN (restrictive component : End plate in bending
Force in bolt row n°2 = 137.4 kN (restrictive component : End plate in bending
Force in bolt row n°3 = 10.9 kN (restrictive component : End plate in bending

Moment allowed by welds = 170.5 kNm >= Sollicitating moment (MSd) = 120 kNm

Level arm

n° bolt-row	1	2	3
level arm(mm)	550	490	39

Components

End plate bending

n° bolt-row	1	2	3
Max. tension(kN)	154.2	145.3	147.2
Mode 1 (End plate)(kN)	180.6	171.7	174.5
Mode 2 (End plate)(kN)	207	198.1	201.7
Mode 3 (End plate)(kN)	154.2	145.3	147.2
Mode 4 (Bolts)(kN)	221.2	221.2	221.2
Mode 5 (Bolts)(kN)	156.9	156.9	158.3
B eff(mm)	78	75	74

Tension in beam web

n° bolt-row	1	2	3
Max. tension(kN)	193.8	185.5	183

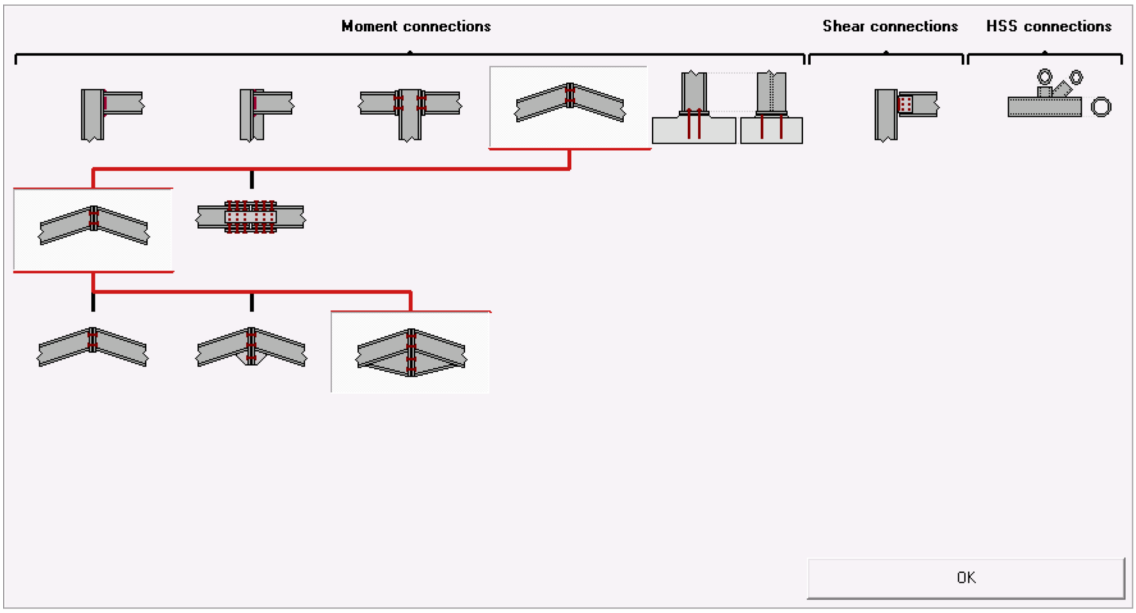
Compression in haunch

Max. compression = 637 kN

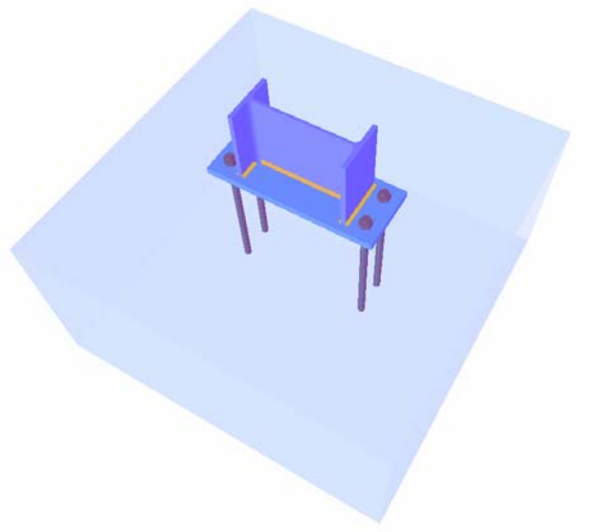
Compression in beam web

Inspecting more closely the detailed results for the end plate bending failure component will inform the user maximum bolt force for the first bolt row is very similar between plate yielding & bolt failure mechanisms. This confirms that bolt size and end plate thickness are optimally “tuned” to each other – the end plate is predicted to fail almost simultaneously with the first bolt row.

The haunched beam to beam connection that has been obtained as the final result, could also have been created directly by making the appropriate choice from the navigation window (see below).



2.3 Tutorial 3 : column base with extended end plate (IS800)

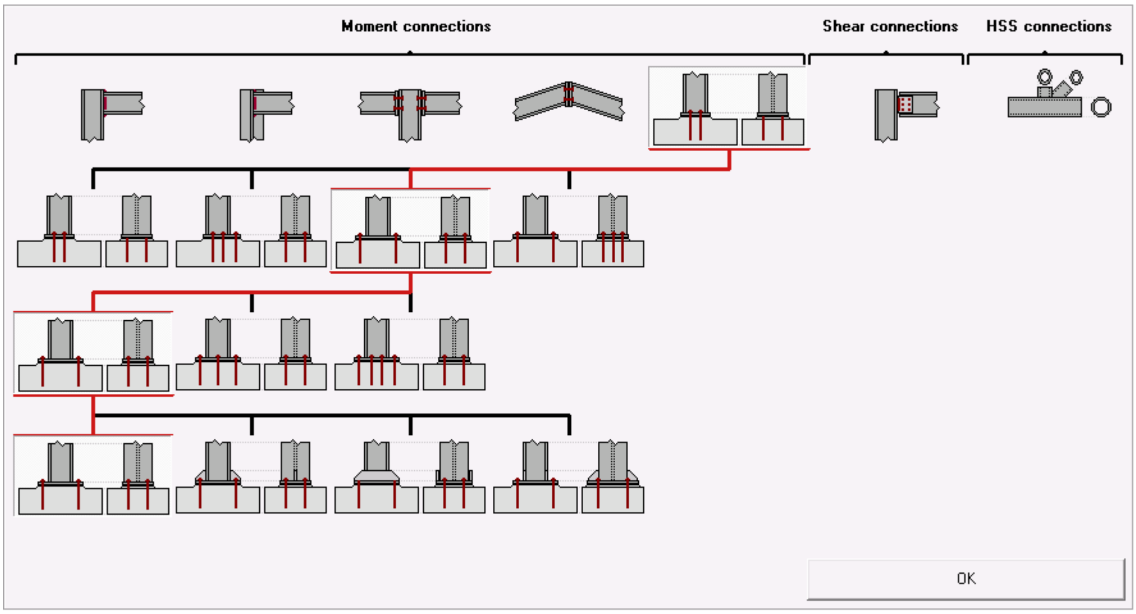


2.3.1 Setting up the model

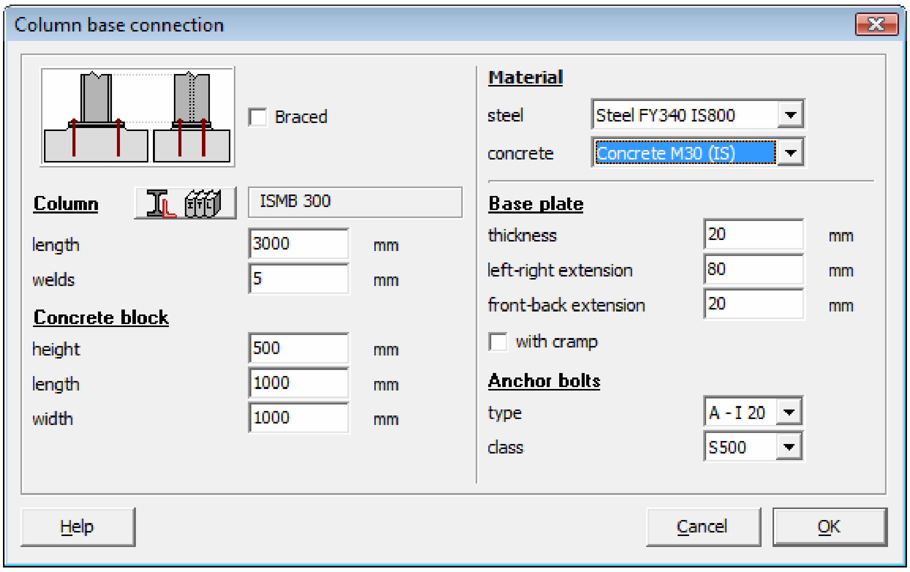
Use the icon to define a new project. In the navigation window, select the connection type labeled “Column base plate’. Then further navigate through the window by choosing the entries

- extended base plate (2 sides - 2 anchor bolts on each row)
- 2 anchor bolt rows

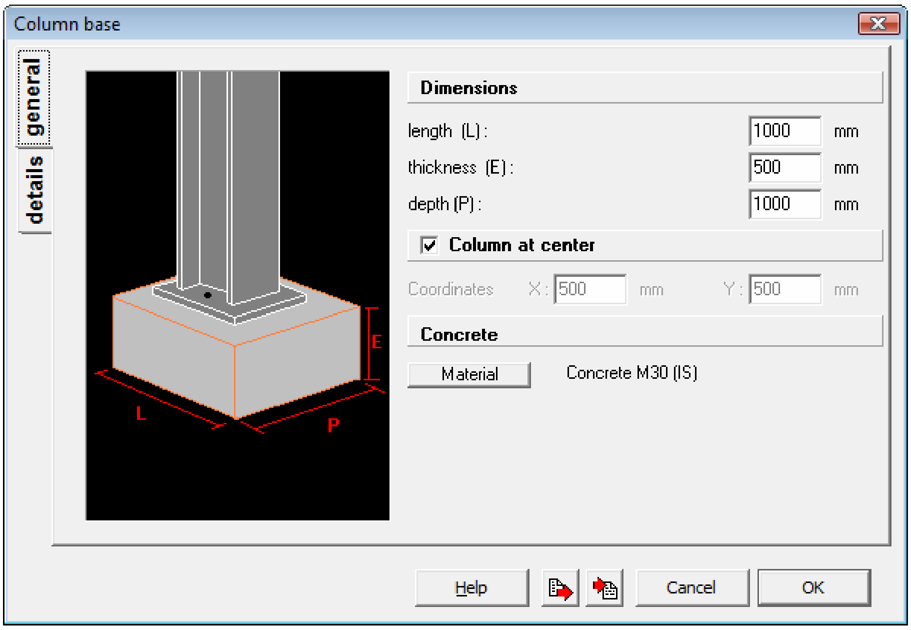
to arrive at a column base connection without any particular stiffener elements.



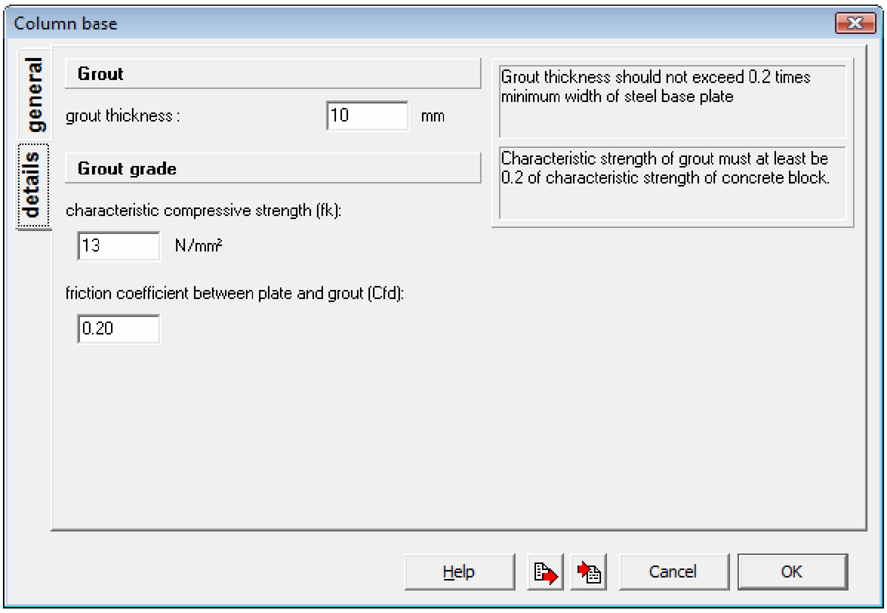
To actually create connection geometry, fill out all parameters as shown in the dialogue below.



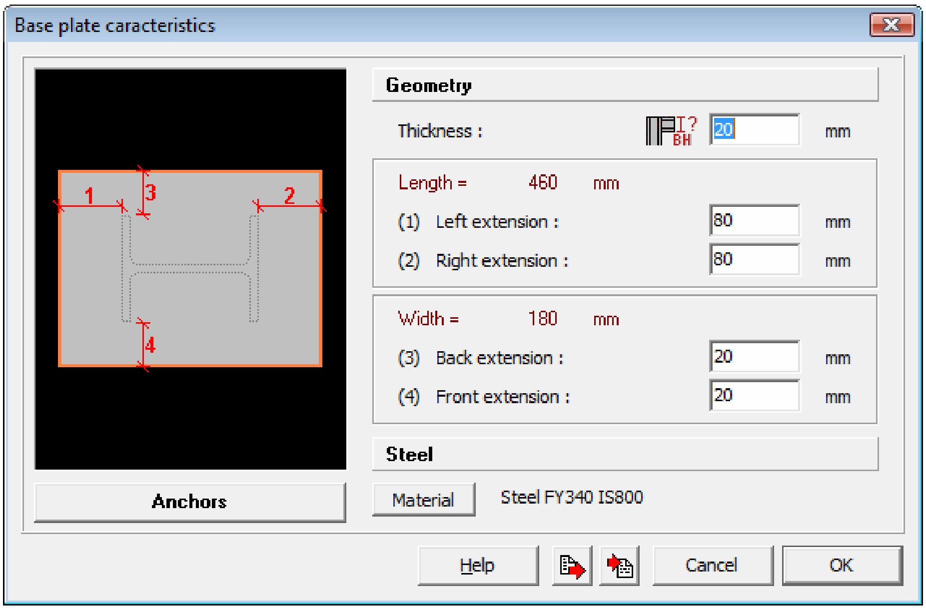
Now double-click on the concrete block to make a dialogue appear in which further details of the concrete base can be verified or modified. Check e.g. if the concrete grade of the base on the "General" tab page has really been defined to be M30 during the previous step, and modify (if necessary) by using the "Material"-button.



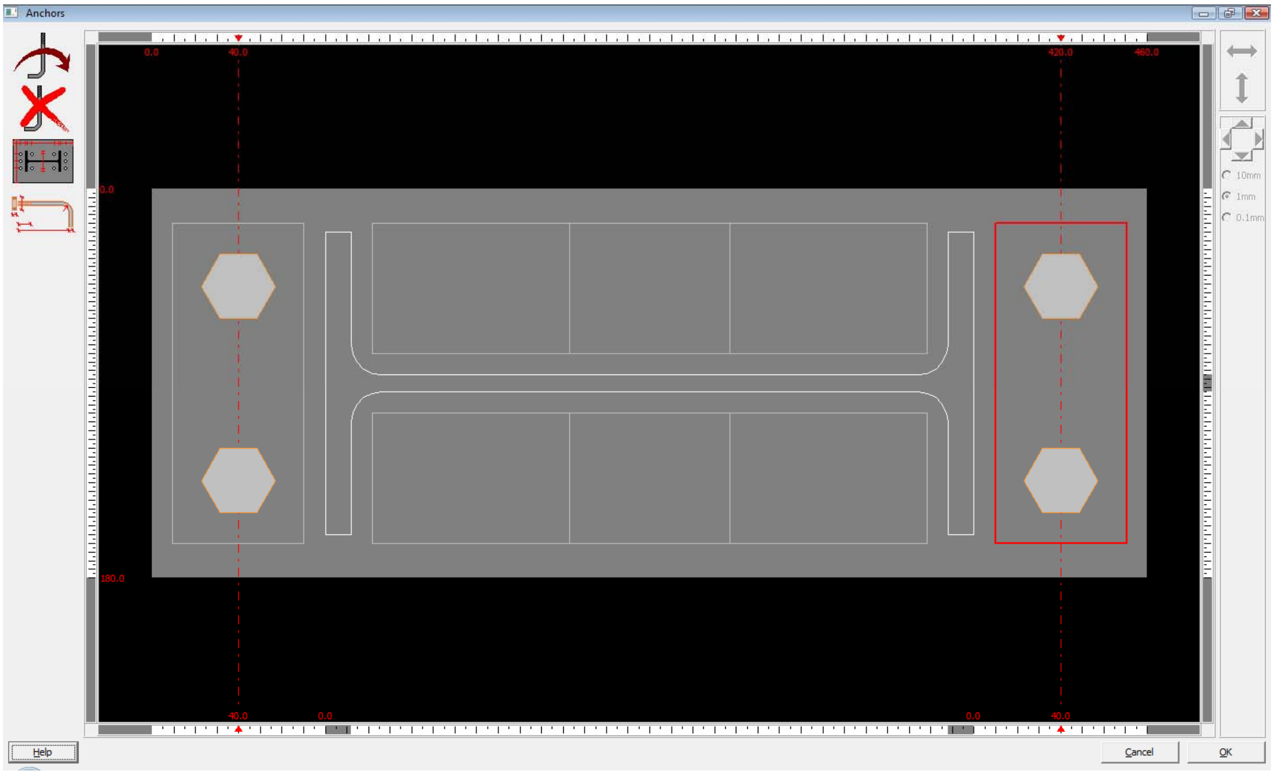
Switch to the 'Details'-tab for further data on grout thickness & grade.

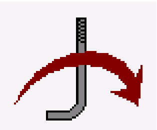


Double-click on the base plate to access its properties.



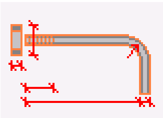
Use the 'Anchors'-function to gain access to anchor bolts details. If needed, maximize the window size to get a good view on anchor bolt lay-out & details.

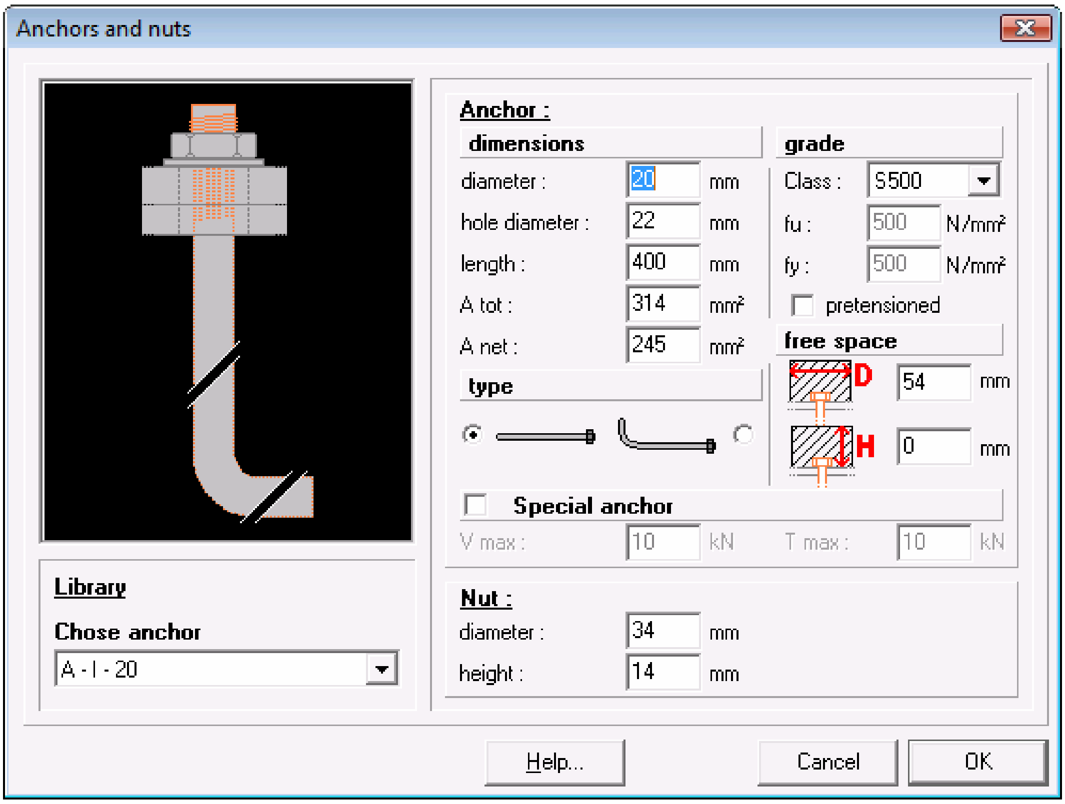


The window not only shows base plate dimensions and anchor bolts positions, but also includes a number of anchor zones that can be used to define the anchor bolts configuration. In case an anchor bolt row needs to be added, the appropriate anchor zone must first be selected using the mouse. The borders of a selected zone will be highlighted in red. Next, the icon  should be used to add a bolt row to the selected zone.

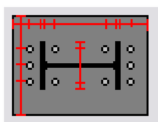
In general, the central part of the base plate can contain up to 4 anchor zones (depending on the available space):

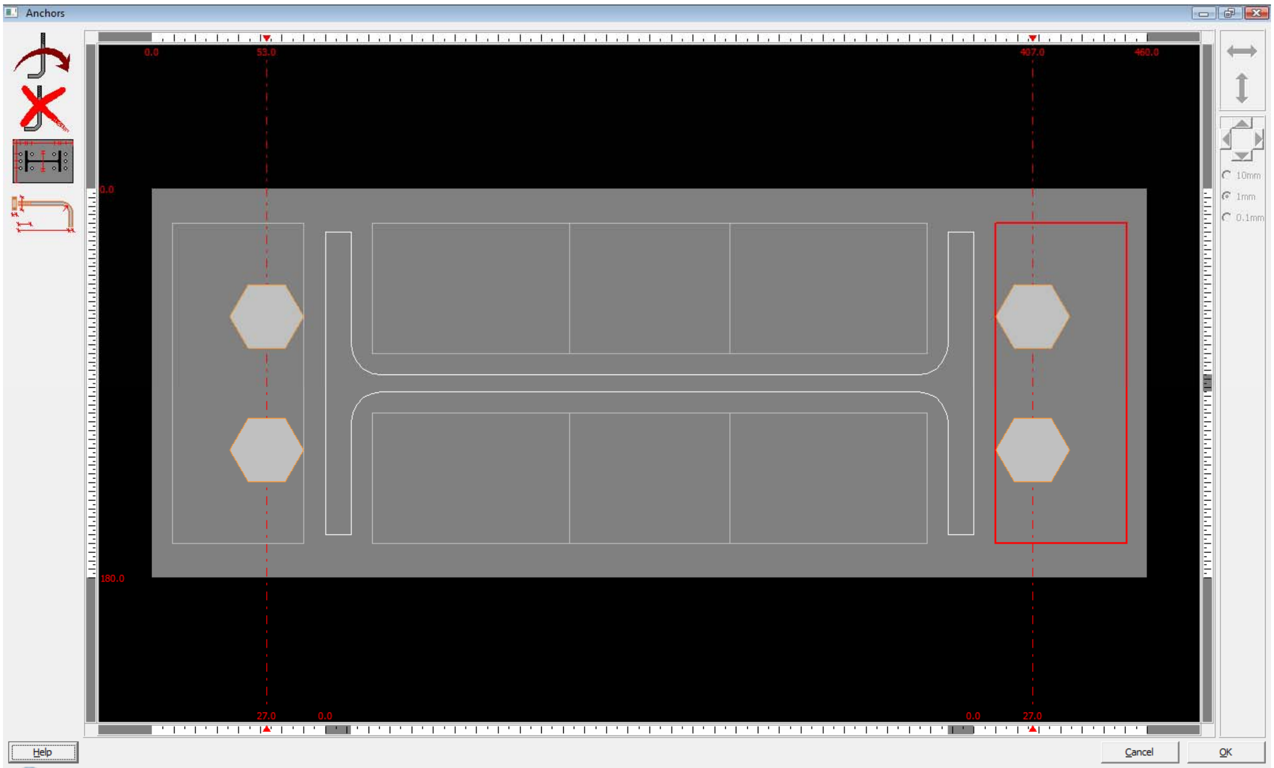
- 2 zones will serve for anchor bolts parallel to the column flanges,
- 2 zones will serve for anchor bolts parallel to the column web. Anchor bolts parallel to the column web will not contribute to the base plate connection's moment resistance, unless no anchor bolts are present in any of the other zones.

The type of anchor bolt should of course also be specified. Use the "Anchor details" icon  to this purpose, which will make the following dialogue window appear.

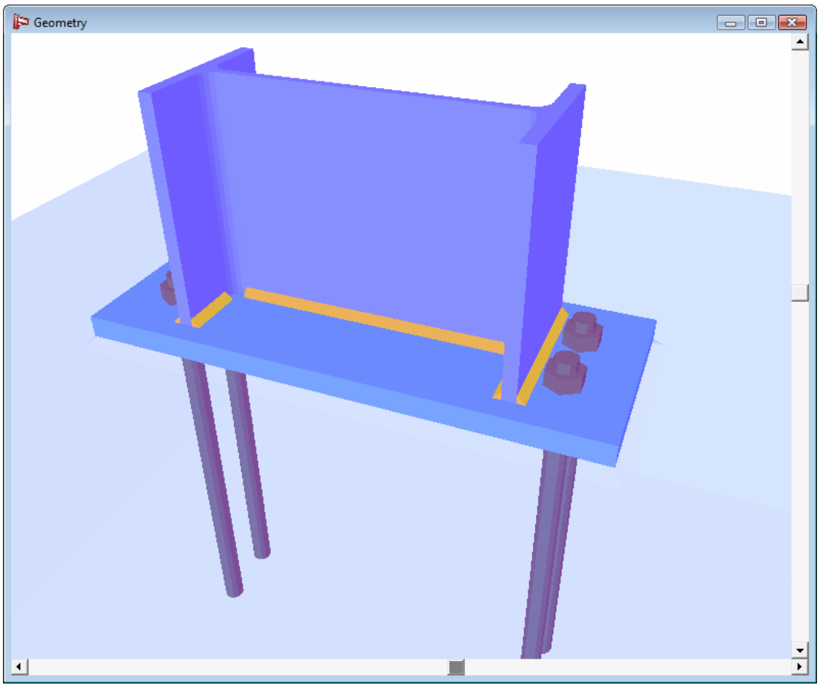


On the left hand side, a specific anchor bolt can be selected from PowerConnect's library of bolts & anchor bolts. For the time being, keep the default 'A-I-20' proposed by the program. 'A-I-20' corresponds to straight anchor bolts with a diameter of 20mm.

