CFSteel

Version 4.2

Volume I

User's Guide

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INTRODUCTION

This release of CFSteel software is intended for design of structural members from cold-formed steel profiles for tension, compression and compression with bending. Additionally, separately you can calculate the geometrical characteristics of the total cross section, effective cross section and the net cross-section. It covers the following types of sections: Channel, Lipped Channel, Lipped Channel with double edge fold stiffeners, Lipped Channel with intermediate web stiffener, Sigma-section, Z-section and double profiles (except Z) from above sections (back-to-back). Calculations according to Eurocodes EN 1993 (EC3), North American Specification AISI S100-16 (AISI) and Russian code SP 260 and SP 16 are implemented. But in this document latter is not reflected. Also, for the tension members from Channel cross-sections it is possible to perform calculations by the methods proposed by G.L. Kulak and E.Y. Wu, C.L. Pan, L. H. Teh, B.P. and Gilbert.

Documentation related to CFSteel software consists of two parts: Volume I – User’s Guide and Volume II – Verification examples. The User’s Guide contains description of software, modes of operation with it, and background of computing methods. Volume II presents results of numerous test calculations in the CFSteel software, which compares with the experimental data and computational results of many researches.

DISCLAIMER

The developers have extensively verified this program and documentation. However, in using the program and documentation, the user accepts and understands that no warranty, expressed or implied, is made with regard to the accuracy of the results of the program. The program is intended for use by qualified professionals familiar with the design of cold-formed steel structural members. The user must be familiar with the relevant design codes, and must understand the basis for calculations and independently verify his own results. The user of CFSteel is responsible for the correctness of the input data and the interpretation of the results.

With best regards,
developers of CFSteel

1. CROSS-SECTION

1.1. General

The software considers the following types of cross-sections: Channel, Lipped Channel, Lipped Channel with double edge fold stiffeners, Lipped Channel with intermediate web stiffener, Sigma-section, Z-section and double profiles (except Z) from above sections (back-to-back) (Figure 1.1).

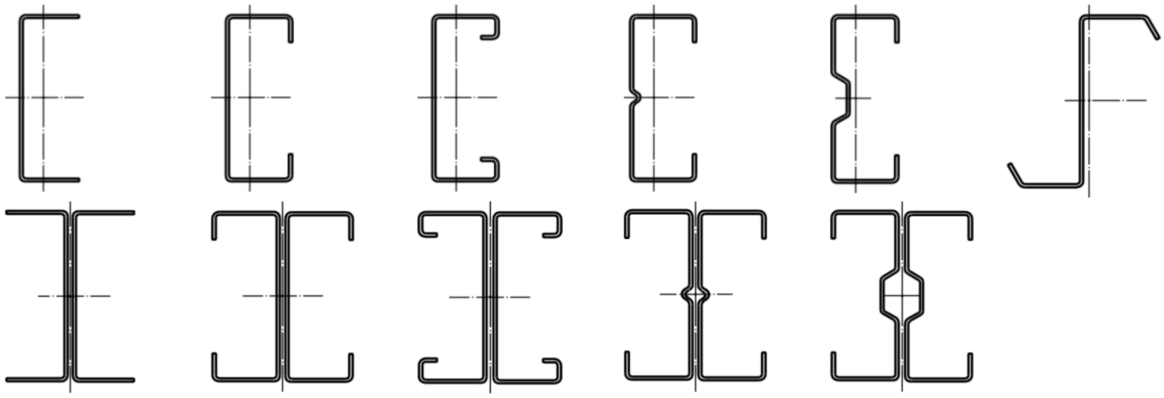


Figure 1.1 – Types of cross-section

1.2. Types of cross-section

1.2.1.1. Channel

A channel cross-section is presented in Figure 1.2. The possibility of different widths of flanges is provided. Permissible dimensions: height $h = 80 \ldots 400$ *mm,* nominal thickness $t = 0{,}7 \ldots 4$ *mm*, width of flanges $b_f = 40 \ldots 200$ *mm,* internal bend radius $r = 1 \ldots 8$ *mm.*

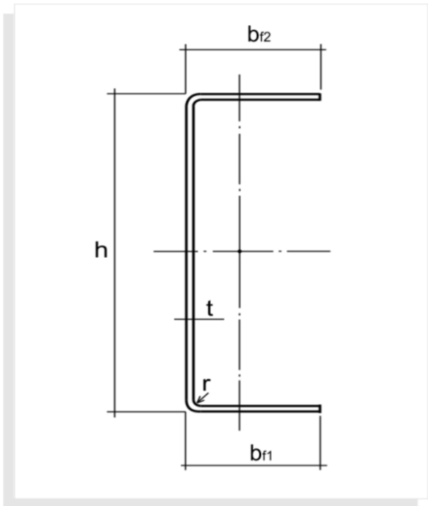


Figure 1.2 – Channel

1.2.2. Lipped Channel

A lipped channel cross-section is presented in Figure 1.3. In some cases the possibility of different widths of flanges, lips or lip angles (α_1, α_2) is provided. Permissible dimensions: *h = 80…400 mm, t = 0,7…4 mm,* b_f *= 40…200 mm, c = 5 mm…1/3 h, α = 60…120°, r = 1…8 mm.*

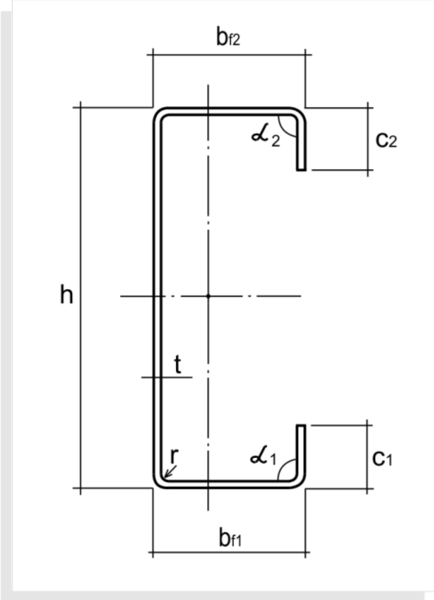


Figure 1.3 – Lipped Channel

1.2.3. Lipped Channel with double edge fold stiffeners

A lipped channel with double edge fold stiffeners is presented in Figure 1.4. In some cases the possibility of different widths of flanges, lips (c_1, c_2, d_1, d_2) or lip angles (α_3, α_4) is provided. Permissible dimensions: *h = 80…400 mm, t = 0,7…4 mm,* b_f *= 40…200 mm, c = 5 mm…1/5 h, d <* $1/3 b_f$ *, α = 90…135°, r = 1…8 mm.*

When calculating the effective cross-section properties, the vertical part of the lip is considered to be always effective.

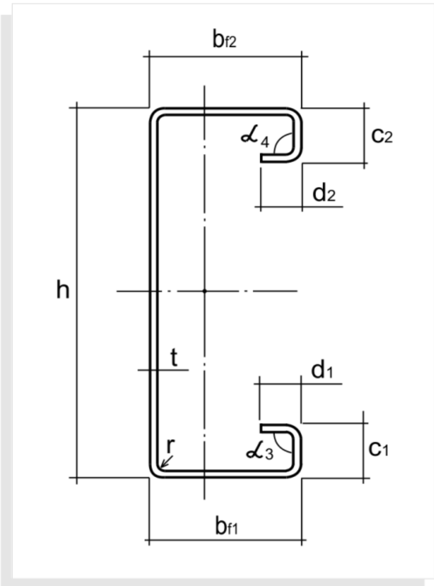


Figure 1.4 – Lipped Channel with double edge fold stiffeners

1.2.4. Lipped Channel with intermediate web stiffener

A lipped channel with intermediate web stiffener is presented in Figure 1.5. In some cases the possibility of different widths of flanges, lips or lip angles (α_1, α_2) is provided. Permissible dimensions: *h = 80…400 mm, t = 0,7…4 mm,* b_f *= 40…200 mm, c = 5 mm…1/3 h,* $d \geq 5$ *mm,* $1{,}5d \leq h_1 \leq 3d$, α *= 60…120°, r = 1…8 mm.*

When calculating the effective properties of the cross-section, the stiffness of web stiffener is considered to be adequate to prevent displacement along axis normal to the web. There remains a possible buckling of the web parts between stiffener and flanges.

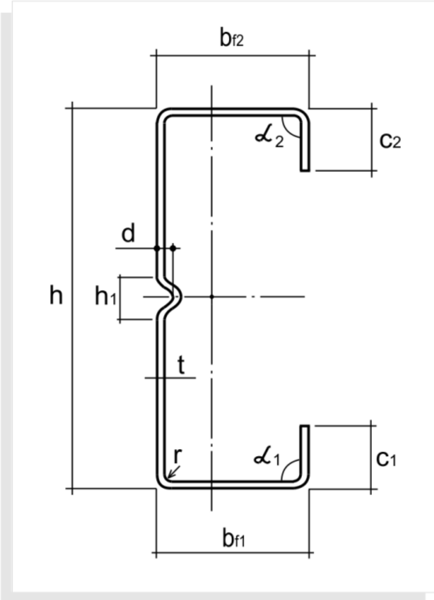


Figure 1.5 - Lipped Channel with intermediate web stiffener

1.2.5. Sigma-section

A sigma-section is presented in Figure 1.6. In some cases the possibility of different widths of flanges, different widths of lips is provided. Permissible dimensions: *h = 80…400 mm, t = 0,7…4 mm,* b_f *= 40…200 mm,* h_1 *= 40 мм…4/5 h,* $h_2 = h_1 - 2d…h_1 - d/3$, *d = 8 мм…*b_f*/2, c = 5 mm…1/3 h, r = 1…8 mm.* In this release of the software, the angles α_1 and α_2 can be set to only 90^0.

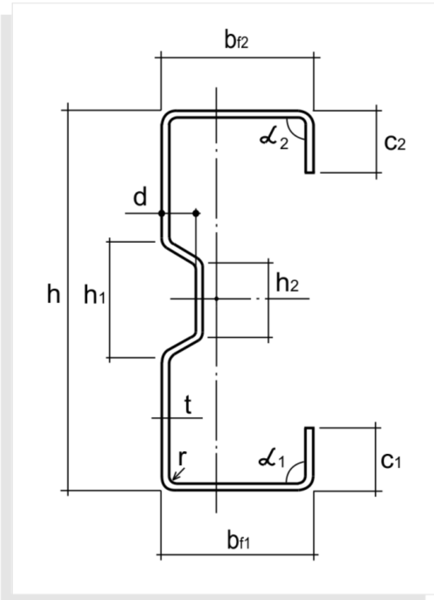


Figure 1.6 - Sigma-section

1.2.6. Double Channel

A double channel cross-section is presented in Figure 1.7. The section consists of two symmetrical channels (back-to-back). Distance between channels is $S \geq 0$. Permissible dimensions: $h = 80 \ldots 400$ *mm*, $t = 0{,}7 \ldots 4$ *mm*, $b_f = 40 \ldots 200$ *mm*, $r = 1 \ldots 8$ *mm*.

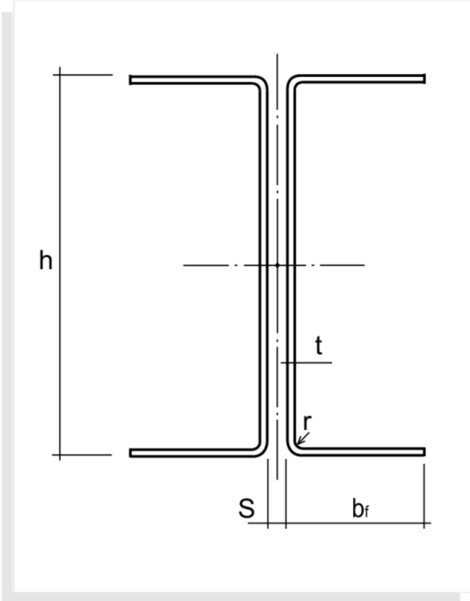


Figure 1.7 – Double Channel

1.2.7. Double Lipped Channel

A double lipped channel cross-section is presented in Figure 1.8. The section consists of two symmetrical lipped channels (back-to-back). The distance between the lipped channels is $S \geq 0$. Permissible dimensions: $h = 80 \ldots 400$ *mm*, $t = 0{,}7 \ldots 4$ *mm*, $b_f = 40 \ldots 200$ *mm*, $c = 5$ *mm*$\ldots 1/3\ h$, $\alpha = 60 \ldots 120°$, $r = 1 \ldots 8$ *mm*.

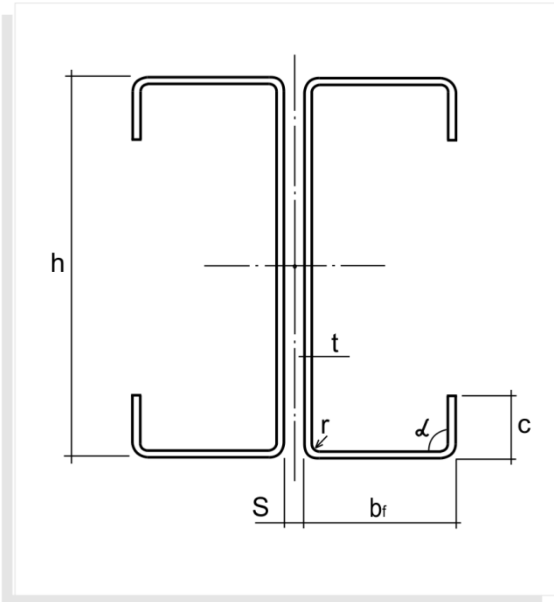


Figure 1.8 – Double Lipped Channel

1.2.8. Double Lipped Channel with double edge fold stiffeners

A double lipped channel with double edge fold stiffeners is presented in Figure 1.9. The section consists of two symmetrical lipped channels with double edge fold stiffeners (back-to-back). The distance between lipped channels is $S \geq 0$. Permissible dimensions: $h = 80 \ldots 400$ *mm*, $t = 0{,}7 \ldots 4$ *mm*, $b_f = 40 \ldots 200$ *mm*, $c = 5$ *mm*$\ldots 1/5\,h$, $d < 1/3 b_f$, $\alpha = 90 \ldots 135°$, $r = 1 \ldots 8$ *mm*.

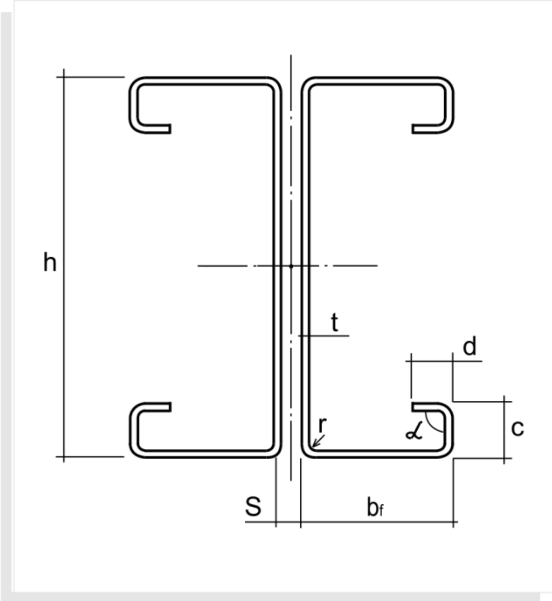


Figure 1.9 – Double Lipped Channel with double edge fold stiffeners

1.2.9. Double Lipped Channel with intermediate web stiffener

A double lipped channel with intermediate web stiffener is presented in Figure 1.10. The section consists of two symmetrical lipped channels with an intermediate web stiffener (back-to-back). The distance between lipped channels is $S \geq 0$. Permissible dimensions: $h = 80 \ldots 400$ *mm*, $t = 0{,}7 \ldots 4$ *mm*, $b_f = 40 \ldots 200$ *mm*, $c = 5$ *mm*$\ldots 1/3\,h$, $d \geq 5$ *mm*, $\alpha = 60 \ldots 120°$, $r = 1 \ldots 8$ *mm*.

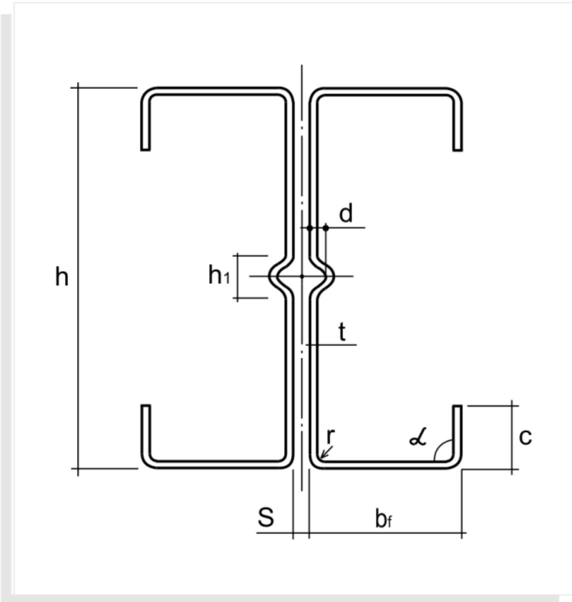


Figure 1.10 – Double Lipped Channel with an intermediate web stiffener

1.2.10. Double Sigma-section

A double Sigma-section is presented in Figure 1.11. The section consists of two symmetrical sigma-sections (back-to-back). The distance between sections is $S \geq 0$. Permissible dimensions: h = *80…400 mm*, t = *0,7…4 mm*, b_f = *40…200 mm*, h_1 = *40 мм…4/5* h, $h_2 = h_1 - 2d…h_1 - d/3$, d = *8 мм…*b_f */2*, c = *5 mm…1/3* h, r = *1…8 mm.* In this release of the software, the angles α_1 and α_2 can be set to only 90^0.

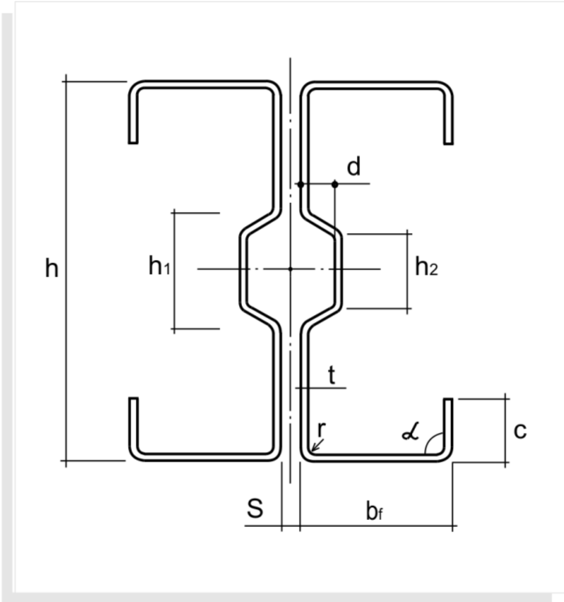


Figure 1.11 – Double Sigma-section

1.3. Section Library

Some cross-sections data bases are already preinstalled. However, a user can create own section library. This can be done in two ways. First, apply a built-in Cross-section Editor. Then, create a file according to the special rules and load it in a special folder. The user must have Administrator rights. If you try to edit the section libraries, you may face inability to save changes in the preinstalled database (file). In this case, first make a copy of a database (*Duplicate*). Then you can edit it and save.

1.3.1. Cross-section Editor

Cross-section Editor allows you to create a new database of sections, edit existing database, and delete the database from the library. To load the section Editor, in the main menu select *File → Section Library*. The main window of the Editor is presented in Figure 1.12.

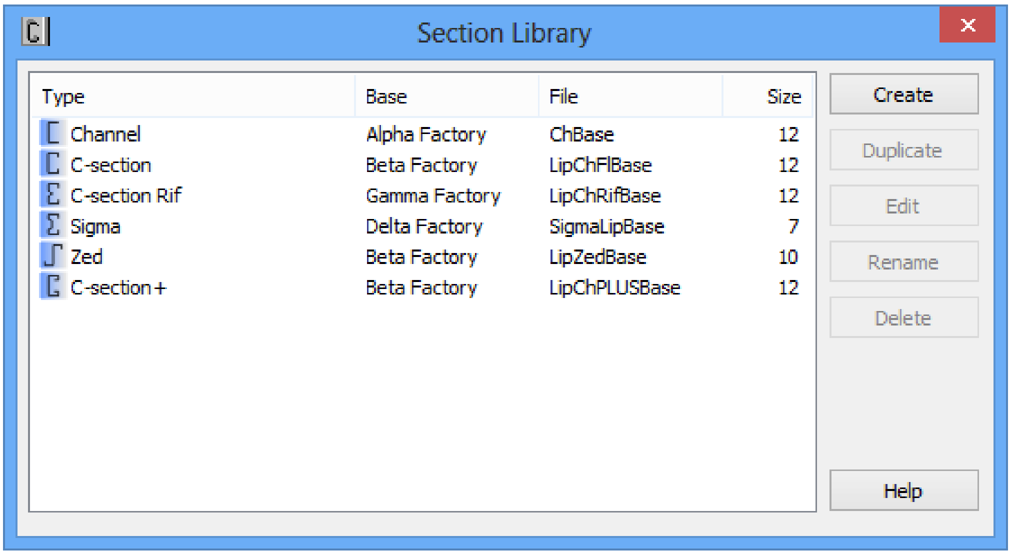


Figure 1.12 – Main window of Cross-section Editor

To create a new database of the section, select *Create*. Then in the window that appears (Figure 1.13) select the *Profile Type* from the list of profiles that are available in the program and an arbitrary *Profile Base Name* for database. The file name should not contain the path and the extension and should conform to the naming conventions in your operating system.

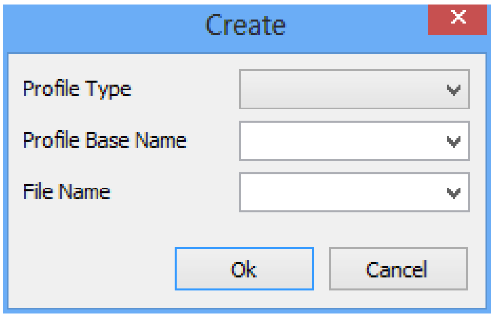


Figure 1.13 – Window *Create* of Cross-section Editor

After you click OK, you receive the data input window (Figure 1.14).

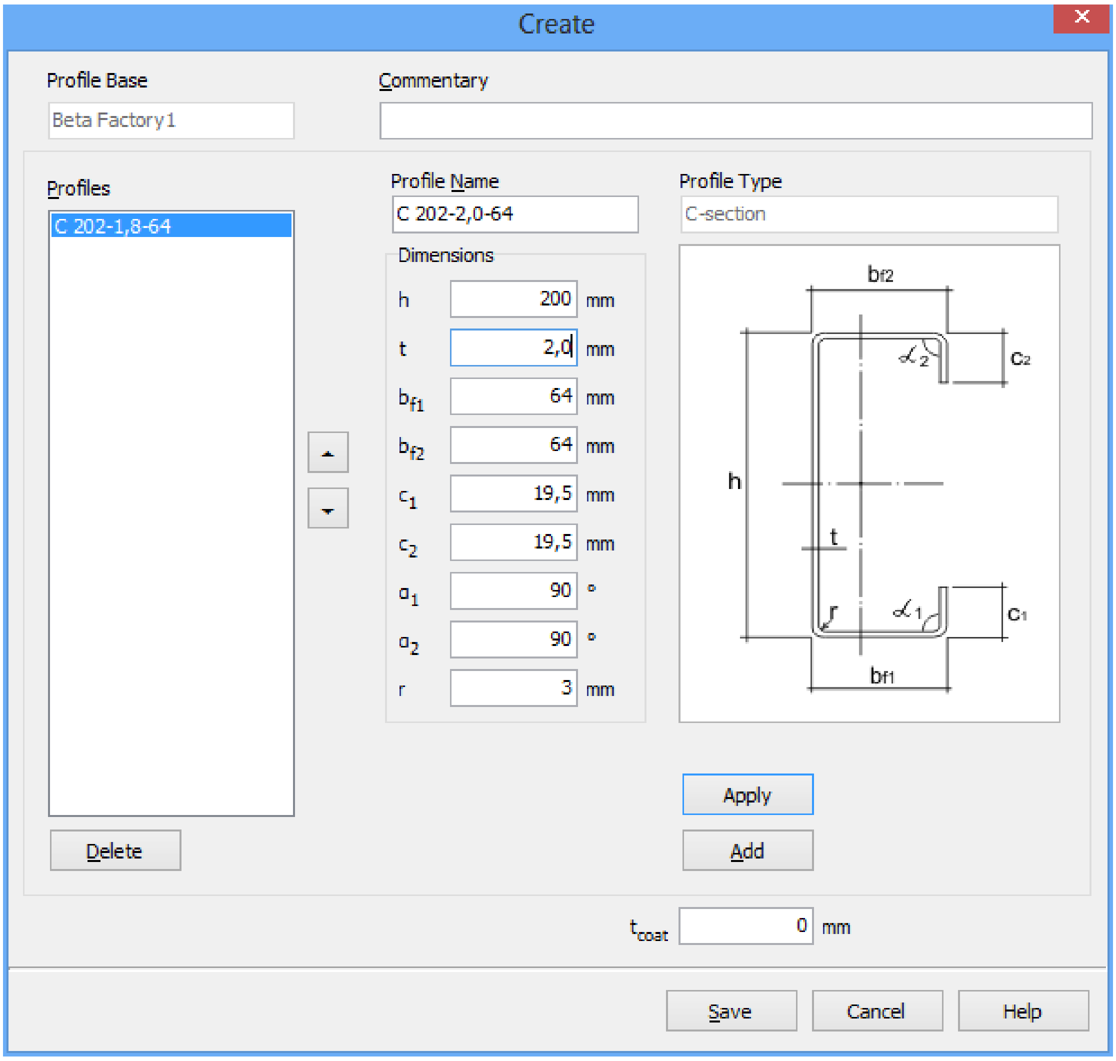


Figure 1.14 – Data input Window

You should enter the name of the section in the *Profile Name* field in the created database. Then enter the corresponding dimensions of the cross section, the thickness of the coating (e.g., zinc) and select button *Add*. The section with introduced name and dimensions will appear in the *Profiles* list. Then you enter the data for the next cross-section and click *Add*, etc. If incorrect data is entered into any section, they need to be repaired and you must click the button *Apply*. The *Delete* button deletes from the *Profiles* list the selected section. Buttons and move the highlighted section along the *Profiles* list. After entering data for all the sections of database, click *Save* to save the base.