As no modifications must be defined as far as anchor bolt choice is concerned, the "Cancel"-button can be used to return to the anchor bolt lay-out window. Use the icon  to optimize anchor bolt positions, to obtain the following lay-out:

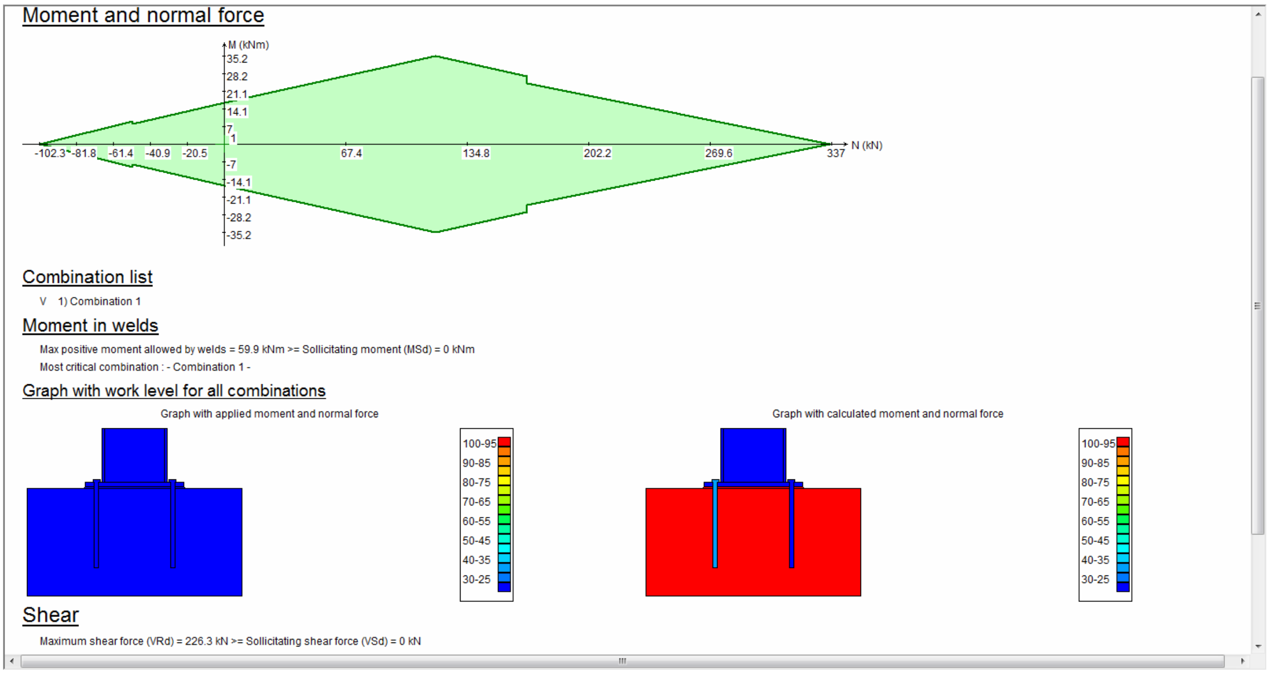


Click ‘OK’ to complete the base plate connection definition. In the ‘Geometry’-window, the following model will now be presented:



2.3.2 Running the connection design analysis

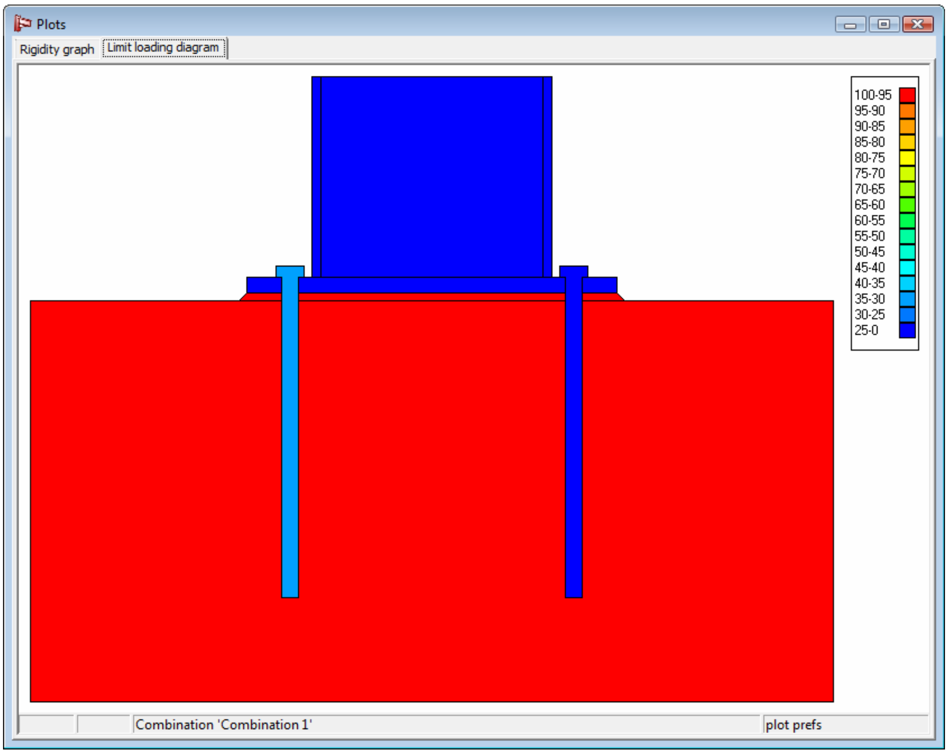
For the current analysis, no specific external loads will be applied. As a consequence, the design analysis will evaluate the connection’s resistance, independent of any loading. The following result will be obtained:



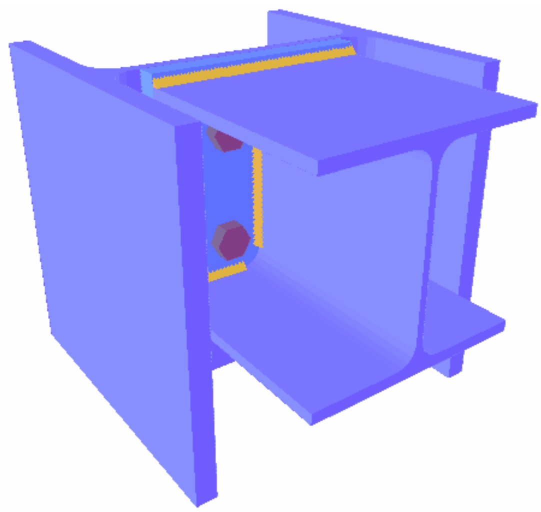
With this particular user scenario, there is no such thing as a “bad” or “good” connection. The resistance that has been calculated should be compared to a specific set of loads to which this type of connection will be subjected to enable that kind of judgment.

Depending on the failure capacity of all parts of the base plate connection, PowerConnect will show a diagram which represents all allowable combinations of bending moment & normal force (compressive forces are positive).

All loads combinations which fall within the green area of this diagram, correspond to loads which can be sustained. In case a particular loads combination falls outside this area, the base plate connection should be modified to resist the applied loading. The more detailed design analysis results that are made available by PowerConnect can be used to better understand the critical connection components and to optimize connection design. Critical components can be identified from the ‘Results diagram’ as shown below, and from the more detailed results reporting.


Plots
Rigidity graph
Limit loading diagram
100-95
95-90
90-85
85-80
80-75
75-70
70-65
65-60
60-55
55-50
50-45
45-40
40-35
35-30
30-25
25-0
Combination 'Combination 1'
plot prefs

2.4 Tutorial 4 : bolted beam to column web (IS800)

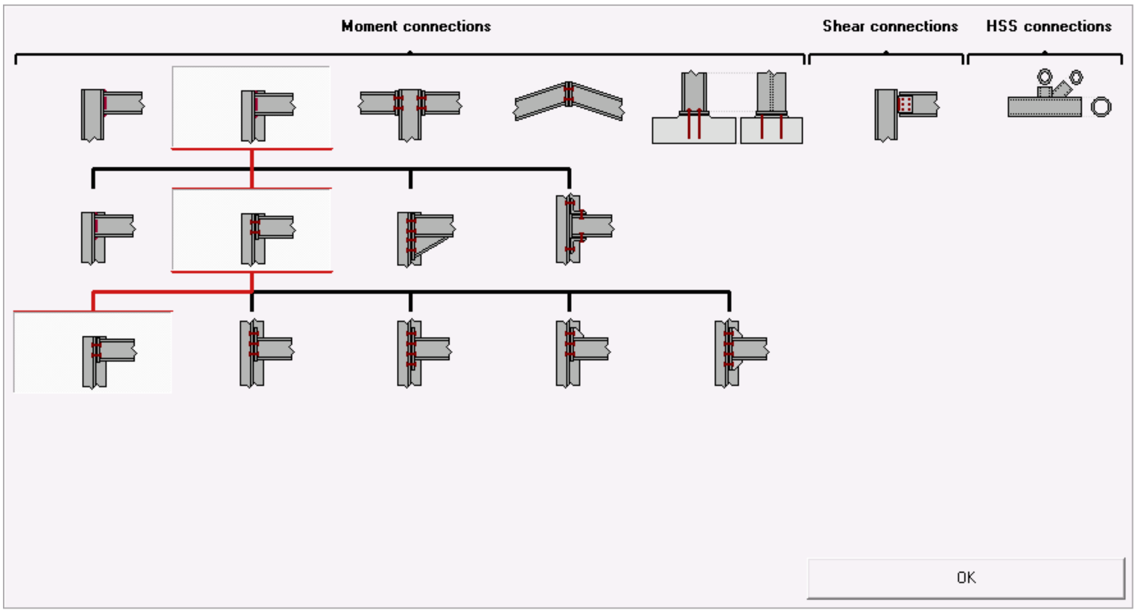


2.4.1 Setting up the model

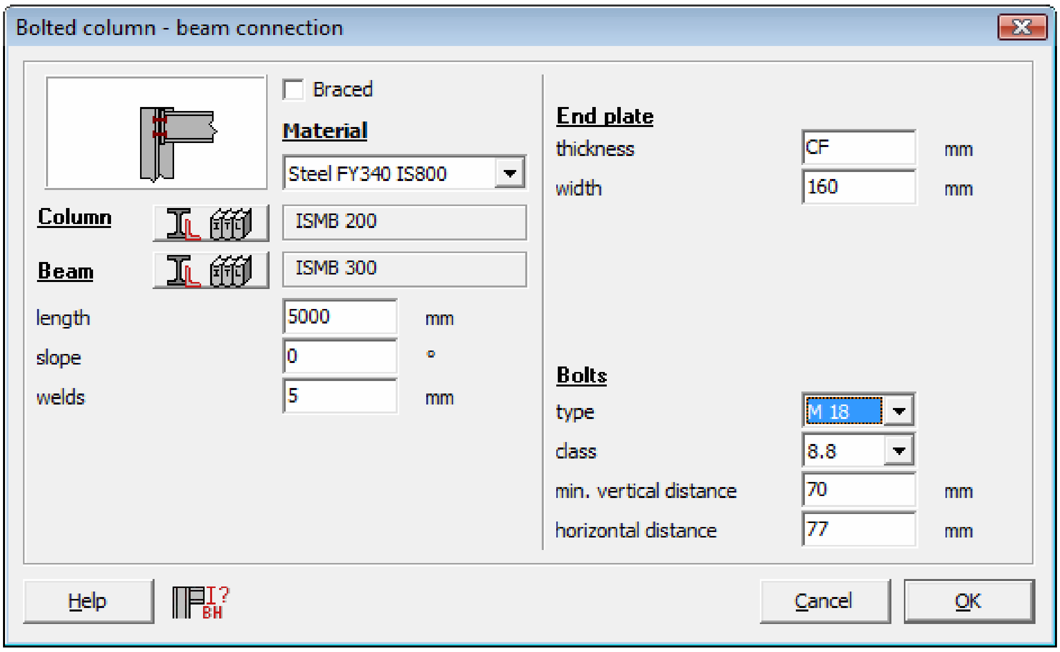
A beam with ISMB 300 section is connected to the web of a column with ISMB 200 section by means of a bolted moment end plate (3 rows of M18 grade bolts). No particular stiffener elements are added.

No loads will be applied on the connection, so that the design analysis will be limited to the evaluation of the connection's resistance in bending & shear.

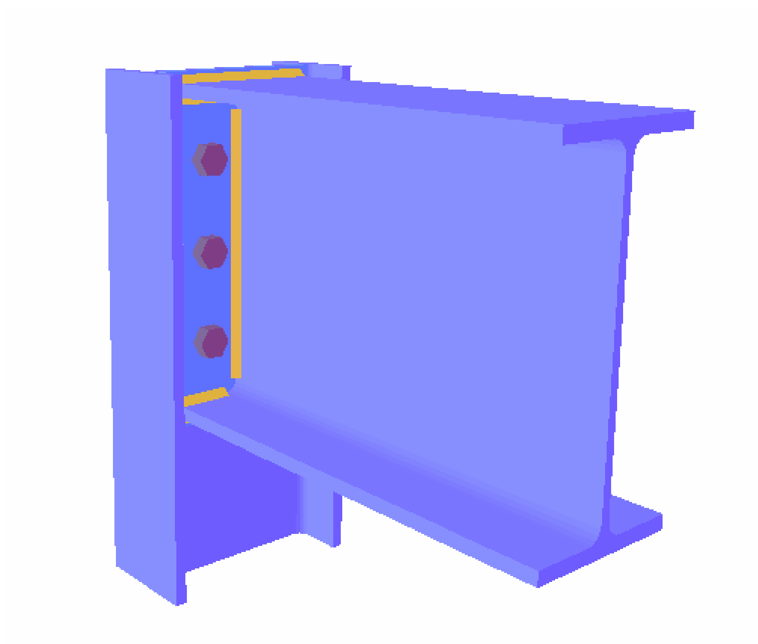
Use the navigation window to arrive at a single-sided beam to column web connection using a flush end plate:

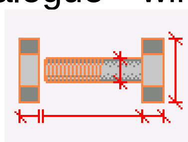


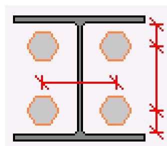
In the next step, make sure that the beam and column sections are defined correctly. Choose other sections from PowerConnect's section library, if needed.

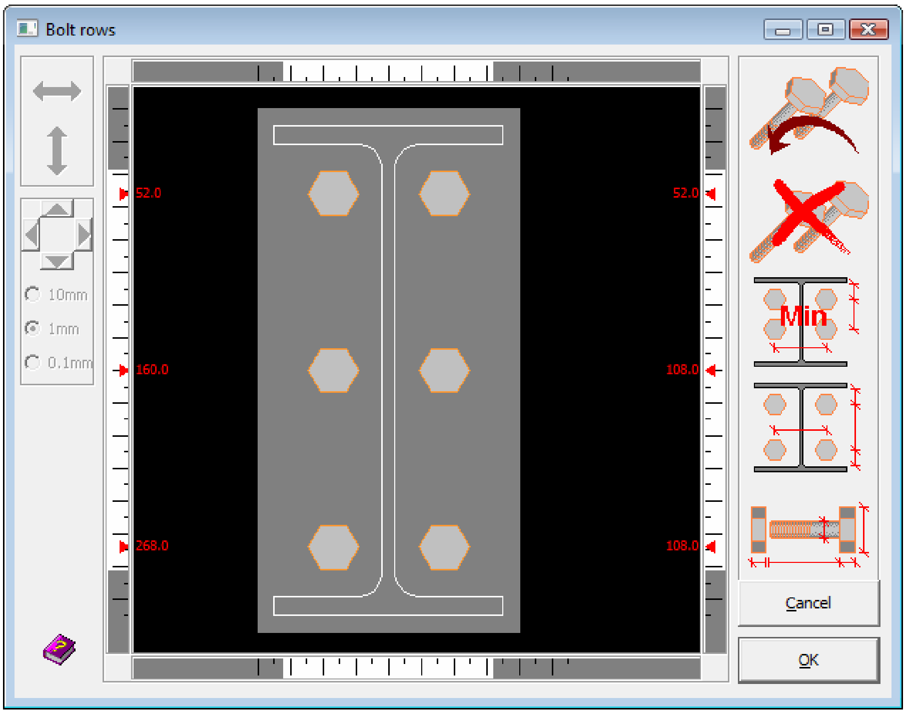


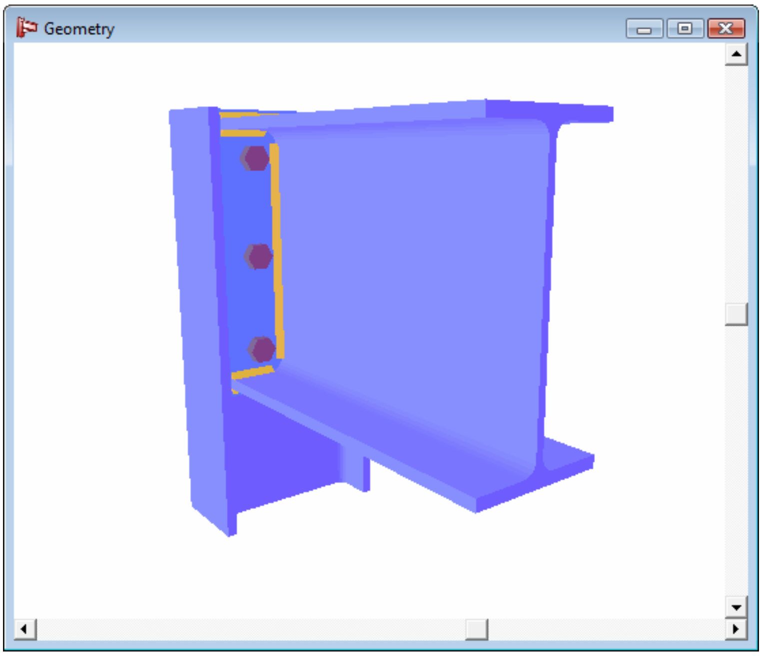
When confirming the above parameters, the following 3D geometry model will be presented.



If needed, end plate & bolt characteristics may still be modified. Double-click on one of the bolts to open the bolt definition dialogue window, and use the  icon to verify whether the currently selected bolts are grade M18 indeed.

Finally, use the  icon to optimize bolt row positions, to arrive at the following lay-out:

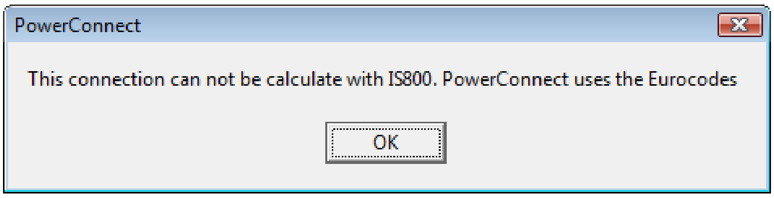




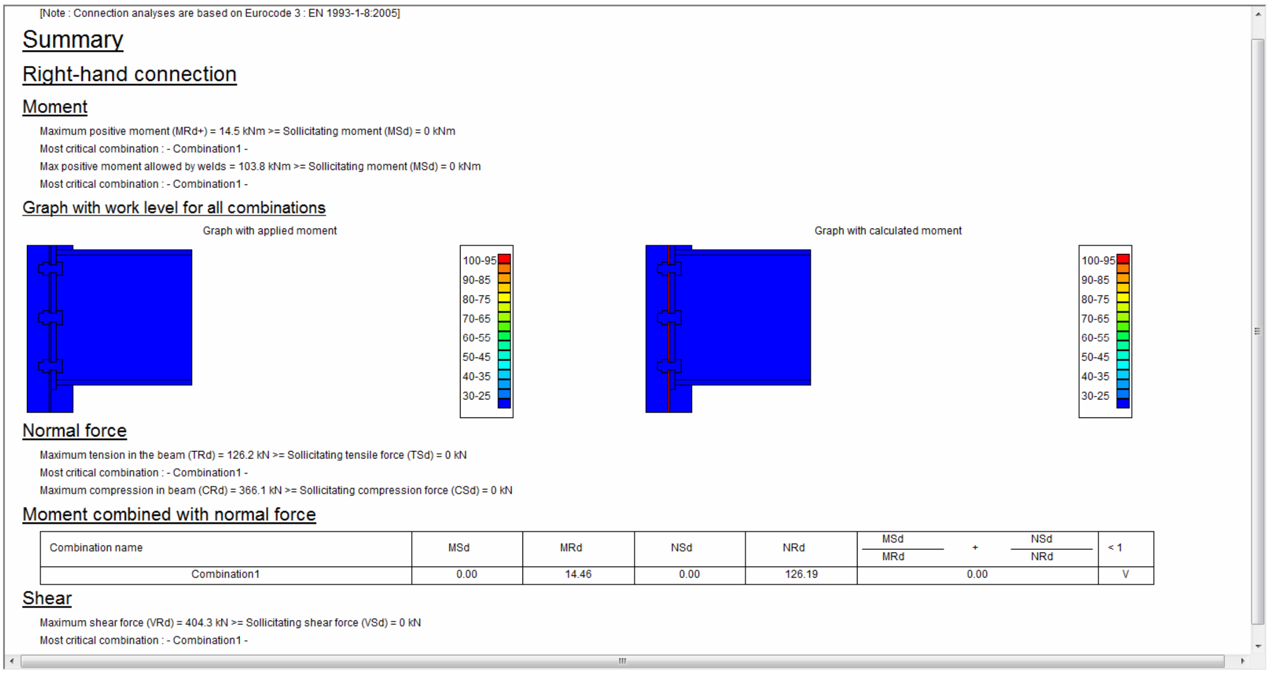
All parameters have now been defined so that now the connection design analysis can be launched.

2.4.2 Running the connection design analysis

Launch the design analysis to evaluate connection resistance. As the IS800 standard does not give any specifications with respect to this type of connection, following warning is issued by PowerConnect.



PowerConnect will automatically switch to the EC3 design standard, and will deliver following results.


[Note : Connection analyses are based on Eurocode 3 : EN 1993-1-8:2005]

Summary

Right-hand connection

Moment

Maximum positive moment (MRd+) = 14.5 kNm >= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -
Max positive moment allowed by welds = 103.8 kNm >= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -

Graph with work level for all combinations

Normal force

Maximum tension in the beam (TRd) = 126.2 kN >= Sollicitating tensile force (TSd) = 0 kN
Most critical combination : - Combination1 -
Maximum compression in beam (CRd) = 366.1 kN >= Sollicitating compression force (CSd) = 0 kN

Moment combined with normal force

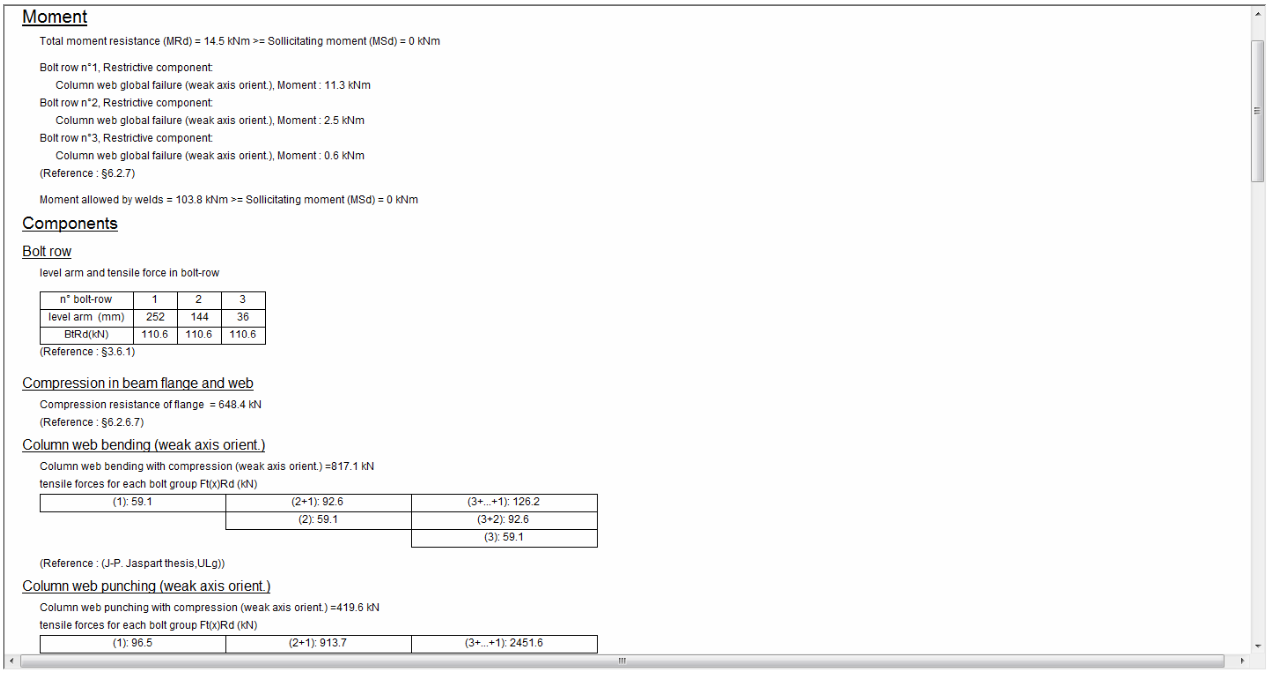
Combination name	MSd	MRd	NSd	NRd	MSd/MRd + NSd/NRd	< 1
Combination1	0.00	14.46	0.00	126.19	0.00	V

Shear

Maximum shear force (VRd) = 404.3 kN >= Sollicitating shear force (VSd) = 0 kN
Most critical combination : - Combination1 -

In case a beam is directly connected to the column web (albeit through the use of an end plate), it may happen that the column web does not provide a sufficiently high resistance. Both local or global failure of the column web may occur. A local failure mechanism occurs when e.g. a bolt row that is subjected to tension, fails.

Three types of local failure mechanisms are possible on the column web: bending, punching or a combination of bending & punching. PowerConnect will screen all possible local & global failure mechanisms and will present detailed analysis results for all of them. In the current case, the connection will fail globally.



Moment

Total moment resistance (MRd) = 14.5 kNm >= Sollicitating moment (MSd) = 0 kNm

Bolt row n°1, Restrictive component:
Column web global failure (weak axis orient.), Moment : 11.3 kNm
Bolt row n°2, Restrictive component:
Column web global failure (weak axis orient.), Moment : 2.5 kNm
Bolt row n°3, Restrictive component:
Column web global failure (weak axis orient.), Moment : 0.6 kNm
(Reference : §6.2.7)

Moment allowed by welds = 103.8 kNm >= Sollicitating moment (MSd) = 0 kNm

Components

Bolt row

level arm and tensile force in bolt-row

n° bolt-row	1	2	3
level arm (mm)	252	144	36
BtRd(kN)	110.6	110.6	110.6

(Reference : §3.6.1)

Compression in beam flange and web

Compression resistance of flange = 648.4 kN
(Reference : §6.2.6.7)

Column web bending (weak axis orient.)