To make any changes to the existing database of profiles, select *Edit* in the main window of section Editor. In the window *Edit* (Figure 1.15) you can edit a section name (*Profile Name* field), a cross-section *Dimensions* and the thickness of the coating. On the *Apply* button, there is a replacement of an old section by the altered one. The *Add* button adds a new section with the changed data into the database.

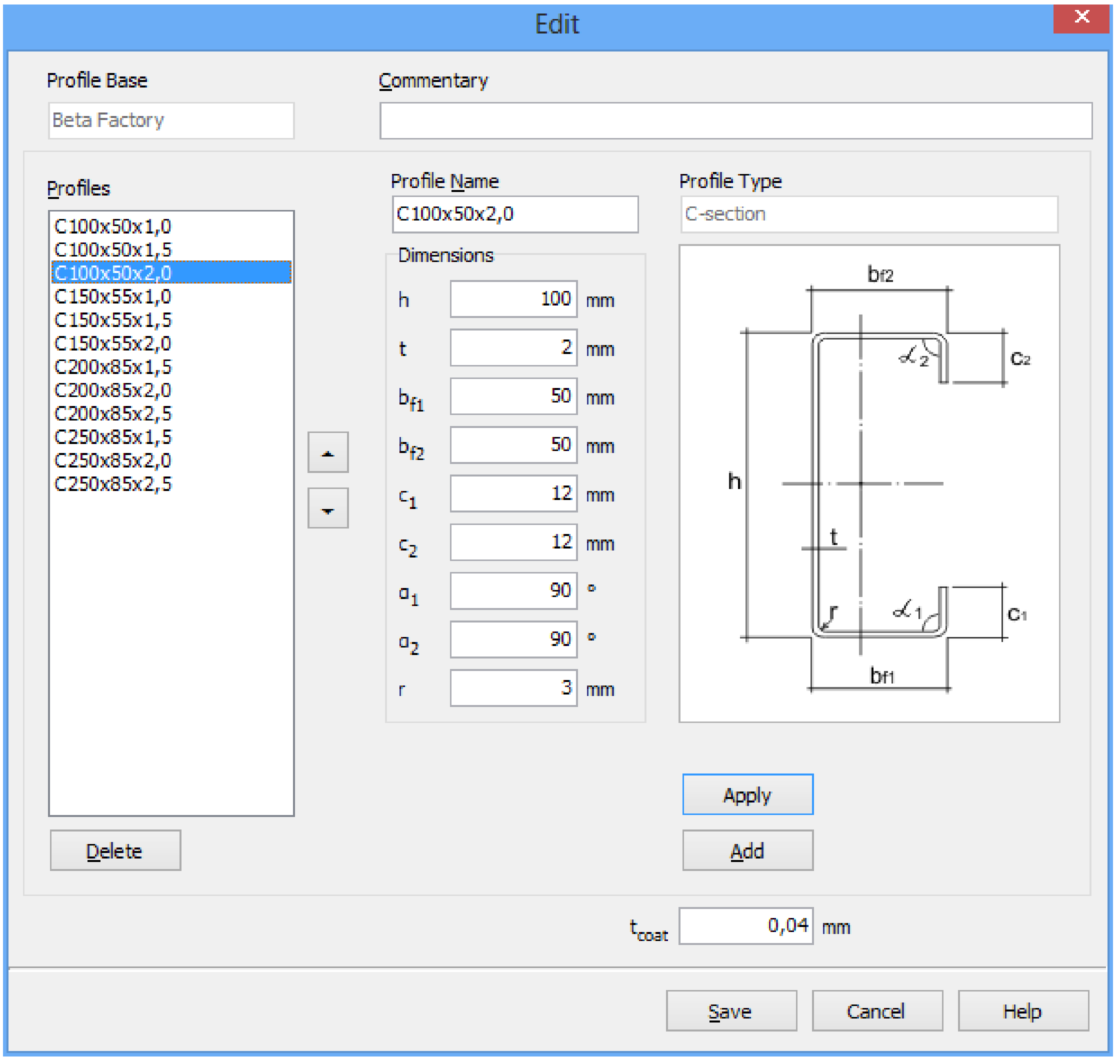


Figure 1.15 – Window *Edit*

To rename an existing database of sections, to reassign the file name to the database without changing the content, use the option *Rename* in the main window of the Editor.

Sometimes, it`s more convenient to create a new database of sections on the basis of the existing one. To do this, select *Duplicate*, enter a new Profile Base Name and a new file name. By OK, the database appears in the *Base* list of the main window. Highlight it and select *Edit*. By the means of Editor you can create a required profiles database.

To remove any database from the Library, select this base in the main window list and click *Delete*.

1.3.2. Creation of the Section Library without the use of the Editor

The user can create a profile library without using the section Editor. It may consist of one or more text (UTF-8) files. Each file contains one base of sections. The number of sections in the base is not limited and must be greater than zero. The file structure must meet the following requirements:

The first line must specify the section type from the list:

Channel	Channel
LippedChannelFlate	C-section
LippedChannelPLUS	C-section with double lips
LippedChannelRif	C-section intermediate web stiffener
SigmaProfileLip	Sigma-section

The second line specifies the name of database and (or) the profiles manufacturer.

The third line contains a commentary to the database of sections. If there are no commentaries, the line should remain empty.

The fourth line gives the steel coating thickness (for example, thickness of zinc coating) in *cm*.

In the fifth and subsequent lines the profile names are given in quotes through the gap (space) and its dimensions in *cm*, and in accordance with the constraints are described in clause 1.2.

The Channel section must be specified (Figure 1.2):

“Name” $h\ t\ b_{f1}\ b_{f2}\ r$

. . . .

The C-section must be specified (Figure 1.3):

“Name” $h\ t\ b_{f1}\ b_{f2}\ c_1\ c_2\ \alpha_1\ \alpha_2\ r$

. . . .

The C-section with double lips must be specified (Figure 1.4):

“Name” $h\ t\ b_{f1}\ b_{f2}\ c_1\ c_2\ d_1\ d_2\ \alpha_3\ \alpha_4\ r$

. . . .

The C-section with intermediate web stiffener must be specified (Figure 1.5):

“Name” $h\ t\ b_{f1}\ b_{f2}\ h_1$ *0.2(always)* $d\ c_1\ c_2\ \alpha_1\ \alpha_2\ r$

. . . .

The Sigma-section must be specified (Figure 1.6):

“Name” $h\ t\ b_{f1}\ b_{f2}\ h_1\ h_2\ d\ c_1\ c_2\ \alpha_1\ \alpha_2\ r$

. . . .

Figure 1.16 shows an example of the database file of Sigma profiles by the name of the manufacturer *Delta Factory*, an empty commentary string, the thickness of the zinc coating of 0,004 *cm.*

```
SigmaProfileLip
Delta Factory

0.004
"Sgm 150-45-1,0" 15 0.1  4.5 4.5 6 4 1 1.2 1.2 90 90 0.3
"Sgm 150-45-1,5" 15 0.15 4.5 4.5 6 4 1 1.2 1.2 90 90 0.3
"Sgm 150-45-2,0" 15 0.2  4.5 4.5 6 4 1 1.2 1.2 90 90 0.3
"Sgm 150-45-2,5" 15 0.25 4.5 4.5 6 4 1 1.2 1.2 90 90 0.3
"Sgm 250-65-1,5" 25 0.15 6.5 6.5 6 4 1 1.8 1.8 90 90 0.3
"Sgm 250-65-2,0" 25 0.2 6.5 6.5 6 4 1 1.8 1.8 90 90 0.3
"Sgm 250-65-2,5" 25 0.2 6.5 6.5 6 4 1 1.8 1.8 90 90 0.3
"Sgm 250-65-3,0" 25 0.3 6.5 6.5 6 4 1 1.8 1.8 90 90 0.3
"Sgm 350-80-1,5" 35 0.15 8 8 6 4 1 2 2 90 90 0.3
"Sgm 350-80-2,0" 35 0.2  8 8 6 4 1 2 2 90 90 0.3
"Sgm 350-80-2,5" 35 0.25 8 8 6 4 1 2 2 90 90 0.3
"Sgm 350-80-3,0" 35 0.3  8 8 6 4 1 2 2 90 90 0.3
```

Figure 1.16 – An example of the section database file

The file should be saved in a folder, its path can be found in CFSteel main menu item *Options → Program Options.* The file extension must be *.sct.

1.4. Steel Library

Numerous steels are already available in the program. However, the user can create his own steel library. This can be done in two ways. You can apply a built-in Steel library Editor or you can also create a file according to the special rules and load it into a special folder. The user must have Administrator rights.

1.4.1. Steel library Editor

Steel library Editor allows you to create new steel databases, edit existing databases and remove databases from the library. To load the steel Editor, select in Main menu *File* → *Steel Library*. The main window of the Editor presents in Figure 1.17.

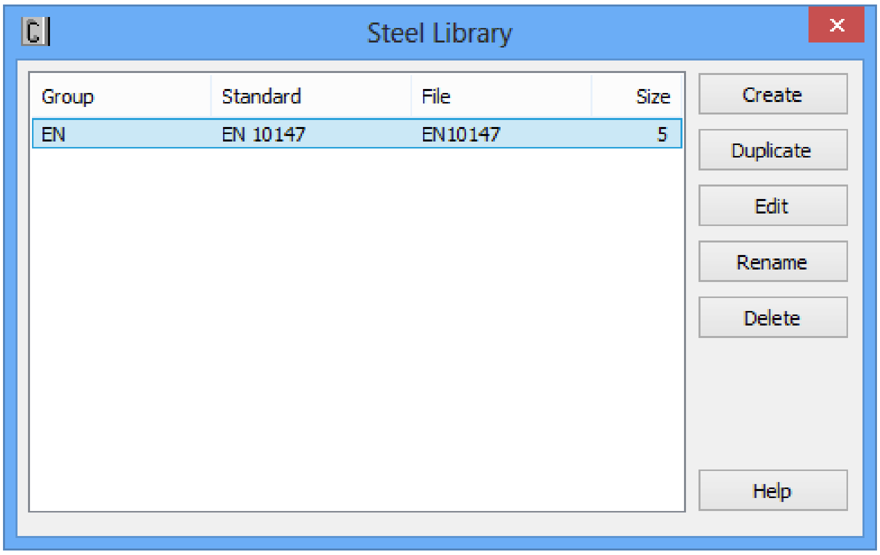


Figure 1.17 – Main window of *Steel library* Editor

To create a new steel database, select *Create*. For this database enter *Standard Group*, *Standard* and *File Name* in the window (Figure 1.18). The file name should not contain the path and the extension and should conform the naming conventions of your operating system.

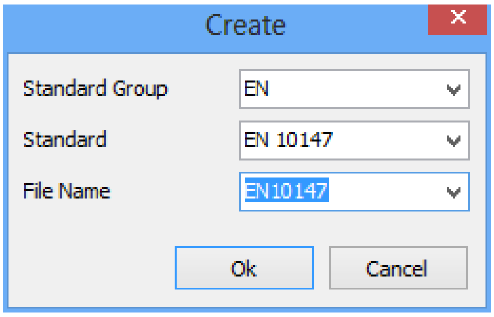


Figure 1.18 – Window *Create* of Steel library Editor

After clicking OK the dialog box of entry data opens (Figure 1.19).

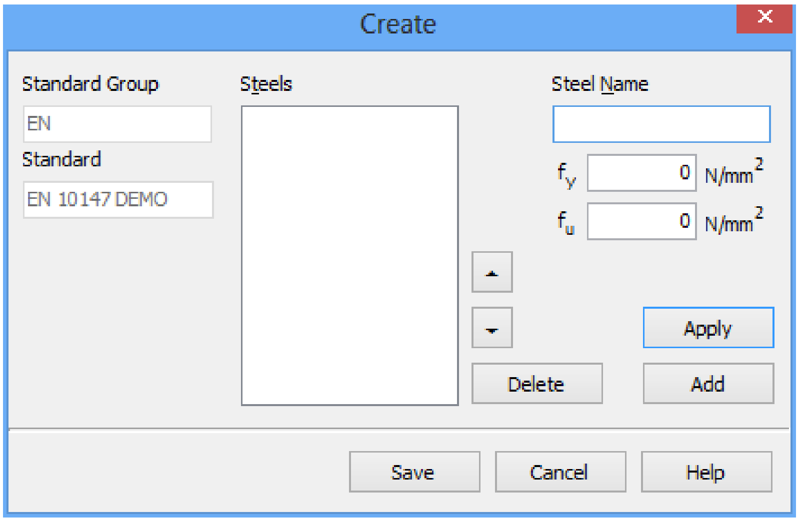


Figure 1.19 – Window of entry data

In the *Steel Name* field enter steel name. Then enter f_y and f_u. The *Add* button adds steel to the list of steels for this Standard.

If you click *Delete*, the selected steel is removed from the list of steels. The buttons and move selected steel along the list of steels. Enter all steels of *Standard* and click *Save*.

In order to make changes to the steel library which already exists, select *Edit* in the main window of the Editor. A window similar to the one shown in figure 1.19 will appear. For selected steel you can make changes in the field *Steel Name*, f_y and f_u. On the *Apply* button, there is a replacement of the old value on altered value. After editing, select *Add*. Steel with parameters from field *Steel Name*, f_y and f_u will be added to the list of steels.

Button *Rename* (Figure 1.17) allows you to rename an existing Standard, to reassign the file name for the Standard, or to put the Standard to the other Standard Group without changing the content.

It is convenient to create a new steel database on the basis of existing one. Select *Duplicate* and enter a new name of *Standard Group*, *Standard* (if required) and *File Name* (it is obligatory). Click *OK*. The database will appear in the list of standards. Highlight it and select *Edit*. Then enter the necessary changes.

To remove standard from the steel library, highlight this standard in the main window and click *Delete*.

To adjust the units and decimal places of stresses f_y and f_u, select *Options* → *Units and Decimal Places (clause 3.2)* from the main menu.

1.4.2. Creation of the Steel Library without using the Editor

The user can create a library of steels without using the Editor. It may consist of one or more text (UTF-8) files. Each file contains one steel database of one standard. The number of steel grades in the standard is not limited. The structure the file should satisfy the following requirements:

The first line specifies the standard group.

The second line specifies the name of the standard.

In the third and subsequent lines indicate the data for the each steel, which is included in this database. Each line consists of three positions separated by a single space. In the first position in quotes is the name of steel. The second position contains the yield strength in кN/cm^2. The third position contains the ultimate tensile strength in кN/cm^2. Figure 1.20 shows an example of the steel database file.

```
EN
EN 10147
"S220GD" 22 30
"S250GD" 25 33
"S280GD" 28 36
"S320GD" 32 39
"S350GD" 35 42
```

Figure 1.20 – An example of steel database file

The file must be saved in a folder, the path to which can be found in main menu *Options → Program Options (clause 3.3).* The file extension must be *.stl.

If the format of steel database doesn`t not fulfil the established pattern, a window with information about this discrepancy will appear.

1.5. Calculation of cross-section properties

You can calculate the properties of cross sections listed in clause 1.1 separately from other calculations. Single profiles can be asymmetric with respect to an axis perpendicular to the web. Double profiles should consist of a cross-section symmetrical about the axis perpendicular to the web.

The user can calculate the properties of a full cross-section, effective and net- cross-section.

You can select a section from the database or enter dimensions of cross-section using the standard dialogue (Figure 2.3.6). You should enter the nominal dimensions. Section properties are calculated for the design steel thickness $t = t_{nom} - t_{coat}$.

Section properties are calculated by usual rules of mechanics, always taking into account the radii of rounded corners.

Effective cross-section properties are calculated for yield stress, and can be calculated according to following codes: EC3 [1,2,14], AISI S100 [5] or SP 260 [17]. For AISI S100 Channel, Lipped channel and double sections from these sections are implemented only. Available load condition:

– Uniform compression;
– Bending about horizontal axis;
– Bending about vertical axis. Web is in compression;
– Bending about vertical axis. Lips are in compression.

For Zed, the effective section properties under uniform compression and bending about the axis perpendicular to the web are calculated.

When calculating the effective section properties according to AISI S100 [5] the holes in any case are not taken into account.

The properties of net cross-section are calculated for the section weakened by holes. Holes can be placed on the web and the flanges according to the type of section.

To input data, select in main menu *Section*. Then, an input window appears, as shown in Figure 1.21.

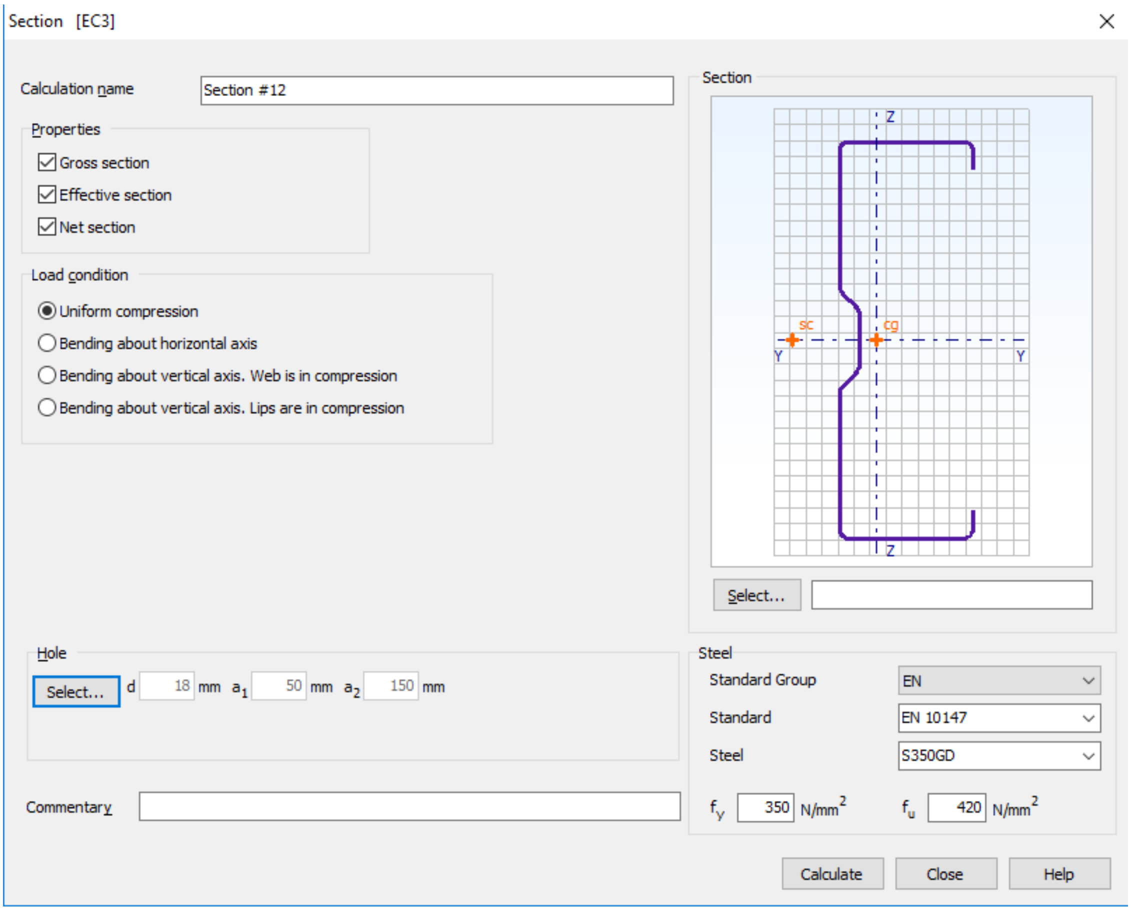


Figure 1.21 – Input data window for calculation of section properties

Calculation results are displayed on the screen and, if necessary, they can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the calculation results is divided into two parts (Figure 1.22). The right side shows a cross-section of a member. The left part contains several tabs. *General data* tab displays the data entered by the user. On the *Gross-section properties*, *Effective cross-section properties* and *Net cross-section properties* tabs displays the corresponding results.

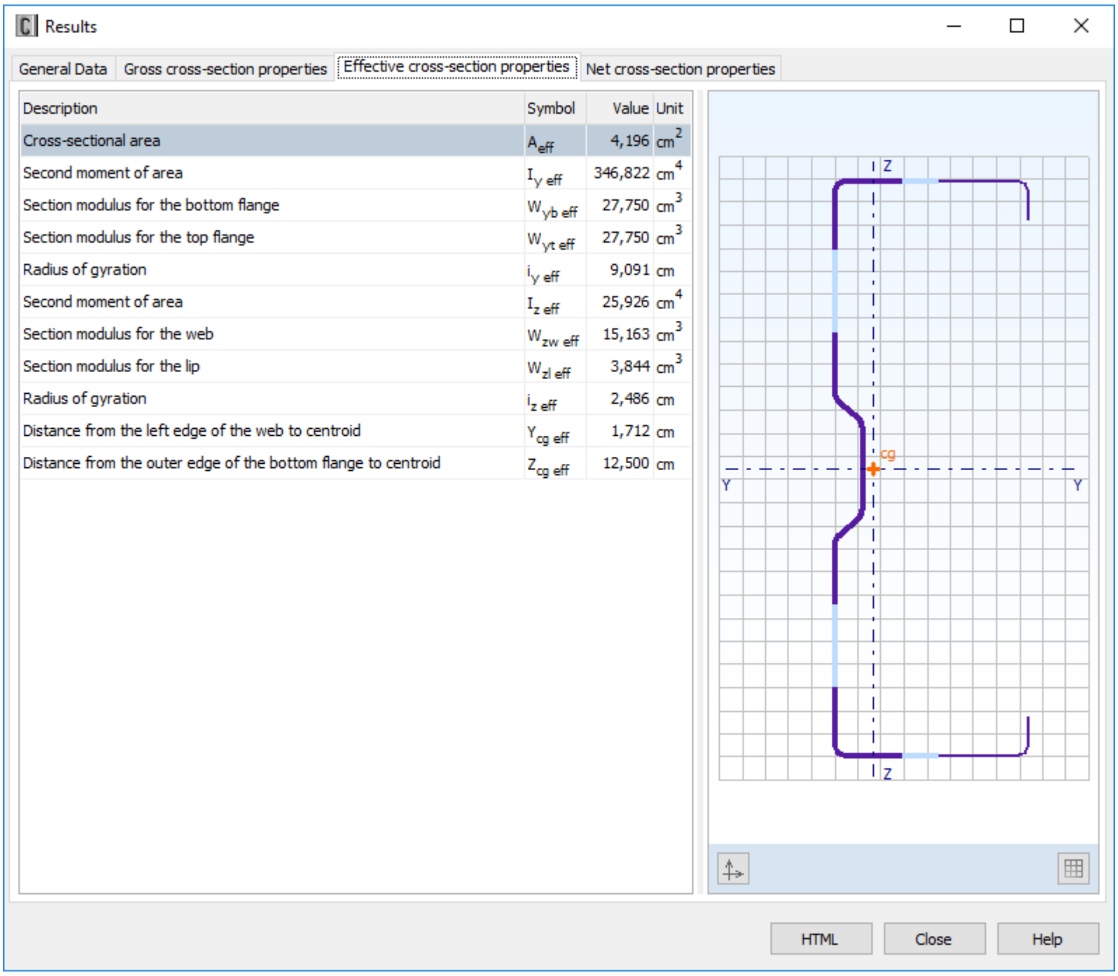


Figure 1.22 – Window of results: *Effective cross-section properties*

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in Microsoft Excel® for further processing or converted to HTML format.

2. STRUCTURAL MEMBERS

2.1. General

The calculation of members in tension, compression and compression with bending are implemented in this software release.

A member may consist of a single profile or double profiles (back-to-back). The following cross-section types are taken into consideration (Figure 1.1): Channel, Lipped Channel, Lipped Channel with double edge fold stiffeners, Lipped Channel with an intermediate web stiffener, Sigma-section. It is assumed that the attachment of a structural member to the adjacent elements (for example, a gusset plate, etc.) is carried out by using nonfrictioned bolted connections. The calculation of the member bearing capacity is performed in cross-sections along the length of the element, taking into account its possible weakening, and at the point of the attachment.

A mandatory condition of an axial compression is the application of compressive force at the center of gravity of the cross section of the member. The second condition is the absence of a local and distortional buckling. The latter applies only for single cross-section members. If at least one of these phenomena occurs, the member is calculated as a compressed one with eccentricity.