Column web bending with compression (weak axis orient.) =817.1 kN
tensile forces for each bolt group Ft(x)Rd (kN)

(1): 59.1	(2+1): 92.6	(3+...+1): 126.2
	(2): 59.1	(3+2): 92.6
		(3): 59.1

(Reference : (J-P. Jaspart thesis,ULg))

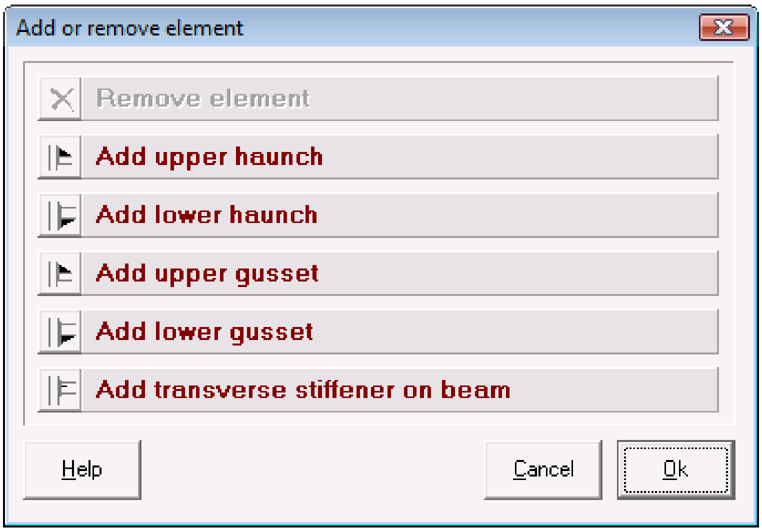
Column web punching (weak axis orient.)

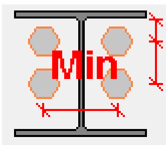
Column web punching with compression (weak axis orient.) =419.6 kN
tensile forces for each bolt group Ft(x)Rd (kN)

(1): 96.5	(2+1): 913.7	(3+...+1): 2451.6

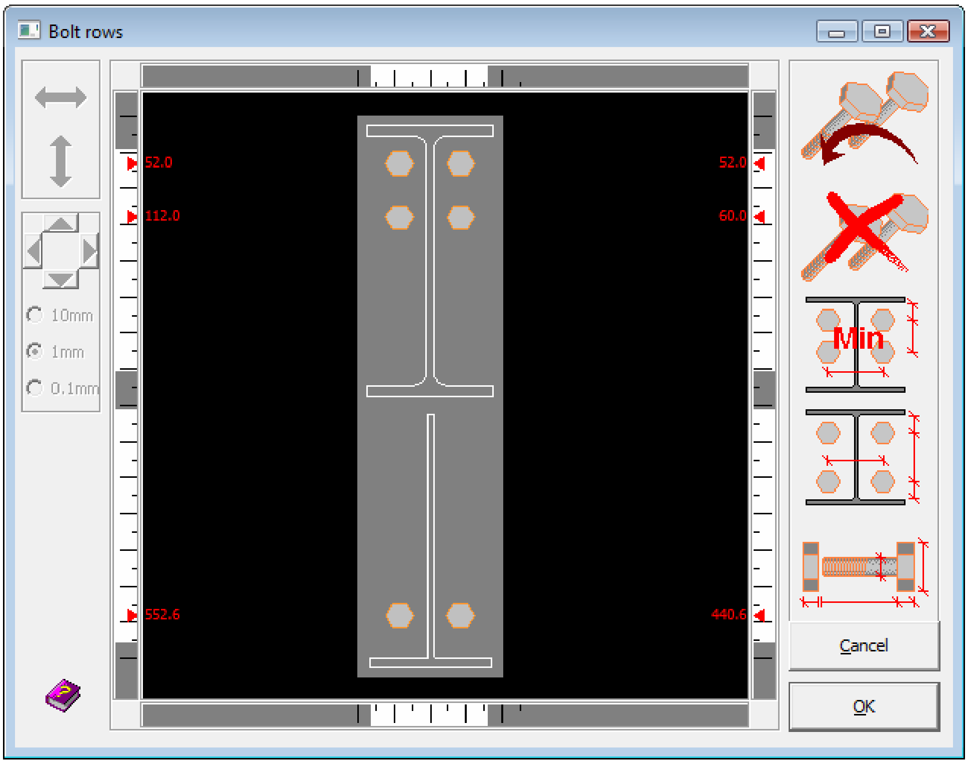
2.4.3 Improving the connection design

Now return to the geometry window and select the beam element with the mouse. Using the right-hand button of the mouse, make all available stiffening elements appear, and select the lower haunch.



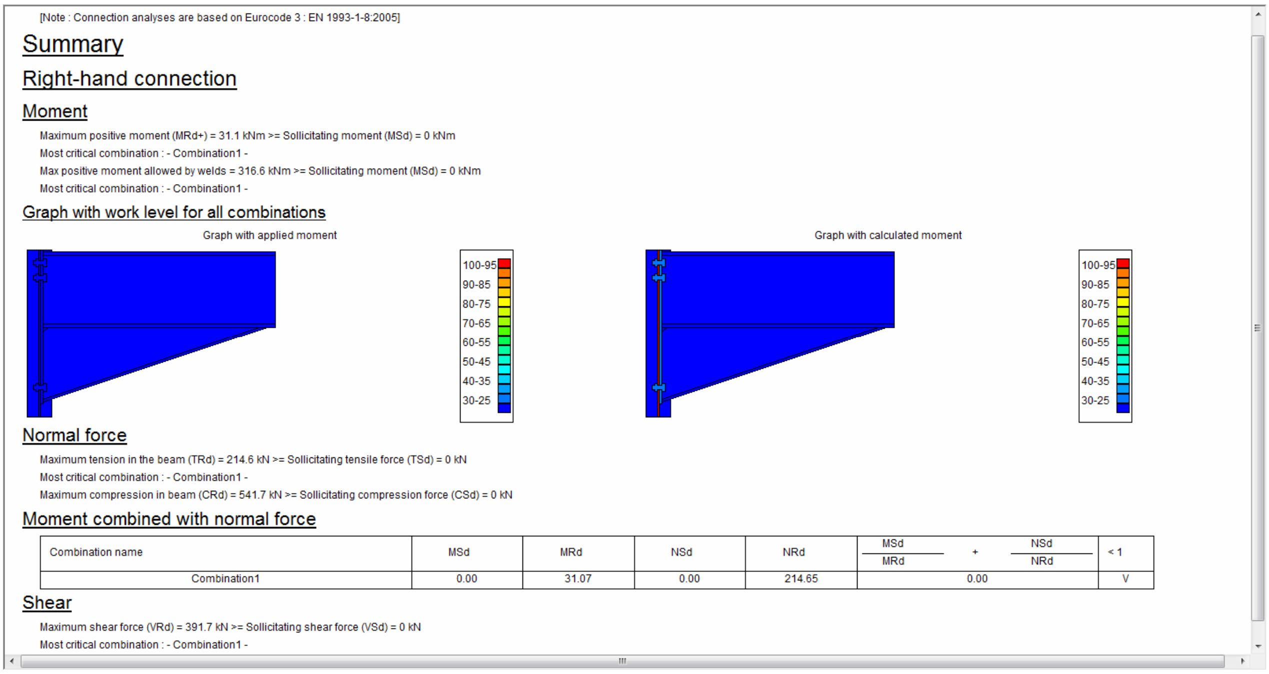
Now double-click on one of the bolts and then use the 

icon to optimize bolt row positions, to arrive at the following lay-out:



2.4.4 Re-running the connection design analysis on the modified connection

Running the connection design analysis on the modified connection will produce following summary results:



[Note : Connection analyses are based on Eurocode 3 : EN 1993-1-8:2005]

Summary

Right-hand connection

Moment

Maximum positive moment (MRd+) = 31.1 kNm >= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -
Max positive moment allowed by welds = 316.6 kNm >= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -

Graph with work level for all combinations

Normal force

Maximum tension in the beam (TRd) = 214.6 kN >= Sollicitating tensile force (TSd) = 0 kN
Most critical combination : - Combination1 -
Maximum compression in beam (CRd) = 541.7 kN >= Sollicitating compression force (CSd) = 0 kN

Moment combined with normal force

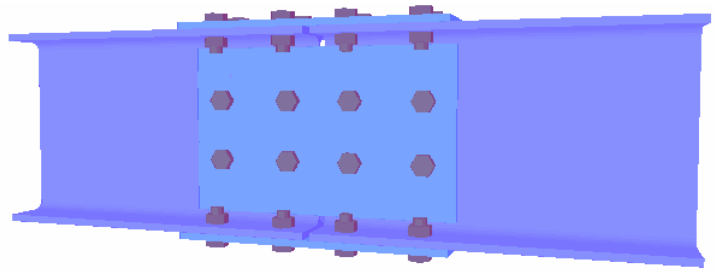
Combination name	MSd	MRd	NSd	NRd	$\frac{MSd}{MRd} + \frac{NSd}{NRd}$	< 1
Combination1	0.00	31.07	0.00	214.65	0.00	V

Shear

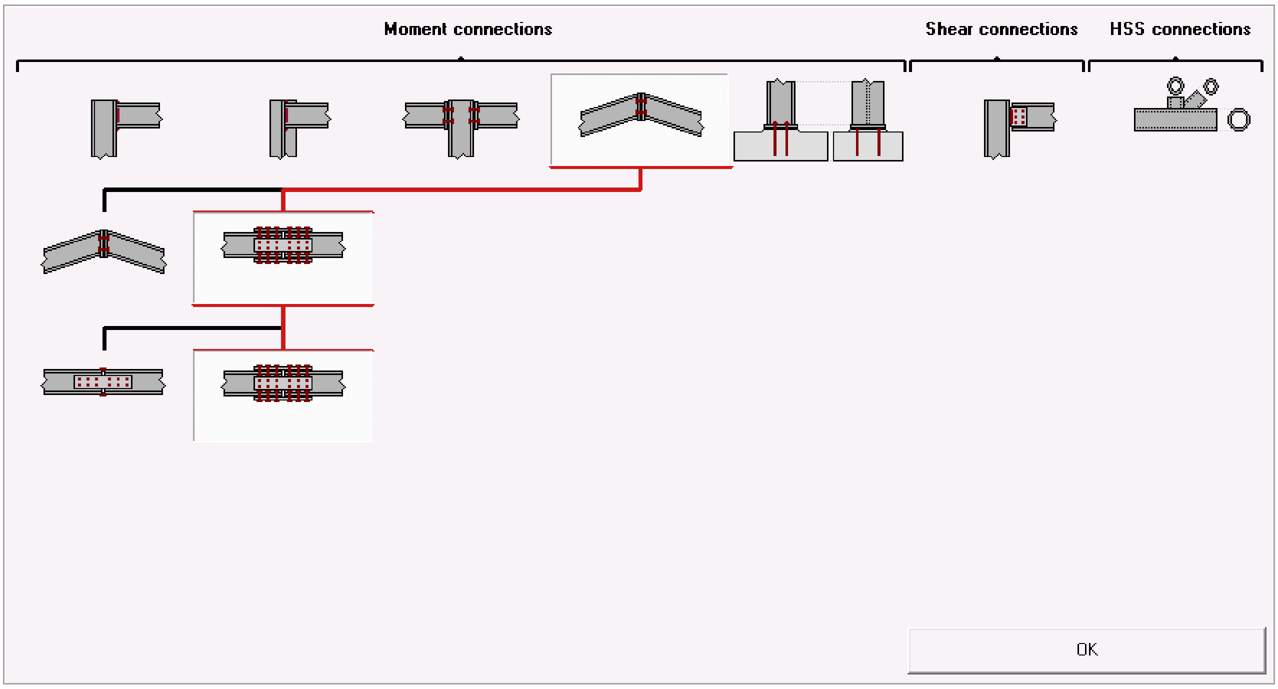
Maximum shear force (VRd) = 391.7 kN >= Sollicitating shear force (VSd) = 0 kN
Most critical combination : - Combination1 -

As a result, the connection’s bending resistance has been increased from 14.5 kNm to 31.1 kNm.

2.5 Tutorial 5: bolted splice (IS800)

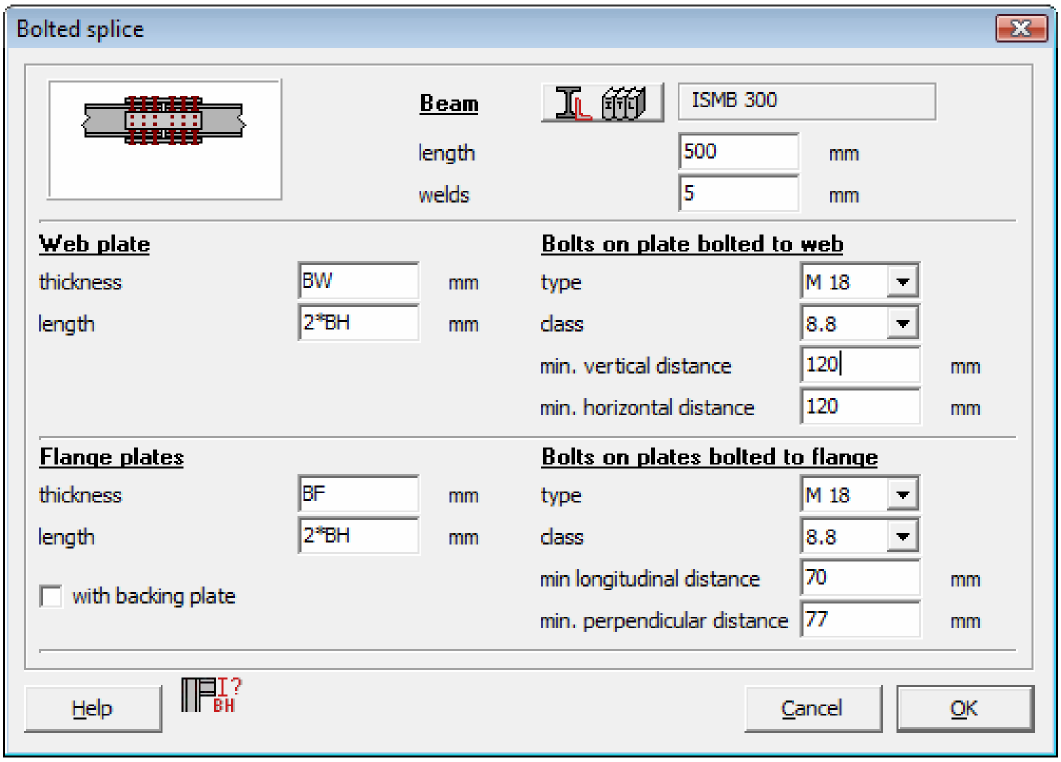


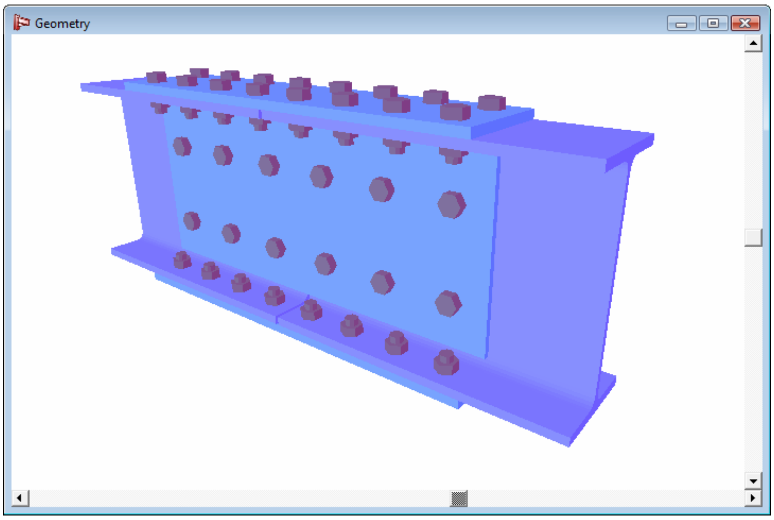
Define a new connection and make the proper choice in the navigation window shown below, to define a bolted beam splice.



Upon confirmation of the above choice, a new dialogue window is presented to complete the definition. In particular, remember to enter the following parameters:

- ISMB 300 section for the beam element
- bolts M18 – grade 8.8 for web & flange plates
- minimum intermediate distances for web plate bolts 120 mm in both directions, to ensure that only 2 bolt rows are used over the height of the web plate

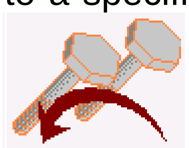
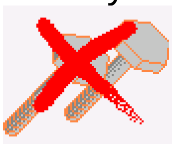


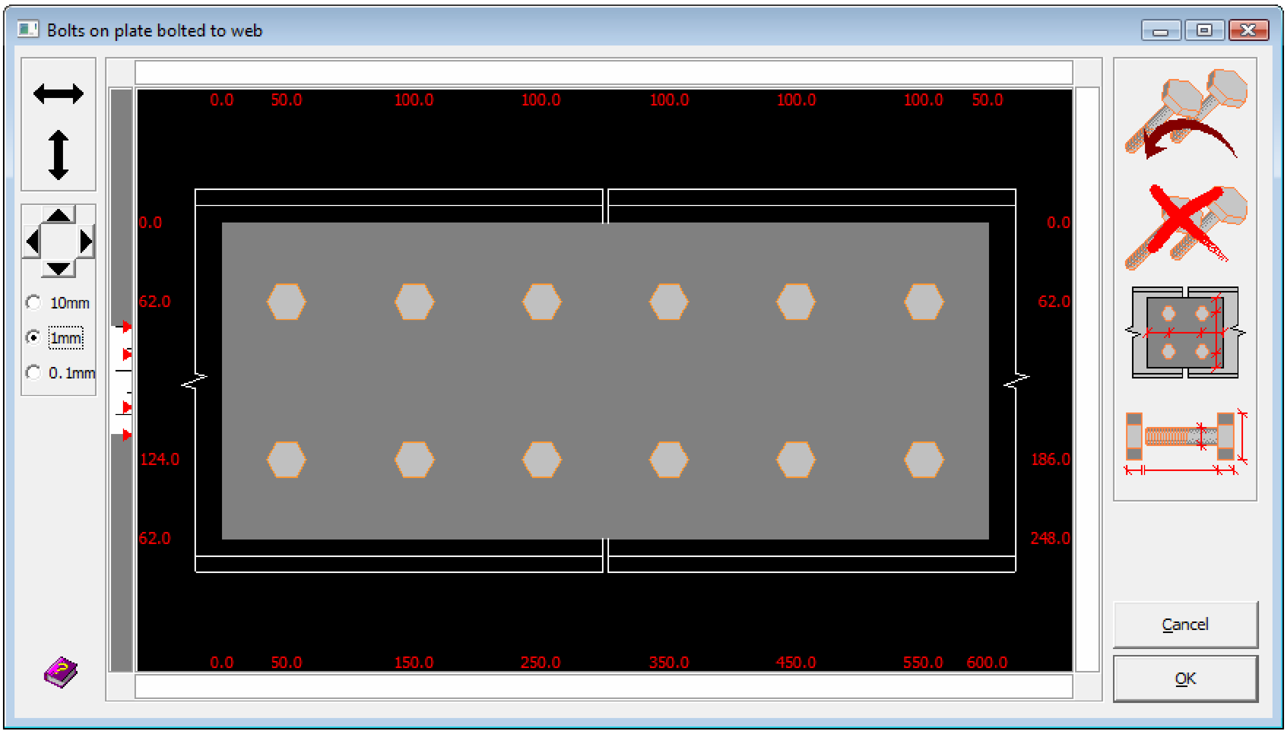


As a result, the beam splice as illustrated in the 3D representation is obtained.

Bolted beam splices are always considered to be symmetrical by PowerConnect. As a consequence, the left half of the connection is identical to the right half of the connection, and any modification that is specified for any of the flanges will automatically be applied also to the other flanges.

During the previous steps, the bolt type and the number of bolt rows for the web plate have been defined. The lay-out of the different bolt rows will now be screened in more detail and bolt positions will be optimized when needed.

Just double-click on any of the bolts on the web plate to enter the appropriate dialogue window. The number of bolts in a vertical row can freely be chosen by the user. Adding a bolt to a specific row is done by selecting a bolt from that row and then use the  icon to actually add a row. Adding a complete bolt row is done by means of the same icon, but ensuring no single bolt row is currently selected. To remove a bolt row, selected one of its bolts and use the  icon.

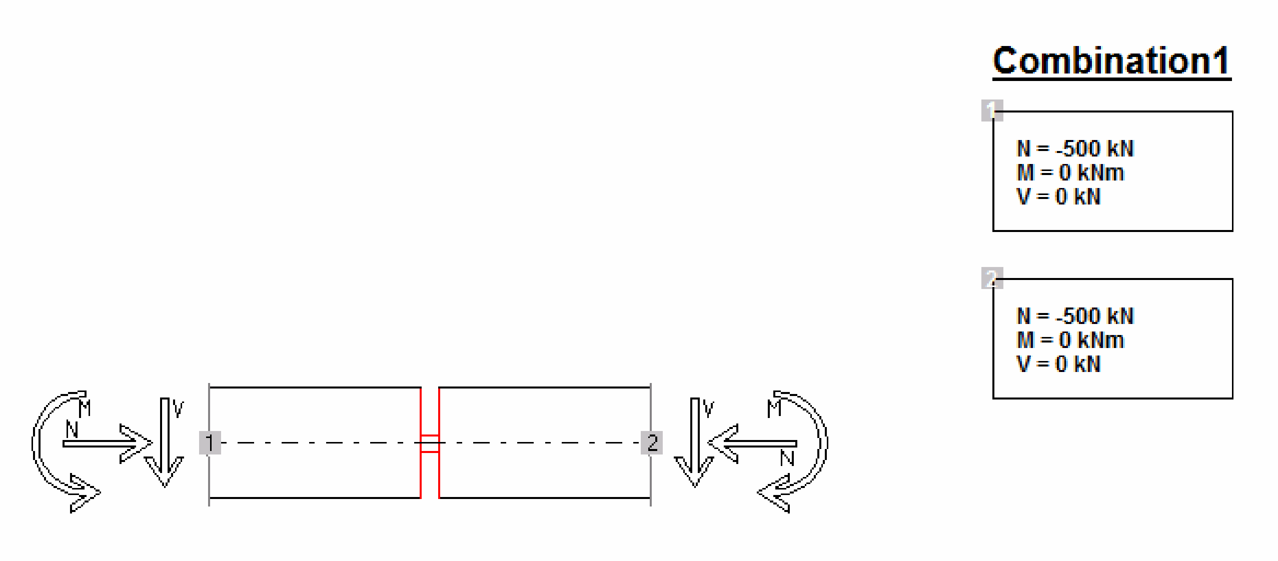


The same procedure can be used for the bolts of the flanges plates. It is sufficient to define the required modifications for one of the flange plates. Because of symmetry conditions, those changes will automatically be propagated to the other flange plate.

For this particular tutorial, it is not required to define any changes. The values that were proposed by PowerConnect after the initial definition steps can be accepted.

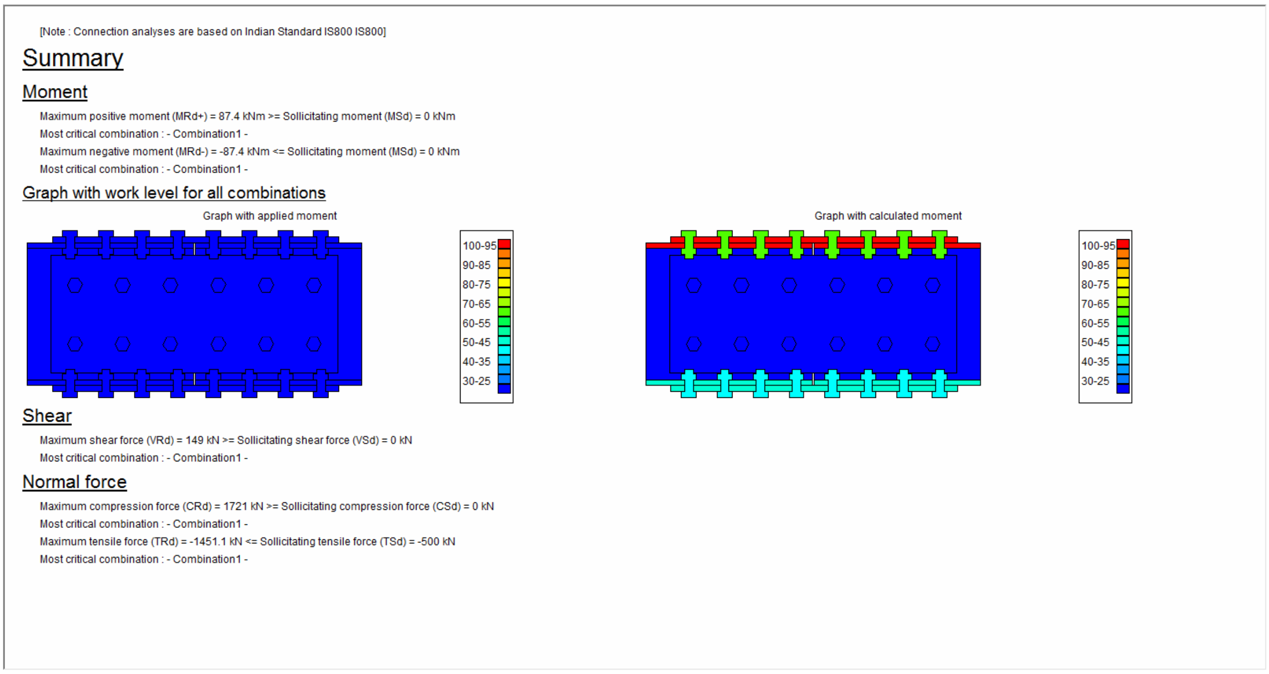
2.5.1 Defining the loads

Switch to the 'Loads'-window by means of the  icon, and apply a tensile load of 500 kN at both sides. Remember: click on the small squares labeled "1" and "2" to actually assign those values to the node and to end up with the situation illustrated below.



2.5.2 Running the connection design analysis

The connection design analysis will deliver following results, using the previously defined parameters:



[Note : Connection analyses are based on Indian Standard IS800 IS800]

Summary

Moment

Maximum positive moment (MRd+) = 87.4 kNm >= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -
Maximum negative moment (MRd-) = -87.4 kNm <= Sollicitating moment (MSd) = 0 kNm
Most critical combination : - Combination1 -

Graph with work level for all combinations

Shear

Maximum shear force (VRd) = 149 kN >= Sollicitating shear force (VSd) = 0 kN
Most critical combination : - Combination1 -

Normal force

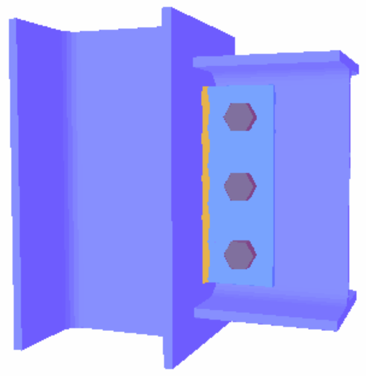
Maximum compression force (CRd) = 1721 kN >= Sollicitating compression force (CSd) = 0 kN
Most critical combination : - Combination1 -
Maximum tensile force (TRd) = -1451.1 kN <= Sollicitating tensile force (TSd) = -500 kN
Most critical combination : - Combination1 -

For this type of connection, PowerConnect will report the ultimate bending moments (both positive and negative). Those bending moments are calculated taking into account the shear force and normal force that have previously been applied to the connection (V = 0 kN & N = - 500 kN).

The analysis results in terms of maximum normal force or shear force do not consider however the presence of a bending moment that is applied to the connection. In case the connection is loaded by a bending moment, maximum shear & normal force values should be reduced.

Further details on the analysis results can be obtained by clicking with the mouse on “Results Preferences” field in the right hand bottom of the PowerConnect window. Choose the appropriate option to obtain the required level of reporting detail.

2.6 Tutorial 6 : shear connection – beam to column flange with fin plate (IS800)



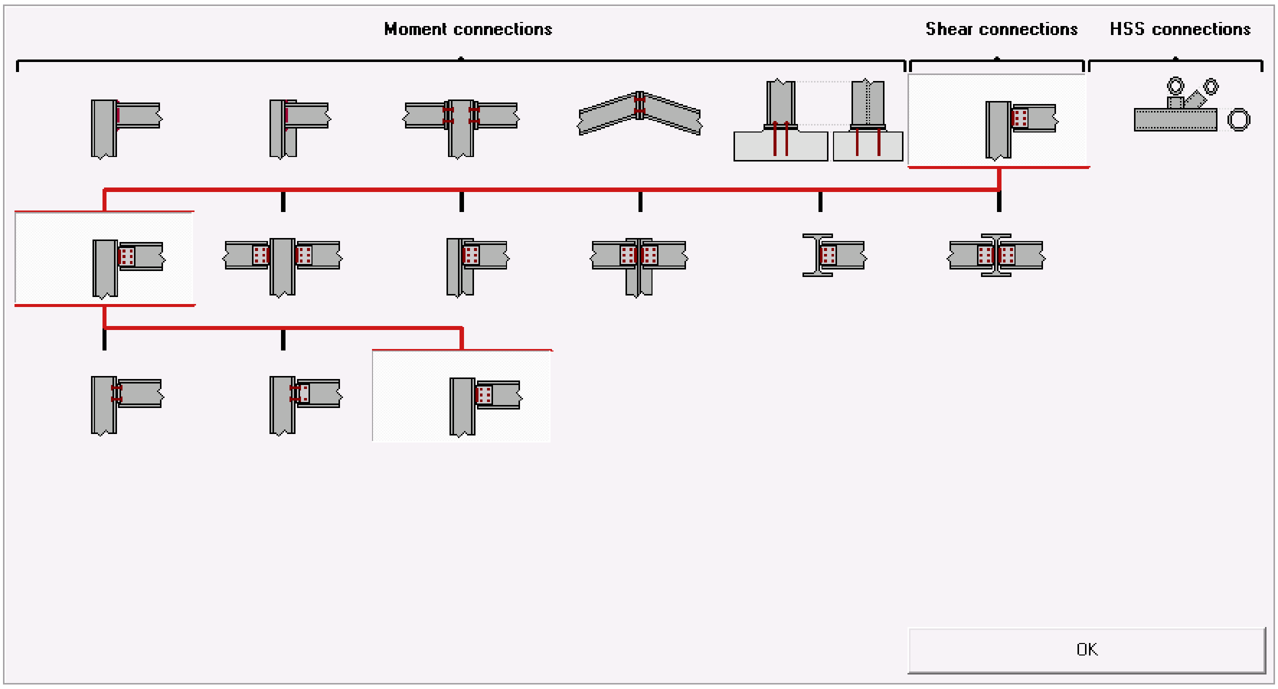
In this first tutorial on shear connection design, the focus will be on a beam to column flange connection through fin plates.

2.6.1 Setting up the model

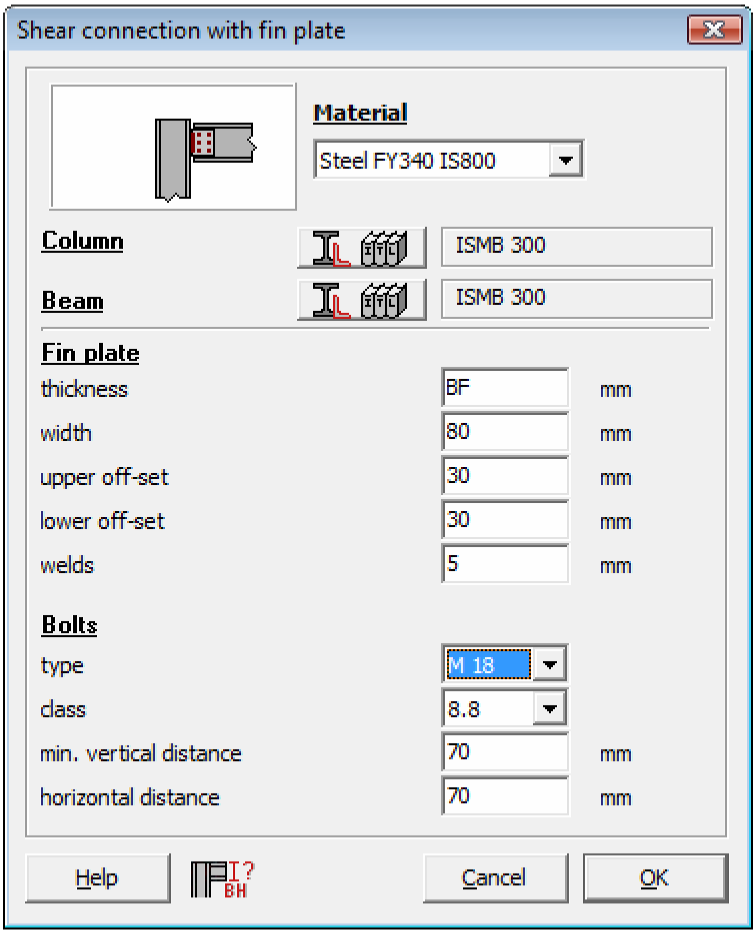
In the PowerConnect navigation window, first select the **Shear Connection** icon to start the navigation. Then choose following specifications to complete the connection type selection:

- Single-sided beam to column flange
- Fin plate

to end up with a selection tree as below:

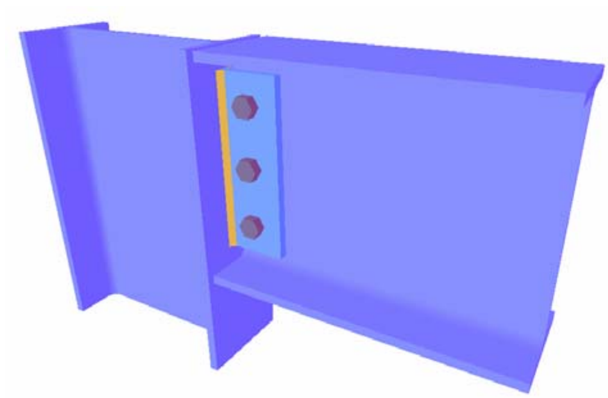


Upon confirmation of this choice through the “OK”-button, a new dialogue window appears in which further details on the connection elements can be entered.



In particular, following parameters should be verified:

- section of column & beam : ISMB 300
- bolts type M18, grade 8.8
- width of fin plate : 80 mm

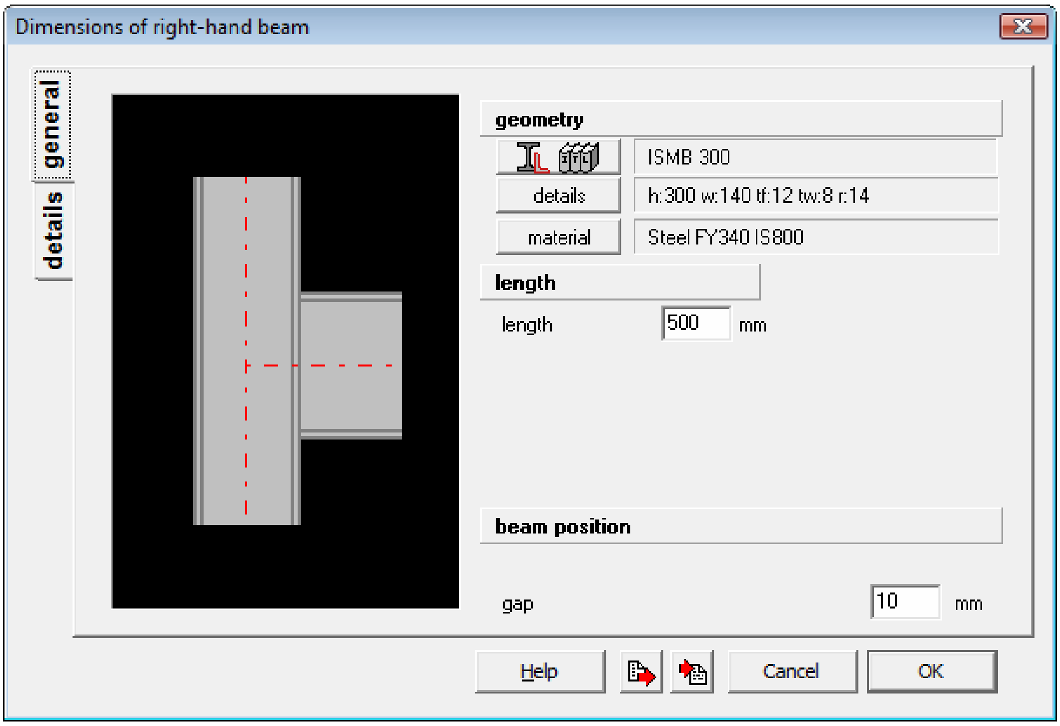


Column and beam length have no impact on the analysis results whatsoever, as all verifications during the analysis are related to shear force only. As this type of connection is verified only for shear force, no bending stiffness is evaluated and the connection is thus assumed to be a pinned connection.

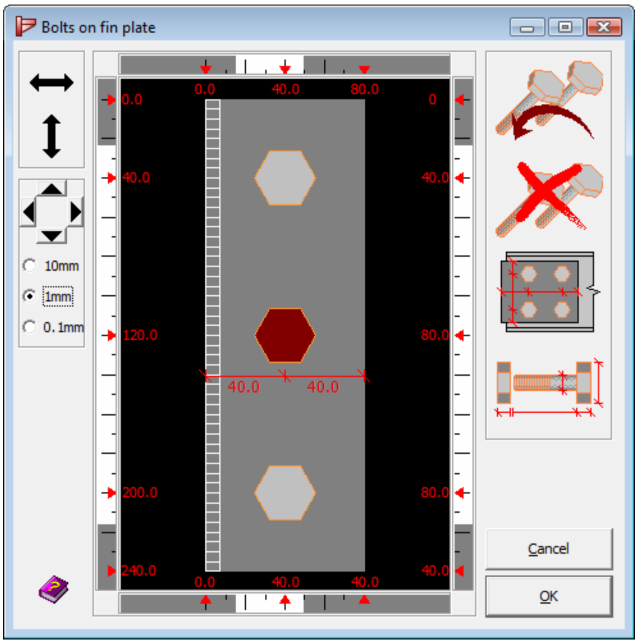
Confirm any modifications to defaults values by means of the 'OK'-button, to arrive at the connection as illustrated alongside.

2.6.2 Verifying the geometry model

Further details on specific connection element scan be obtained by double-clicking on any element with the mouse. For example, double-click on the beam to verify that a gap of 10mm has been specified between the beam and column, and modify if needed.

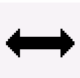


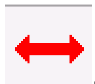
The position of the bolts will also be verified. Double-click on any of the bolts to see that all bolts are positioned centrally with respect to the fin plate.

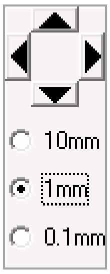


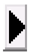
Assume now that all bolts should be moved horizontally to the right over a distance of 5mm. PowerConnect has a number of tools, next to the optimized bolt positioning functions, to define bolt positions manually. To start with, it is important to understand that those tools operate on horizontal bolt rows, and that each tool requires the selection of a single horizontal bolt row. As in the current example each bolt row contains exactly 1 bolt, bolts need to be selected individually in this example and then the requested horizontal shift can be specified.

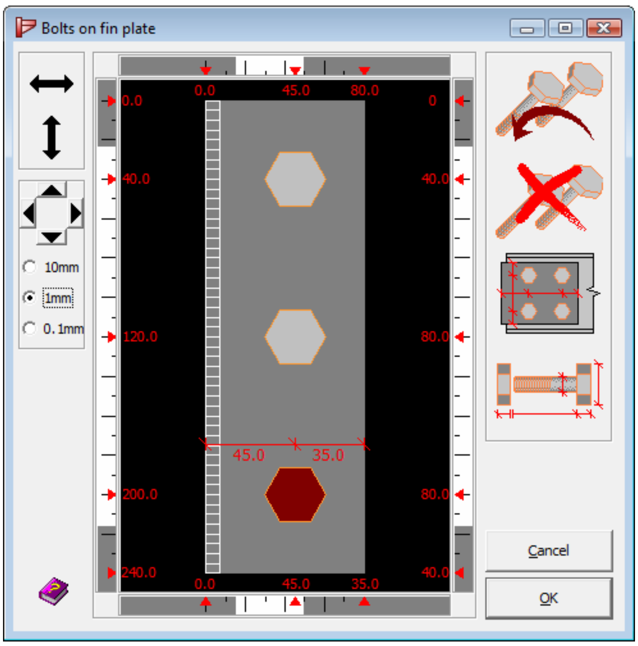
Select the first bolt, and a number of items on the left hand side of the window will be activated



Use the icon and the color will switch to red . This indicates that the selected bolt can easily be moved horizontally by sliding it with the mouse. Use this tool only for roughly repositioning selected bolts.



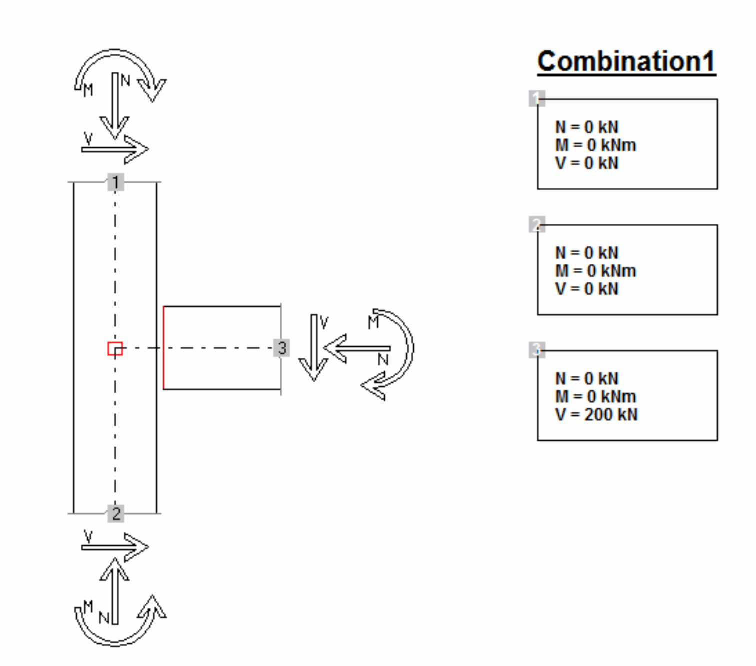
This function can be used in case an exact repositioning of bolts is required. First select the requested precision (0.1, 1 or 10mm – select 1mm for the current application. Then press the  icon five times to move the selected bolted by 5mm to the right. Repeat this operation for the other bolts, to arrive at the status illustrated below.



Confirm the new lay-out using the ‘OK’-button to return to the 3D ‘Geometry’-window.

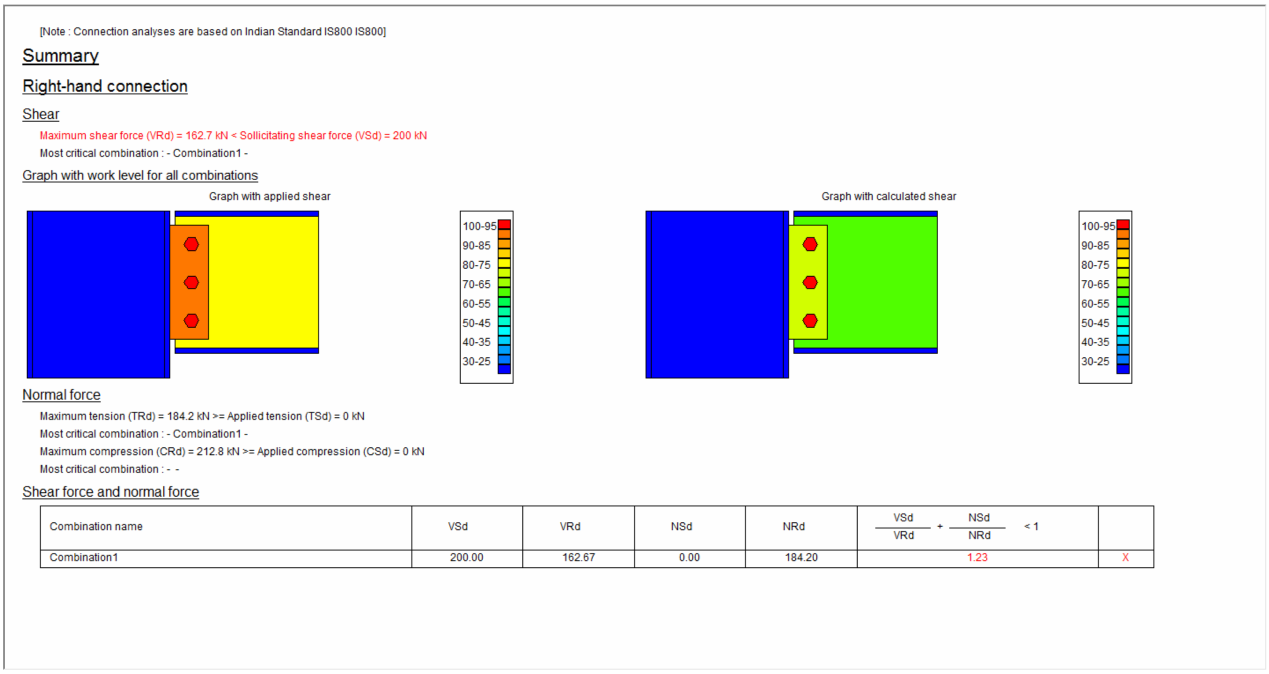
2.6.3 Defining the loads

Switch to the ‘Loads’-window using the icon, click with the mouse on the label “3” shown on the 2D geometry representation to enter a shear force of 200 kN. As a result, the contents of the ‘Loads’-window should look as follows:



2.6.4 Running the connection design analysis

Use the icon to launch the design analysis. This analysis will present following summary, from which it can be concluded that the connection needs modification in order to be able to resist to the applied shear force.



[Note : Connection analyses are based on Indian Standard IS800 IS800]

Summary

Right-hand connection

Shear

Maximum shear force (VRd) = 162.7 kN < Sollicitating shear force (VSd) = 200 kN

Most critical combination : - Combination1 -

Graph with work level for all combinations

Normal force

Maximum tension (TRd) = 184.2 kN >= Applied tension (TSd) = 0 kN

Most critical combination : - Combination1 -

Maximum compression (CRd) = 212.8 kN >= Applied compression (CSd) = 0 kN

Most critical combination : - -

Shear force and normal force

Combination name	VSd	VRd	NSd	NRd	$\frac{VSd}{VRd} + \frac{NSd}{NRd} < 1$	
Combination1	200.00	162.67	0.00	184.20	1.23	X

The color graphs above indicate that the bolts are the most critical elements of the connection. To better understand the connection's actual failure mechanism, switch to more detailed reporting by clicking with the mouse on the 'Results Preferences' field at the right hand bottom of the PowerConnect window.

Results with components for -Combination1-

Right-hand connection

Shear

Shear resistance (VRd) for the connection = 162.7 kN

The shear sollicitation (VSd) = 200 kN > Shear resistance (VRd) = 162.7 kN

Restrictive component = Shear in bolts on right-hand fin plate

Components

Shear in welds on fin plate

Shear resistance of welds = 221.5 kN

Shear in bolts on fin plate

Shear resistance of bolts = 162.7 kN

Bearing of bolts on fin plate

Bearing resistance = 310.4 kN

Shear force in fin plate

Shear resistance of fin plate = 398.6 kN

Shear in net section = 422 kN

Shear in total section = 513.9 kN

Shear by block = 398.6 kN

Shear in beam web

Shear resistance of beam web = 265.7 kN

Shear in total section = 501.2 kN

Shear in net section = 454.9 kN

Shear by block = 265.7 kN

Bending in fin plate

Shear resistance limited by bending in fin plate = 791.3 kN

Buckling of fin plate

Shear resistance limited by buckling of fin plate = 4557.7 kN

Normal force

Compression = (CSd = 0 kN) <= 212.8 kN (CRd)

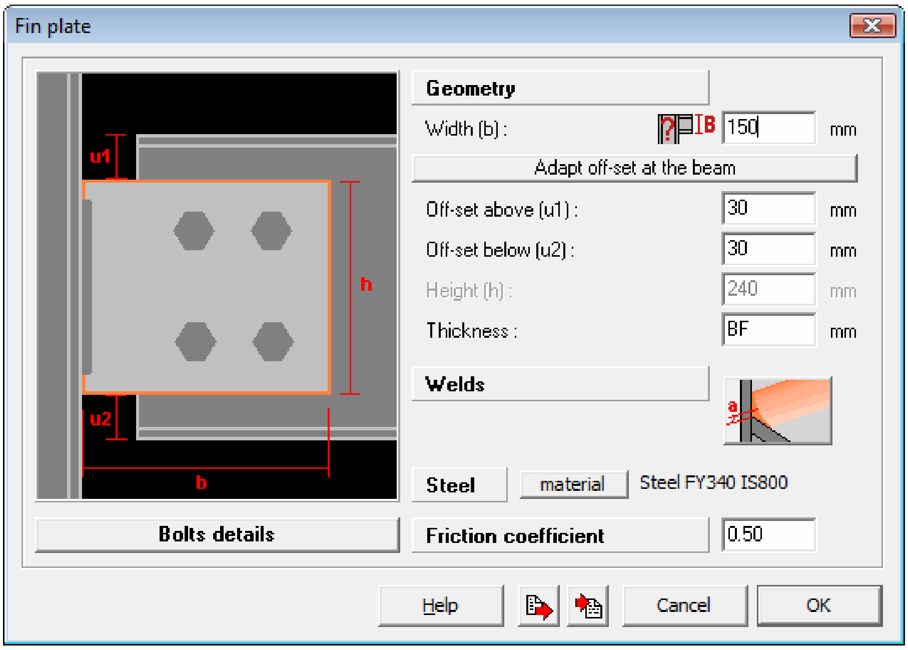
Restrictive element for max compression : Shear in bolts on fin plate

Tension = (TSd = 0 kN) <= 184.2 kN (TRd)

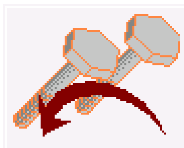
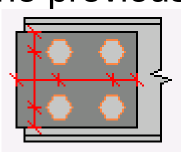
This information confirms that the connection's resistance is limited by bolt shear. Furthermore, it is clear that the next critical component is shear in the welds – the corresponding failure load is about 10% higher than the shear force that is applied to the connection. This is important information, as it indicates that increasing the number of bolts should normally deliver the required design strength.

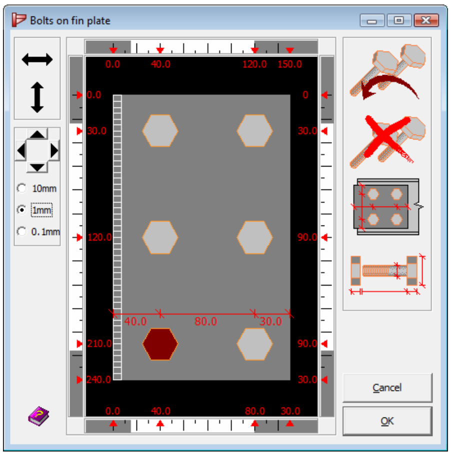
2.6.5 Improving the connection design

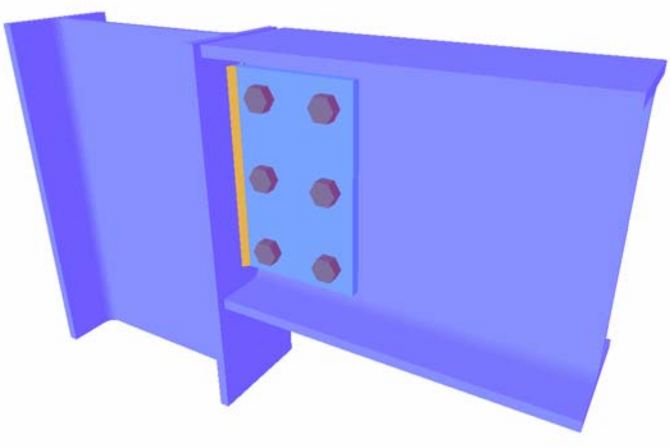
Considering previously specified minimum distances between bolts, this can only be achieved by increasing the fin plate width from 80mm to 150mm. Just double-click on the fin plate and adapt the width in the dialogue window that appears (see below).