Members compressed with bending (beam-column) are calculated as follows: a) members compressed with eccentricity, b) members with axial compression force and bending moment. In single section profiles the eccentricity or bending moment acts in the plane perpendicular to the web. In double section profiles the eccentricity or bending moment acts in the plane of the web. The bending moment can arise from the application of transverse loads or to be directly applied to the ends of the member. The simultaneous presence of the eccentricity and the bending moment is not provided. A letter designation of the axes in the cross sections is made in accordance with the applied codes.

Design results are displayed on the screen and, if necessary, can be transferred to Microsoft Excel® for the further processing or converted to HTML format.

The window of the design results is divided into two parts. A right side shows a cross section of a member. A left part can contain from three to six tabs, depending on the design type (tension or compression), codes and the availability of calculations which are based on the net cross-section. A *General Data* tab displays the data entered by the user. A *Gross cross-section properties* tab contains the properties of the gross cross-section, including the weight per meter of the profile. *Effective cross-section properties* and *Net cross-section properties* tabs show relevant properties of the cross-section. The presence or absence of these tabs depends on the type of the design.

The *Design results* tab is functionally divided into two parts. The upper part contains a list of the executed checks (design criterion). This list depends on the codes, according to which design is performed, the values of the entered data, as well as the design settings defined by user in the menu item *Options → Design Details* (clause 3.1). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates if the check is satisfied or not, and the clause (section) or the formula (equation) of the relevant code, according to which this calculation was performed.

In the bottom of the window detailed information is provided about the values of the calculation parameters included in the current check. Each parameter is given: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.

Units within the metric system and number of decimal places a user can set in the main menu *Options → Units and decimal places* (clause 3.2).

By clicking the button located at the bottom of the window, the user can submit information about the performed calculation in Microsoft Excel® for further processing or convert to HTML format. You can define in the menu item *Options → Program Options* (clause 3.3) where it will be sent to the output stream by default. Also, you can specify the full amount of information or some part of it will be converted.

To identify results in printed form it is recommended to enter the name of a member/calculation and detailed comments in the fields *Member Name*, *Commentary* of the input windows.

2.2. Net cross-section

If a member has a cross section with holes along the length, a user is provided with the option to enter the location and diameter of the holes in such sections. It is done differently for tensioned and compressed members.

A *Select…* button is provided in the calculation of compressed members in the appropriate dialogue windows. The dialogue box shown in Figure 2.2.1 appears after clicking.

Presence of holes in the web and flanges is provided. There can be from one up to four holes with arbitrary location in the web. There can be only an even number of holes on the web for Lipped Channel with an intermediate web stiffener and Sigma-section. A flange can have only one hole. In the top and bottom flanges holes can be located (in general case) in different places. There can be different hole diameters in web and flanges.

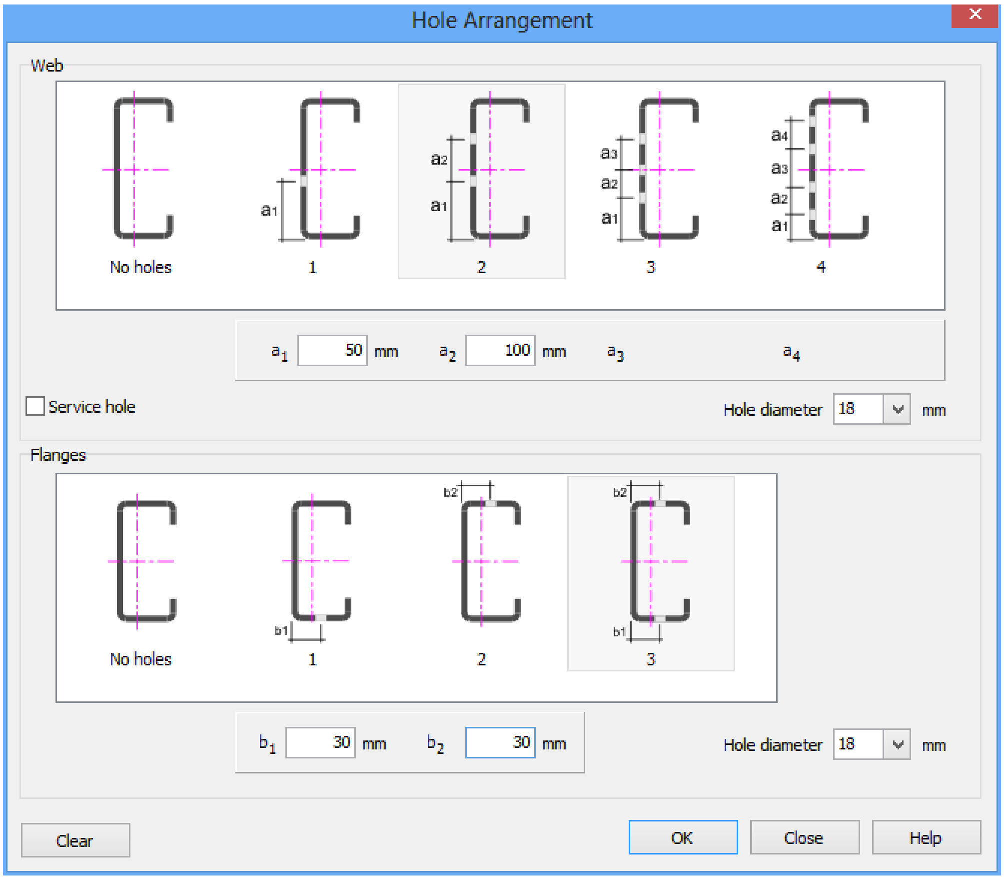


Figure 2.2.1 – Window for entering data about the holes

If a member has a cross-section with a service hole (for example, for the communication), in this case it is necessary to mark *Service hole* and enter its dimensions. Simultaneous presence of bolt holes and service hole is not provided.

The *Clear* button resets the entered data and returns to the section without holes.

For tensioned members in areas of attachment to adjacent structure elements location of the holes in the cross-section is as important, as their placement along tension force. That`s why the input of a pattern of holes in attachment for tensioned members is made in a different way. Detailed description is given in the relevant clauses associated with design of tensioned members.

2.3. Design according to European code EC3

2.3.1. National Annexes

You can configure the CFSteel individually according to any National Annex by entering appropriate design parameters in the menu item *Options → Design Details* (clause 3.1). Definition of the following parameters is given below:

– partial factors γ_{M0}, γ_{M1} and γ_{M2} EN 1993-1-1 clause 6.1(1) [1], EN 1993-1-3 clause 2(3) [2];
– imperfection factors for lateral torsional buckling curves α_{LT} clause 6.3.2.2 [1];
– parameters $\overline{\lambda}_{LT,0}$, β clause 6.3.2.3(1) [1] and $\chi_{LT\,mod}$ clause 6.3.2.3(2) [1].

2.3.2. Tension

2.3.2.1. Design procedure

Axial tensioned members may consist of a single profile or double profiles (back-to-back). It is assumed that the attaching of a structural member to the adjacent elements (for example, a gusset plate, etc.) is carried out by using nonfrictioned bolted connections. The design is performed in the member connection and along the member taking into account possible weakening. The attachment is implemented through the web of cross-section, through the flanges of cross-section or through the web and the flanges together (Figure 2.3.1).

The following calculations are performed for tensioned members:

– prevention of excessive elongation of the member;
– prevention of rupture of weakened cross-section if the weakening takes place along the member;
– the slenderness check.

At the point of attachment the calculations are carried out according to the following criteria:

– prevention of rupture of the weakened by bolt holes cross-section;
– check the bearing resistance of a member;
– check the block shear resistance at the connection.

At the point of attachment only the calculations related to capacity of the member are performed. The comprehensive design of connection is not possible. User should calculate the connection separatly.

In general, the design is performed in the form of inequality

$$\frac{N_{Ed}}{N_{t,Rd}} \le 1, \tag{2.3.1}$$

where N_{Ed} is the design normal force, $N_{t,Rd}$ is the design value of the resistance to tension normal force in accordance with the design criterion.

The design resistance of the gross cross-section $N_{tg,Rd}$ is determined by:

$$N_{tg,Rd} = f_{ya} A_g / \gamma_{M0}\,, \tag{2.3.2}$$

where A_g is the gross area of the cross-section, γ_{M0} is the partial factor for resistance of cross-section to excessive yielding (6.1 [1], 2(3) [2]). You may edit the value of γ_{M0} in accordance with the National Annex of any country. On default γ_{M0} =1,0 as recommended in the General part of EC3.
f_{ya} is the average yield strength (3.2.2(3) [2]):

$$f_{ya} = f_{yb} + (f_u + f_{yb})\frac{knt^2}{A_g} \leq \frac{f_u + f_{yb}}{2}, \tag{2.3.3}$$

where f_{yb} is the nominal value of basic yield strength, f_u is the ultimate tensile strength, k is a numerical coefficient that depends on the type of forming as follows: k=7 for roll forming; k=5 for other methods of forming, n is a number of 90^0 bends in the cross-section, t is a design core thickness of the steel material before cold-forming, exclusive of metal and organic coatings.
A user can choose (clause 3.1) whether to apply an average yield strength f_{ya} or a nominal value of basic yield strength f_{yb} in (2.3.2). While calculating the cross-section area design thickness $t = t_{nom} - t_{coat}$ is taken into account.

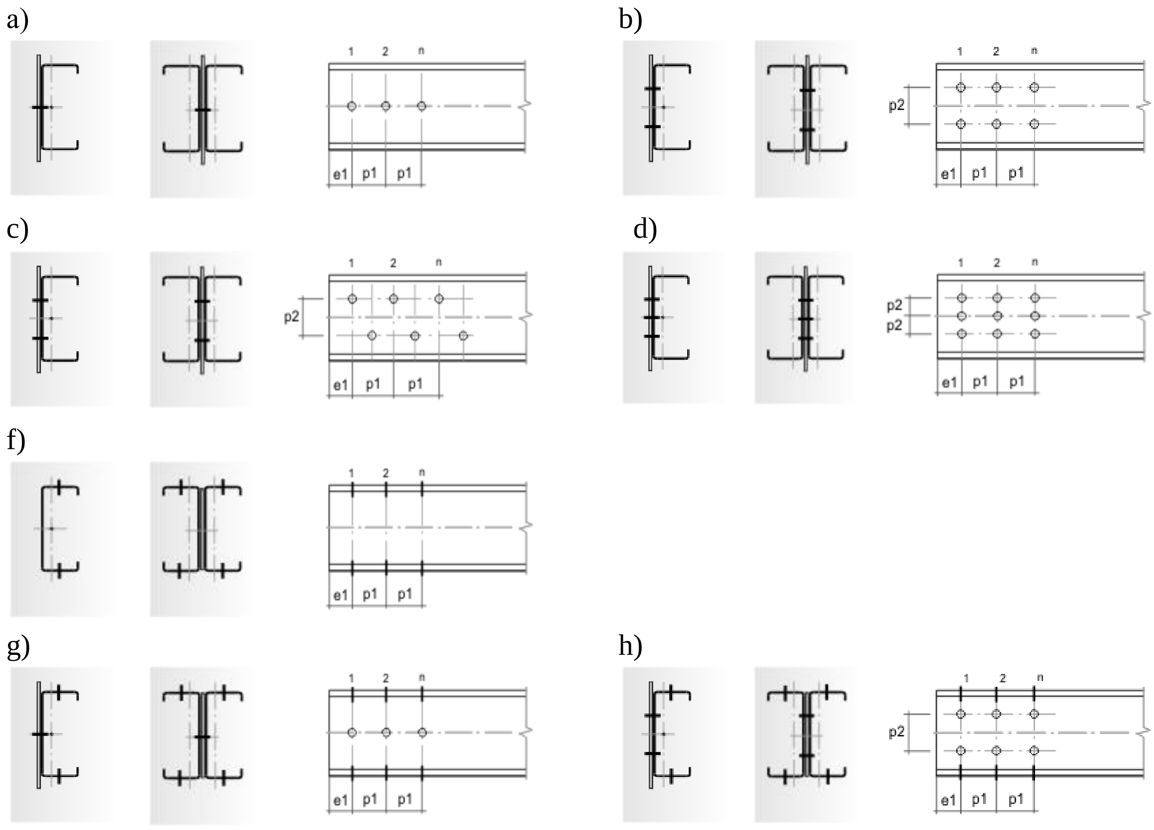


Figure 2.3.1 – Attaching of members: a,b,c,d – through the web;
f – through the flanges; g,h – through the web and the flanges

If a member includes weakening along the length, the design resistance of a net cross-section along the member $N_{tn,Rd}$ is determined by (6.2.3(2) [1])

$$N_{tn,Rd} = 0,9 A_n f_u / \gamma_{M2}, \tag{2.3.4}$$

where A_n is the net area of the cross-section along the member (weakening should be symmetrical about the longitudinal axis of the member (clause 2.3.2.2)); γ_{M2} is a partial factor for resistance of a net cross-section to fracture at bolt holes. You may edit the value of γ_{M2} in accordance with the National Annex. On default γ_{M2} =1,25 is as recommended in the General part of EC3.

Slenderness check (if required; see clause 3.1) is performed in accordance with the inequality

$$\lambda_{max} \leq \lambda_u, \tag{2.3.5}$$

where λ_{max} is a maximum slenderness of the member: $\lambda_{max} = \max(\lambda_y, \lambda_z)$; λ_u is an ultimate slenderness, which is specified by the user; $\lambda_y = \mu_{ty}L/i_y$, $\lambda_z = \mu_{tz}L/i_z$; $\mu_{ty} = \mu_{tz}=1$; L is the length of the member; i_y and i_z are the radiuses of gyration of gross cross-section.

The design resistance for rupture in a net cross-section at the connection with the holes for element connected only by one part (the wall or the flanges) is determined by (6.2.3(5) [1], 6.1.2(2) [2], 3.10.3 [3]:

– two cross rows of the bolts

$$N_{tu,Rd} = \beta_2 A_n f_u / \gamma_{M2} , \tag{2.3.6,a}$$

– three or more cross rows of the bolts

$$N_{tu,Rd} = \beta_3 A_n f_u / \gamma_{M2} , \tag{2.3.6,b}$$

where β_2 *and* β_3 are reduction factors dependent on the pitch p_1 (Figure 2.3.1) as given in Table 3.8 [3]. For intermediate values of p_1 the value of β is determined by the linear interpolation, A_n is the net area of the cross section taking into account clause 6.2.2.2 [1] if it is necessary.

While calculating a cross section net area (if the member is connected by the flanges), only a part of the web is taken into account, adjacent to every flange, but it does not exceed the sum of a flange width and a lip width.

The design resistance for rupture in the net cross-section (if a member connected by whole cross-section (Figure 2.3.1,g,h)) is determined as a minimum value of (2.3.2) and (clause 6.1.2(1) [2]):

$$N_{tu,Rd} = (1 + 3r\left(\frac{d_0}{u} - 0{,}3\right))A_n f_u / \gamma_{M2} \ \leq \ A_n f_u / \gamma_{M2}, \tag{2.3.7}$$

where r = [number of bolts at the cross-section] / [total number of bolts in the connection], d_0 is the nominal diameter of the hole, $u = 2e_2 \leq p_2$ (Table 8.4 [2]), A_n is the cross-section net area in the connection.

The design bearing resistance of a member with $t < 3$ *mm* at the connection is determined by (Table 8.4 [2])

$$N_{tb,Rd} = 2{,}5 k_t \alpha_b f_u d_b t n_b / \gamma_{M2} , \tag{2.3.8}$$

where $0{,}75\ mm \leq t \leq 1{,}25\ mm$ $k_t = (0{,}8t + 1{,}5)/2{,}5$; for $t > 1{,}25\ mm$ $k_t = 1$; α_b is the minimum value of 1,0 and $e_1/(3d_b)$; d_b is the diameter of the bolt; n_b is the number of bolts in the connection.

For $t \geq 3mm$ the design bearing resistance is determined (Table 3.4 [3]):

$$N_{tb,Rd} = k_1 \alpha_b f_u d_b t n_b / \gamma_{M2} , \tag{2.3.9}$$

where a) for edge bolts: k_1 is the smallest of $2{,}8e_2/d_0 - 1{,}7$ or 2,5; b) for inner bolts k_1 is the smallest of $1{,}4p_2/d_0 - 1{,}7$ or 2,5; α_b is the smallest of α_d , f_{ub}/f_u or 1,0. In the direction of load transfer: for end bolts $\alpha_d = e_1/3d_0$; for inner bolts $\alpha_d = p_1/3d_0 - 1/4$. f_{ub} is the ultimate tensile strength of the bolt.

The twice value of design bearing resistance is taken for double cross-sections.

The design block shear resistance at the connection according to clause 3.10.2 [3]

$$N_{tbs,Rd} = k_t f_u A_{nt} / \gamma_{M2} + \left(\frac{1}{\sqrt{3}}\right) f_y A_{nv} / \gamma_{M0}, \tag{2.3.10}$$

where A_{nt} is the net area subjected to tension; A_{nv} is the net area subjected to shear; k_t is a coefficient, that depended on eccentricity of connection. Figure 2.3.2 presents implemented cases of block shear.

For case b) $k_t = 0{,}5$. In other cases of member connecting $k_t = 1$. The twice value of design block shear resistance is taken for double cross-sections. If the connection has one longitudinal row of bolts, the calculation for block shear is not implemented.

Numeric values of γ_{M0} and γ_{M2} may be edited by a user in accordance with any National Annex (clause 3.1).

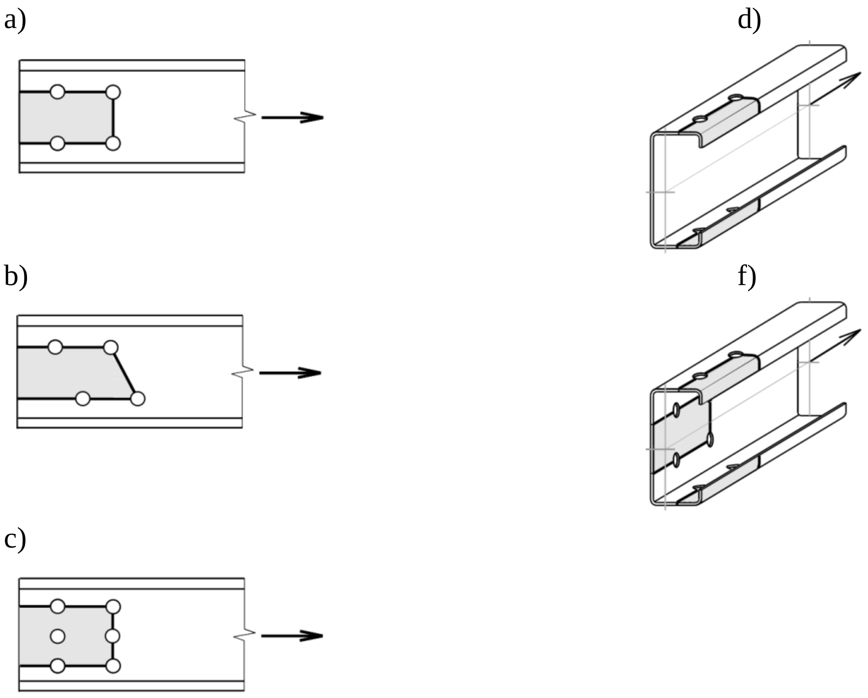


Figure 2.3.2 – Cases of block shear

2.3.2.2. Input data

To input data, select in main menu *Member → Tension*. In the input window *Tension* (Figure 2.3.3) you can enter a member name (name of calculation or design), a design tension force N_{Ed}, a member length L.

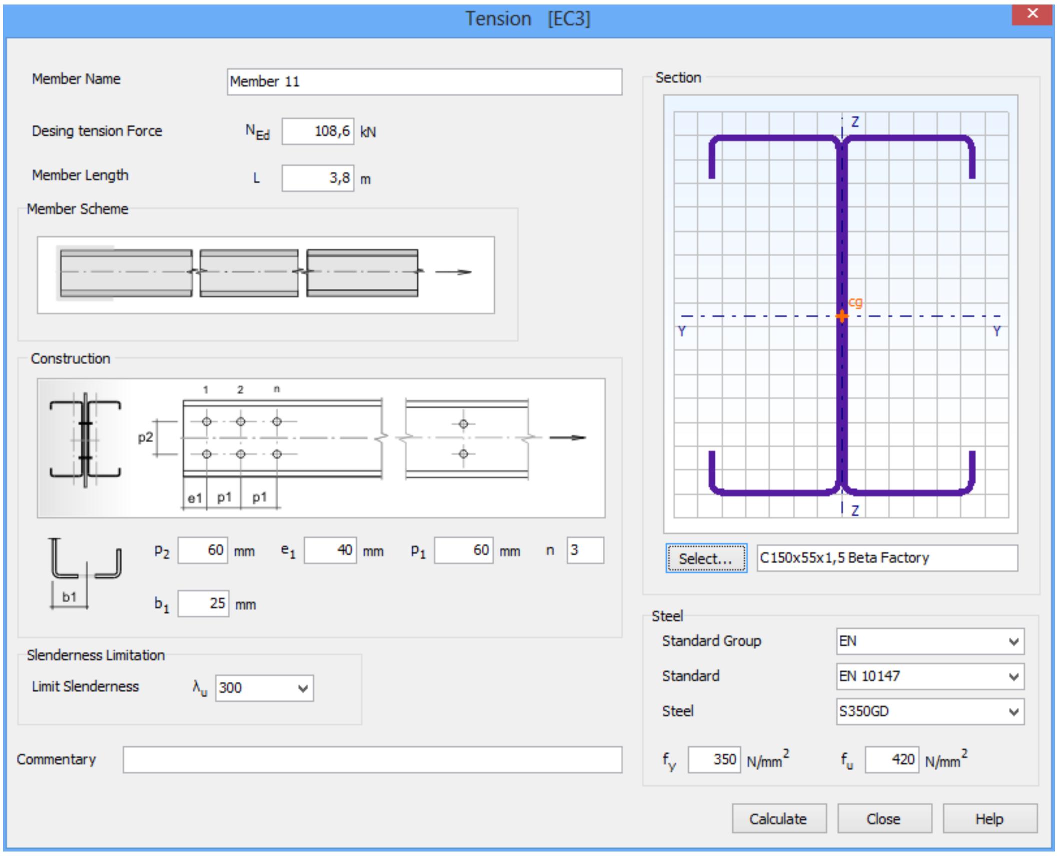


Figure 2.3.3 – Input data window for tension members

To determine the construction of the attachment to the adjacent element, click the left mouse button at the place of connection in the *Member Scheme* (Figure 2.3.3). In the dialog box *Type of Connection* (Figure 2.3.4) select the construction of the connection to adjacent elements. A hole diameter at the point of attachment is defined in the main menu item *Options* → *Design Details* → *General*.

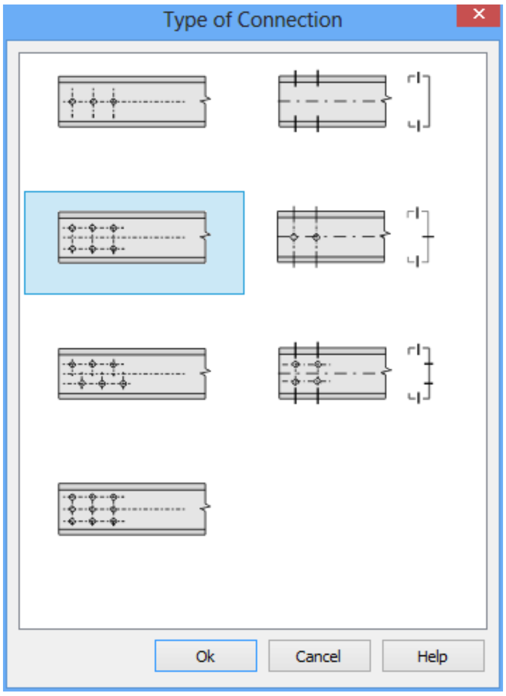


Figure 2.3.4 – Dialog box *Type of Connection*

If there is a weakening along the member, you should click the left mouse button at the middle part of the member on the *Member Scheme* (see Figure 2.3.3). In the dialog box *Type of Opening along the Member* (Figure 2.3.5) select construction of the weakening and input the diameter of the equivalent hole. By varying the diameter, you can enter the equivalent value of another form of weakening. It is assumed, that opening is symmetrical about longitudinal axis of the member.

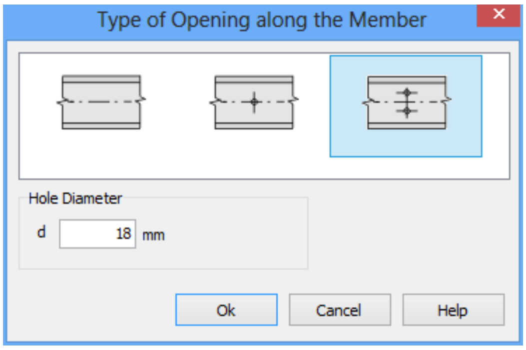


Figure 2.3.5 – Dialog box *Type of Opening along the Member*

Then you can input dimensions of the connection (Figure 2.3.3).

To select a cross-section of the member, click a button *Select*. Figure 2.3.6 presents the window *Profile Selection*.