Next, a bolt will be added on each bolt row. Proceed as follows:

- select the bolt on the first row and use the  icon to add a bolt on the same row
- repeat the previous step for the second and the third bolt row
- use the  icon to automatically reposition the bolts





2.6.6 Re-running the connection design analysis on the modified connection

Running the connection design analysis on the modified connection will produce following component-level detail:

Results with components for -Combination1-

Right-hand connection

Shear

Shear resistance (VRd) for the connection = 190.2 kN
The shear sollicitation (VSd) = 200 kN > Shear resistance (VRd) = 190.2 kN
Restrictive component = Shear in welds on right-hand fin plate

Components

Shear in welds on fin plate

Shear resistance of welds = 190.2 kN

Shear in bolts on fin plate

Shear resistance of bolts = 246.7 kN

Bearing of bolts on fin plate

Bearing resistance = 353.1 kN

Shear force in fin plate

Shear resistance of fin plate = 328.2 kN
Shear in net section = 422 kN
Shear in total section = 513.9 kN
Shear by block = 328.2 kN

Shear in beam web

Shear resistance of beam web = 375.1 kN
Shear in total section = 501.2 kN
Shear in net section = 454.9 kN
Shear by block = 375.1 kN

Bending in fin plate

Shear resistance limited by bending in fin plate = 445.1 kN

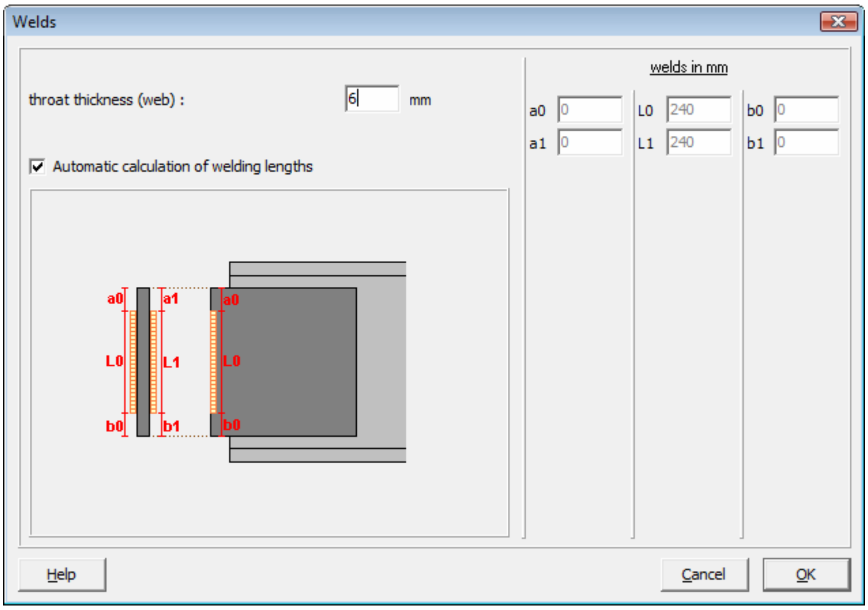
Buckling of fin plate

Shear resistance limited by buckling of fin plate = 811.2 kN

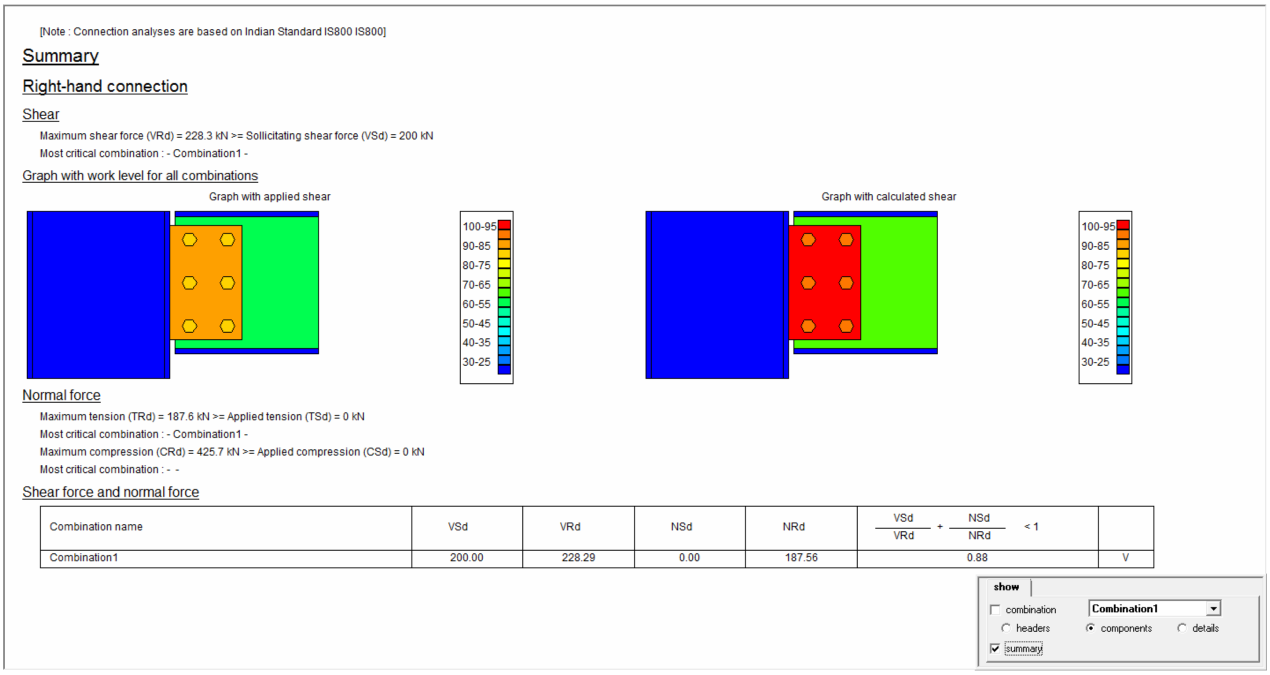
Normal force

Compression = (CSd = 0 kN) <= 425.7 kN (CRd)
Restrictive element for max compression : Shear in bolts on fin plate
Tension = (TSd = 0 kN) <= 184.2 kN (TRd)

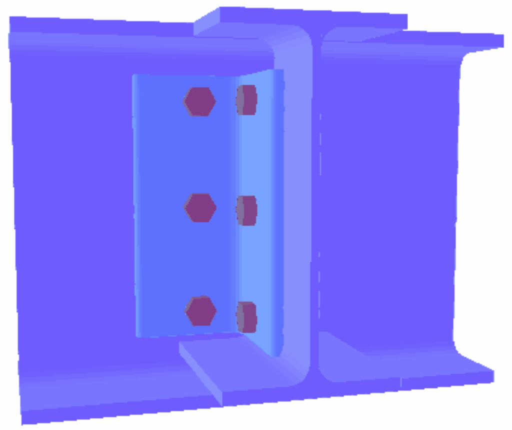
Connection shear resistance has been increased from 162.7 kN to 190.2 kN, which is insufficient to resist the applied shear load of 200 kN. It can be seen from the results that shear in the welds has now become the most critical component. The maximum shear in the welds has been reduced from 221.5 kN to 190.2 kN by introducing an extra bolt row. This can easily be explained by the fact that the eccentricity between the C.O.G. of the bolts and the C.O.G. of the welds has increased, thereby introducing an extra moment load on the welds. The connection resistance can only be enhanced if weld throat thickness is increased, eg. from 5 to 6mm (see dialogue below, which will appear on the screen by double-clicking on one of the welds).



As can be seen from the below results summary, connection resistance has been increased up to 228.3 kN.

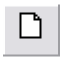


2.7 Tutorial 7 : shear connection – beam to beam web with bolted angle cleats (IS800)



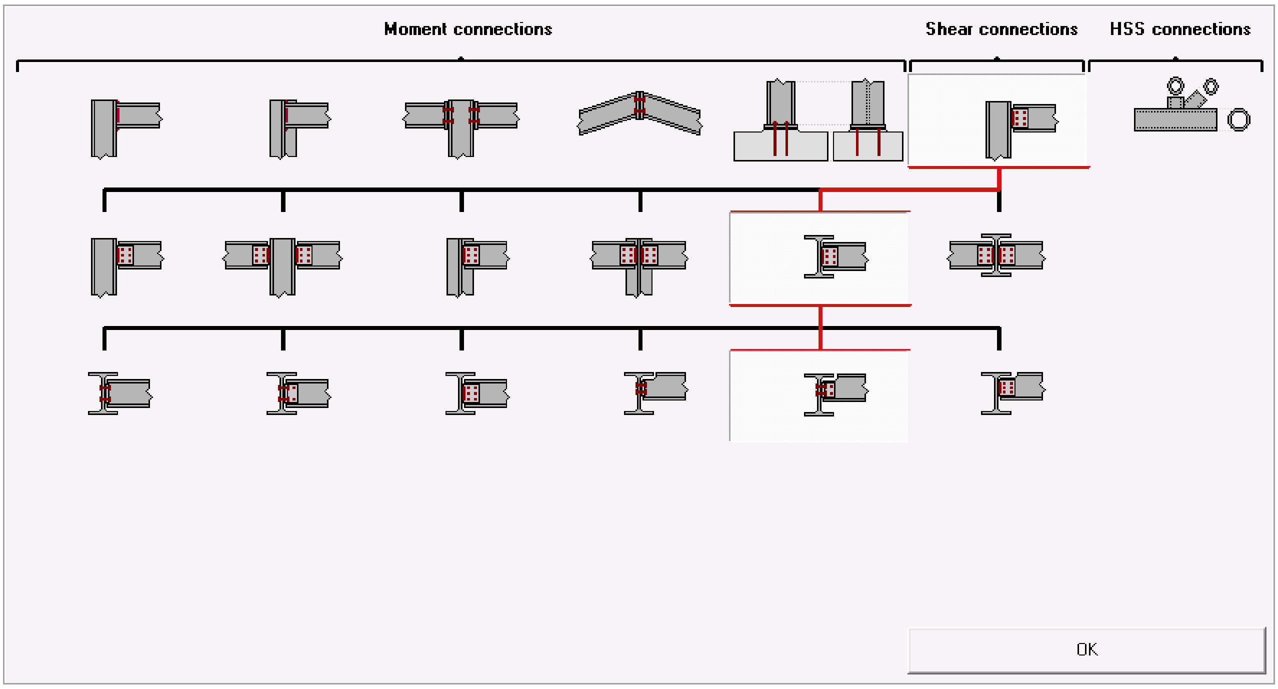
As a second example for shear connections, a beam to beam connection, using bolted angle cleats will be considered.

2.7.1 Setting up the model

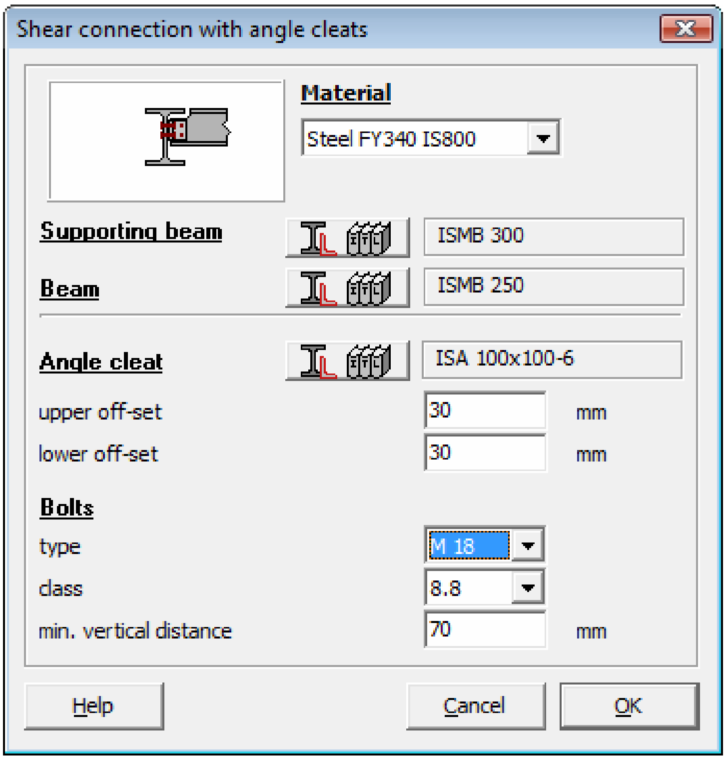
Create a new PowerConnect project using the  icon. In the PowerConnect navigation window, first select the Shear Connection icon to start the navigation. Then choose following specifications to complete the connection type selection:

- Single-sided beam to web
- Coped beam to bolted angle cleat

to end up with a selection tree as below:



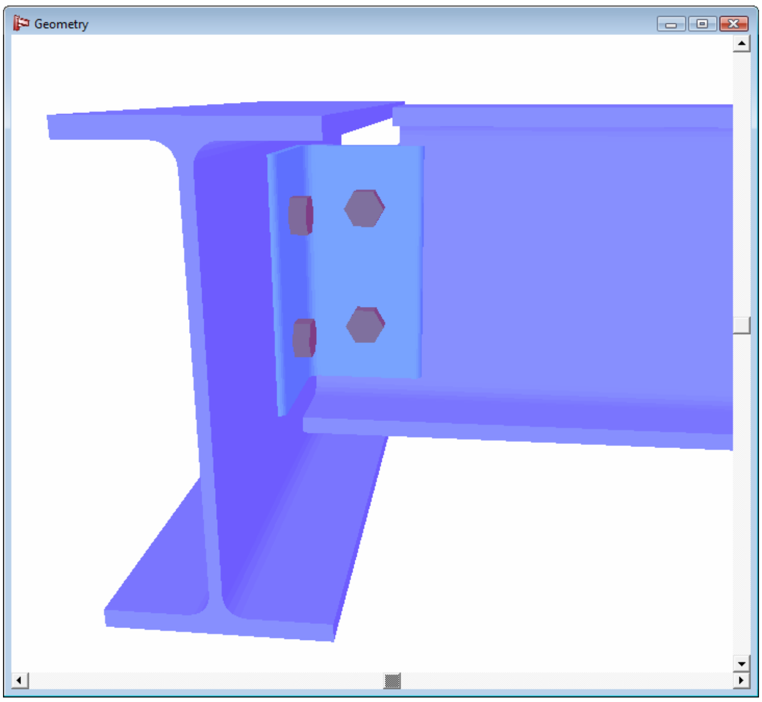
Confirm this choice with the 'OK'-button and then define further details in the following dialogue window.



In particular, following parameters should be verified:

- section of supporting beam : ISMB 300
- section of beam : ISMB 250
- angle cleat : ISA 100x100-6
- bolts of type M18, grade 8.8

Confirm with the ‘OK’-button to end up with the connection shown below.

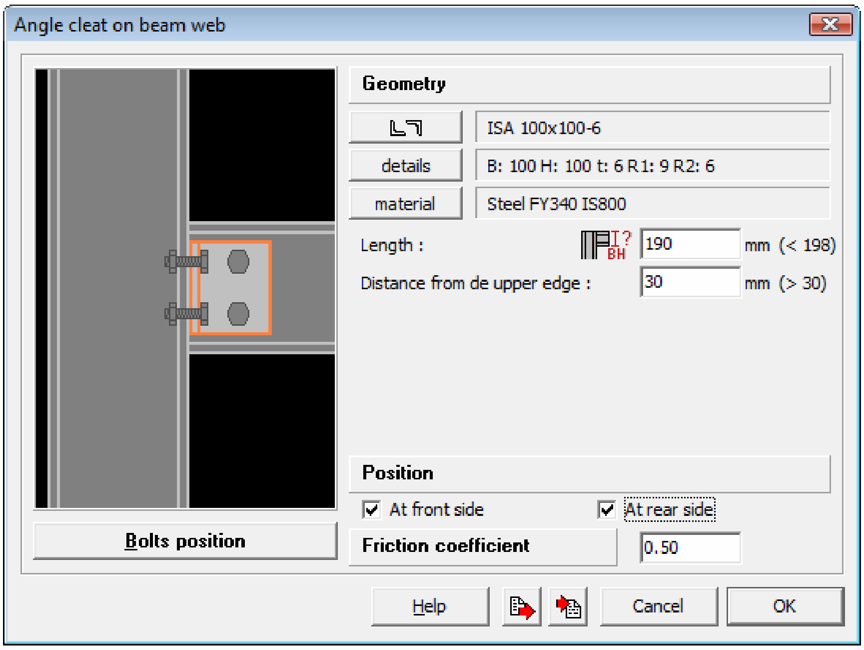


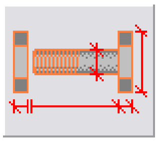
With this type of connection, the upper surfaces of both beams are automatically aligned. In case the lower surfaces of the beams should be aligned, click with the right-hand button on the PowerConnect ‘Geometry’-window and choose the appropriate entry in the floating which allows to align the bottom surfaces of both beams. With this particular example, remain with the upper surfaces aligned.

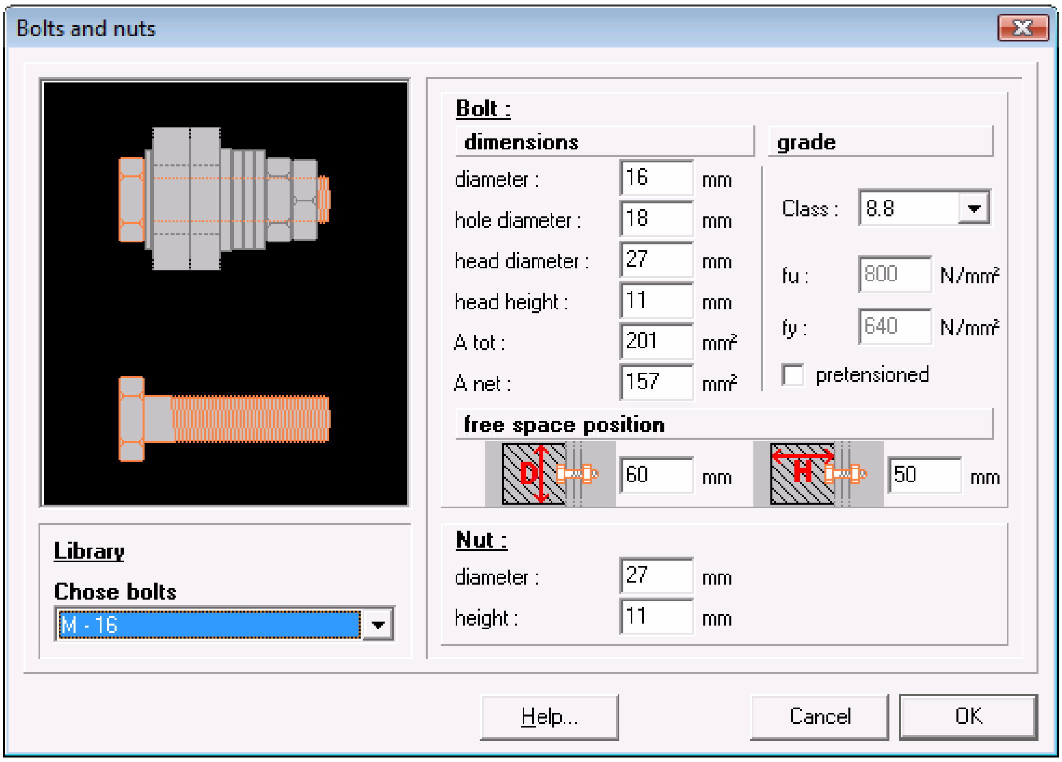
2.7.2 Verifying the connection elements

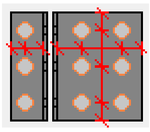
The connection which has just been created can directly be used for design analysis. It remains however possible to manually change the characteristics of any connection element (or at least to verify them) by double-clicking on the element. This can be done for the supporting beam and for the other beam, but keep the values as they are proposed by default.

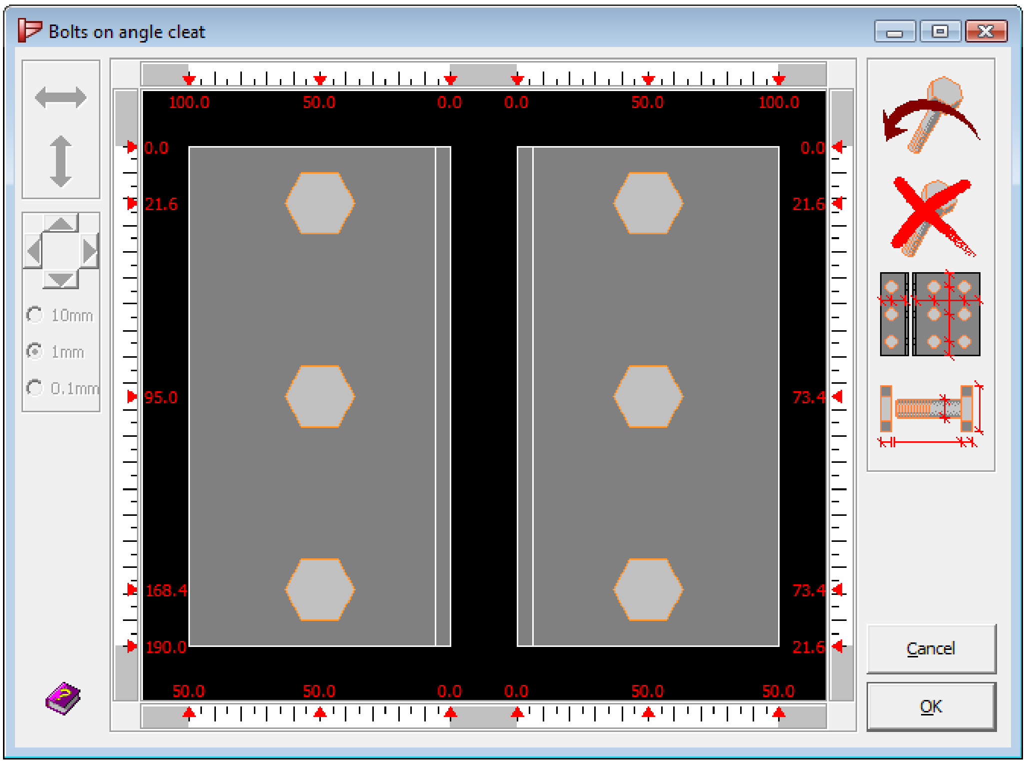
Now double-click on the angle cleat, and verify if angle cleats have been foreseen at both sides of the beam web. If not, make sure both the “Front side” and “Rear side” options have been checked.



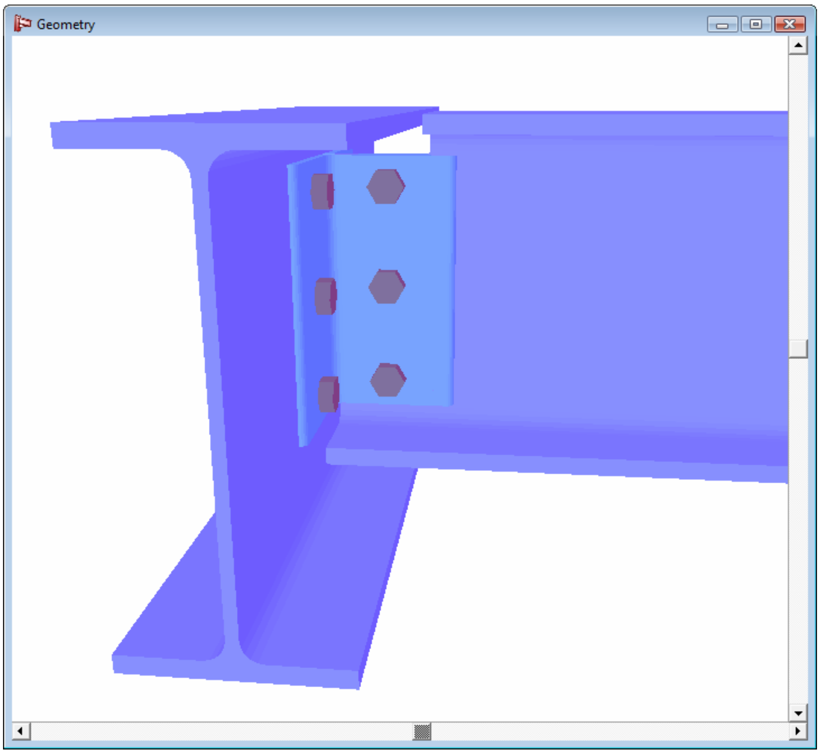
Finally, have a closer look at the bolts. Just double-click on any one of them, and use the  icon to change the bolt type from M18 to M16 (8.8 grade).



Optimize bolt positions by means of the button , and finally confirm this change to arrive at the following bolt lay-out:



which corresponds to the connection below:



2.7.3 Running the connection design analysis

No loads are applied on the connection, as the only interest is to evaluate maximum shear resistance.