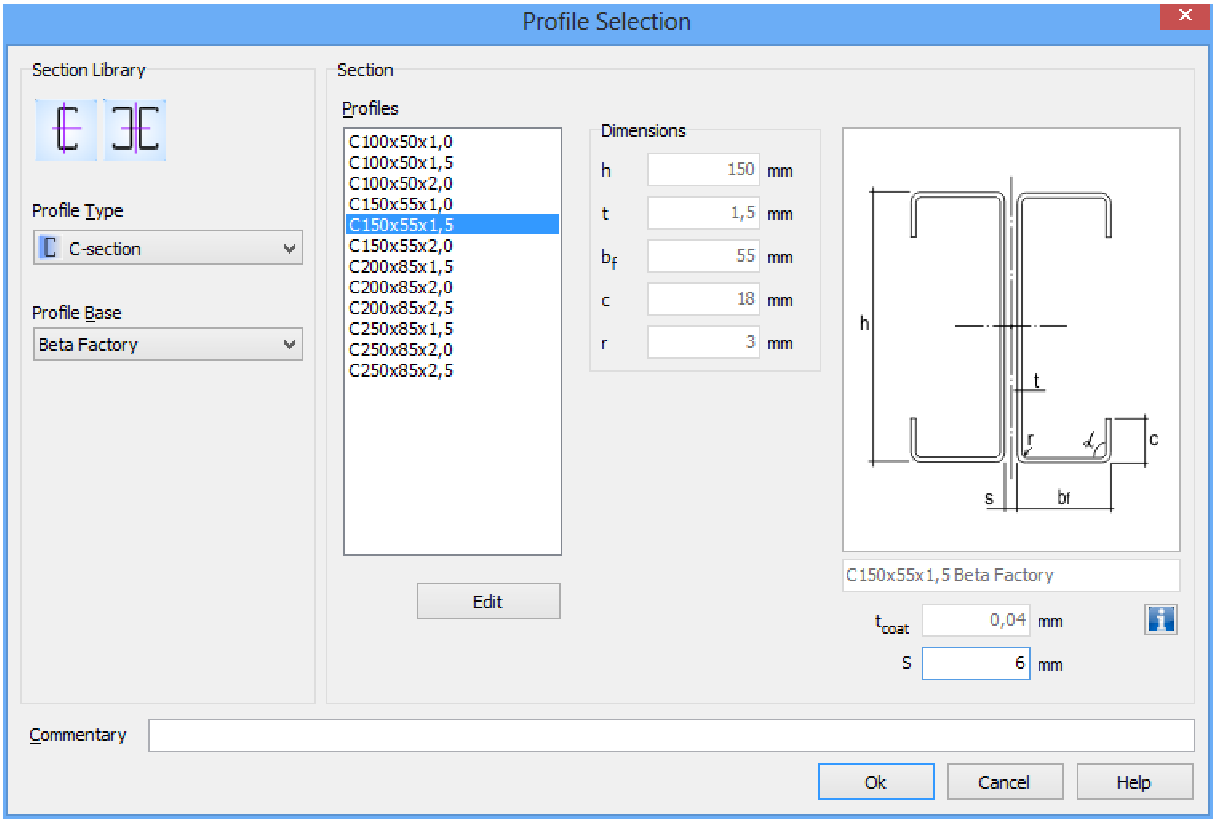


Figure 2.3.6 – Window *Profile Selection*

You can select: a single or a double section, *Profile Type*, a database of this profile and a profile from the database. The favorite cross section is automatically selected at the first appearance of the window. The user can assign to a favorite cross section (clause 3.1). When you first sign in the window for the session with the program it will automatically be selected as a favorite cross section. Next time you enter the window, the last cross section will be selected.

Additionally, a user can enter its own dimensions of the selected profile type. This can be done by selecting *Edit*. Dimensions must be in the permissible range values stipulated in 1.2. In this mode you can also edit the thickness of the zinc coating t_{coat}.

Use button to show information window with properties of entered cross-section.

Steel shall be assigned by selecting from the steel library or by directly entering data on the *Steel* panel (Figure 2.3.3). In the latter case, mandatory fields are: yield strength and ultimate tensile strength. At the first appearance of the window *Tension*, favorite steel is automatically selected. The user assigns the favorite steel (clause 3.1). When you first sign in the window for the session with the program it will automatically be selected favorite steel. When you enter in the window the next time the last steel will be selected. These data can be edited.

If it is necessary to perform the check of member slenderness (clause 3.1 - *Design Details*), enter the limit slenderness in the window *Tension (Figure 2.3.3)*.

2.3.2.3. Design results

Design results are displayed on the screen and, if necessary, can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the design results is divided into two parts (Figure 2.3.7). The right side shows a cross-section of a member. The left part contains three tabs. *General data* tab displays a name of a member (a name of calculation or design), a design tension force, a member length, construction of the element and dimensions of the connection, a section name, a manufacturer name or a database name, a cross section with dimensions, a steel data, comments.

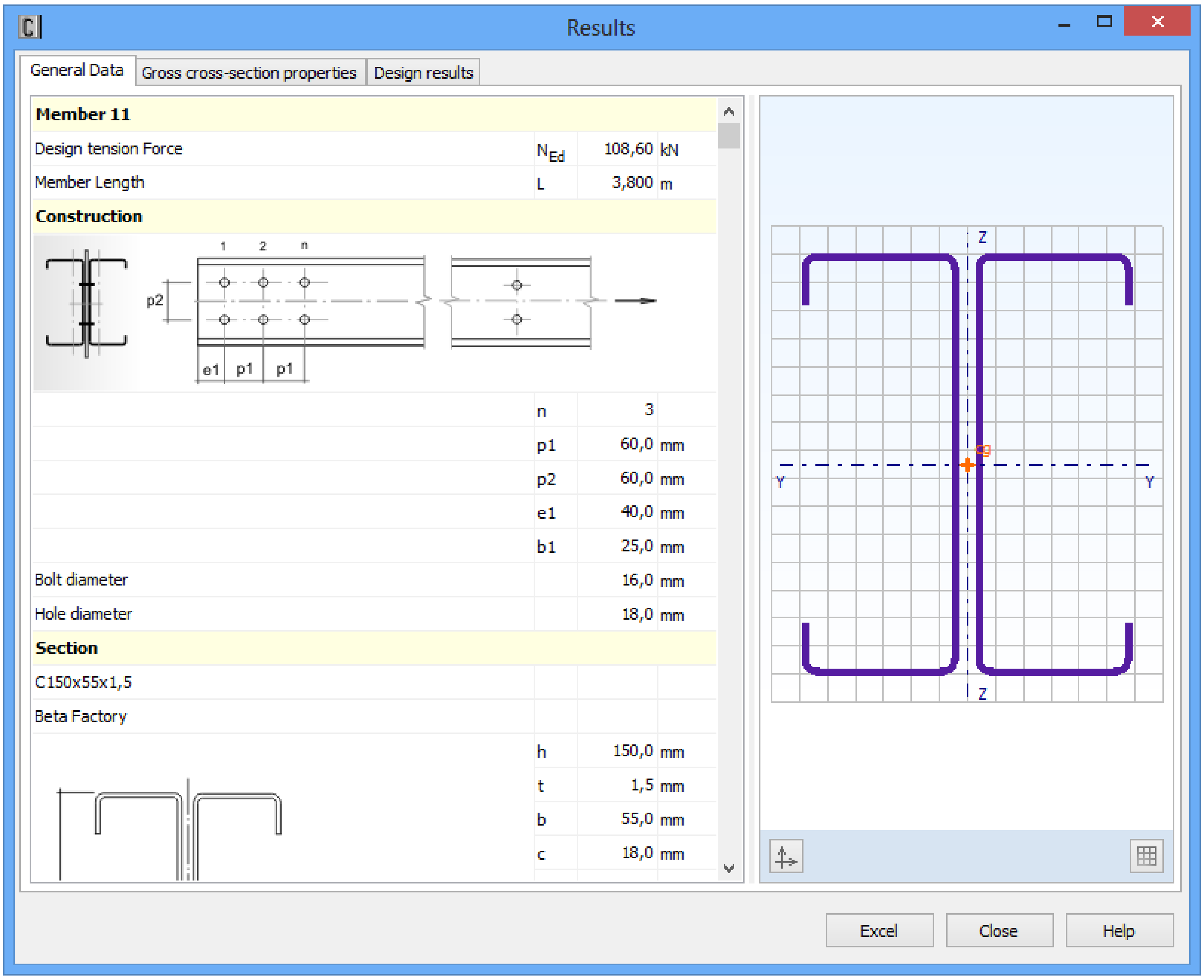
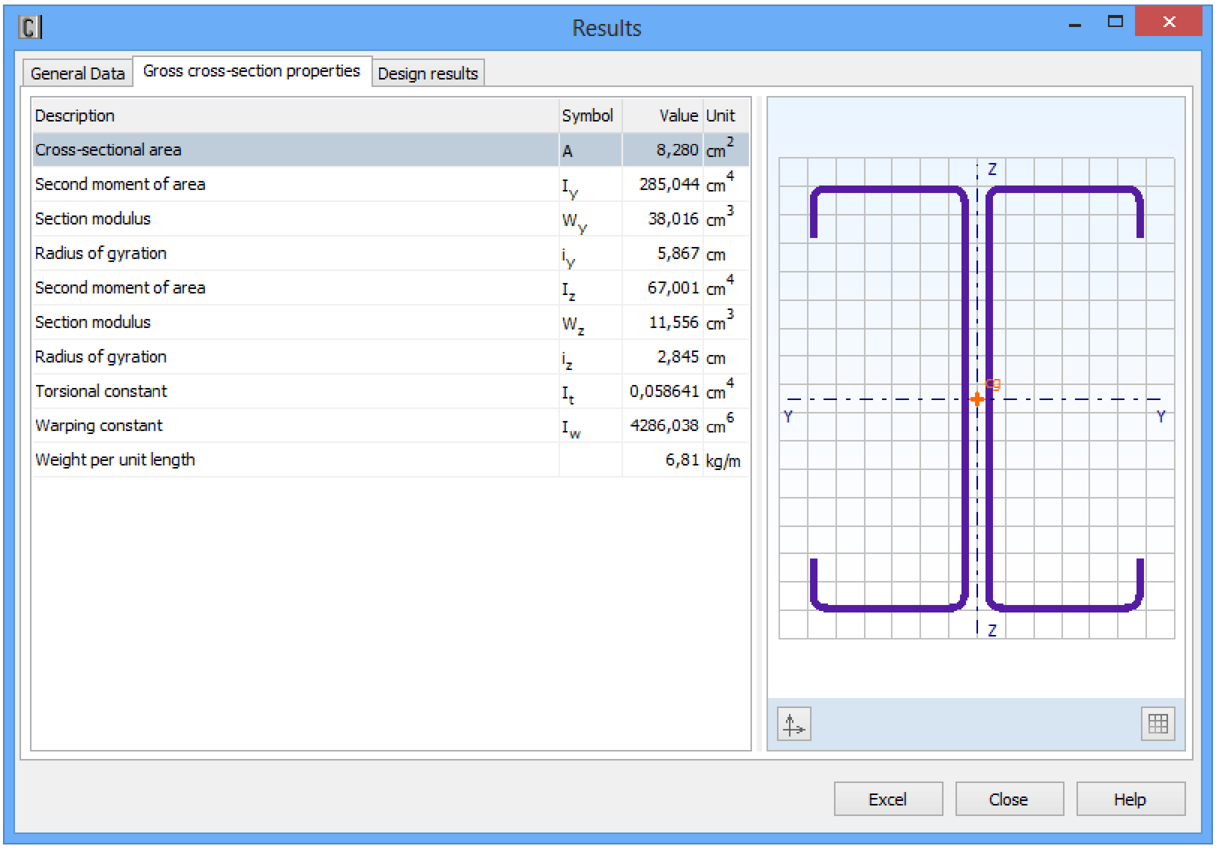


Figure 2.3.7 – Window of results: *General data*

The *Gross cross-section properties* tab (Figure 2.3.8) contains gross cross-section properties, including the weight per meter of the profile.

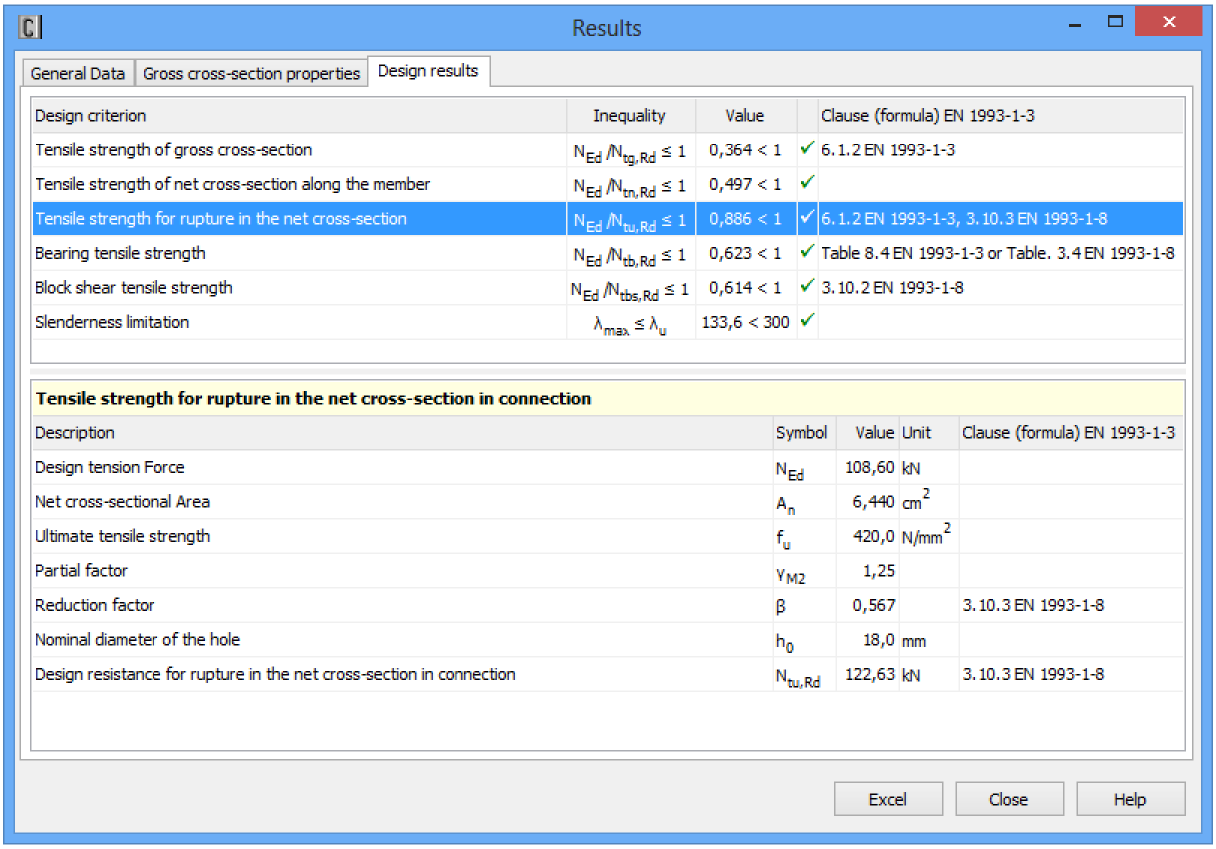
The *Design results* tab (Figure 2.3.9) is functionally divided into two parts. The upper part contains the list of the executed checks (design criterion). This list depends on the values of the entered data, as well as design settings defined by the user in the menu item *Options* → *Design Details* (clause 3.1). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates the check is satisfied or not, and the clause (section) or the formula (equation) of the relevant code, according to which this calculation was performed.

Detailed information is provided in the bottom of the window about the values of the calculation parameters included in the current check. Several characteristics are given for each parameter: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.



Description	Symbol	Value	Unit
Cross-sectional area	A	8,280	cm^2
Second moment of area	I_y	285,044	cm^4
Section modulus	W_y	38,016	cm^3
Radius of gyration	i_y	5,867	cm
Second moment of area	I_z	67,001	cm^4
Section modulus	W_z	11,556	cm^3
Radius of gyration	i_z	2,845	cm
Torsional constant	I_t	0,058641	cm^4
Warping constant	I_w	4286,038	cm^6
Weight per unit length		6,81	kg/m

Figure 2.3.8 – A Results Window: *Gross cross-section properties*



Design criterion	Inequality	Value		Clause (formula) EN 1993-1-3
Tensile strength of gross cross-section	$N_{Ed}/N_{tg,Rd} \le 1$	0,364 < 1	✓	6.1.2 EN 1993-1-3
Tensile strength of net cross-section along the member	$N_{Ed}/N_{tn,Rd} \le 1$	0,497 < 1	✓	
Tensile strength for rupture in the net cross-section	$N_{Ed}/N_{tu,Rd} \le 1$	0,886 < 1	✓	6.1.2 EN 1993-1-3, 3.10.3 EN 1993-1-8
Bearing tensile strength	$N_{Ed}/N_{tb,Rd} \le 1$	0,623 < 1	✓	Table 8.4 EN 1993-1-3 or Table. 3.4 EN 1993-1-8
Block shear tensile strength	$N_{Ed}/N_{tbs,Rd} \le 1$	0,614 < 1	✓	3.10.2 EN 1993-1-8
Slenderness limitation	$\lambda_{max} \le \lambda_u$	133,6 < 300	✓	

Tensile strength for rupture in the net cross-section in connection

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Design tension Force	N_{Ed}	108,60	kN	
Net cross-sectional Area	A_n	6,440	cm^2	
Ultimate tensile strength	f_u	420,0	N/mm^2	
Partial factor	γ_{M2}	1,25		
Reduction factor	β	0,567		3.10.3 EN 1993-1-8
Nominal diameter of the hole	h_0	18,0	mm	
Design resistance for rupture in the net cross-section in connection	$N_{tu,Rd}$	122,63	kN	3.10.3 EN 1993-1-8

Figure 2.3.9 – A Results Window: *Design results*

Units within the metric system and number of decimal places the user can be set in the main menu *Options → Units and decimal places* (clause 3.2).

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in Microsoft Excel® for further processing or converted to HTML format. You can define in the menu item *Options → Program Options* (clause 3.3) where default will be sent to the output stream. Also, you can specify the full amount of information or some part of it will be converted.

2.3.3. Axial compression

2.3.3.1. Design procedure

The following calculations are performed for compressed members:

- strength design (design resistance of a cross-section);
- flexural buckling design;
- torsional and/or torsional-flexural buckling design;
- design for compression with eccentricity (for single cross-section with local and/or distortional buckling);
- slenderness check.

Each cross-section of the compressed member should satisfy the following conditions:

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1\,, \tag{2.3.11}$$

where N_{Ed} is the design compression force; $N_{c,Rd}$ is the design value of the resistance for compression.

If the effective area A_{eff} is equal to the gross area A, the design resistance of a cross-section for compression $N_{c,Rd}$ is determined by (6.1.3(1) [2])

$$N_{c,Rd} = A(f_y + (f_{ya} - f_y)\,4\,(1 - \bar{\lambda}/\overline{\lambda_{e1}}))/\gamma_{M0} \leq Af_{ya}/\gamma_{M0}, \tag{2.3.12}$$

where f_y is the nominal value of basic yield strength; f_{ya} is the average yield strength (2.3.3); $\bar{\lambda}$ is the slenderness of the element which corresponds to the largest value of $\bar{\lambda}$ / $\overline{\lambda_{e1}}$ (see 6.1.3(1) [2]); γ_{M0} is the partial factor for resistance of cross-section (6.1 [1], 2(3) [2]). You may edit the value of γ_{M0} in accordance with the National Annex. On default γ_{M0} =1,0is as recommended in the General part of EC3.

The equality of the effective area and a gross-cross section area takes place in relatively thick profiles. CFSteel performs a reduction of cross-section automatically in accordance with clause 5.5.2 and 5.5.3 EC3 [2].

If the effective area A_{eff} is less than the gross area A, the design resistance of a cross-section for compression $N_{c,Rd}$ is determined by (6.1.3(1) [2])

$$N_{c,Rd} = A_{eff}\ f_{ya}/\gamma_{M0}. \tag{2.3.13}$$

The buckling of axial compressed members check is performed in accordance with the inequality:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1\,, \tag{2.3.14}$$

where $N_{b,Rd}$ is the design buckling resistance of a compression member.

Axial compressed members are members of a single section, local and distortional buckling of which are provided, and any members with double section (regardless of, or not provided the local and distortional buckling).

In accordance with clause 5.5.2 [1] where are four classes of cross-sections:

- Class 1 cross-section are those which can form a plastic hinge with the rotation capacity required from plastic analysis without reduction of the resistance.

- Class 2 cross-sections are those which can develop their plastic moment resistance, but have limited rotation capacity because of local buckling.
- Class 3 cross-sections are those in which the stresses in the extreme compression fiber of the steel member assuming an elastic distribution of stress can reach the yield strength, bur local buckling is liable to prevent development of the plastic moment resistance.
- Class 4 cross-sections are those in which local buckling will occur before the attainment of yield stress in one or more parts of the cross-section.

If any cross-section of a member it is provided with a local buckling or distortional buckling, CFSteel considers it to be class 4 cross-section. Otherwise, the cross-section is classified as class 3.

The design buckling resistance of the compression member is determined in accordance with the clause 6.2.2 [2] and clause 6.3.1[1]:

3 class cross-section

$$N_{b,Rd} = \chi A \ f_y / \gamma_{M1} , \tag{2.3.15,a}$$

4 class cross-section

$$N_{b,Rd} = \chi A_{eff} \ f_y / \gamma_{M1} , \tag{2.3.15,b}$$

where χ is the reduction factor for the relevant bucrling mode; γ_{M1} is the partial factor for resistance of members to instability assessed by member checks (6.1 [1], 2(3) [2]). You may edit the value of γ_{M1} in accordance with the National Annex. On default γ_{M1} =1,0 is as recommended in the General part of EC3.

Holes at the ends of the member for its attachment to adjacent component of the structure are not taken into account, when A and A_{eff} are calculated.

The value of χ of the appropriate non-dimensional slenderness $\bar{\lambda}$ is determined from the relevant buckling curve according to:

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}} \ , \qquad \chi \le 1 \tag{2.3.16}$$

where

$$\phi = 0,5 \left(1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2\right). \tag{2.3.17}$$

For a flexural buckling mode:

3 class cross-section

$$\bar{\lambda} = \frac{L_{cr}}{i} \frac{1}{\lambda_1} , \tag{2.3.18,a}$$

4 class cross-section

$$\bar{\lambda} = \frac{L_{cr}}{i} \frac{\sqrt{\frac{A_{eff}}{A}}}{\lambda_1} , \tag{2.3.18,b}$$

where L_{cr} is buckling length in the buckling plane considered ($L_{cr,y} = k_y L$, $L_{cr,z} = k_z L$); i is a radius of duration about the relevant axis. i is determined using the properties of the gross cross-section.

$$\lambda_1 = \pi \sqrt{\frac{E}{f_y}} . \tag{2.3.19}$$

The value of the factor α, taken into account the initial imperfections, is determined according to Table 2.3.1 (Table 6.1 [1]) for the appropriate buckling curve, which with regard to the cross-section shape is determined according to Table 6.3 [2].

Table 2.3.1 – Imperfection factors for buckling curves

Buckling curve	a_0	a	b	c	d
Imperfection factor α	0,13	0,21	0,34	0,49	0,76

Design value of the buckling resistance for flexural buckling mode $N_{bF,Rd}$ is determined according to (2.3.15) as the minimum value from calculations about the *Y* and *Z* axes.

When considers torsional buckling mode and torsion-flexural buckling mode, the value of $\bar{\lambda}$ is calculated as follows:

3 class cross-section

$$\bar{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}}, \tag{2.3.20,a}$$

4 class cross-section

$$\bar{\lambda} = \sqrt{\frac{A_{eff}\ f_y}{N_{cr}}}, \tag{2.3.20,б}$$

where N_{cr} is the elastic critical force for the relevant buckling mode based on the gross sectional properties.

The elastic critical force $N_{cr,T}$ for torsional buckling in accordance with clause 6.2.3 [2] is calculated from

$$N_{cr,T} = \frac{1}{i_0^2}\left(GI_t + \frac{\pi^2 EI_w}{L_T^2}\right), \tag{2.3.21}$$

where $i_0^2 = i_y^2 + i_z^2 + y_0^2 + z_0^2$ (y_0^2, z_0^2 are the shear centre co-ordinates with respect to the cetroid of the gross cross-section; I_t is the torsion constant of the gross cross-section; I_w is the warping constant of the gross cross-section; L_T is the buckling length of the member for torsional buckling ($L_T = k_T L$). In accodance with clause 6.2.3(9) [2] depending on the attaching conditions, it may accept the following values of $k_T = L_T/L$: 1,0 – for connections that provide partial restraint against torsion and warping (Figure 6.13(a) [2]); 0,7 – for connections that provide significant restraint against torsion and warping (Figure 6.13(b) [2]). Value $k_T = L_T/L$ is entered by the user.

The design buckling resistance $N_{bT,Rd}$ for torsion is calculated from (2.3.15) with appropriate reduction factor χ.

For double symmetric cross-sections $N_{cr,TF} = N_{cr,T}$ (clause 6.2.3(6) [2]).

For single cross-sections that are mono-symmetric the elastic critical force $N_{cr,TF}$ for torsional-flexural buckling is determined from (6.2.3 [2])

$$N_{cr,TF} = \frac{N_{cr,y}}{2\beta}\left(1 + \frac{N_{cr,T}}{N_{cr,y}} - \sqrt{\left(1 - \frac{N_{cr,T}}{N_{cr,y}}\right)^2 + 4\left(\frac{y_0}{i_0}\right)^2 \frac{N_{cr,T}}{N_{cr,y}}}\right), \tag{2.3.22}$$

with

$$\beta = 1 - \left(\frac{y_0}{i_0}\right)^2. \tag{2.3.23}$$

Reduction factor χ is determined from (2.3.16) using the relevant buckling curve for buckling about the *Z* axis obtained from Table 6.3 [2].

The design buckling resistance $N_{bTF,Rd}$ for torsion-flexural buckling is calculated from (2.3.15) with appropriate reduction factor χ.

The final value of the design buckling resistance $N_{b,Rd}$ in (2.3.14) is defined as the minimum of the $N_{bF,Rd}$, $N_{bT,Rd}$ and $N_{bTF,Rd}$.

In single sections the transition from gross cross-section to effective cross-section is accompanied by a change in the position of the centroid. It is assumed that the axial load remains at the centroid of the original gross cross-section. Thus, there is a shift e_N of the centroidal axes. The member can no longer be considered as an axial compressed and is considered to be compressed with eccentricity e_N in the plane *Y-Y*. Eccentricity e_N is calculated as displacement of the effective cross-section centroid relative to centroid of the gross cross-section. In this case, mono-symmetric single cross-section eccentrically-compressed members are considered.

The design cross-section with the combined effect of axial compression N_{Ed} and bending moment $\Delta M_{z,Ed} = e_N N_{Ed}$ should satisfy the criterion (clause 6.1.9 [2]):

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{\Delta M_{z,Ed}}{M_{cz,Rdcom}} \leq 1, \tag{2.3.24}$$

where $N_{c,Rd}$ is calculated by (2.3.13); $M_{cz,Rdcom}$ is the moment resistance for the maximum compressive stress in the effective cross-section that is subject only to moment (clause 6.1.4.1 [2]):

$$M_{cz,Rdcom} = W_{zeffcom}\ f_y/\gamma_{M0}\ , \tag{2.3.25}$$

where $W_{zeffcom}$ is the effective section modulus for the fibre with maximum compressive stress.

Also, if $M_{cz,Rdten} \leq M_{cz,Rdcom}$ the following check is performed

$$\frac{\Delta M_{z,Ed}}{M_{cz,Rdten}} - \frac{N_{Ed}}{N_{c,Rd}} \leq 1, \tag{2.3.26}$$

where $M_{cz,Rdten} = W_{zefften}\, f_y / \gamma_{M0}$.

In the results the maximum value of the left side of inequalities (2.3.24) and (2.3.26) is shown.

If the user marks the necessity of the check of net section in the menu item *Options → Design Details* (clause 3.1) and enters any option of the cross-section weakening (clause 3.1) simultaneously, then appropriate check is performed.

The design resistance of net cross-section of axial compression member:

$$N_{c,Rd} = A_n\ f_{ya}/\gamma_{M2}. \tag{2.3.27}$$

For eccentrically compressed members the check is performed according to (2.3.24) and (2.3.26) substituting the properties of the net cross-section A_n, $W_{zcom\ net}$ and $W_{zten\ net}$.

If the user does not enter a weakening of the cross-section or do not mark the necessity of the check of the net section in the menu item *Options → Design Details* (clause 3.1), this check is not performed.

The member subject to axial compression N_{Ed} and bending moment $M_{,Ed}$ should satisfy the criterion (clause 6.2.5 [2]):

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1\ , \tag{2.3.28}$$

where $M_{Ed} = e_N N_{Ed}$; $N_{b,Rd}$ is the smallest value of the design resistances of axial compression member for: flexural buckling mode $N_{bF,Rd}$, torsional buckling mode $N_{bT,Rd}$ and torsional-flexural buckling mode $N_{bTF,Rd}$.

The design buckling resistance moment $M_{b,Rd}$:

$$M_{b,Rd} = \chi_{LT} W_z\ f_y/\gamma_{M1}, \tag{2.3.29}$$

where W_z is the effective section modulus for the fibre with maximum compressive stress about axis Z: $W_z = W_{zeffcom}$. While calculating W_z holes at the ends of the member for attachment to adjacent parts of the structure are not taken into account.

The value of reduction factor for lateral-torsional buckling χ_{LT} for the appropriate non-dimensional slenderness $\overline{\lambda_{LT}}$ is calculated from (clause 6.3.2.2 [1] (general case)):

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \overline{\lambda}_{LT}^{\,2}}}\ , \qquad \chi_{LT} \leq 1 \tag{2.3.30}$$

with

$$\phi_{LT} = 0,5\ \left(1 + \alpha_{LT}\left(\overline{\lambda_{LT}} - 0,2\right) + \overline{\lambda}_{LT}^{\,2}\right), \tag{2.3.31}$$

where α_{LT} is an imperfection factor from Table 2.3.2 (Table 6.3 [1])

In accordance with clause 6.2.4 [2] it uses the buckling curve *b* to determine the α_{LT}. Thus, α_{LT} = 0,34.

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_z f_y}{M_{cr}}}, \tag{2.3.32}$$

where M_{cr} is the elastic critical moment for lateral-torsional buckling based on the gross cross sectional properties.

Table 2.3.2 Imperfection factors for lateral-torsional buckling curves

Buckling curve	a	b	c	d
Imperfection factor α_{LT}	0,21	0,34	0,49	0,76

The value of M_{cr} is written in accordance with ECCS TC №119 [15]. For the member from single section (with $I_z > I_y$) that is symmetrical about the Y (minor) axis for bending about the Z (major) axis the elastic critical moment for lateral-torsional buckling is written in general case:

$$M_{cr} = C_1 \frac{\pi^2 E I_y}{(L_{cr,LT})^2}\left(\sqrt{\left(\frac{k}{k_w}\right)^2 \frac{I_w}{I_y} + \frac{\left(L_{cr,LT}\right)^2 G I_t}{\pi^2 E I_y} + \left(C_2 y_g - C_3 y_j\right)^2} - \left(C_2 y_g - C_3 y_j\right)\right), \tag{2.3.33}$$

where C_1 is the factor depending on the shape of the bending moment diagram over the length L. In the case of the constant bending moment $C_1 = 1{,}0$.

It is assumed that the member has no intermediate restraints along the length that prevents lateral-torsional buckling. Therefore, $L_{cr,LT} = L$ (L is the member length).

The effective (buckling) length factor k refers to the end rotation according to the plan (entered by user). The effective (buckling) length factor k_w refers to end warping. Normal conditions of restraint at each end of the member were taken: $k = k_w = 1{,}0$. It means:

– restrained against lateral movement, free to rotate on plan;
– restrained against rotation about the longitudinal axis, free to warp.

$C_2 \cdot y_g$ is the parameter depending on the level of transverse load application relative to the shear centre. It is taken $C_2 y_g = 0$ [15].

$C_3 \cdot y_j$ is the parameter depending on the degree of cross-section asymmetry. Value of y_j is calculated in accordance with [15]:

if $\psi_f \geq 0$

$$y_j = 0{,}8\, \psi_f \frac{h_c}{2}, \tag{2.3.34,a}$$

if $\psi_f < 0$

$$y_j = \psi_f \frac{h_c}{2}, \tag{2.3.34,б}$$

where

$$\psi_f = \frac{I_{fc} - I_{ft}}{I_{fc} + I_{ft}}, \tag{2.3.35}$$

where I_{fc} is the second moment of area of the compression flange about the Y axis; I_{ft} is the the second moment of area of the tension flange. It is assumed, that the cross-section is replaced by the I-section with unequal flanges in accordance with Figure 2.3.10. y_j is positive when the flange with the larger value of second moment of area is in compression. h_c is the distance between centroids of the flanges in the I-section. $C_3 = 1{,}0$ [15].

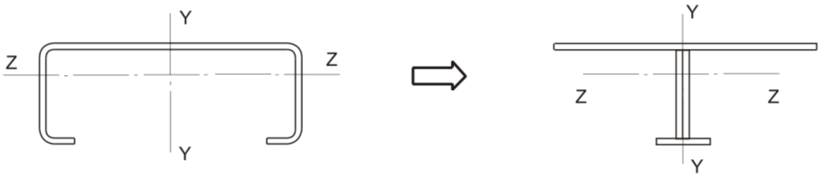


Figure 2.3.10 – Simulation of single cross-section by I-section in the plane of bending

If the user marks the necessity of the check for limit slenderness (clause 3.1), it is performed in accordance with the inequality

$$\lambda \leq \lambda_u, \qquad (2.3.36)$$

where λ is the largest value of slenderness about Y and Z axes: $k_y L/i_y$ и $k_z L/i_z$; λ_u is the value of the ultimate slenderness entered by user.

2.3.3.2. Input data

To input data, select in main menu *Member* → *Column*. Then, an input window appears, as shown in Figure 2.3.11.

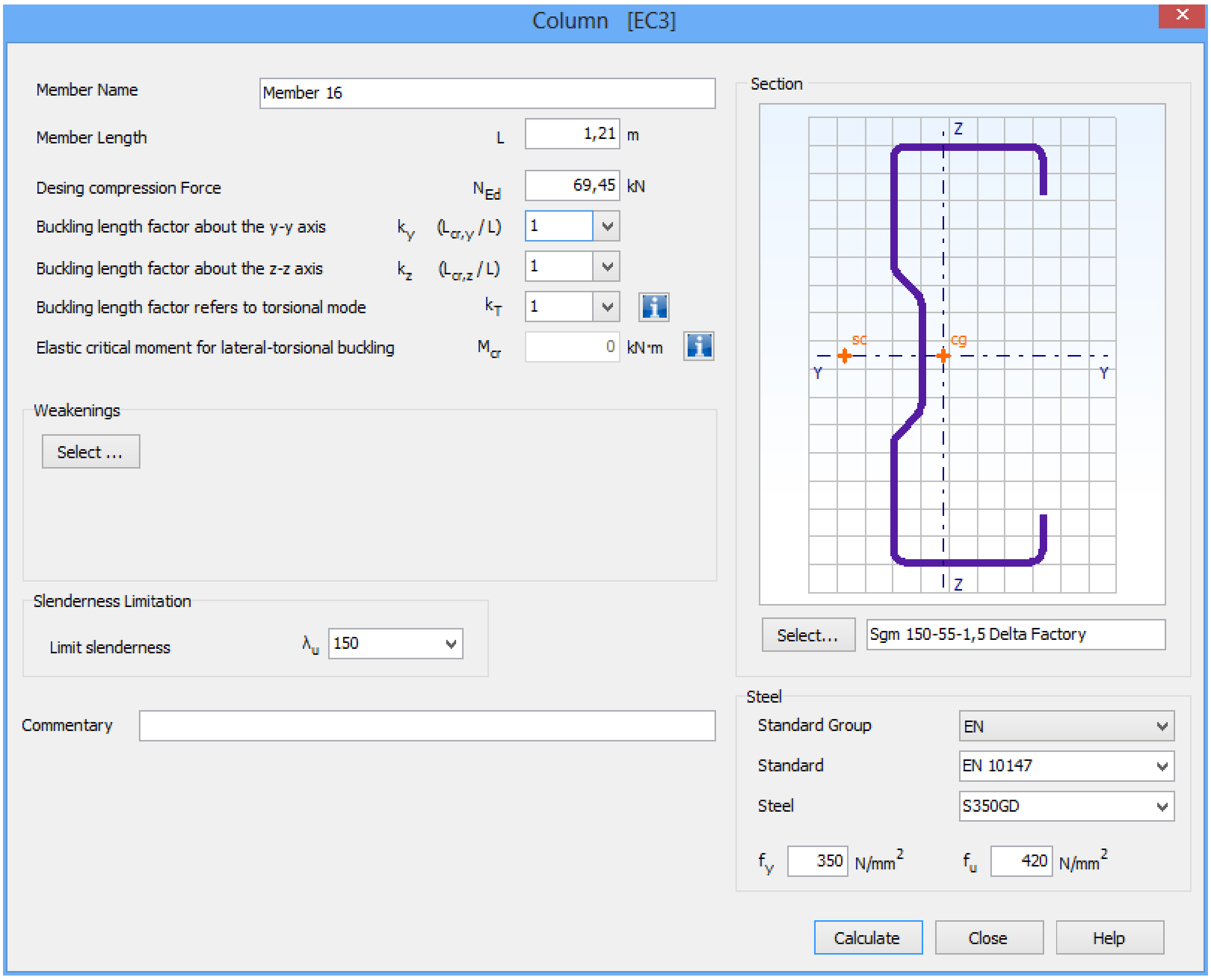


Figure 2.3.11 – Input data window for compression members

You can define a member name (name of calculation or design), design compression force N_{Ed}, member length L, buckling length factors about the Y and Z axes (k_y и k_z), buckling length factor refers to torsional buckling k_T . It takes into account the calculation of the buckling length of the member for torsional buckling: $L_T = k_T L$ (see clause 2.3.3.1).

You can define the value of the elastic critical moment for lateral-torsional buckling M_{cr} , but only if it is a selected item *Input the value of* M_{cr} in menu *Options → Design Details* (see clause 3.1). Otherwise, the value of M_{cr} is calculated in the program by the method described in 2.3.3.1.

Further, you can assign a cross-section of the member. To do it, click the *Select* button ... The dialog box appears (Figure 2.3.6), where you define the cross-section.

If the member has cross-sections with the holes (at the point of attachment or along the length) you can define data about the opening by clicking the *Select* button ... on the *Weakening* panel and enter the hole parameters in the dialog box that appears (clause 2.2).

Steel can be assigned by selecting from the steel library or by directly entering data on the *Steel* panel (Figure 2.3.11). In the latter case, mandatory fields are: yield strength and ultimate tensile strength. . At the first appearance of the *Column* window, steel is automatically selected – steel is favorite. The user assigns the favorite steel (clause 3.1). When you first sign in the window for the session with the program, it will automatically select steel as favorite. Next time you enter the window, the last steel will be selected. These data can be edited.

If it is necessary to perform the member slenderness check (clause 3.1 - *Design Details*), enter the limit slenderness in the *Column* window *(Figure 2.3.11)*.

2.3.3.3. Design results

Design results are displayed on the screen and, if necessary, they can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the design results is divided into two parts (Figure 2.3.12). The right side shows a cross-section of a member. The left part contains four or five tabs. *General data* tab displays the data entered by the user.

Gross cross-section properties tab contains the properties of gross cross-section, including the weight per meter of the profile. *Effective cross-section properties* tab (Figure 2.3.13) contains the properties of the effective cross-section. If there are sections with holes, *Net cross-section properties* tab with the appropriate data is shown.

Design results tab (Figure 2.3.14) is functionally divided into two parts. The upper part contains the list of the executed checks (design criterion). This list depends on the codes, according to which calculation is performed (clause 2.3.3.1), the entered data is evaluated, as well as design settings defined by user in the menu item *Options → Design Details* (clause 3.1). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates the check is satisfied or not, and the clause (section) or the formula (equation) of the relevant code, according to which this calculation was performed.

In the bottom of the window detailed information is provided on the values of the calculation parameters included in the current check. The following features are given for each parameter: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.

Units within the metric system and number of decimal places the user can use, can be set in the main menu *Options → Units and decimal places* (clause 3.2).

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in Microsoft Excel® for further processing or convert to HTML format.

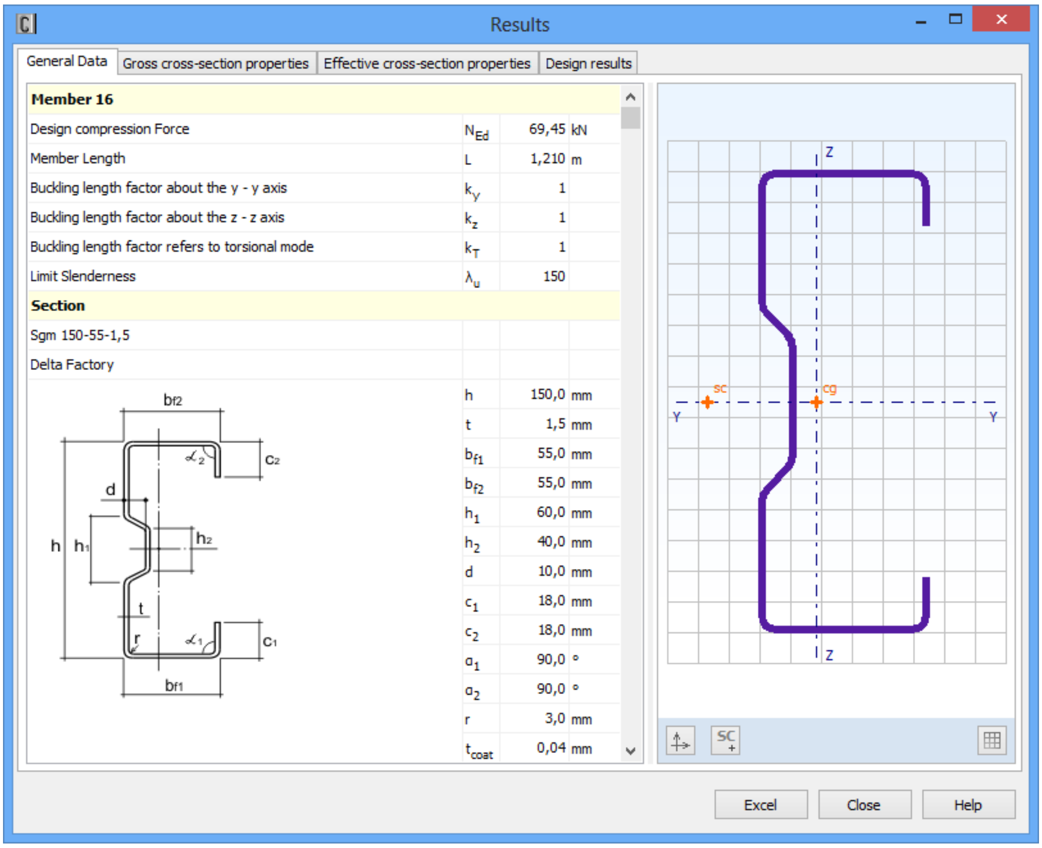


Figure 2.3.12 – Window of results: *General data*

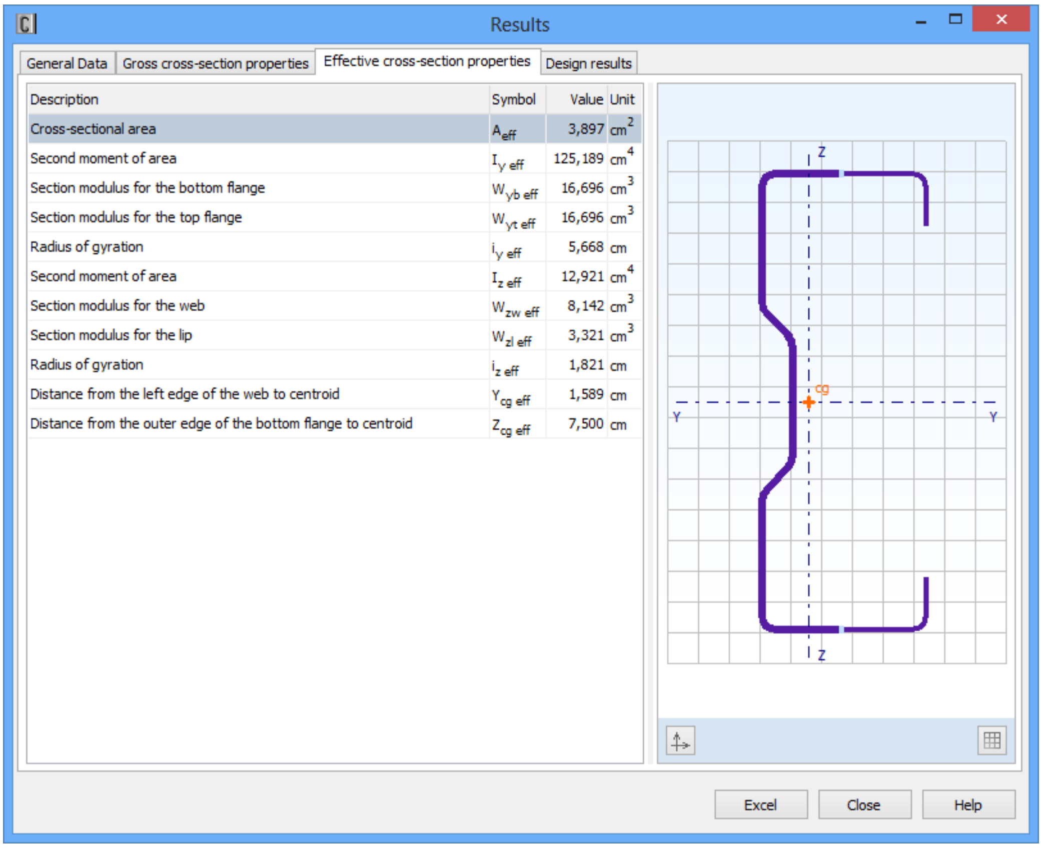


Figure 2.3.13 – Window of results: *Effective cross-section properties*

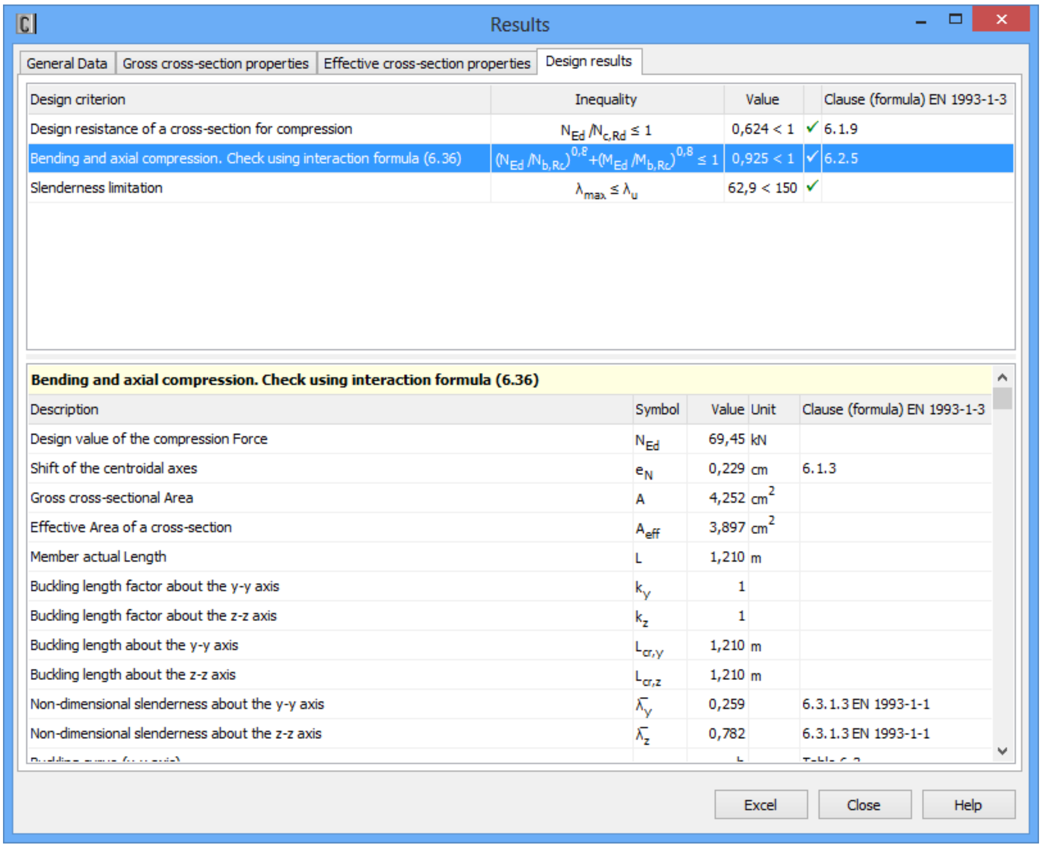


Figure 2.3.14 – Window of results: *Design results*

2.3.4. Compression with bending

2.3.4.1. Design procedure

The following calculations are performed for compressed with bending members:

– strength design (design resistance of a cross-section);
– design resistance of net cross-section;
– design for buckling;
– slenderness check.

Single cross-sections subject to combined axial compression and bending moment should satisfy the criterion

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{Ed} + \Delta M_{Ed}}{M_{c,Rd\ com}} \leq 1, \qquad (2.3.37)$$

where N_{Ed} is the design value of the axial force; M_{Ed} is the design value of the bending moment; $N_{c,Rd}$ is the design resistance of a cross-section for compression; ΔM_{Ed} is the additional moment $\Delta M_{Ed} = e_N N_{Ed}$ (clause 6.1.9(2) [2]) in which e_N is the shift of centroidal axis due to axial force (clause 6.1.3(3) [2]). If the cross-section is fully effective or double section, then $e_N = 0$.

If the effective area A_{eff} is equal to the gross area A (section with no reduction due to local or distortional buckling):

$$N_{c,Rd} = A\, f_y / \gamma_{M0}. \qquad (2.3.38,a)$$

If $A_{eff} < A$ (section with reduction due to local or distortional buckling):

$$N_{c,Rd} = A_{eff}\, f_y / \gamma_{M0}, \qquad (2.3.38,b)$$

The design moment resistance of a single cross-section for bending $M_{c,Rd\ com}$ is determined as follows:

the cross-section is fully effective

$$M_{c,Rd\ com} = W_{z\ com}\ f_y/\gamma_{M0}, \tag{2.3.39,a}$$

the cross-section with reduction

$$M_{c,Rd\ com} = W_{zeff\ com}\ f_y/\gamma_{M0}, \tag{2.3.39,b}$$

where $W_{z\ com}$ is the gross cross-section modulus for the most compressed fiber about the Z axis; $W_{zeff\ com}$ is the effective cross-section modulus for the most compressed fiber about the Z axis.