[Note : Connection analyses are based on Indian Standard IS800 IS800]

Summary

Right-hand connection

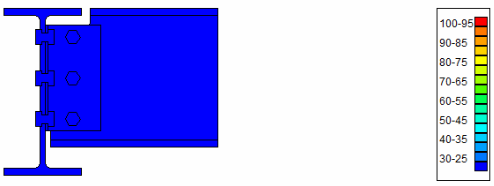
Shear

Maximum shear force (VRd) = 87.1 kN >= Sollicitating shear force (VSd) = 0 kN

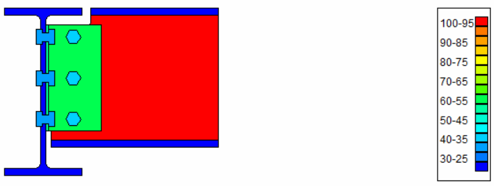
Most critical combination : - Combination1 -

Graph with work level for all combinations

Graph with applied shear



Graph with calculated shear



Normal force

Maximum tension (TRd) = 44.7 kN >= Applied tension (TSd) = 0 kN

Most critical combination : - Combination1 -

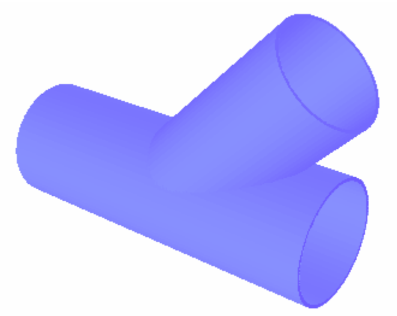
Maximum compression (CRd) = 128.2 kN >= Applied compression (CSd) = 0 kN

Most critical combination : - -

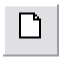
Shear force and normal force

Combination name	VSd	VRd	NSd	NRd	$\frac{VSd}{VRd} + \frac{NSd}{NRd} < 1$	
Combination1	0.00	87.10	0.00	44.66	0.00	V

2.8 Tutorial 8 : HSS connection (circular members)

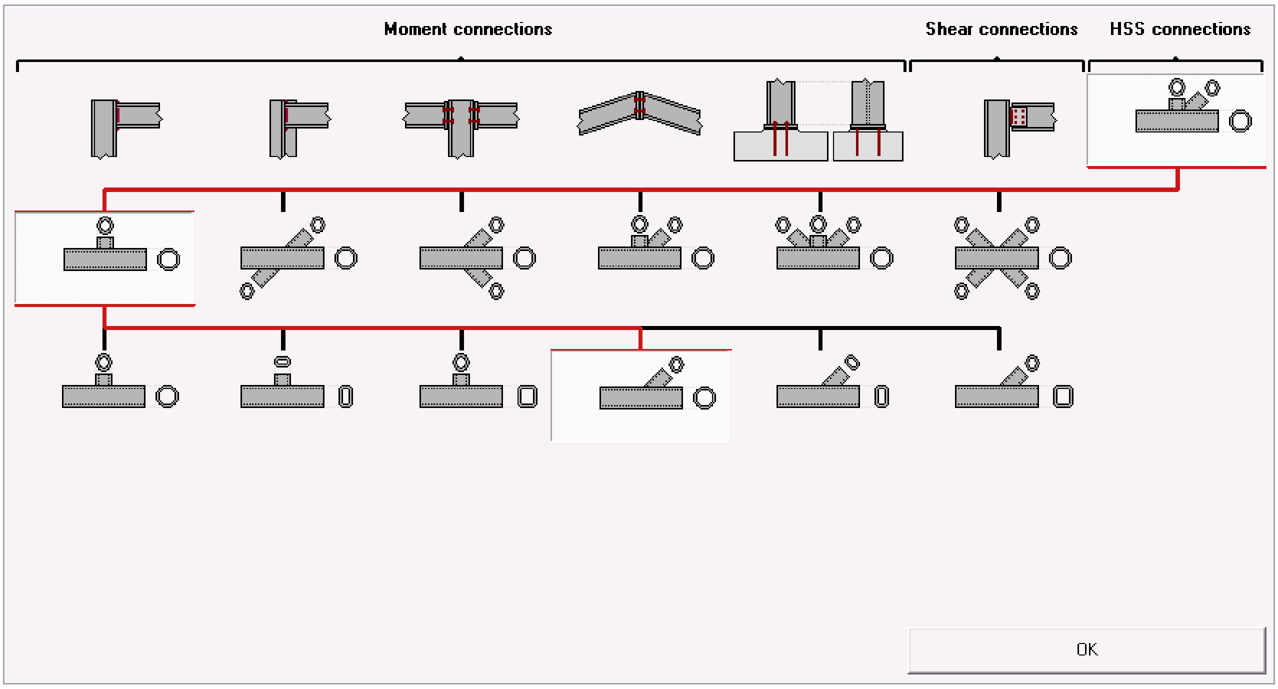


2.8.1 Setting up the model

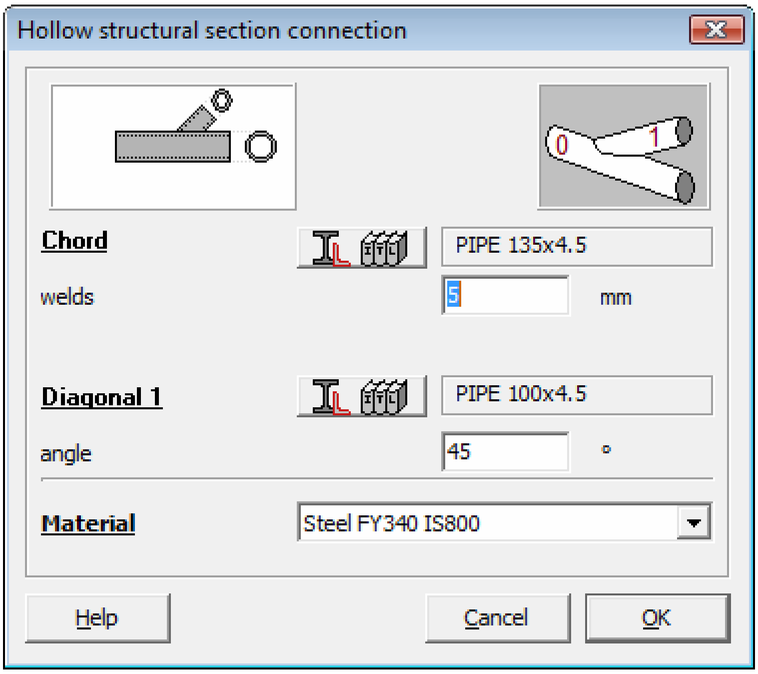
Click on the icon  to start a new PowerConnect project and select the **HSS Connections** icon from the navigation window. Choose following specifications to complete the connection type selection:

- Y/T connections
- Y (circular)

corresponding to the selection tree shown below:



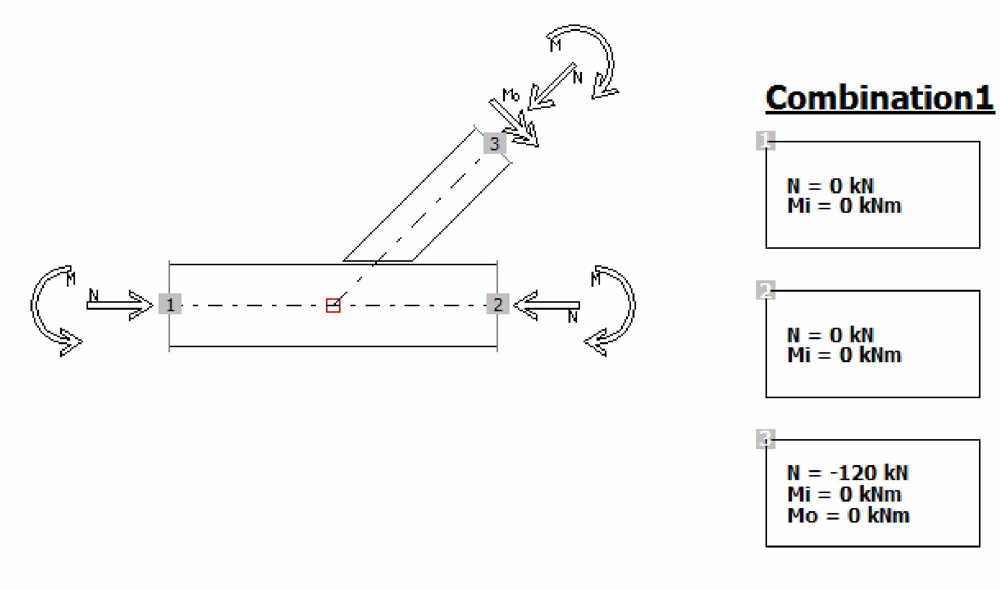
In a next dialogue window, further details can be provided on hollow structural sections (including their relative orientation) and welds. Make sure to enter values as given in the dialogue window below.



If wanted, further details on the hollow structural sections can be obtained (or modifications can be defined) by double-clicking on the corresponding members in the 3D visualization of the connection geometry.

2.8.2 Defining the loads

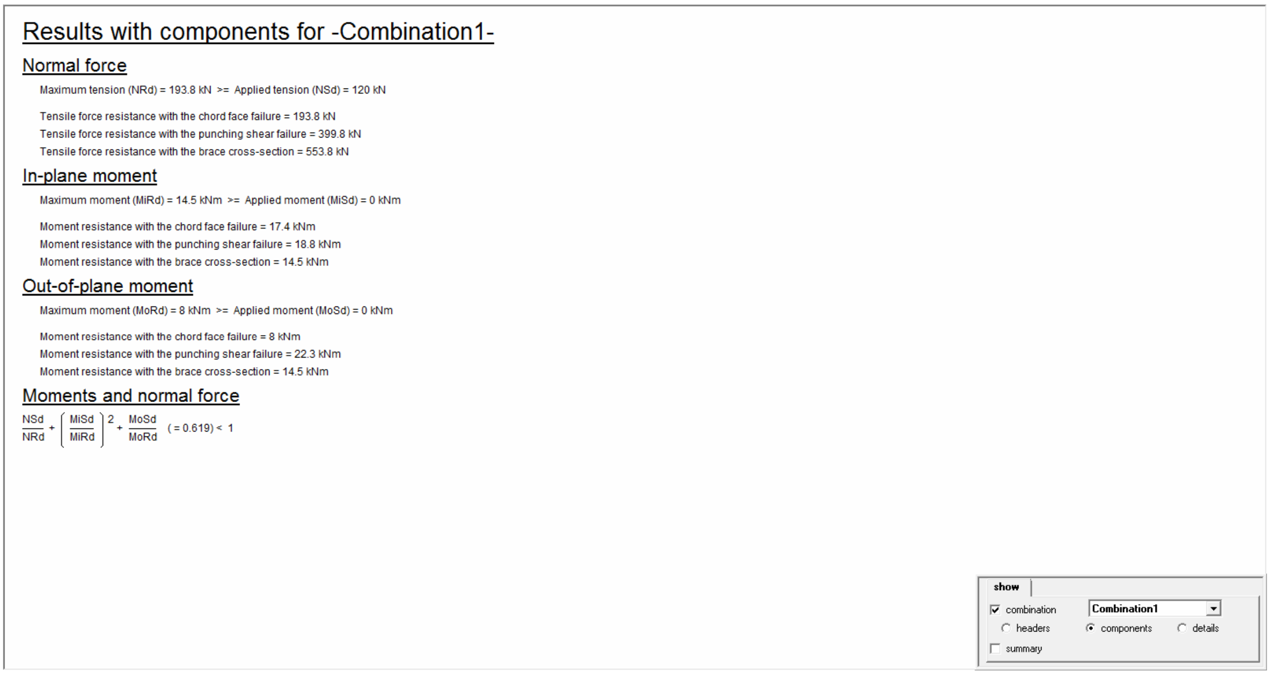
To apply a tensile load of 120kN to the diagonal chord, switch to the 'Loads'-window by means of the  icon. Click with the mouse on the label "3" of the 2D geometry representation in this 'Loads'-window to impose the load (use a value of -120kN to ensure a tensile load is defined).



2.8.3 Running the design analysis

Launch the design analysis . At this time, it should be remarked IS800 does not give any specification with respect to HSS connection design. Therefore, PowerConnect will inform the user that this connection type cannot be calculated according to IS800. It will automatically switch to the EC3 method, of which the implementation is actually based on a number of formula published by CIDECT, allowing for the analysis of a limited type of HSS connection configurations. This limits somewhat the number of connection types that can currently be analyzed by PowerConnect. Limitations are mostly related to the type of loads that can be considered during the analysis.

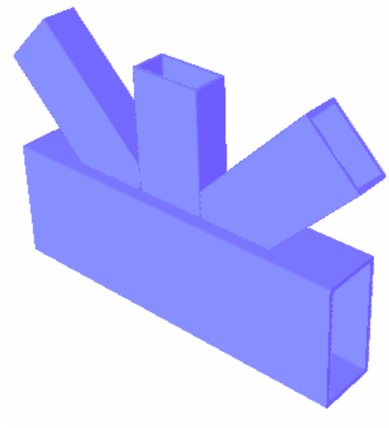
For the HSS connection that has been defined, the analysis will deliver following results.



PowerConnect evaluates the maximum values for different types of loads that can be applied on the connection, in particular normal forces and in-plane & out-of-plane bending moments.

PowerConnect will furthermore use those values to summarize the overall “loading level” of the connection, by comparing applied loads to maximum resistance using a dedicated combination formula. As such, judgment of connection strength really becomes a straightforward matter.

2.9 Tutorial 9 : HSS connections (rectangular members)

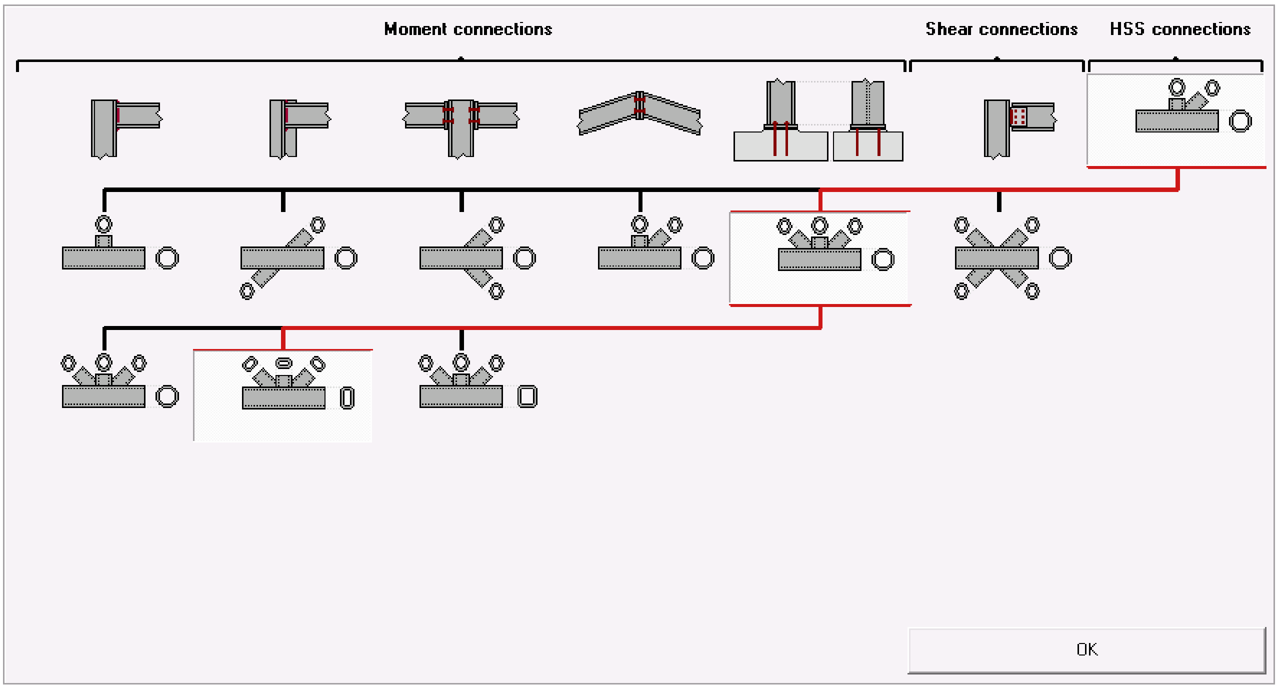


2.9.1 Setting up the model

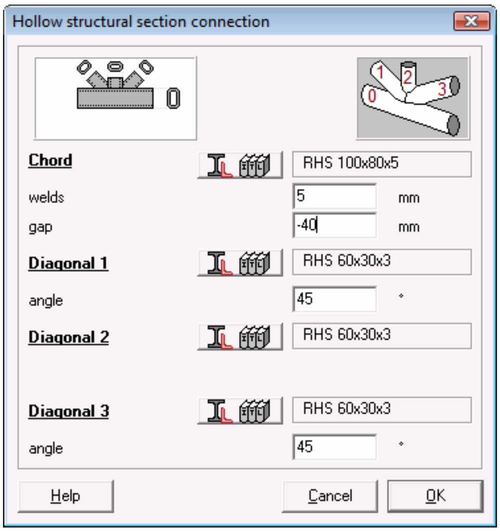
Click on the icon to start a new PowerConnect project and select the **HSS Connections** icon from the navigation window. Choose following specifications to complete the connection type selection:

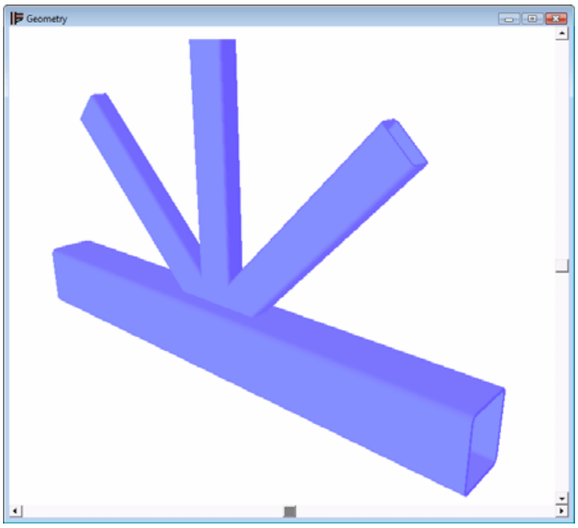
- KT connections
- KT (rectangular)

corresponding to the selection tree shown below:



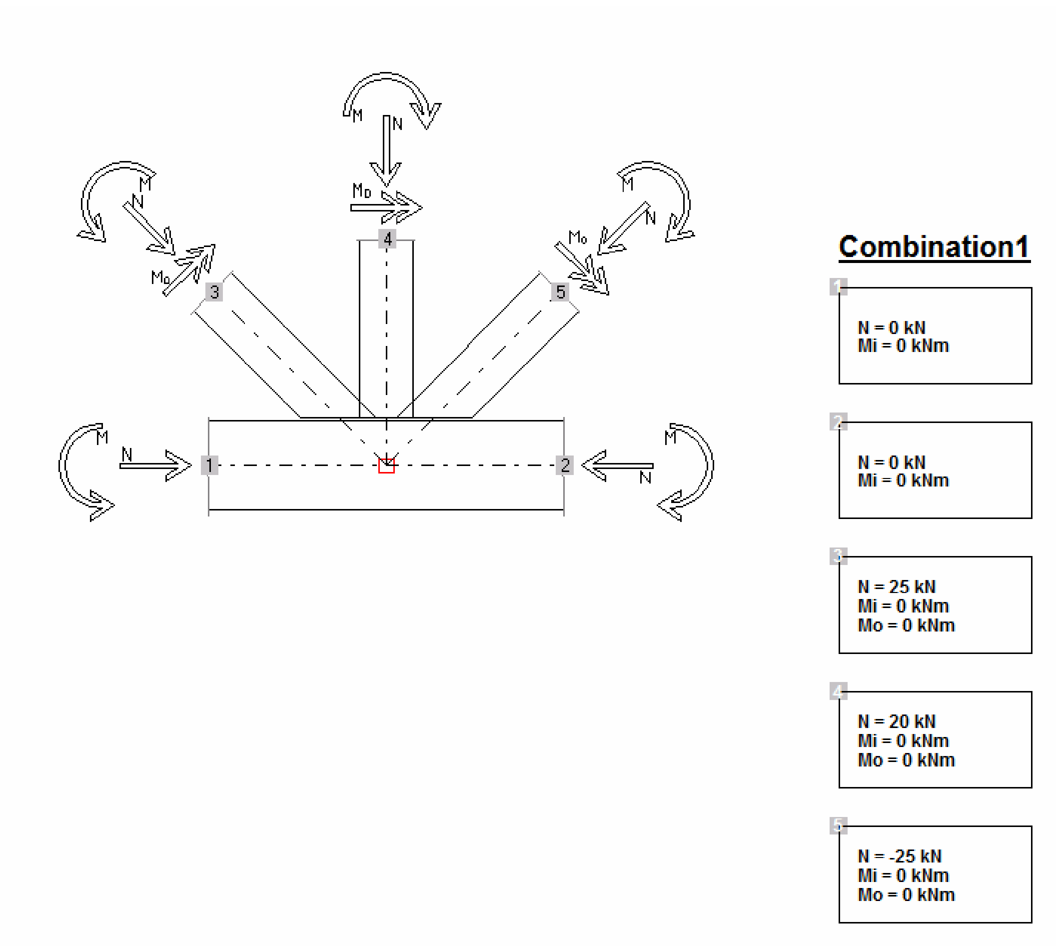
For the main chord, a 100*80*5 section will be used, whereas for a 60*30*3 section will be used for all diagonals. Accept all other values as proposed by default by PowerConnect.





2.9.2 Defining the loads

Now switch to the ‘Loads’-windows and apply the loads as illustrated below, by clicking with the mouse on the appropriate labels with the 2D geometry representation.



2.9.3 Running the connection design analysis

The design analysis will present following results, and thus confirm that the connection can withstand the specified loads.

Summary

Left-hand hollow section

Moments and normal force

NSd	NRd	MiSd	MiRd	MoSd	MoRd	$\frac{NSd}{NRd} + \frac{MiSd}{MiRd} + \frac{MoSd}{MoRd}$
25 kN	90,5 kN	-0,3 kNm	1,6 kNm	0 kNm	0 kNm	0,470

NSd = Sollicitating normal force in secondary tube
NRd = Normal force resistance of secondary tube
MiSd = Sollicitating in-plane moment on secondary tube
MiRd = In-plane moment resistance of secondary tube
MoSd = Sollicitating out-of-plane moment on secondary tube
MoRd = Out-of-plane moment resistance of secondary tube

The most critical combination is : Combination1

Middle hollow section

Moments and normal force

NSd	NRd	MiSd	MiRd	MoSd	MoRd	$\frac{NSd}{NRd} + \frac{MiSd}{MiRd} + \frac{MoSd}{MoRd}$
20 kN	55,7 kN	0 kNm	1,6 kNm	0 kNm	0 kNm	0,359

NSd = Sollicitating normal force in secondary tube
NRd = Normal force resistance of secondary tube
MiSd = Sollicitating in-plane moment on secondary tube
MiRd = In-plane moment resistance of secondary tube
MoSd = Sollicitating out-of-plane moment on secondary tube
MoRd = Out-of-plane moment resistance of secondary tube

The most critical combination is : Combination1

Right-hand hollow section

Moments and normal force

NSd	NRd	MiSd	MiRd	MoSd	MoRd	$\frac{NSd}{NRd} + \frac{MiSd}{MiRd} + \frac{MoSd}{MoRd}$
25 kN	90,5 kN	-0,3 kNm	1,6 kNm	0 kNm	0 kNm	0,470

NSd = Sollicitating normal force in secondary tube
NRd = Normal force resistance of secondary tube
MiSd = Sollicitating in-plane moment on secondary tube
MiRd = In-plane moment resistance of secondary tube
MoSd = Sollicitating out-of-plane moment on secondary tube
MoRd = Out-of-plane moment resistance of secondary tube

The most critical combination is : Combination1

All upper hollow sections

In-plane moment

Combination1 : |MiSd(3) + MiSd(2) - MiSd(1)| (=0 kNm) <= MiRd (= 4,8 kNm)

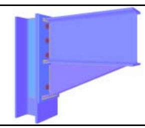
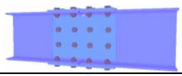
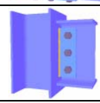
Out-of-plane moment

Combination1 : |MoSd(1) + MoSd(2) + MoSd(3)| (=0 kNm) <= MoRd (= 0 kNm)

3 PowerConnect reporting tutorials – IS800

Using some of the tutorial examples described in section 2 of this manual, the current section will focus on the information that is needed to get started with PowerConnect reporting in a short time frame. The reporting capabilities will not be described in detail, as the documentation related to this subject is covered in a separate reference manual.

<u>Inventory of reporting tutorials:</u>

Page	Section	Tutorial contents	Design code	Connection
page 72	§ 3.1	Tutorial 1 : bolted beam to column flange (IS800)	IS800	
page 78	§ 3.2	Tutorial 2 : bolted splice (IS800)	IS800	
page 83	§ 3.3	Tutorial 3 : shear connection – beam to column flange with fin plate	~~(IS800)~~ EC3	

3.1 Tutorial 1 : bolted beam to column flange (IS800)

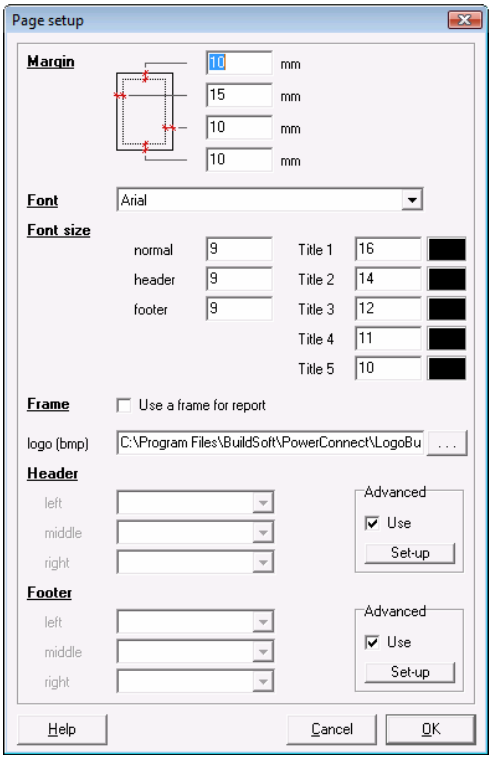
This reporting tutorial is based on the model created in section 2.1 of this manual.

3.1.1 Page setup

Before the actual report contents will be defined, the report page setup should be specified. Any page setup definition performed by the user will be remembered by PowerConnect, and will therefore be used also to create any subsequent report until new modification to the current page setup will be specified. For all reporting tutorials in this manual, we will stick with the page setup definition as specified in this section.

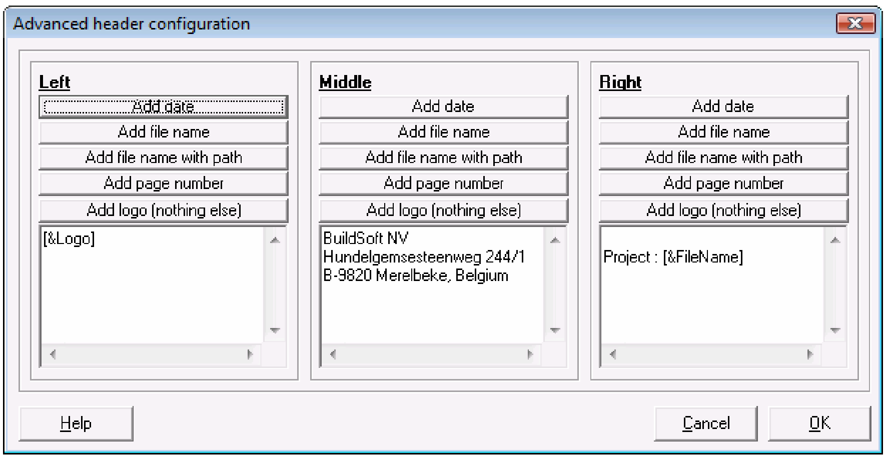
To start the page setup, use the menu command ‘File – Page setup’, so that the dialogue window below will be launched.

Apart from the rather obvious options related to definition of margins, fonts and font size, this dialogue allows to define the location of a bitmap file that should be used to include a logo in the report. If needed, the user can also request the text and graphics of the report to be included in a frame by selecting the option ‘Use a frame for report’. This option is not activated with the current reporting tutorial.

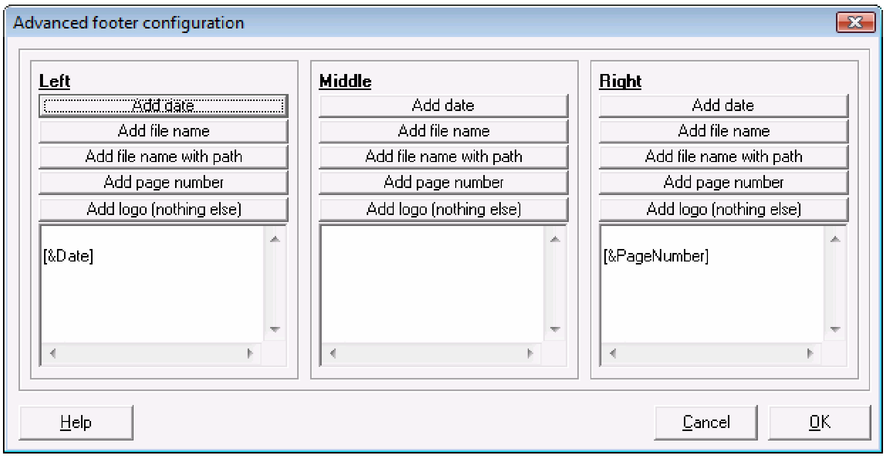


To define report header & footer, the user can either use a number of preconfigured fields or enter into an advanced definition mode. Switch to this advanced definition mode, and enter the data as shown below:

- for the report header:



- for the report footer:



3.1.2 Report configuration

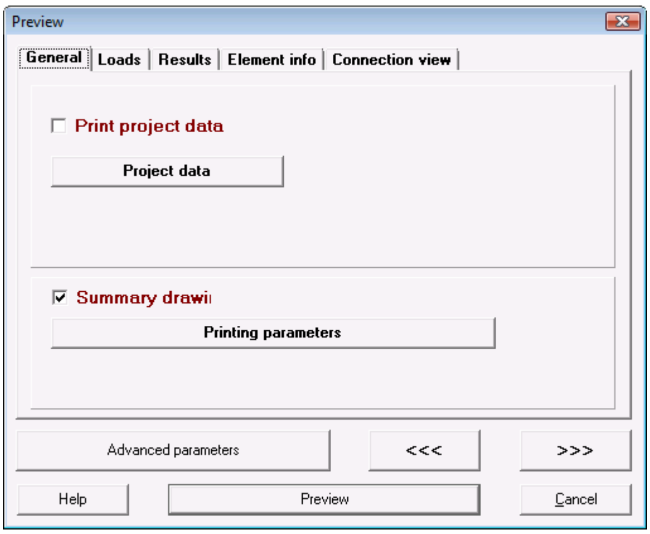
The report can be configured in either one of the following three modes:

- **Preview** (initiated by the  icon of the icon toolbar),
- **Print report** (initiated by the  icon of the icon toolbar),
- **Print report to R**TF (initiated by the  icon of the icon toolbar).