If $M_{c,Rd\ ten} < M_{c,Rd\ com}$ the following criterion should also be satisfied (clause 6.1.9 [2]):

$$\frac{M_{Ed} + \Delta M_{Ed}}{M_{c,Rd\ ten}} - \frac{N_{Ed}}{N_{c,Rd}} \leq 1, \tag{2.3.40}$$

where $M_{c,Rd\ ten}$ is the design moment resistance of a cross-section for maximum tensile stress if subjected only to moment about the Z axis:

the cross-section is fully effective

$$M_{c,Rd\ ten} = W_{z\ ten}\ f_y/\gamma_{M0}, \tag{2.3.41,a}$$

the cross-section with reduction

$$M_{c,Rd\ ten} = W_{zeff\ ten}\ f_y/\gamma_{M0}, \tag{2.3.41,b}$$

where $W_{z\ ten}$ is the gross cross-section modulus for the most tensioned fiber about the Z axis; $W_{zeff\ com}$ is the effective cross-section modulus for the most tensioned fiber about the Z axis.

Double cross-sections subject to combined axial compression and bending moment should satisfy the criterion

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{Ed}}{M_{c,Rd\ min}} \leq 1, \tag{2.3.42}$$

where $M_{c,Rd\ min}$ is the design moment resistance of a cross-section calculated using the minimum cross-section modulus:

the cross-section is fully effective

$$M_{c,Rd\ min} = W_{y\ min}\ f_y/\gamma_{M0}, \tag{2.3.43,a}$$

The cross-section with reduction

$$M_{c,Rd\ min} = W_{yeff\ min}\ f_y/\gamma_{M0}, \tag{2.3.43,b}$$

where $W_{y\ min}$ is the minimum section modulus for gross cross-section about the Y axis: $W_{y\ min} = min\ \{W_{y\ com}, W_{y\ ten}\}$; $W_{yeff\ min}$ is the minimum section modulus for effective cross-section about the Y axis: $W_{yeff\ min} = min\ \{W_{yeff\ com}, W_{yeff\ ten}\}$.

If the user marks the necessity of the check of net section in the menu item *Options → Design Details* (clause 3.1) and enters any option of the cross-section weakening (clause 2.2) simultaneously, then appropriate check is performed.

Single net cross-sections should satisfy the criterion

$$\frac{N_{Ed}}{N_{nc,Rd}} + \frac{M_{Ed} + \Delta M_{Ed}}{M_{nc,Rd\ com}} \leq 1, \tag{2.3.44}$$

where

$$N_{nc,Rd} = A_n\ f_y/\gamma_{M2} \tag{2.3.45}$$

and

$$M_{nc,Rd\ com} = W_{nz\ com}\ f_y/\gamma_{M2}, \tag{2.3.46}$$

where A_n is the net area of a cross-section; $W_{nz\ com}$ is the net cross-section modulus for the most compressed fiber about the Z axis; γ_{M2} is the partial factor for resistance of net cross-section with bolt holes.

If $M_{nc,Rd\ ten} < M_{nc,Rd\ com}$ the following criterion should also be satisfied (clause 6.1.9 [2]):

$$\frac{M_{Ed} + \Delta M_{Ed}}{M_{nc,Rd\ ten}} - \frac{N_{Ed}}{N_{nc,Rd}} \leq 1, \tag{2.3.47}$$

where

$$M_{nc,Rd\ ten} = W_{nz\ ten}\ f_y/\gamma_{M2}. \tag{2.3.48}$$

Double net cross-sections should satisfy the criterion

$$\frac{N_{Ed}}{N_{nc,Rd}} + \frac{M_{Ed}}{M_{nc,Rd\ min}} \leq 1, \tag{2.3.49}$$

where $M_{nc,Rd\ min}$ is the design moment resistance of a net cross-section calculated using the minimum cross-section modulus:

$$M_{nc,Rd\ min} = W_{ny\ min}\ f_y/\gamma_{M2}, \tag{2.3.50}$$

where $W_{ny\ min}$ is the minimum section modulus for net cross-section about the Y axis: $W_{ny\ min} = min\ \{W_{ny\ com}, W_{ny\ ten}\}$.

The design for buckling can be performed in two ways. The first way is to design according to the clause 6.2.5 [2] :

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1\ , \tag{2.3.51}$$

where M_{Ed} is the design value of the bending moment including the additional moment $\Delta M_{Ed} = e_N\ N_{Ed}$. If the cross-section is fully effective or double section, then $e_N = 0$, and $\Delta M_{Ed} = 0$.

$N_{b,Rd}$ is the minimum value of:

– the design buckling resistance of the compression member for flexural mode about the Y axis ($N_{yb,Rd}$);
– the design buckling resistance of the compression member for flexural mode about the Z axis ($N_{zb,Rd}$);
– the design buckling resistance for torsion ($N_{bT,Rd}$);
– the design buckling resistance for torsion-flexural buckling ($N_{bTF,Rd}$).

$M_{b,Rd}$ is the design bending moment resistance for lateral-torsional buckling which is determined in accordance with clauses 6.2.4 [2] and 6.3.2 [1] using the buckling curve b:

$$M_{b,Rd} = \chi_{LT}\ W\ f_y/\gamma_{M1}, \tag{2.3.52}$$

where χ_{LT} is the reduction factor for lateral-torsional buckling, which is calculated according to clause 6.3.2.2 [1] for general cases; W is the section modulus as follows: $W = W_{com}$ for Class 3 cross-sections, $W = W_{effcom}$ for Class 4 cross-sections; γ_{M1} is the partial factor for resistance of members to instability assessed by member checks (6.1 [1], 2(3) [2]).

$$\overline{\lambda_{LT}} = \sqrt{\frac{W f_y}{M_{cr}}}\ , \tag{2.3.53}$$

where M_{cr} is the elastic critical moment for lateral-torsional buckling based on gross cross sectional properties.

The value of M_{cr} is written in accordance with ECCS TC №119 [15]. For the member from single section (with $I_z > I_y$) that is symmetrical about the Y (minor) axis for bending about the Z (major) axis the elastic critical moment for lateral-torsional buckling is written in general case:

$$M_{cr} = C_1 \frac{\pi^2 E I_y}{(L_{cr,LT})^2}\left(\sqrt{\left(\frac{k}{k_w}\right)^2 \frac{I_w}{I_y} + \frac{\left(L_{cr,LT}\right)^2 G I_t}{\pi^2 E I_y} + \left(C_2 y_g - C_3 y_j\right)^2} - \left(C_2 y_g - C_3 y_j\right)\right), \tag{2.3.54}$$

where C_1 is the factor depending on the shape of the bending moment diagram over the member length L; C_2 is the factor depending on the level of transverse load application relative to the shear centre; C_3 is the factor depending on the degree of cross-section asymmetry; $L_{cr,LT}$ is the value of buckling length for lateral-torsional buckling (entered by a user); k is the effective (buckling) length factor refers to end rotation on plan (entered by a user); k_w is the effective (buckling) length factor refers to end warping (entered by a user); I_w is the warping constant; I_t is the torsion constant; y_g is the coordinate of the point of transverse load application; y_j is the value depending on the degree of cross-section asymmetry.

For a member from a double section (bi-symmetric cross-section) with $I_y > I_z$ bending about the Y (major) axis the elastic critical moment for lateral-torsional buckling is written [15] as follows:

$$M_{cr} = C_1 \frac{\pi^2 E I_z}{(L_{cr,LT})^2} \left(\sqrt{\left(\frac{k}{k_w}\right)^2 \frac{I_w}{I_z} + \frac{(L_{cr,LT})^2 G I_t}{\pi^2 E I_z} + (C_2 z_g)^2} - (C_2 z_g) \right), \tag{2.3.55}$$

The effect of the distribution of bending moment along the length at the critical moment for lateral-torsional buckling is taken into account by factor C_1. The user can enter the value of C_1, C_2 and C_3. References below are the values of the factors C contained in [15]. Table 2.3.3 provides the value of factors C_1 and C_3 for members loaded only by the end moments. Table 2.3.4 provides the value of factors C_1, C_2 and C_3 for members loaded only by transverse load.

Figures 2.3.16 – 2.3.19 graphically present the values of factors C_1 and C_2 for case of combined application of end moments and transverse load (Figure 2.3.15). Where μ is the ratio of the moment due to transverse load to the maximum moment M.

For (a) Figure 2.3.15:

$$\mu = \frac{q\,L^2}{8M}, \tag{2.3.56,a}$$

For (b) Figure 2.3.15:

$$\mu = \frac{F\,L}{4M}. \tag{2.3.56,b}$$

A sign convention for μ is defined as follows: $\mu > 0$ if M and transverse load (q or F), each supposed acting alone, bend the member in same direction (i.e. as shown in Figure 2.3.15); $\mu < 0$ in the outher situation.

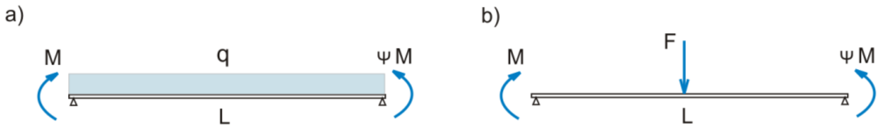


Figure 2.3.15 – End moments combined with a transverse load

Table 2.3.3 – Values of factors C_1 and C_3 corresponding to values of effective length factor k. End moment loading [15]

End moment and support conditions условия	Bending moment diagram	Value of k	Values of factors		
			C_1	C_3	
				$\psi_f \le 0$	$\psi_f > 0$
		1,0	1,00	1,000	
		0,5	1,05	1,019	
		1,0	1,14	1,000	
		0,5	1,19	1,017	
		1,0	1,31	1,000	
		0,5	1,37	1,000	
		1,0	1,52	1,000	
		0,5	1,60	1,000	
		1,0	1,77	1,000	
		0,5	1,86	1,000	
		1,0	2,06	1,000	0,850
		0,5	2,15	1,000	0,650
		1,0	2,35	1,000	1,3-1,2 ψ_f

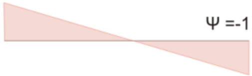
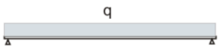
		0,5	2,42	0,950	0,77- ψ_f
		1,0	2,60	1,000	0,55- ψ_f
		0,5	2,45	0,850	0,35- ψ_f
		1,0	2,60	- ψ_f	- ψ_f
		0,5	2,45	0,125-0,7 ψ_f	-0,125-0,7ψ_f

Table 2.3.4 - Values of factors C_1, C_2 and C_3. Loading by transverse load [15]

Loading and support condition	Bending moment diagram	Value of k	Value of factors		
			C_1	C_2	C_3
		1,0	1,12	0,45	0,525
		0,5	0,97	0,36	0,478
		1,0	1,35	0,59	0,411
		0,5	1,05	0,48	0,338
		1,0	1,04	0,42	0,562
		0,5	0,95	0,31	0,539

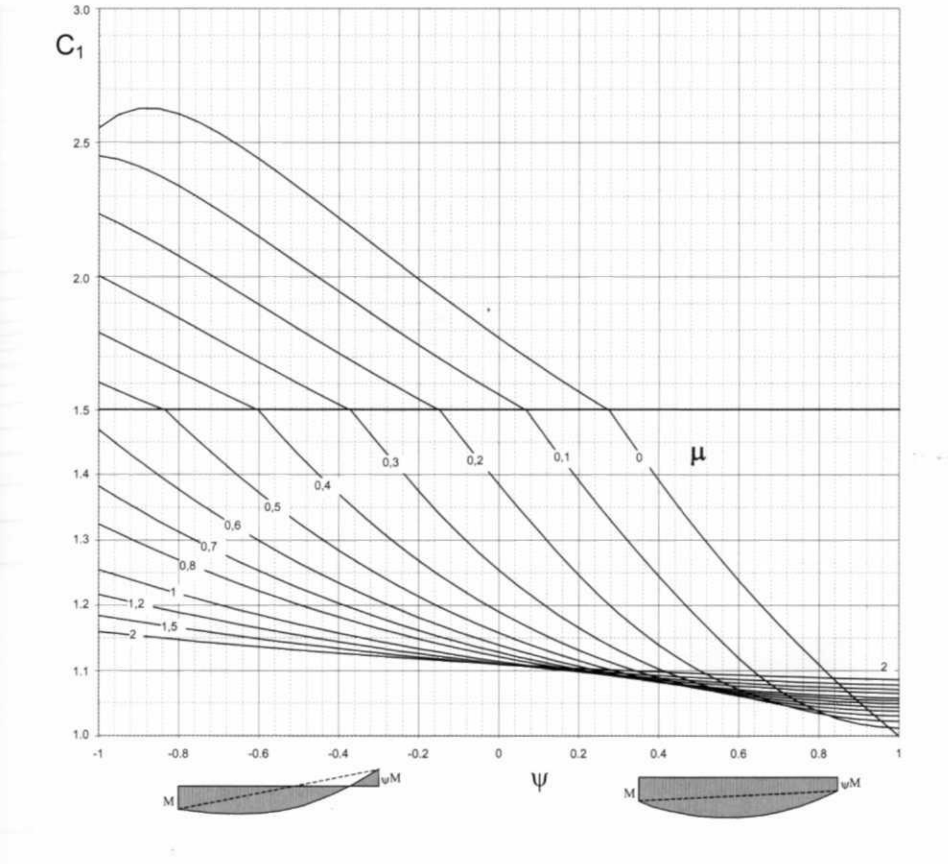


Figure 2.3.16,a – C_1 factor: end moment and uniform load - $\mu > 0$ [15]

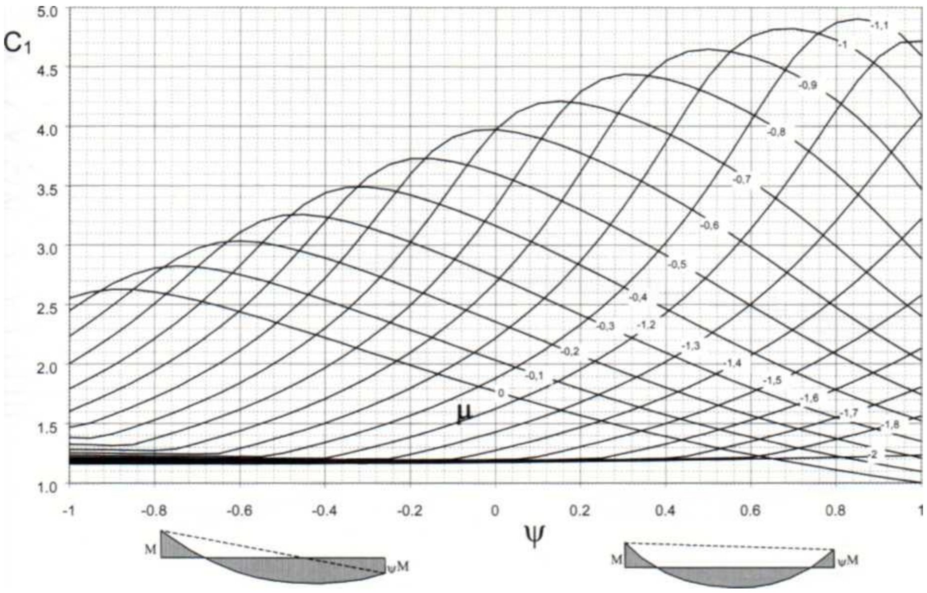


Figure 2.3.16,b – C_1 factor: end moment and uniform load - $\mu < 0$ [15]

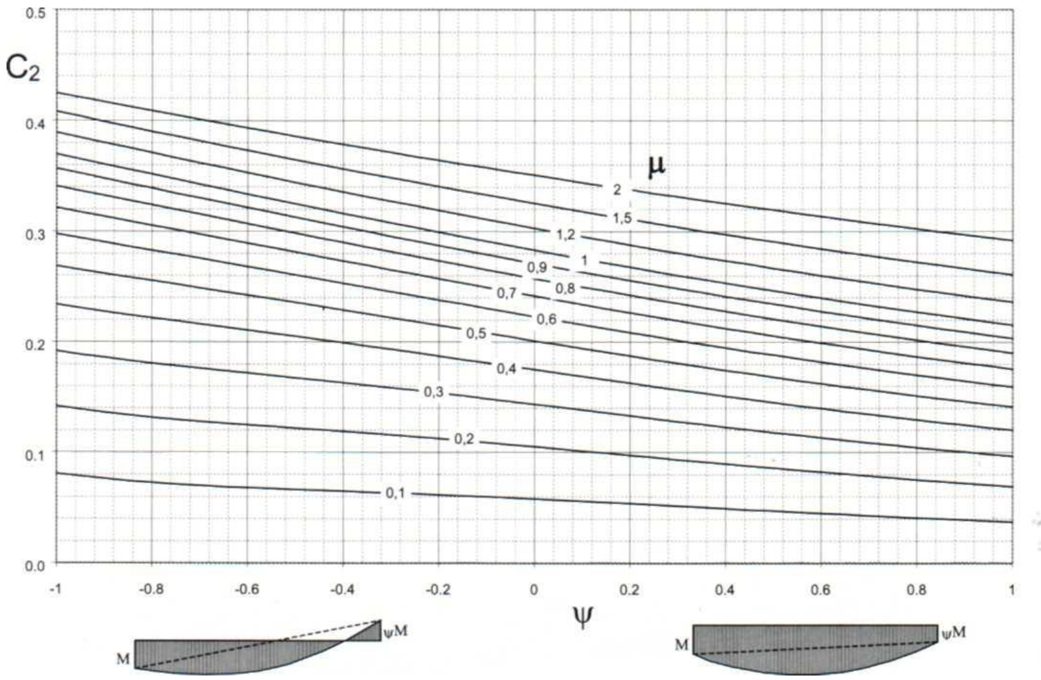


Figure 2.3.17,a – C_2 factor: end moment and uniform load: $\mu > 0$ [15]

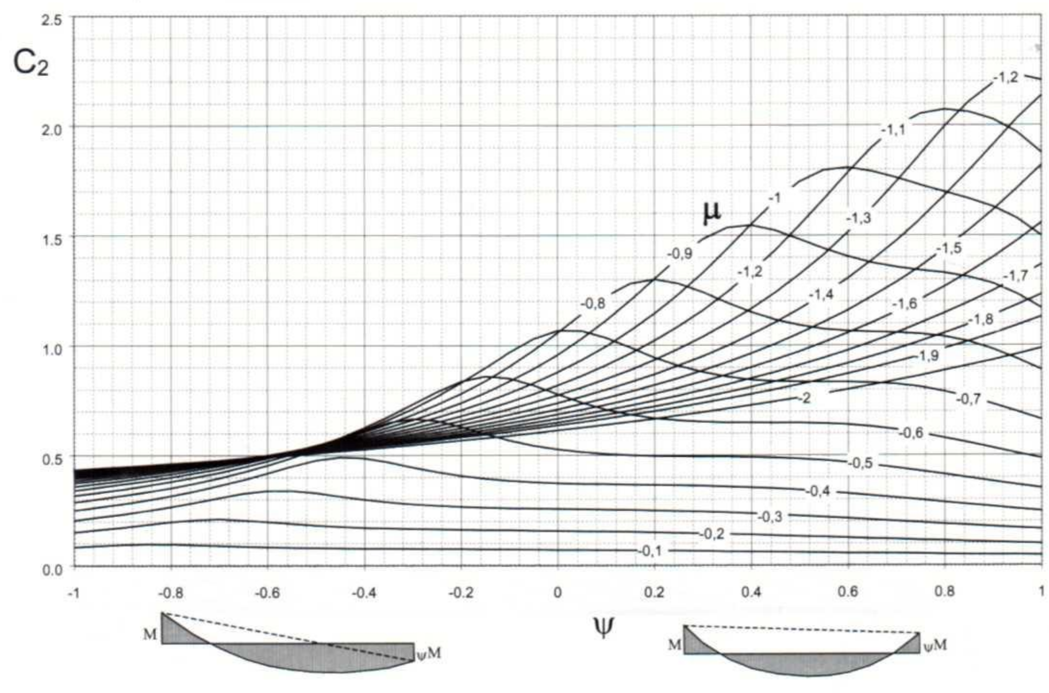


Figure 2.3.17,b – C_2 factor: end moment and uniform load: $\mu < 0$ [15]

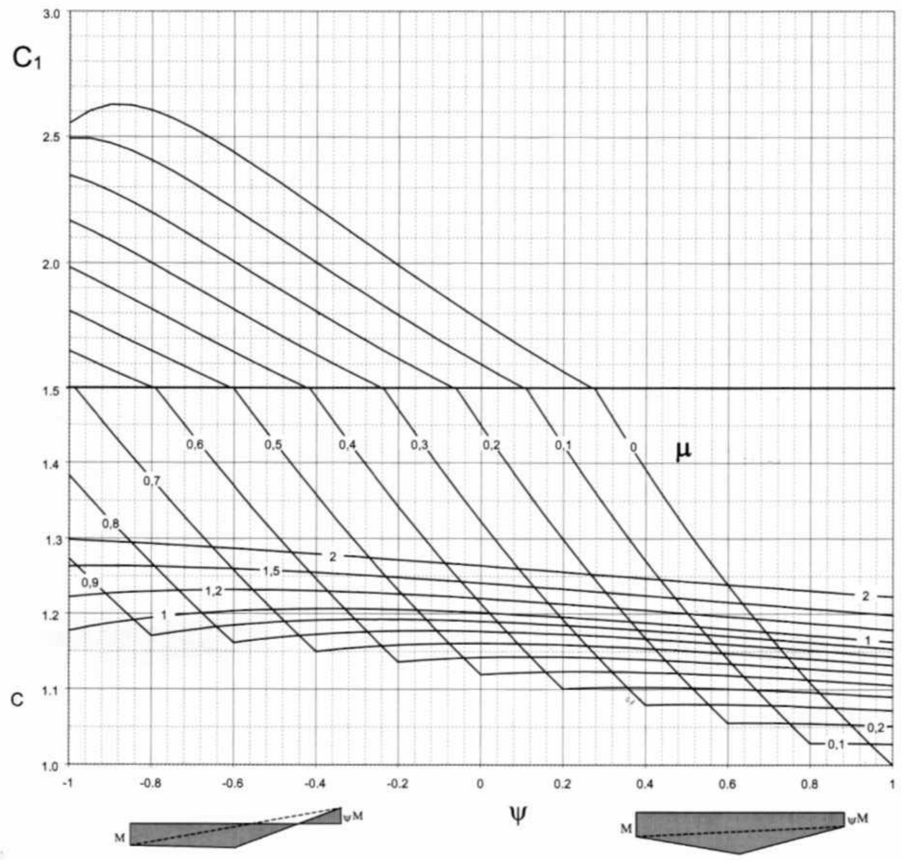


Figure 2.3.18,a – C_1 factor: end moment and point load - $\mu > 0$ [15]

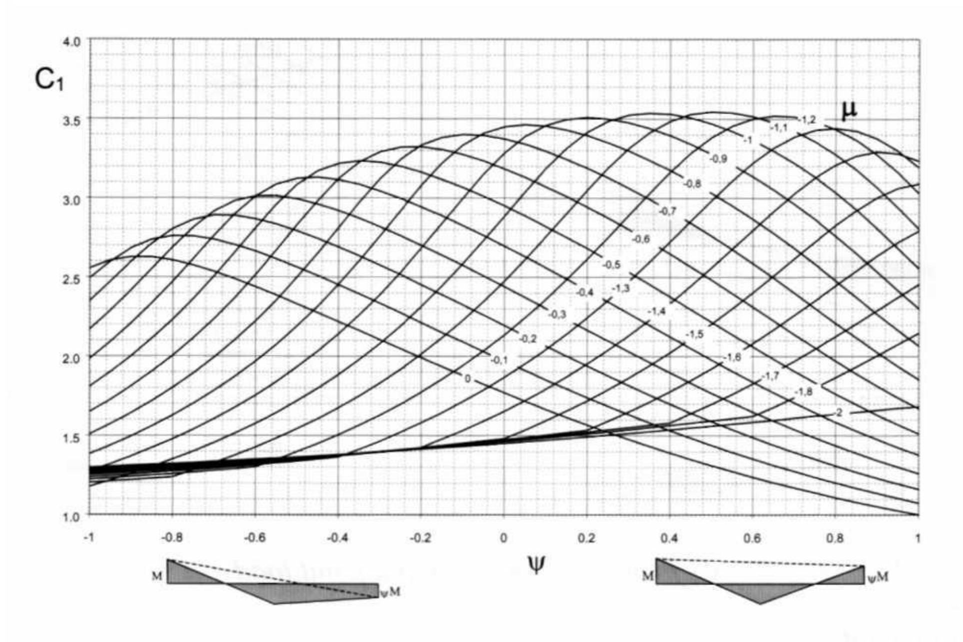


Figure 2.3.18,b – C_1 factor: end moment and point load - $\mu < 0$ [15]

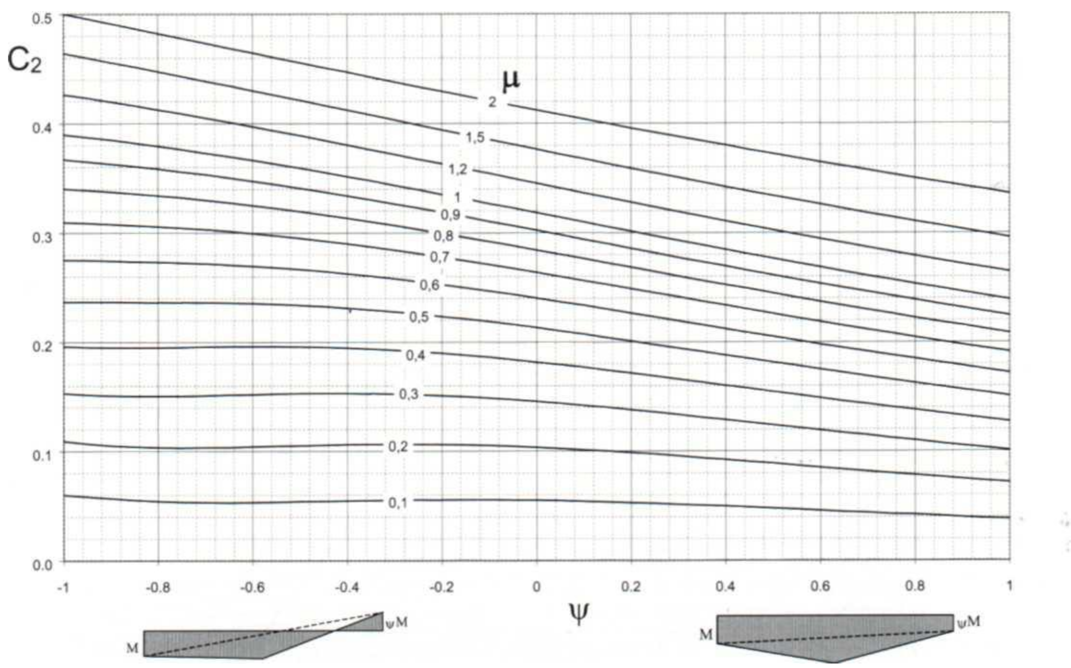


Figure 2.3.19,a – C_2 factor: end moment and point load - $\mu > 0$ [15]

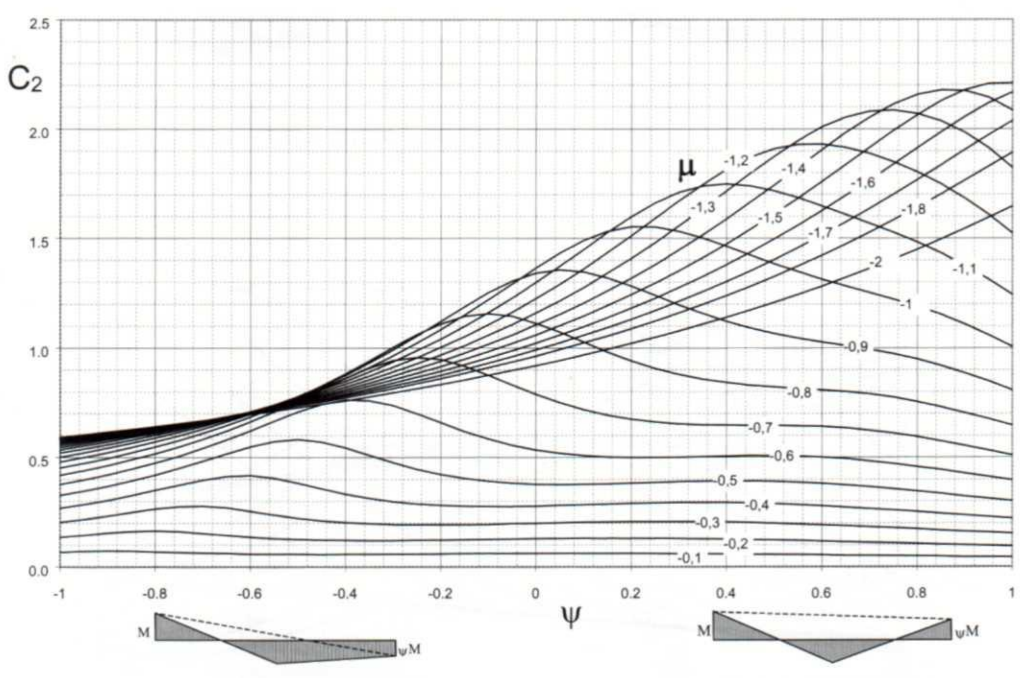


Figure 2.3.19,b – C_2 factor: end moment and point load - $\mu < 0$ [15]

If the member is subjected to transverse load, the level of load application relative to the shear centre is important to determine the critical moment M_{cr}. The influence of this circumstance is taken into account by the product $C_2{\cdot}y_g$ for single profiles and $C_2{\cdot}z_g$ – for double profiles. Where $y_g(z_g)$ is the coordinate of the load application point. Depending on the load application point, transverse loads can be stabilizing or destabilizing, and thus can decisively influence on the elastic critical moment. If a transverse load acts toward the shear centre, it has a destabilizing effect. If the load acts from the shear centre, on the contrary, it has a stabilizing effect. If the load is applied in the shear centre, its influence is neutral. Implemented cases of transverse load application are shown in Figure 2.3.20.

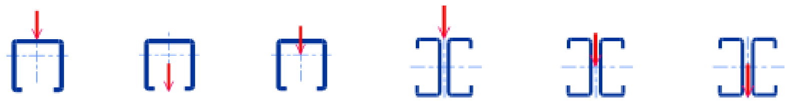


Figure 2.3.20 – Implemented cases of load application

In single profiles (cross-section with one axis of symmetry) the influence of a section asymmetry in the plane of bending in the expression of M_{cr} is taken into account by C_3y_j. Where y_j is the value dependent on the degree of cross-section asymmetry in the plane of bending. The value of y_j is computed according to the method [15] as described in clause 2.3.3.1. For double cross-sections with two axes of symmetry $C_3y_j = 0$.

In equations (2.3.54) and (2.3.55) factor k is related to rotation at the end section about the weak axis. K = 1,0 in the case of no restraint at both ends of the member; k = 0,7 is for one end fixed and one end free; k = 0,5 is for full restraint at both ends. If a member has a discrete restraint out of plane of bending along the length, the above refers to the part of the member between the adjacent restraints. A user should enter consistent values of lateral torsional buckling length $L_{cr,LT}$ and factor k.

Factor k_w in the equations (2.3.54) and (2.3.55) refers to a warping restraint of the end sections. K = 1,0 is in the case of no restraint at both ends of the member; k = 0,7 is for one end fixed and one end free; k = 0,5 is for both ends warping fixed.

Members subjected to combined bending and axial compression can also be alternatively designed according to inequalities (clause 6.3.3 [1]):
single section member (bending about the Z axis)

$$\frac{N_{Ed}}{\chi_z\, N_{Rk}\,/\gamma_{M1}} + k_{zz}\,\frac{M_{zEd}}{\chi_{LT}\, M_{zRk}\,/\gamma_{M1}} \leq 1, \tag{2.3.57,a}$$

$$\frac{N_{Ed}}{\chi_y\, N_{Rk}\,/\gamma_{M1}} + k_{yz}\,\frac{M_{zEd}}{\chi_{LT}\, M_{zRk}\,/\gamma_{M1}} \leq 1, \tag{2.3.57,b}$$

double section member (bending about the Y axis)

$$\frac{N_{Ed}}{\chi_y\, N_{Rk}\,/\gamma_{M1}} + k_{yy}\,\frac{M_{yEd}}{\chi_{LT}\, M_{yRk}\,/\gamma_{M1}} \leq 1, \tag{2.3.58,a}$$

$$\frac{N_{Ed}}{\chi_z\, N_{Rk}\,/\gamma_{M1}} + k_{zy}\,\frac{M_{yEd}}{\chi_{LT}\, M_{yRk}\,/\gamma_{M1}} \leq 1, \tag{2.3.58,b}$$

where $M_{z(y)Ed}$ is a design value of the maximum moment along the member, including for Class 4 section, the additional moment $\Delta M_{Ed} = e_N\, N_{Ed}$; N_{Rk} is the characteristic resistance to normal force of the critical cross-section $N_{Rk} = f_y\, A$ (for Class 3 - the value A is the gross cross-section area, for Class 4 - $A = A_{eff}$); $M_{z(y)Rk}$ is a characteristic moment resistance of the critical cross-section $M_{z(y)Rk} = f_y\, W_{z(y)\,min}$; $\chi_{z(y)}$ is a reduction factor due to a flexural buckling; χ_{LT} is a reduction factor due to a lateral torsional buckling (clause 6.3.2.2 [1]).

Here and below, the first subscript denoting the axes is given for a single cross section, (bending about the Z axis), the second (in brackets) is for a double cross section, (bending about the Y axis).

The interaction factors $k_{yy}(k_{zz})$, $k_{zy}(k_{yz})$, taking into account the combined actions of tension forces and bending moment, are determined by the Method 1 (Annex A [1]).
for a single section member:

$$k_{zz} = C_{m,z}\, C_{m,LT}\, \frac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,z}}}, \tag{2.3.59,a}$$

$$k_{yz} = C_{m,z}\, C_{m,LT}\, \frac{\mu_y}{1 - \dfrac{N_{Ed}}{N_{cr,z}}}, \tag{2.3.59,b}$$

for a double section member:

$$k_{yy} = C_{m,y}\, C_{m,LT}\, \frac{\mu_y}{1 - \dfrac{N_{Ed}}{N_{cr,y}}}, \tag{2.3.60,a}$$

$$k_{zy} = C_{m,y}\, C_{m,LT}\, \frac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,y}}}, \tag{2.3.60,b}$$

where $N_{cr,z}$ is the elastic flexural buckling force about the Z axis; $N_{cr,y}$ is the elastic flexural buckling force about the Y axis.

Factors $C_{m,z(y)}$ and $C_{m,LT}$ are determined by the values of non-dimensional slenderness for lateral-torsional buckling due to uniform bending moment $\overline{\lambda_0}$:

$$\overline{\lambda_0} = \sqrt{\frac{W_{z(y)com}\ f_y}{M_{cr,0}}}, \tag{2.3.61}$$

where $W_{z(y)\,com}$ is the cross-section modulus about the axis Z (for single cross-section) or about the axis Y (for double cross-section) for the most compressed fibre of cross-section; $M_{cr,o}$ is the elastic critical moment for lateral-torsional buckling for the pure bending case [15]:

$$M_{cr,0} = \sqrt{\frac{\pi^2 E\, I_{y(z)}}{(L_{cr,L\,T})^2}\left(GI_T + \frac{\pi^2 EI_w}{(L_{cr,L\,T})^2}\right)}, \quad (2.3.62)$$

where $I_{y(z)}$ is the second moment of area about axis *Y* or *Z*; I_T is the torsional constant; I_w is the warping constant; $L_{cr,LT}$ is the value of buckling length for laterai-torsional buckling.
If

$$\overline{\lambda_0} \leq 0{,}2\,\sqrt{C_1}\,\sqrt[4]{1 - \frac{N_{Ed}}{N_{cr,TF}}} \quad (2.3.63,a)$$

then $C_{m,z(y)} = C_{m,z(y)\,0}$, $C_{m,L\,T} = 1{,}0$;
if

$$\overline{\lambda_0} > 0{,}2\,\sqrt{C_1}\,\sqrt[4]{1 - \frac{N_{Ed}}{N_{cr,TF}}} \quad (2.3.63,b)$$

then

$$C_{m,z(y)} = C_{m,z(y)0} + \left(1 - C_{m,z(y)0}\right)\frac{\sqrt{\varepsilon_{z(y)}}\,a_{L\,T}}{1 + \sqrt{\varepsilon_{z(y)}}\,a_{L\,T}}, \quad (2.3.64)$$

$$C_{m,L\,T} = C^2_{m,z(y)}\frac{a_{L\,T}}{\sqrt{\left(1 - \frac{N_{Ed}}{N_{cr,y(z)}}\right)\left(1 - \frac{N_{Ed}}{N_{cr,T}}\right)}} \geq 1, \quad (2.3.65)$$

where C_1 is the factor, taking into account effect of the distribution of bending moment along the length at the critical moment for lateral-torsional buckling (Table 2.3.3, 2.3.4, Figures 2.3.16, 2.3.18); $C_{m,z(y)0}$ is the equivalent uniform moment factor determined from Table A.2 [1]. For the general case the user can enter the value of the maximum moment and the value of the maximum member displacement along the member (see 2.3.4.2); $C_{m,z(y)}$ is the factor, taking into account the influence of axial compressive force on the critical bending moment at the nonuniform moment diagram; $N_{cr,T}$ is the elastic torsional buckling force; $N_{cr,TF}$ is the elastic torsional-flexural buckling force; $a_{LT} = 1 - I_T/I_{z(y)} \geq 0$.
Class 3 cross-sections:

$$\varepsilon_{z(y)} = \frac{M_{Ed}}{N_{Ed}}\frac{A}{W_{z(y)}}, \quad (2.3.66,a)$$

Class 4 cross-sections:

$$\varepsilon_{z(y)} = \frac{M_{Ed}}{N_{Ed}}\frac{A_{eff}}{W_{z(y)eff}}. \quad (2.3.66,b)$$

Parameter $\mu_{z(y)}$ is determined from equation (Table A.1 [1]):

$$\mu_{z(y)} = \frac{1 - \frac{N_{Ed}}{N_{cr,z(y)}}}{1 - \chi_{z(y)}\frac{N_{Ed}}{N_{cr,z(y)}}}, \quad (2.3.67)$$

where $\chi_{z(y)}$ is the reduction factor for the flexural buckling mode about the appropriate axis.

2.3.4.2. Input data

To input data, select in main menu *Member* → *BeamColumn*. Further, an input window appears for single cross-section members Figure 2.3.21, and for double cross-section members Figure 2.3.22.

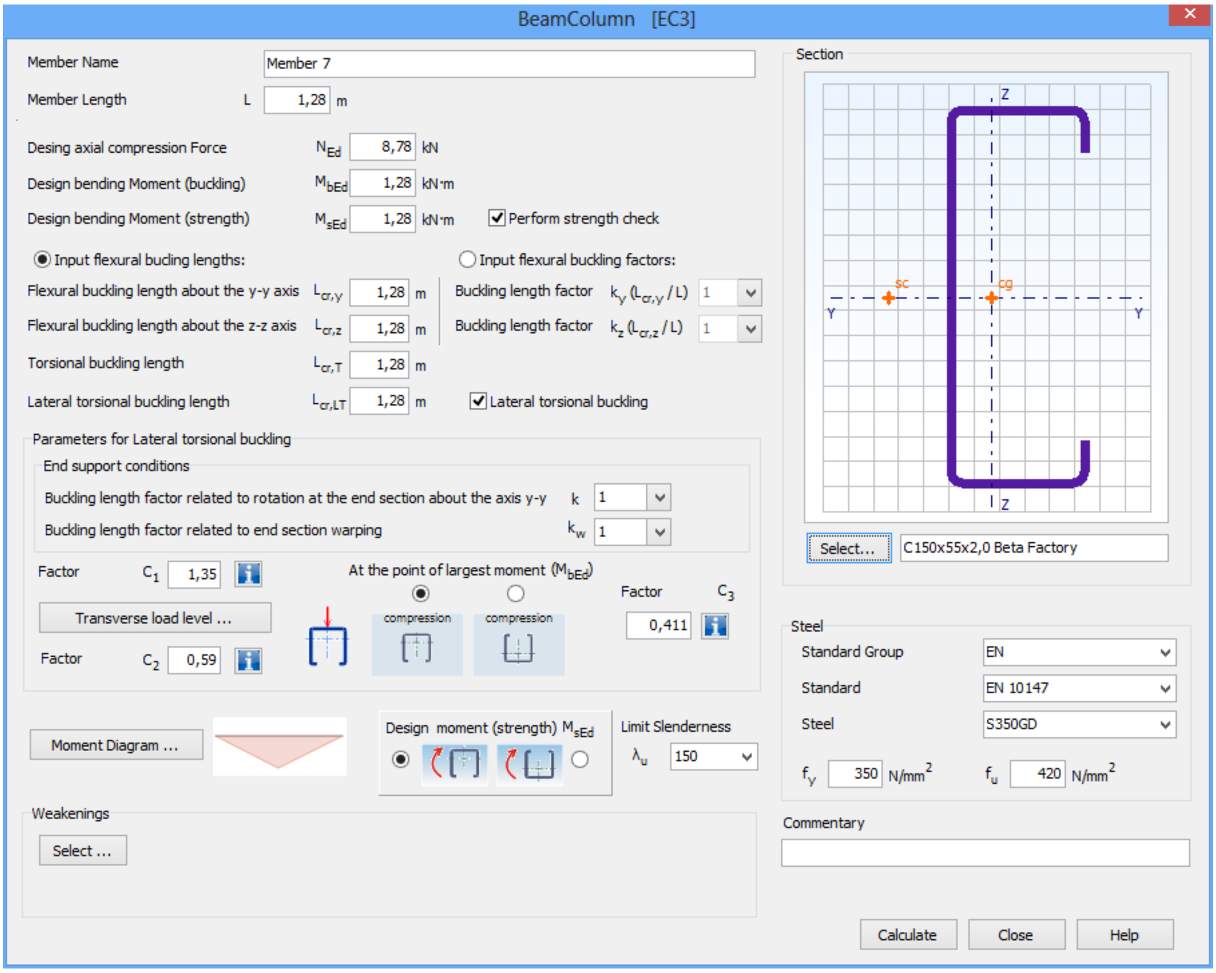


Figure 2.3.21 - Input data window for compression with bending members (single cross-section)

You can define a member name (name of calculation, design or project), a member length L, a design axial compression force N_{Ed}, a design bending moment M_{bEd} for buckling design, a design bending moment M_{sEd} for strength design (the latter is required if the *Perform strength check* box is labeled). In general case, the values of M_{bEd} and M_{sEd} might be different. The strength calculation is performed on the action of M_{sEd}, and for a single section with a not fully effective cross-section for the summarized volume $M_{sEd}+e_N N_{Ed}$. It is necessary to specify the direction of bending moment M_{sEd} for a single section. It compresses the web or the flanges (lips) (Figure 2.3.21).

If you select the *Perform check for resistance of net cross-section* item in main menu *Options → Design Details* (clause 3.1) and enter *Weakening* in the input window *BeamColumn*, strength calculation will be performed for the net cross-section. If you do not enter weakening, strength calculation will be performed for a gross cross-section (Class 3 cross-section) or for an effective cross-section (Class 4 cross-section). If the *Perform check for resistance of net cross-section* box is not marked, but weakening data was inputted, there will be a contradiction, and strength calculation will not be performed. Therefore, it is necessary to reset all the data about the weakened cross-section. However, if the *Perform strength check* box (Figure 2.3.21, Figure 2.3.22) is not marked, the strength calculation is not performed.

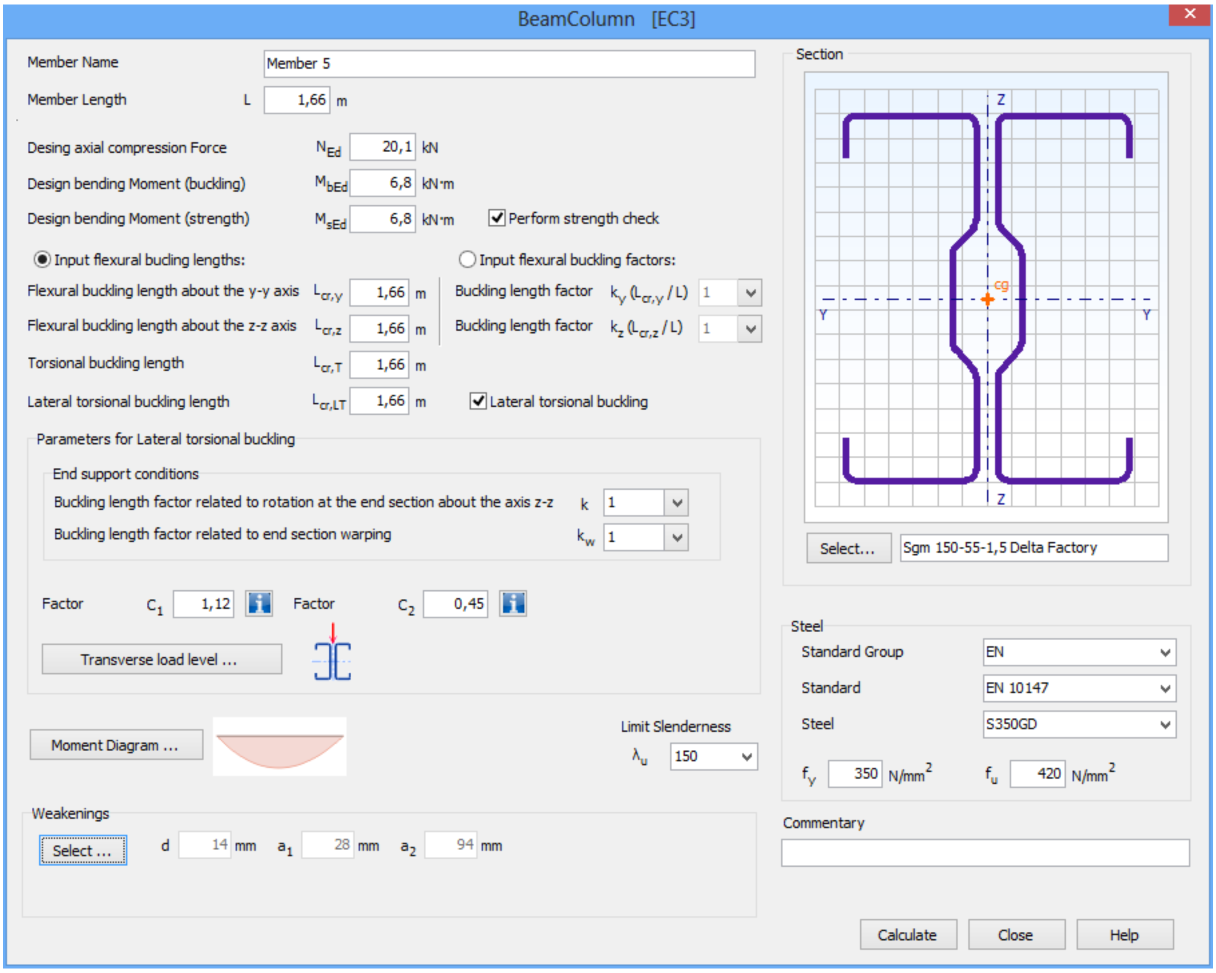


Figure 2.3.22 - Input data window for compression with bending members
(double cross-section)

You can choose how to define flexural buckling lengths. There are two options: direct input buckling lengths about the *Y* and *Z* axes ($L_{cr,y}$ and $L_{cr,z}$) as shown in Figure 2.3.22, and the input buckling length factors about appropriate axes k_y and k_z (Figure 2.3.21) with further automatic calculation of buckling lengths $L_{cr,y} = k_y L$, $L_{cr,z} = k_z L$.

The determination of cross section type and dimension, as well as steel data is carried out in a standard way as described above.

Torsional buckling length $L_{cr,T}$ and lateral-torsional buckling length $L_{cr,LT}$ should also be entered, as well as other parameters for a lateral-torsional design: a buckling length factor refers to the end rotation on plan k; a buckling length factor refers to the end warping k_w; C_1 – a factor reflecting the effect of the distribution of bending moment along the length at the critical moment for a lateral-torsional buckling; C_2 – a factor dependent on the level of transverse load application relative to the shear centre and C_3 – a factor dependent on the degree of cross-section asymmetry (only for single sections). Some recommendations for assigning values of these factors are contained in clause 2.3.4.1.

You should assign the level of load application relative to the shear centre, which is important for calculation of elastic critical moment for a lateral-torsional buckling M_{cr} (clause 2.3.4.1). To do this, select the *Transverse load level…* button Dialog box shown in Figure 2.3.2.3, will appear. Its appearance depends on the type of a cross-section: single or double.

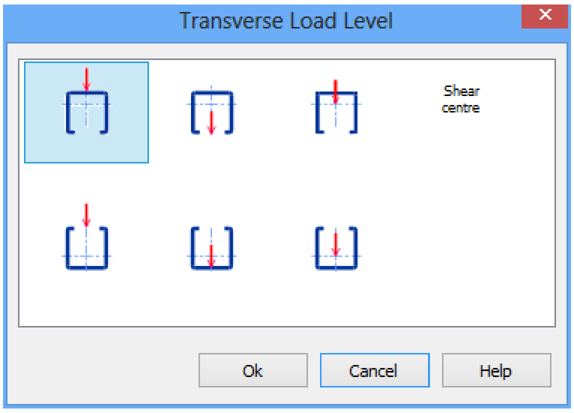


Figure 2.3.23 – Dialog box for determination of the level of load application

For single sections it is necessary to assign the direction of bending moment in a cross-section with a maximum value of M_{bEd} (Figure 2.3.21).

To calculate factor $C_{m,z(y)0}$ (equivalent uniform moment factor determined from Table A.2 [1]), select the *Moment Diagram* button, then select the most suitable case in dialog box (Figure 2.3.24).