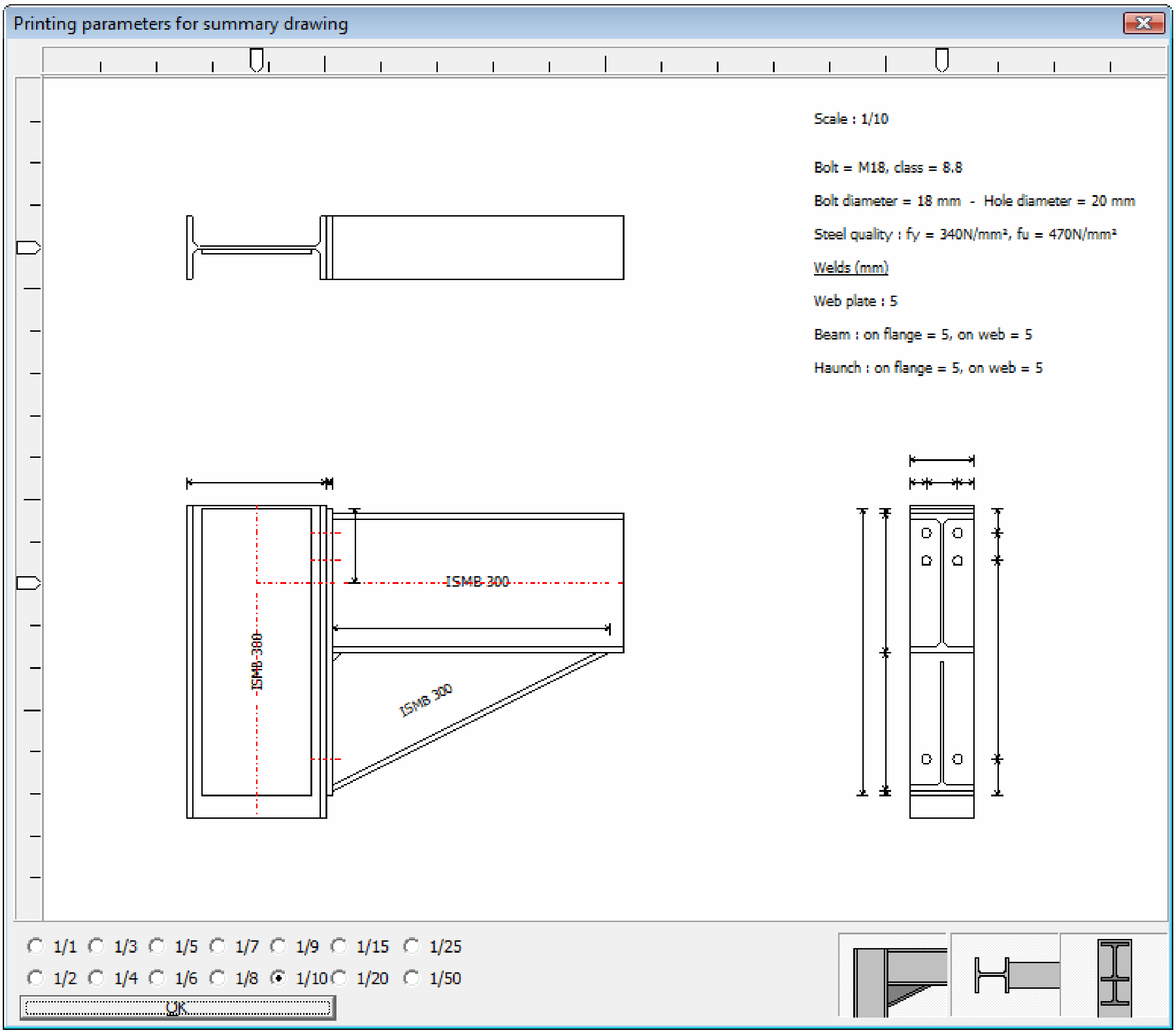
Irrespective of the chosen configuration mode, the working procedure is the same. In the scope of this tutorial, we will use the **Preview** mode.

In Preview or another configuration mode, 5 tab pages are available in the dialogue window used to define report contents. In this tutorial, only the first 3 tab pages will be used.

Start by selecting the option ‘Summary drawing’ on the first tab page. By doing so, the report will start with a summary overview of the entire connection geometry. How this summary overview should look like, can be defined by using the button ‘Printing parameters’, which opens a canvas window in which the summary overview definition can completed.

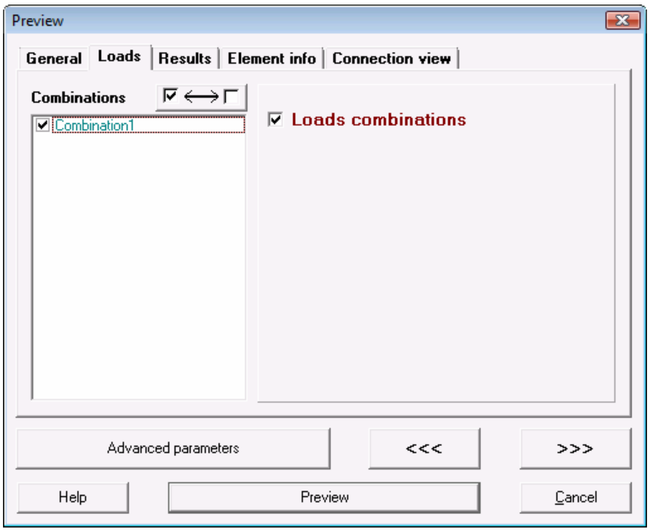


To create the kind of summary drawing shown below, make sure to select all connection views shown at the right-hand bottom part of the canvas window. Use the cursor icons to position the selected drawings in the appropriate positions, and also make sure the proper scale is selected (the selected scale of 1/10 is appropriate for a report on A4 paper format).

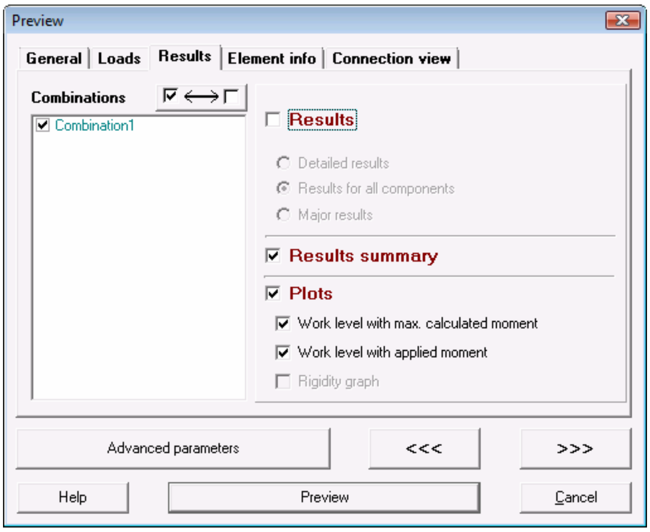


As soon as a proper lay-out has been defined, confirm by means of the 'OK'-button to return to the definition dialogue window.

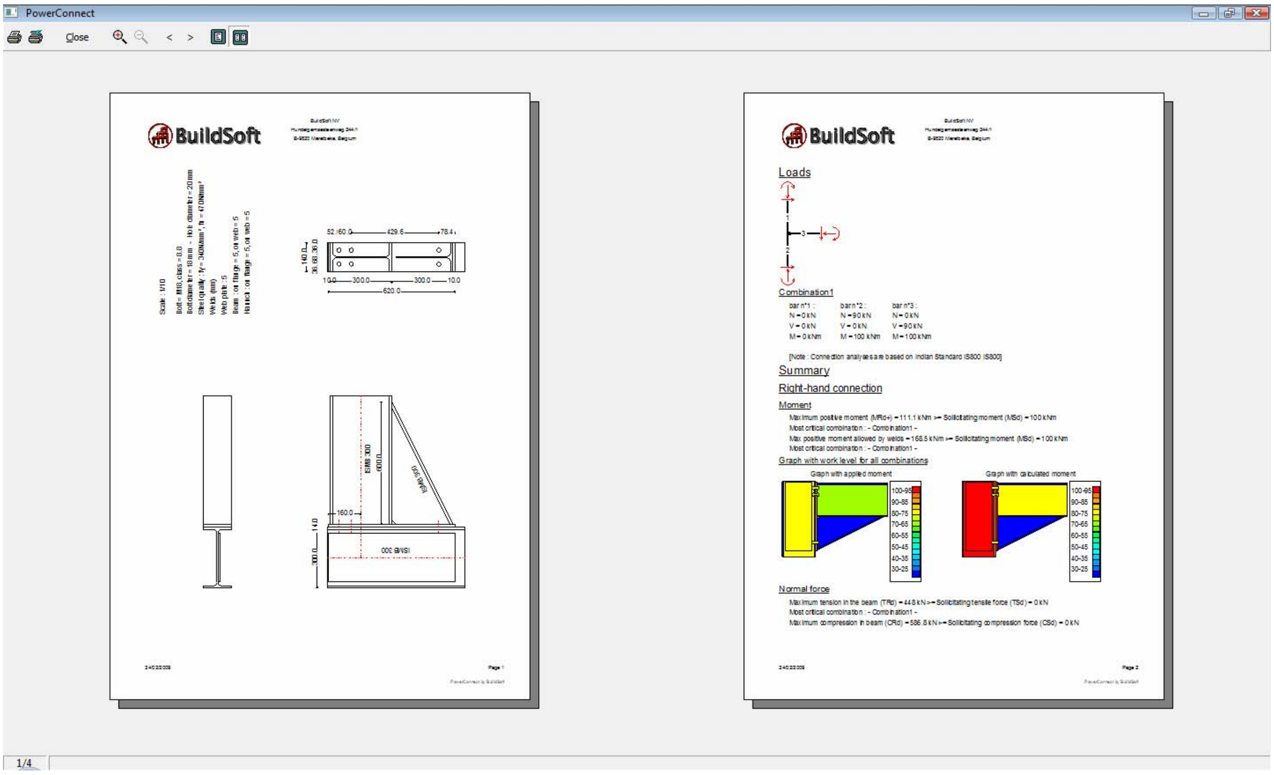
Now switch to the second tab page, and make sure that the option 'Loads combinations' is selected. This will ensure that the report includes an overview of all defined loads combinations. In case more than 1 loads combination is present, you should also make sure to select the loads combinations to be used for reporting in the list on the left-hand side. In the current tutorial example, 'Combination1' should be selected as indicated below.

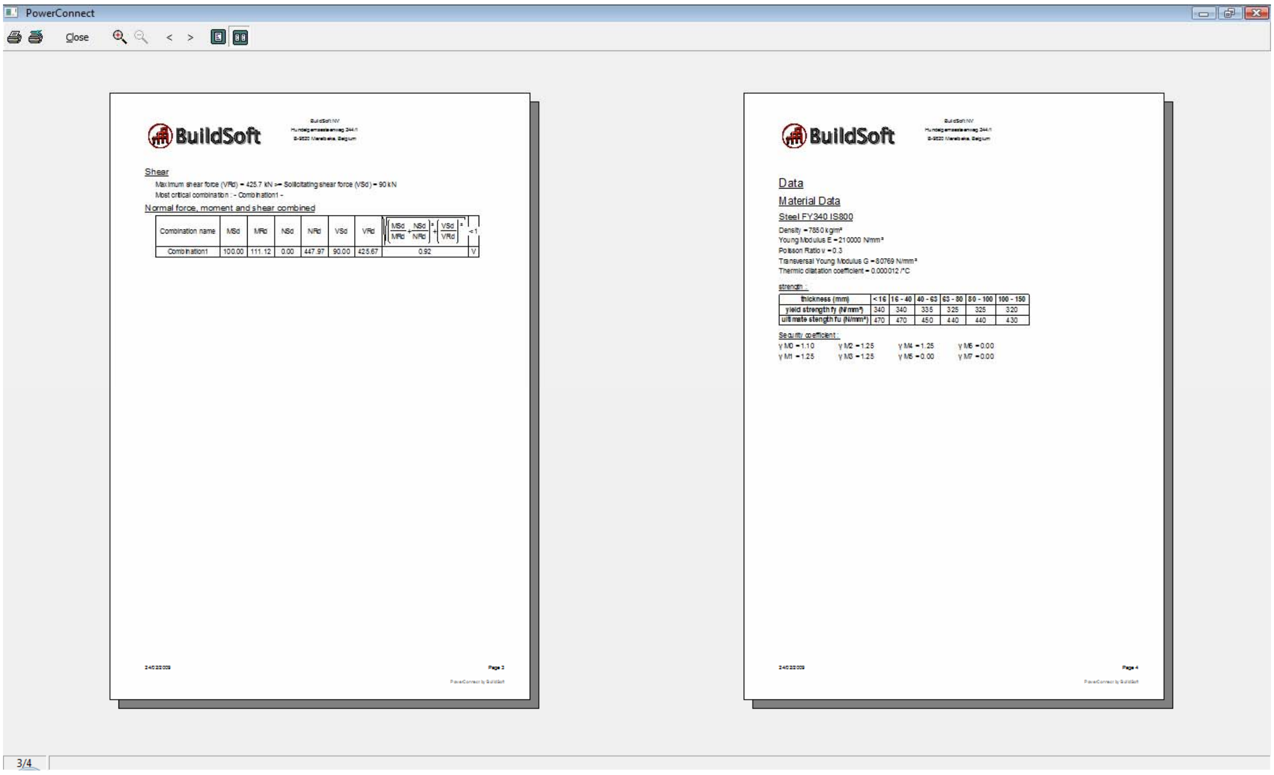


Now switch to the third tab page to specify how analysis results should be reported. Within this first reporting tutorial, the entire focus is on the creation of a concise analysis report. To do so, select the options ‘Results summary’ and ‘Plots’ as indicated below.



The report configuration can now be considered to be complete, and the report itself can be visualized by means of the ‘Preview’ button at the bottom of the dialogue window. The outcome will be a report as shown below.





In case the current report should be available in PDF-format, use the appropriate PDF button. If not, use the 'Close'-button to return to the PowerConnect working environment. To actually print the report that has just been configured, use the icon  to enter in **Print report** mode, and use the 'Print' button to send the report to the selected printer.

3.2 Tutorial 2 : bolted splice (IS800)

This reporting tutorial is based on the model created in section 2.5 of this manual.

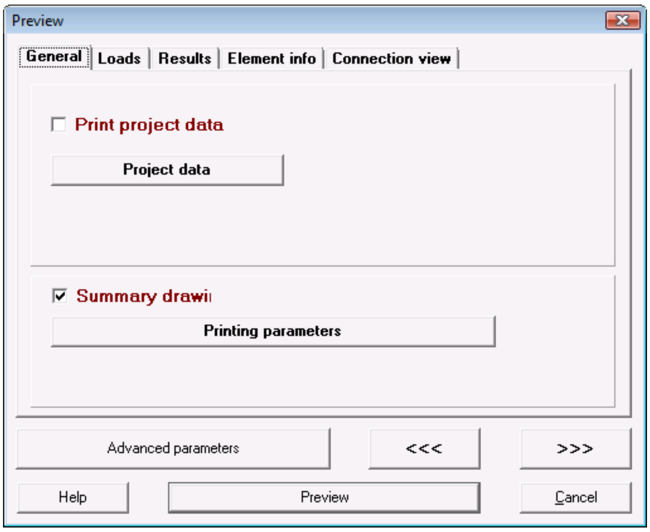
3.2.1 Page setup

No changes will be made to the page setup defined in section 3.1.1 of this manual. The user should return to this section for more information on the current page setup.

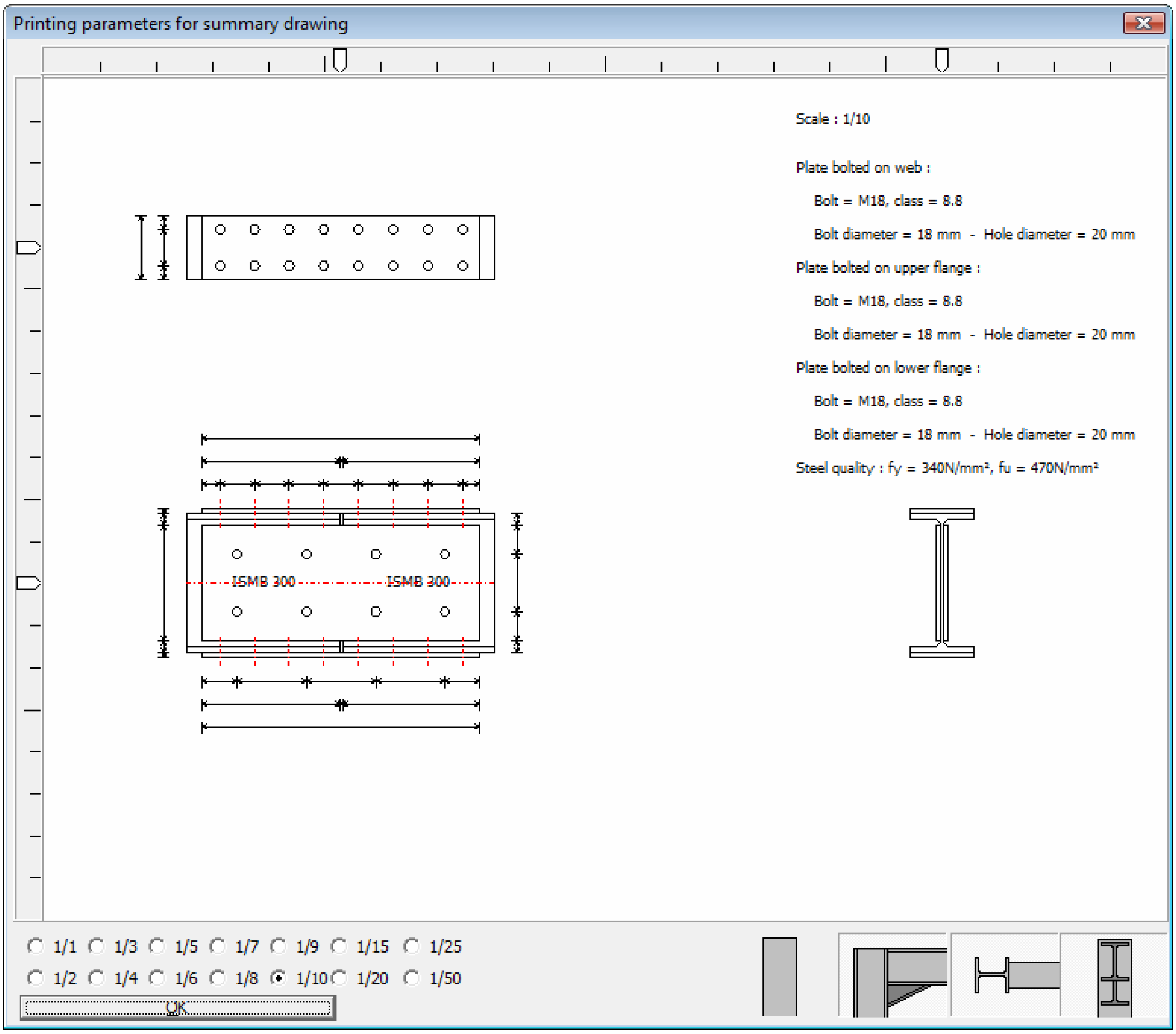
3.2.2 Report configuration

Go to **Preview** mode by means of the  icon of the icon toolbar.

Again, start by selecting the option 'Summary drawing' on the first tab page and define how this summary overview should look like by using the button 'Printing parameters', which opens a canvas window to complete the summary overview definition.

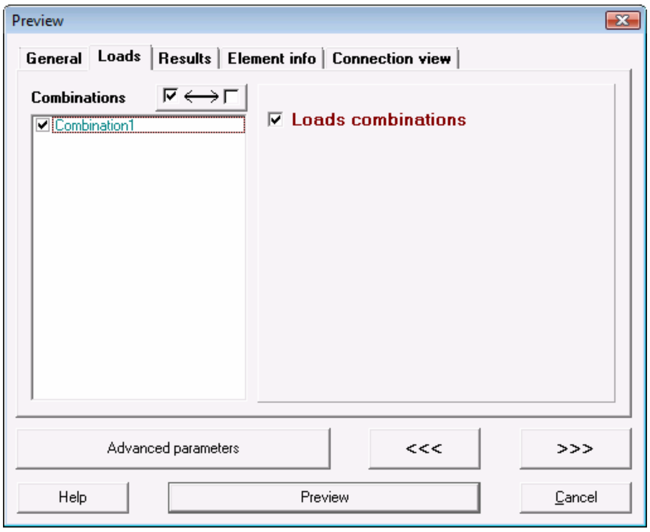


To create the kind of summary drawing shown below, make sure to select all connection views shown at the right-hand bottom part of the canvas window. Use the cursor icons to position the selected drawings in the appropriate positions, and also make sure the proper scale is selected (the selected scale of 1/10 is appropriate for a report on A4 paper format).

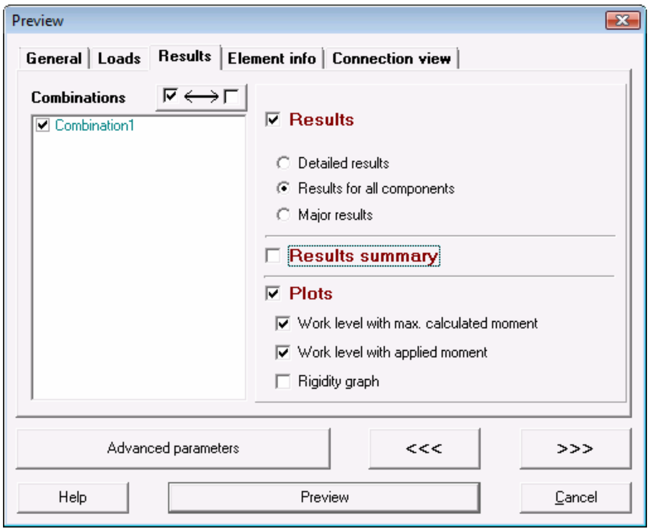


As soon as a proper lay-out has been defined, confirm by means of the 'OK'-button to return to the definition dialogue window.

Now switch to the second tab page, and make sure that the option 'Loads combinations' is selected. This will ensure that the report includes an overview of the loads combination that is part of this project, at least if 'Combination1' is selected as indicated below.

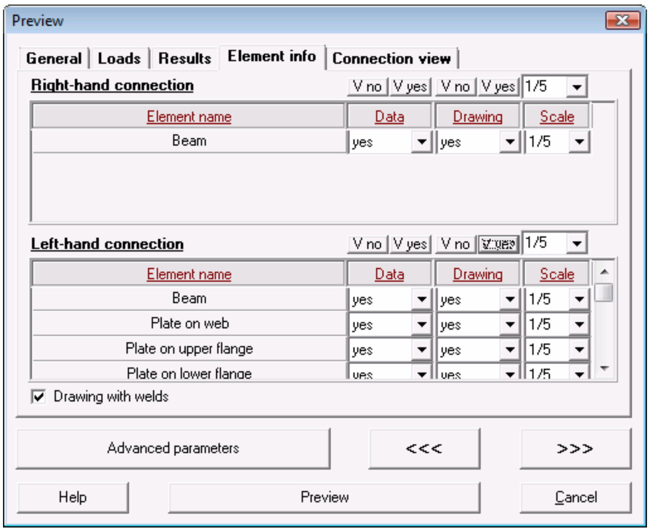


Now switch to the third tab page to specify how analysis results should be reported. Within this second reporting tutorial, the focus is on the creation of a more detailed analysis report. To do so, select the options ‘Results – Results for all components’ and ‘Plots’ as indicated below.

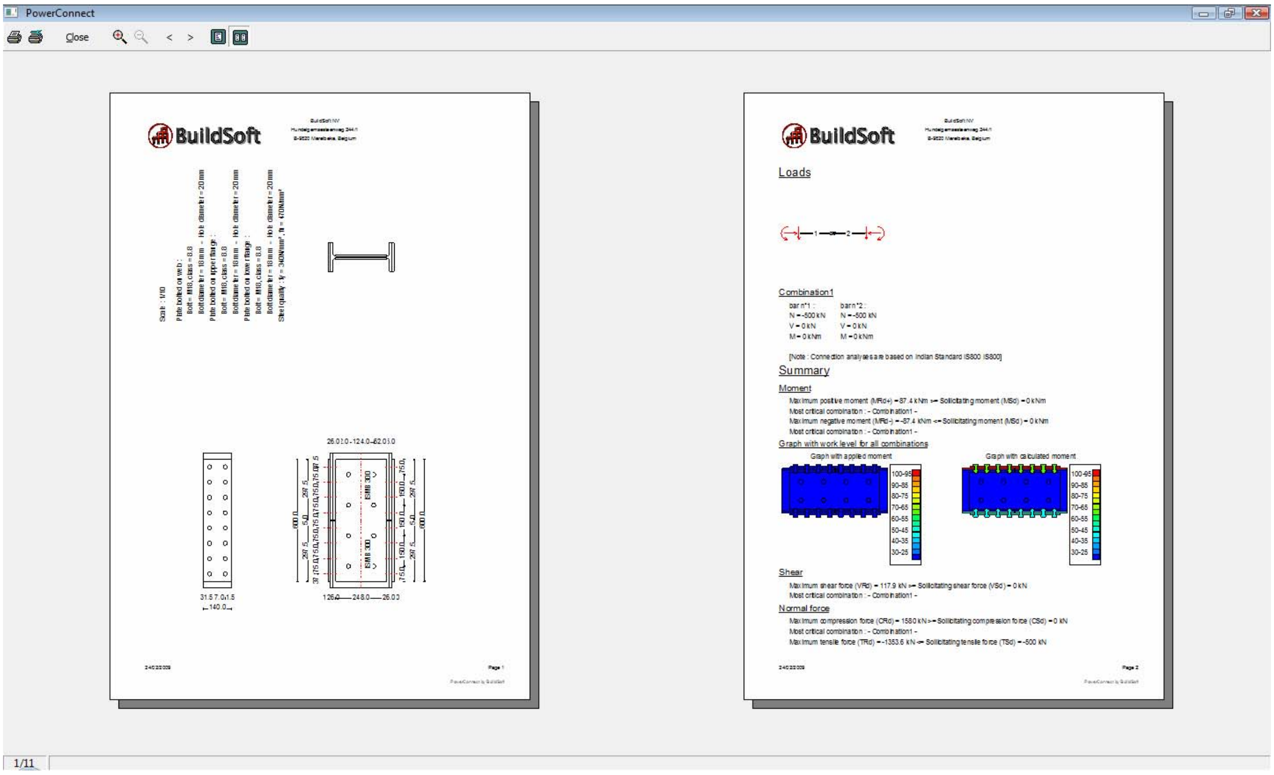


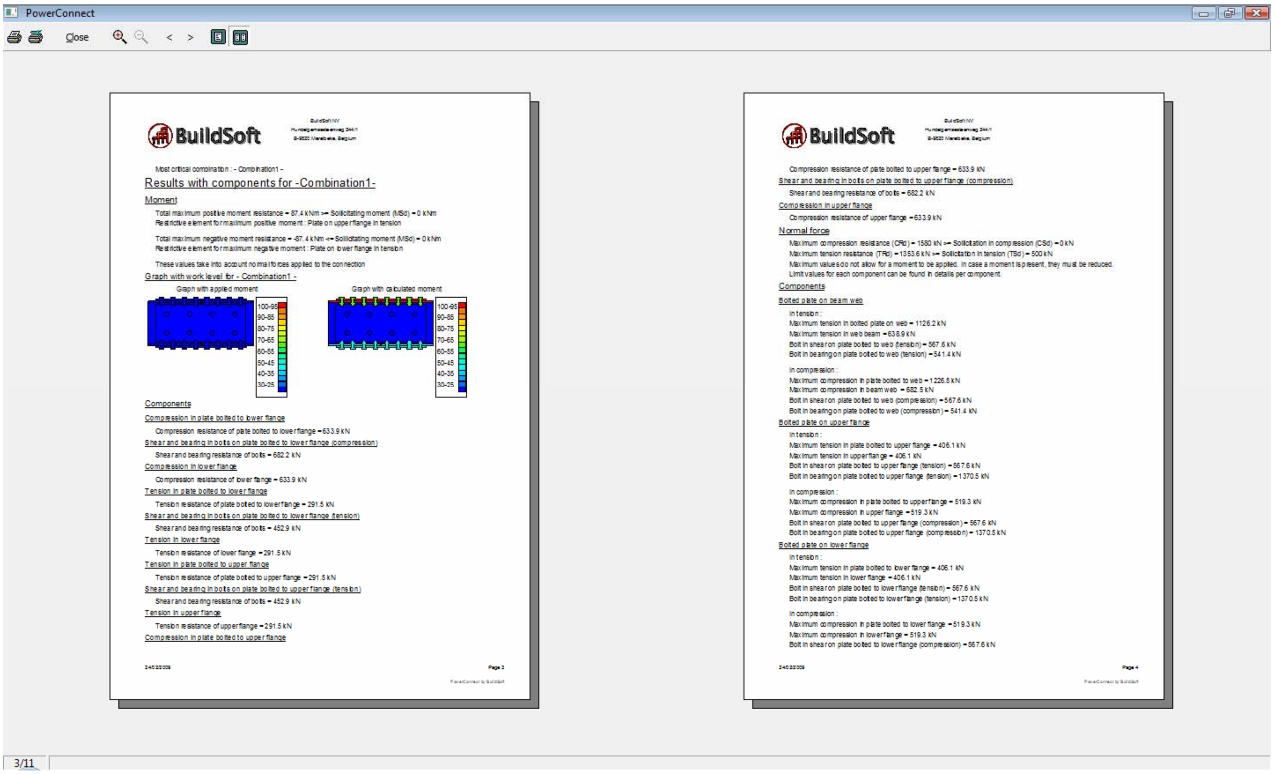
Now switch to the fourth tab page to specify that detailed drawings and data of all individual connection elements are to included into the report. For all elements, make sure to specify ‘Yes’ for both the ‘Data’ and ‘Drawing’ columns. This can be done for each entry individually, by selecting ‘Yes’ from the available pull-down menus. Alternatively, the buttons ‘V Yes’ on top of the columns can be used to convert globally to this setting for all elements.

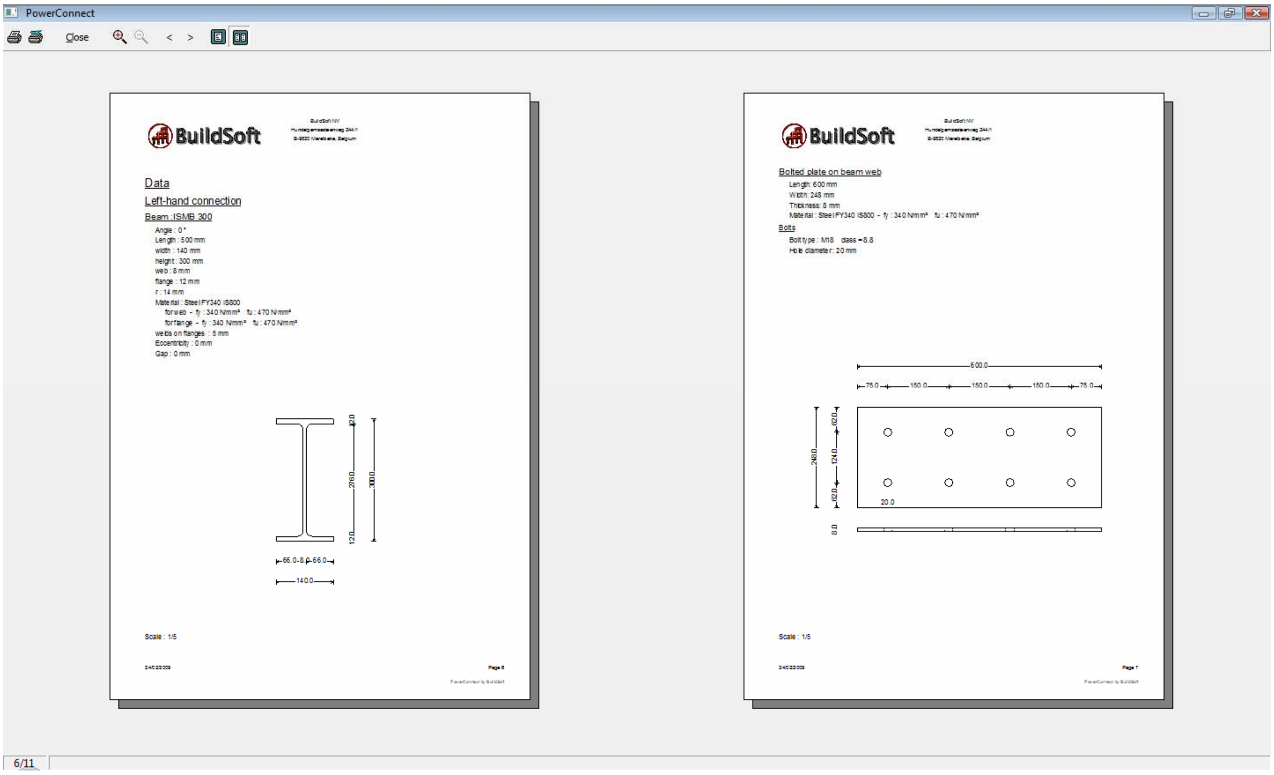
In the ‘Scale’ column, a proper scale can be defined to be used for the individual element drawings. Again, this scale can be defined globally by choosing the proper scale factor through the pull-down menu on top of the column. It should be remarked that the drawing will always be rescaled automatically by PowerConnect in case it will not fit on the selected page format. If it does fit, the scale as defined by the user will not be modified.



The report configuration can now be considered to be complete, and the report itself can be visualized by means of the ‘Preview’ button at the bottom of the dialogue window. The outcome will be a 10 page report as shown in part below (first 6 pages only).







In case the current report should be available in PDF-format, use the appropriate PDF button. If not, use the ‘Close’-button to return to the PowerConnect working environment. To actually print the report that has just been configured, use the icon to enter in **Print report** mode, and use the ‘Print’ button to send the report to the selected printer.

3.3 Tutorial 3 : shear connection – beam to column flange with fin plate (IS800)

This reporting tutorial is based on the model created in section 2.6 of this manual.

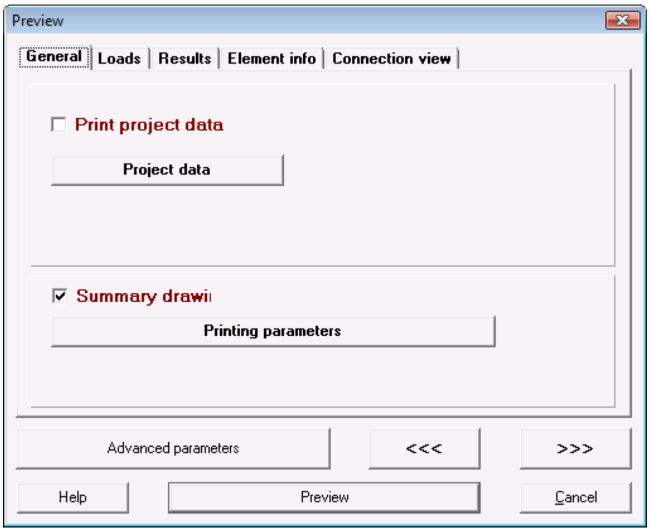
3.3.1 Page setup

No changes will be made to the page setup defined in section 3.1.1 of this manual. The user should return to this section for more information on the current page setup.

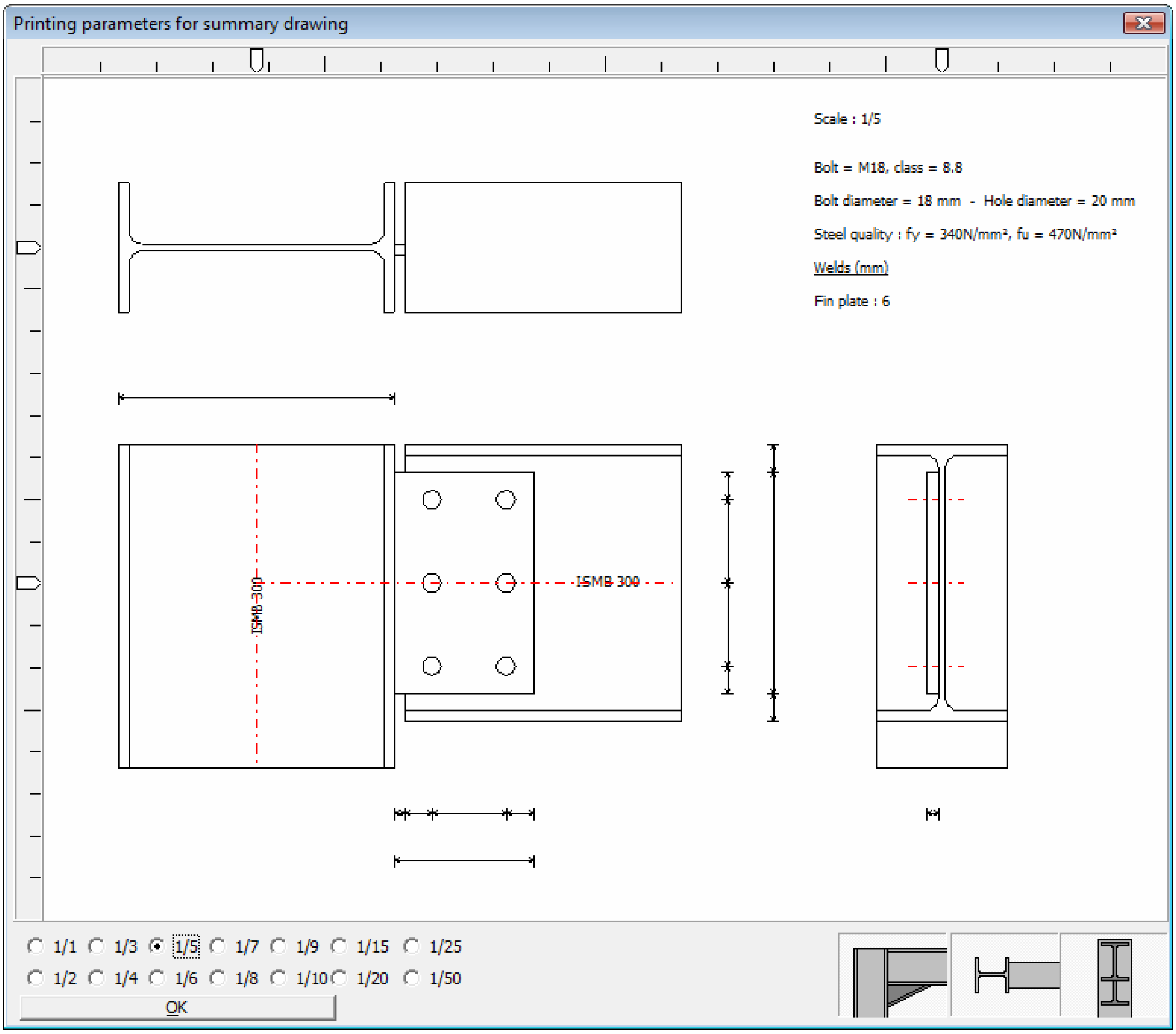
3.3.2 Report configuration

Go to **Preview** mode by means of the  icon of the icon toolbar.

Again, start by selecting the option ‘Summary drawing’ on the first tab page and define how this summary overview should look like by using the button ‘Printing parameters’, which opens a canvas window to complete the summary overview definition.

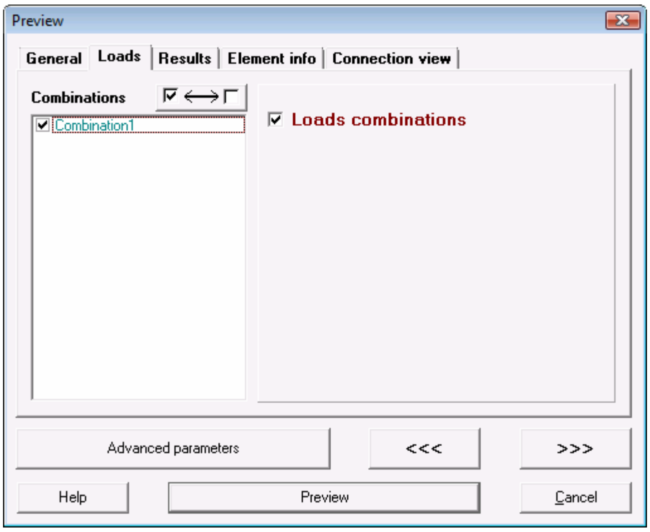


To create the kind of summary drawing shown below, make sure to select all connection views shown at the right-hand bottom part of the canvas window. Use the cursor icons to position the selected drawings in the appropriate positions, and also make sure the proper scale is selected (the selected scale of 1/5 is appropriate for a report on A4 paper format).

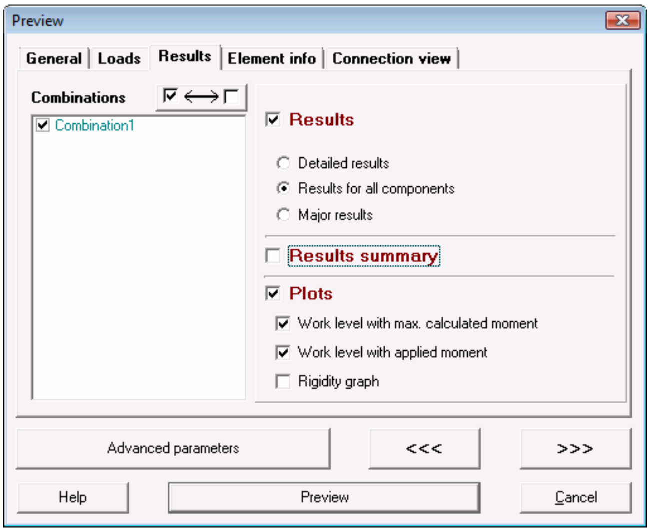


As soon as a proper lay-out has been defined, confirm by means of the ‘OK’-button to return to the definition dialogue window.

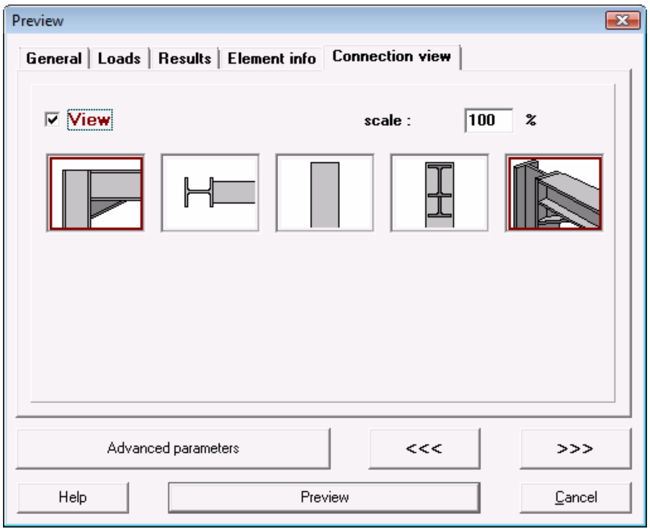
Now switch to the second tab page, and make sure that the option ‘Loads combinations’ is selected. This will ensure that the report includes an overview of the loads combination that is part of this project, at least if ‘Combination1’ is selected as indicated below.



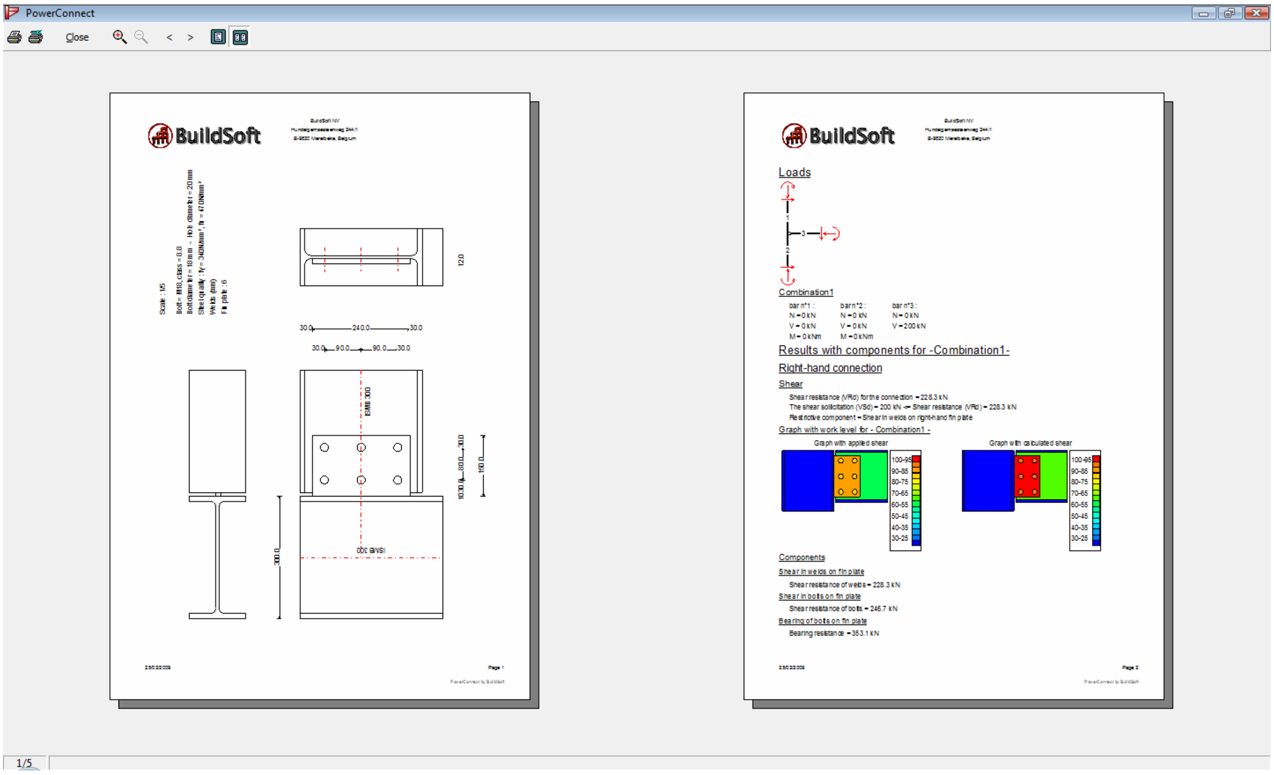
Now switch to the third tab page to specify how analysis results should be reported. Within this second reporting tutorial, the focus is on the creation of a more detailed analysis report. To do so, select the options ‘Results – Results for all components’ and ‘Plots’ as indicated below.

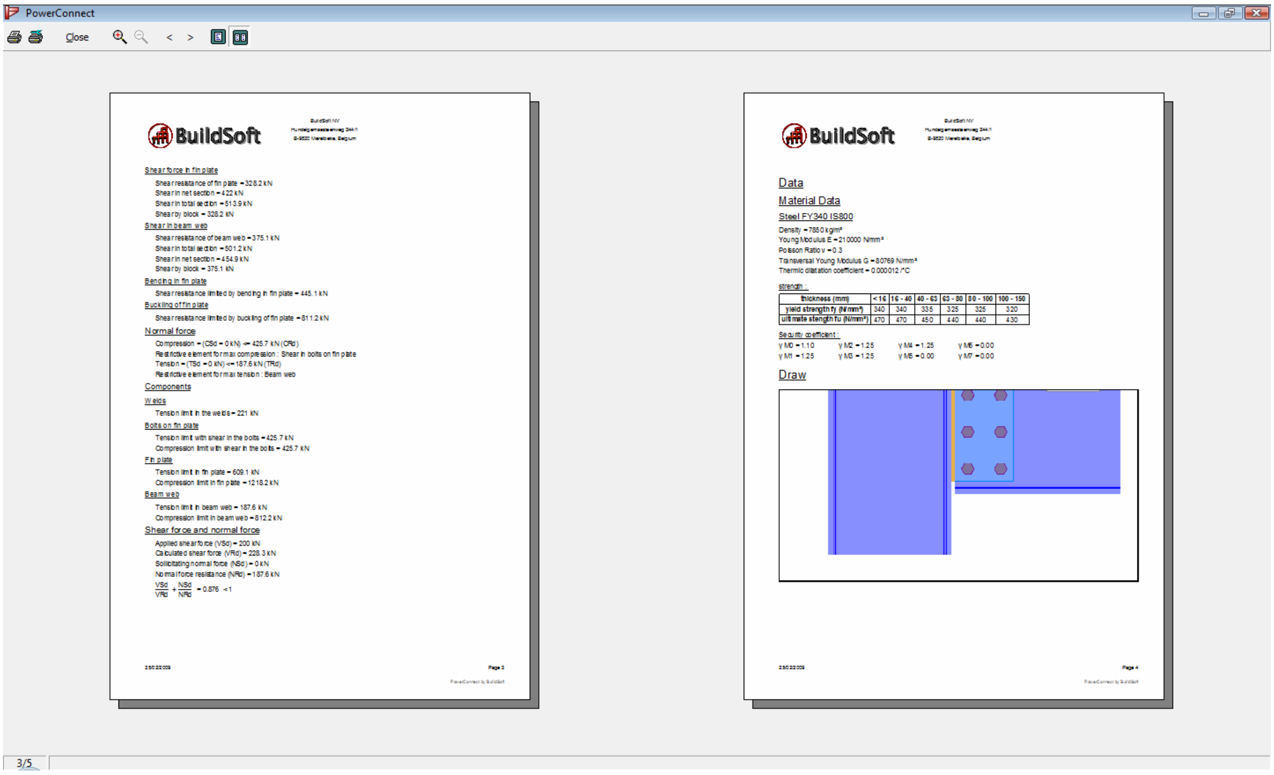


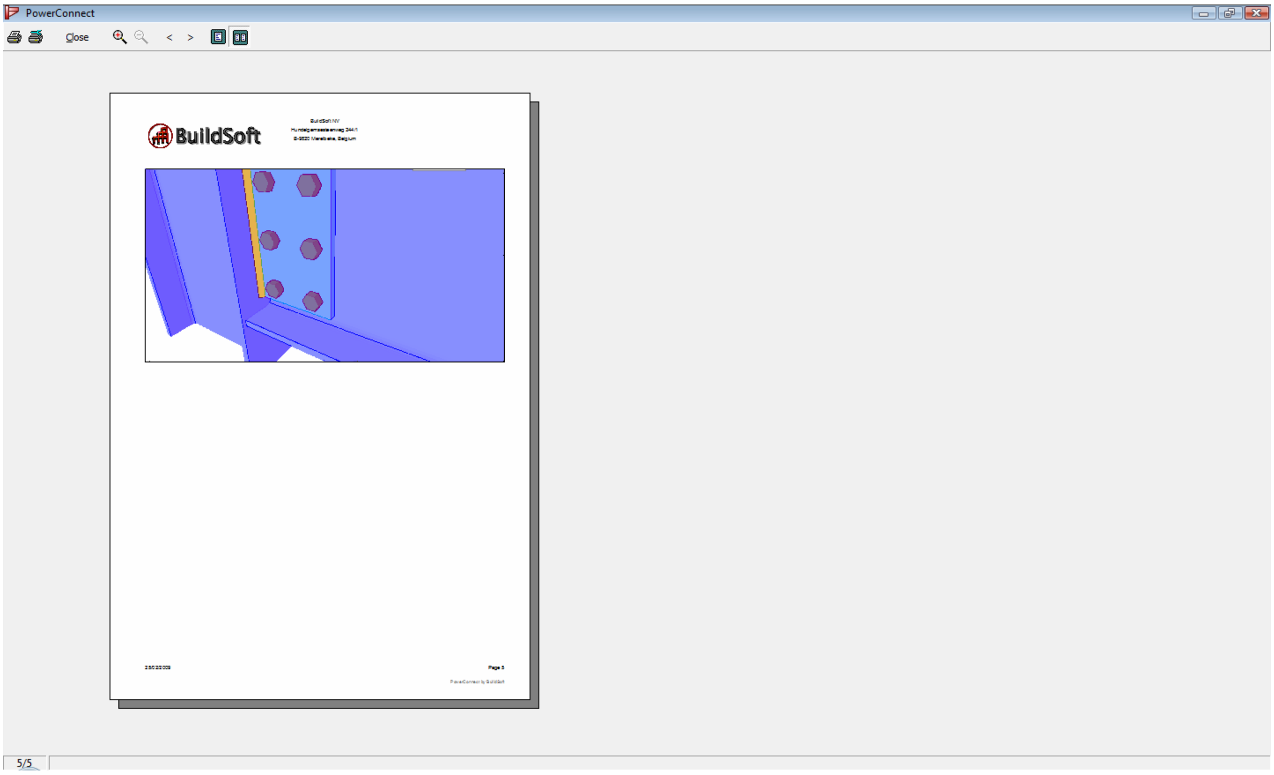
Now switch to the fifth tab page to specify that rendered views of the entire connection are to included into the report. Select the option ‘View’ and make sure to select both the 3D and the front view icons.



The report configuration can now be considered to be complete, and the report itself can be visualized by means of the ‘Preview’ button at the bottom of the dialogue window. The outcome will be a 5 page report as shown below.







In case the current report should be available in PDF-format, use the appropriate PDF button. If not, use the ‘Close’-button to return to the PowerConnect working environment. To actually print the report that has just been configured, use the icon to enter in **Print report** mode, and use the ‘Print’ button to send the report to the selected printer.