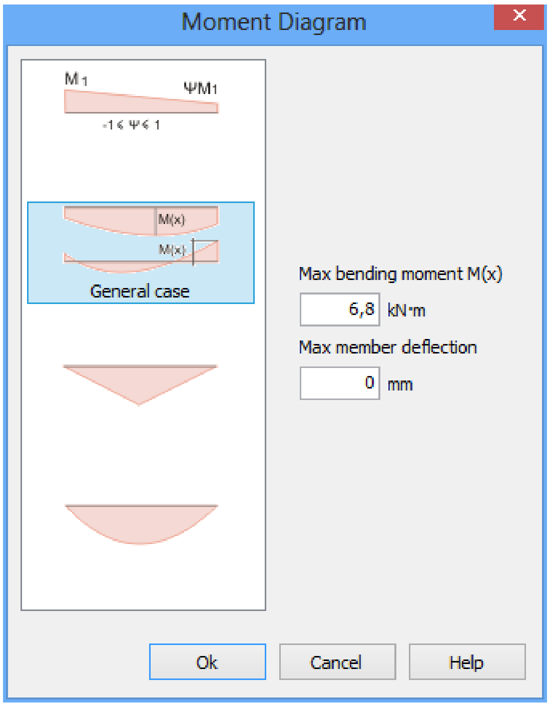


Figure 2.3.24 – Dialog box to select a moment diagram

When you select *General case*, you should enter the value of maximum bending moment and a maximum deflection along the member. The latter can be obtained, for example, by FEM software.

2.3.4.3. Design results

Design results are presented in a similar manner as described in clause 2.1 and shown in previous calculations. The Figures 2.3.25 – 2.3.29 present some of the window with design results. The Figures 2.3.30 – 2.3.35 present the document, obtained after exporting results to Microsoft Excel®.

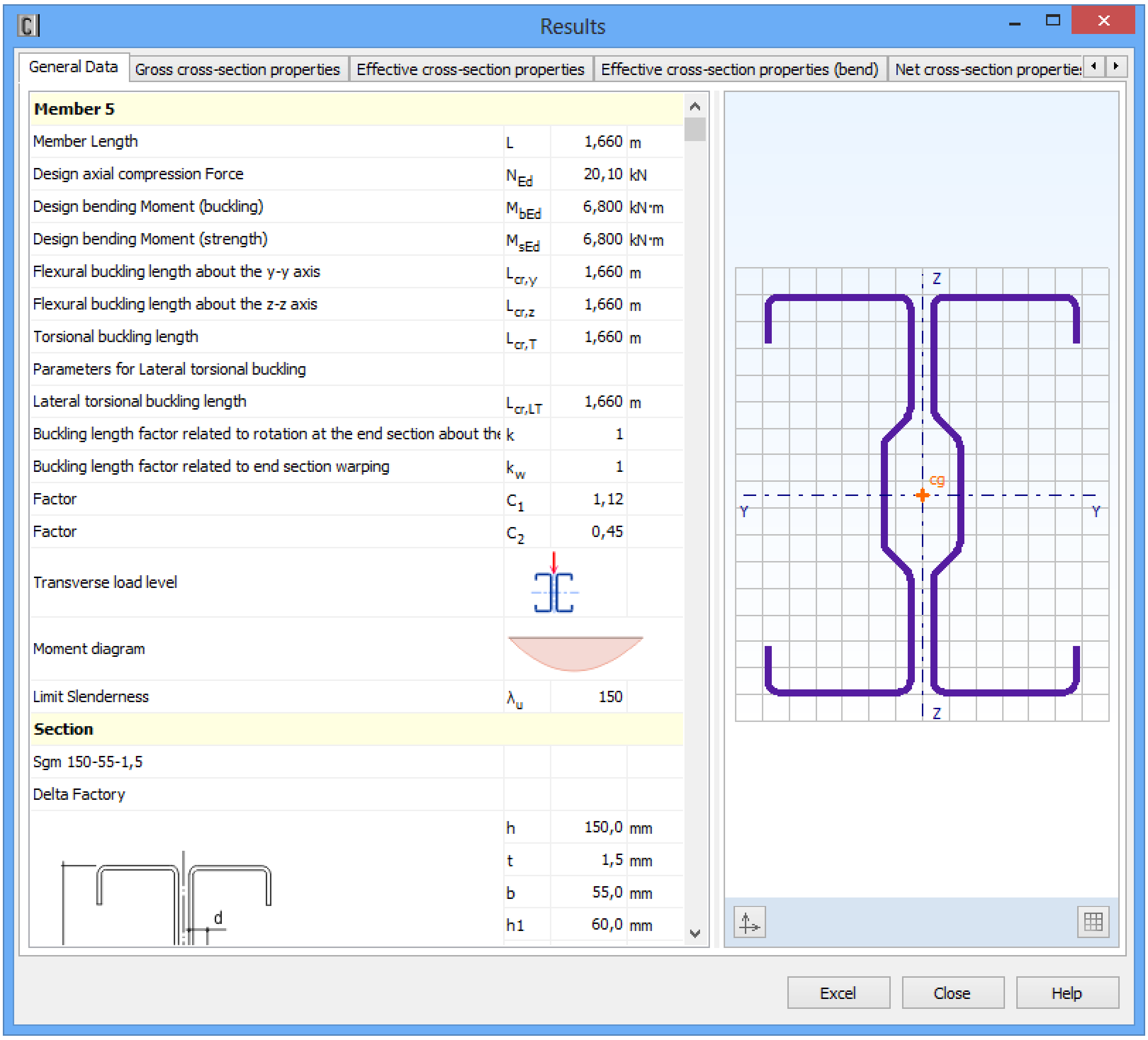


Figure 2.3.25 – Window of results: *General data*

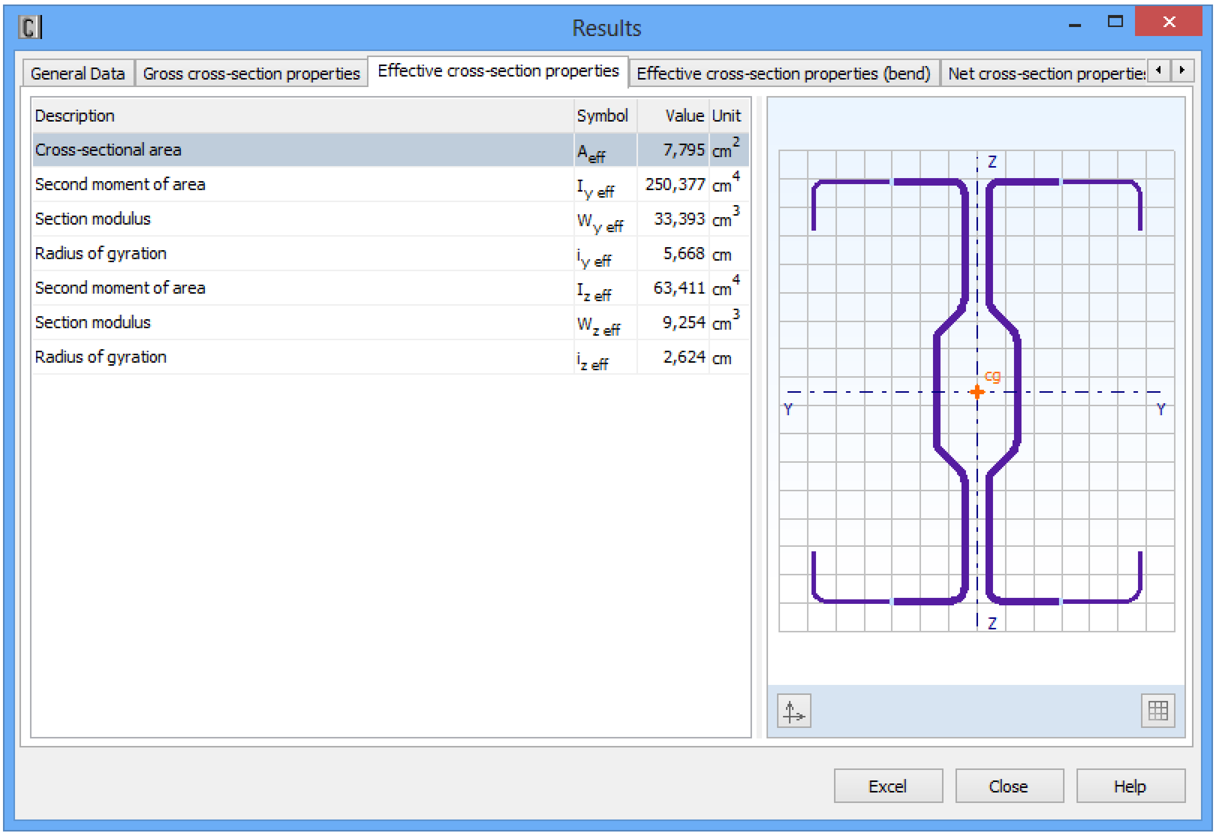


Figure 2.3.26 – Window of results: *Effective cross-section properties (uniform compression)*

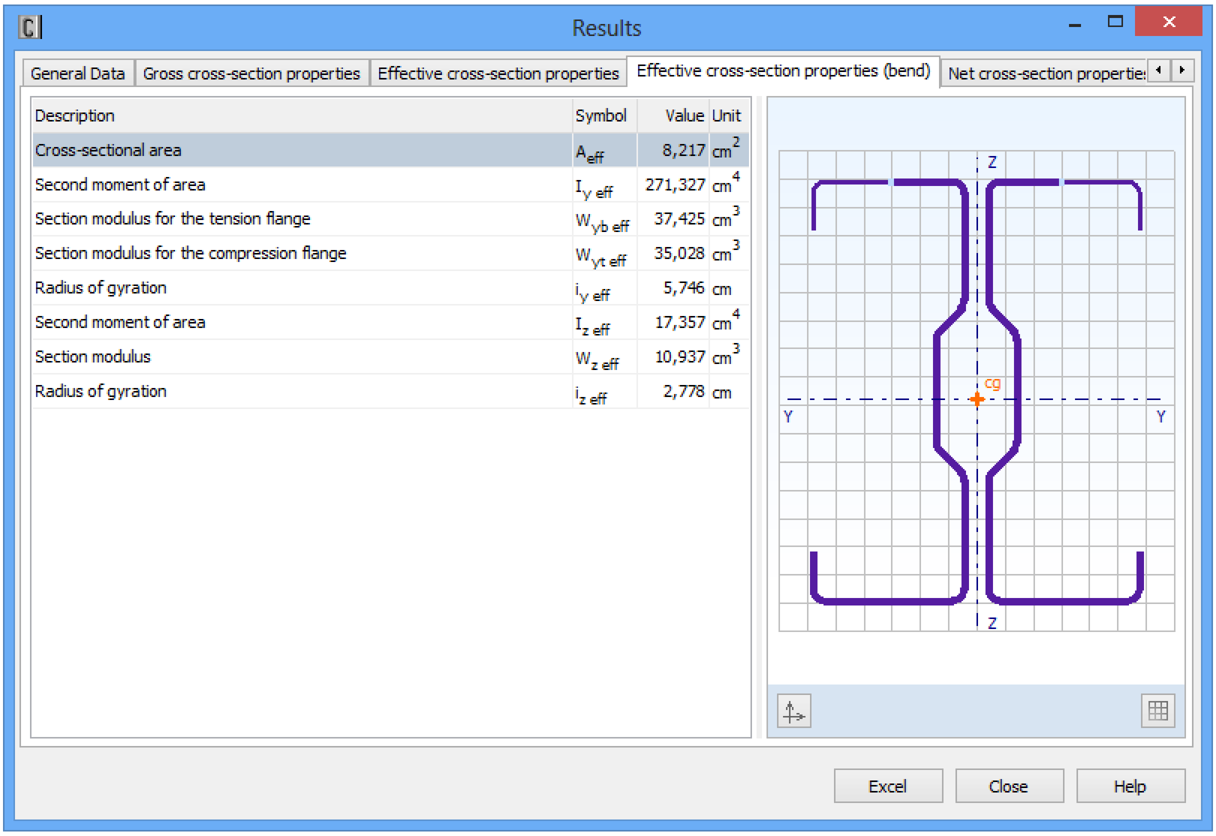


Figure 2.3.27 – Window of results: *Effective cross-section properties (bending)*

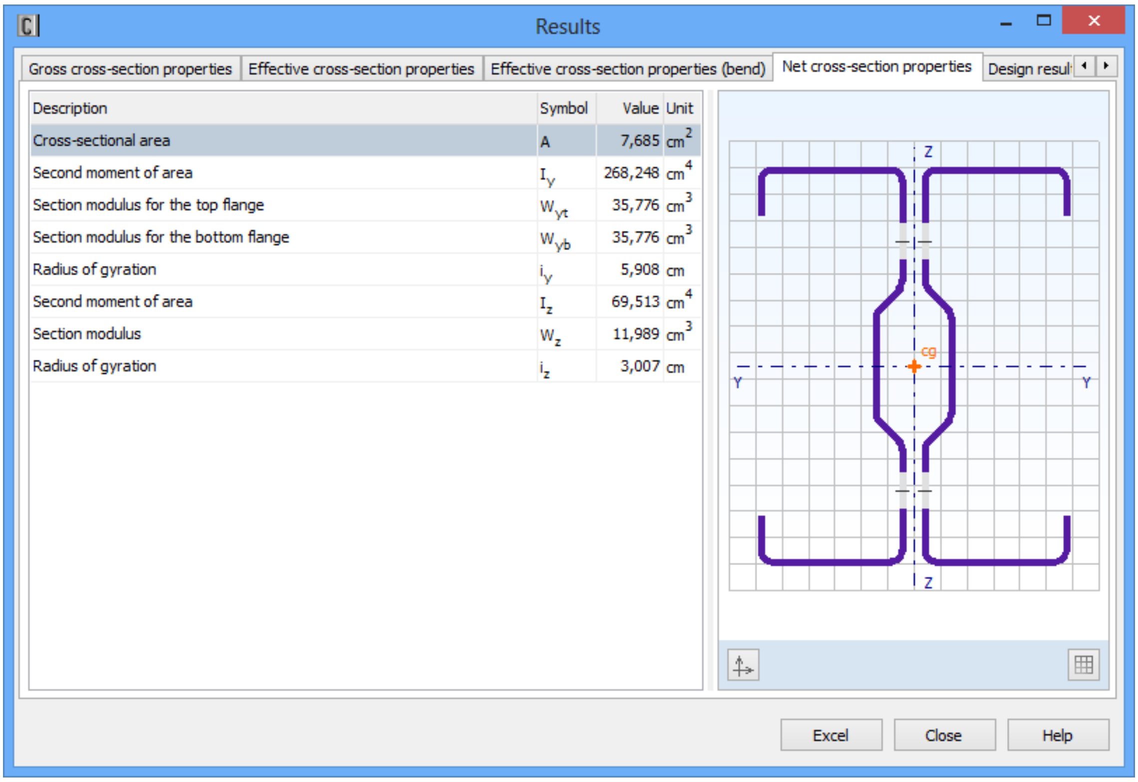


Figure 2.3.28 – Window of results: *Net cross-section properties*

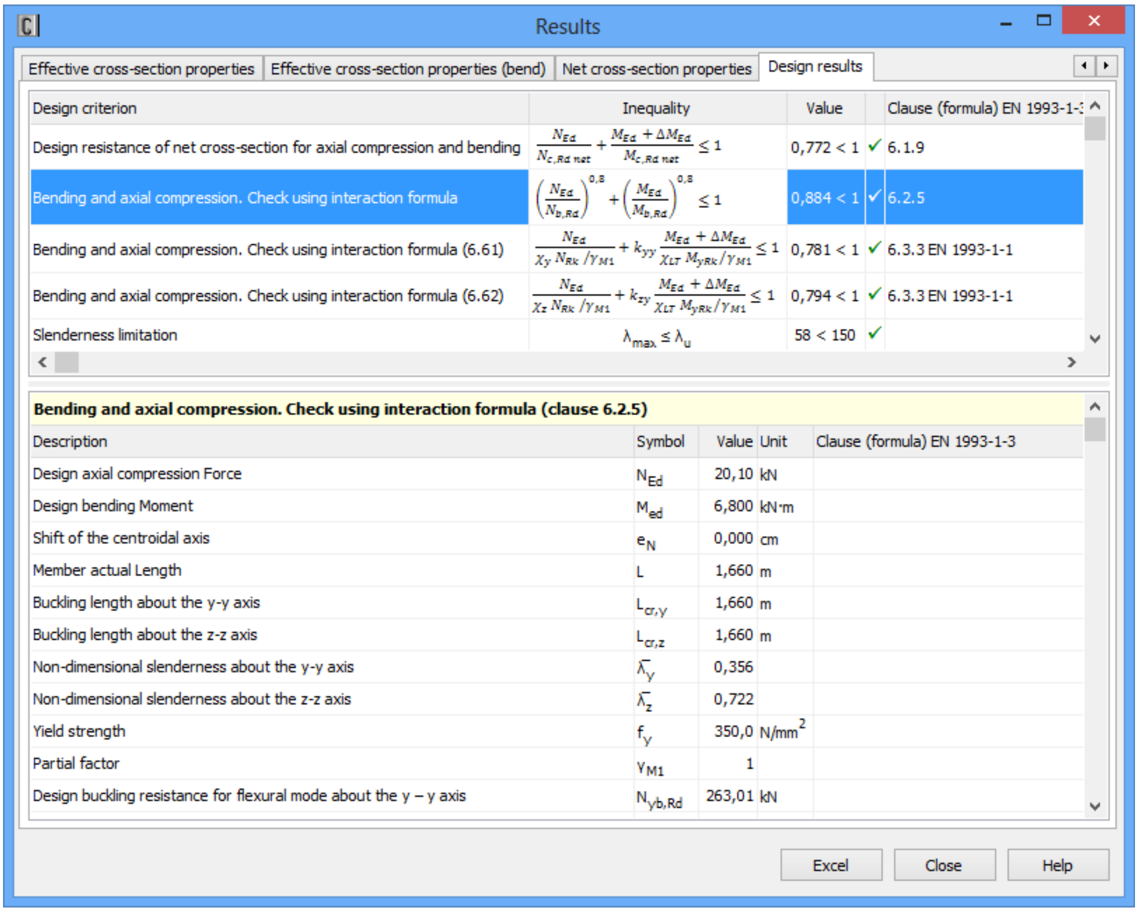


Figure 2.3.29 – Window of results: *Design results*

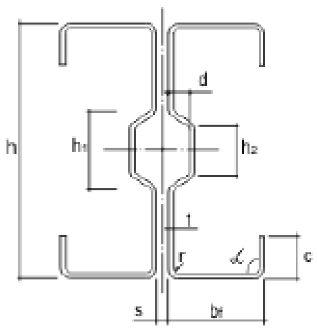
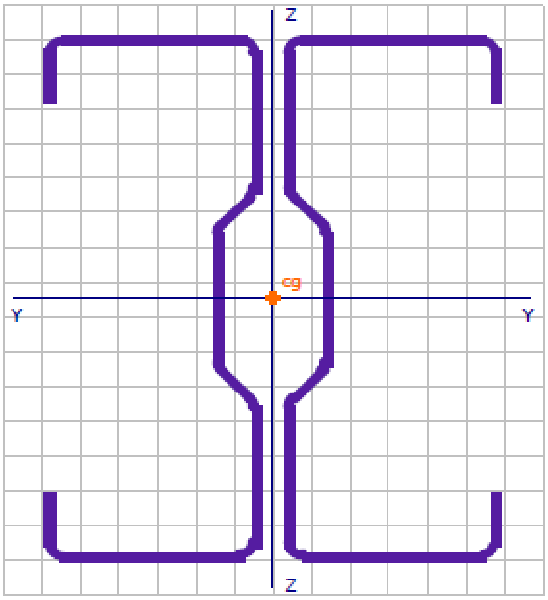
Delta Engineering Software	*CFSteel 4.0.1*		page 1
http://www.CFSteel.ru	User		
mailto:deltaing@mail.ru	EC3		31.05.2016
Member 5			
Member Length	L	1,660	m
Design axial compression Force	N_{Ed}	20,10	kN
Design bending Moment (buckling)	M_{bEd}	6,800	kN·m
Design bending Moment (strength)	M_{sEd}	6,800	kN·m
Flexural buckling length about the y-y axis	$L_{cr,y}$	1,660	m
Flexural buckling length about the z-z axis	$L_{cr,z}$	1,660	m
Torsional buckling length	$L_{cr,T}$	1,660	m
Parameters for Lateral torsional buckling			
Lateral torsional buckling length	$L_{cr,LT}$	1,660	m
Buckling length factor related to rotation at the end section about the z-z axis	k	1	
Buckling length factor related to end section warping	k_w	1	
Factor	C_1	1,12	
Factor	C_2	0,45	
Transverse load level			
Moment diagram			
Limit Slenderness	λ_u	150	
Section			
	h	150,0	mm
	t	1,5	mm
	b	55,0	mm
	h_1	60,0	mm
	h_2	40,0	mm
	d	10,0	mm
	c	18,0	mm
	r	3,0	mm
	t_{coat}	0,04	mm
	S	6,0	mm
Net cross-section			
Web			
Diameter	d	14,0	mm
Dimension	a_1	28,0	mm
	a_2	94,0	mm
Steel			
Standard Group		EN	
Standard		EN 10147	
Steel		S350GD	
Yield strength	f_y	350,0	N/mm²
Ultimate tensile strength	f_u	420,0	N/mm²
Modulus of elasticity	E	210000,0	N/mm²
Poisson ratio	ν	0,3	

Figure 2.3.30 – *General data*

Delta Engineering Software	*CFSteel 4.0.1*	page 2
http://www.CFSteel.ru	user	
mailto:deltaing@mail.ru	EC3	31.05.2016

Member 5

Sgm 150-55-1,5 Delta Factory



Description	Symbol	Value	Unit
Cross-sectional area	A	8,503	cm^2
Second moment of area	I_y	286,443	cm^4
Section modulus	W_y	38,203	cm^3
Radius of gyration	i_y	5,804	cm
Second moment of area	I_z	69,630	cm^4
Section modulus	W_z	12,009	cm^3
Radius of gyration	i_z	2,862	cm
Torsional constant	I_t	0,057782	cm^4
Warping constant	I_w	4289,034	cm^6
Weight per unit length		7,00	kg/m

Figure 2.3.31 – *Gross cross-section properties*

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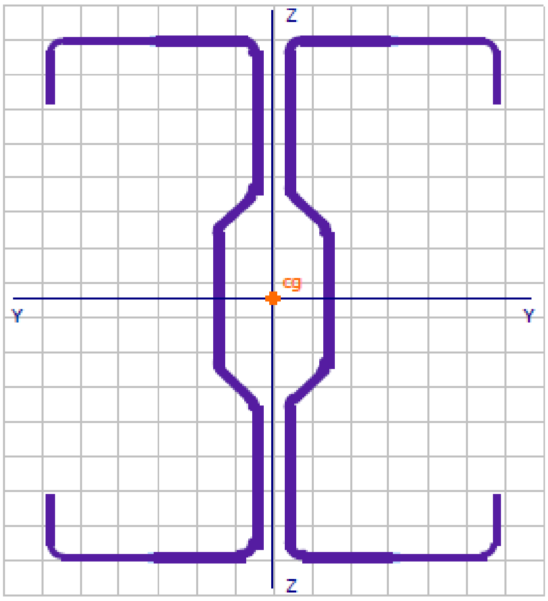
http://www.CFSteel.ru		user	
mailto:deltaing@mail.ru		EC3	31.05.2016

Member 5

Sgm 150-55-1,5 Delta Factory



Description	Symbol	Value	Unit
Cross-sectional area	A_{eff}	7,795	cm^2
Second moment of area	$I_{y\ eff}$	250,377	cm^4
Section modulus	$W_{y\ eff}$	33,393	cm^3
Radius of gyration	$i_{y\ eff}$	5,668	cm
Second moment of area	$I_{z\ eff}$	63,411	cm^4
Section modulus	$W_{z\ eff}$	9,254	cm^3
Radius of gyration	$i_{z\ eff}$	2,624	cm

Figure 2.3.32 – *Effective cross-section properties (uniform compression)*

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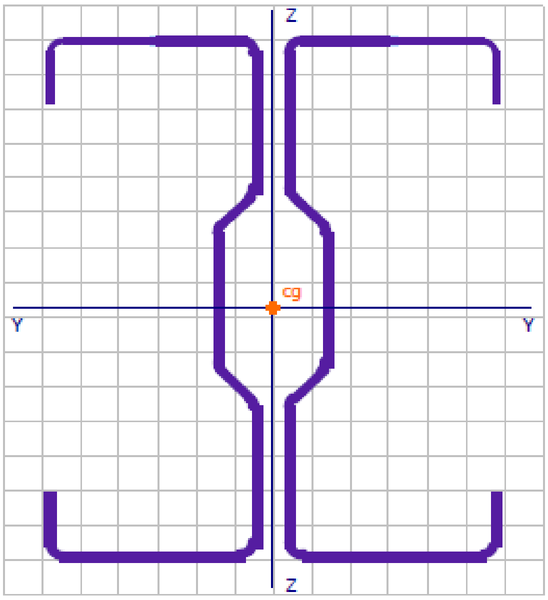
http://www.CFSteel.ru	user	
mailto:deltaing@mail.ru	EC3	31.05.2016

Member 5

Sgm 150-55-1,5 Delta Factory



Description	Symbol	Value	Unit
Cross-sectional area	A_{eff}	8,217	cm^2
Second moment of area	$I_{y\,eff}$	271,327	cm^4
Section modulus for the tension flange	$W_{yb\,eff}$	37,425	cm^3
Section modulus for the compression flange	$W_{yt\,eff}$	35,028	cm^3
Radius of gyration	$i_{y\,eff}$	5,746	cm
Second moment of area	$I_{z\,eff}$	0,000	cm^4
Section modulus	$W_{z\,eff}$	10,937	cm^3
Radius of gyration	$i_{z\,eff}$	2,778	cm

Figure 2.3.33 – *Effective cross-section properties (bending)*

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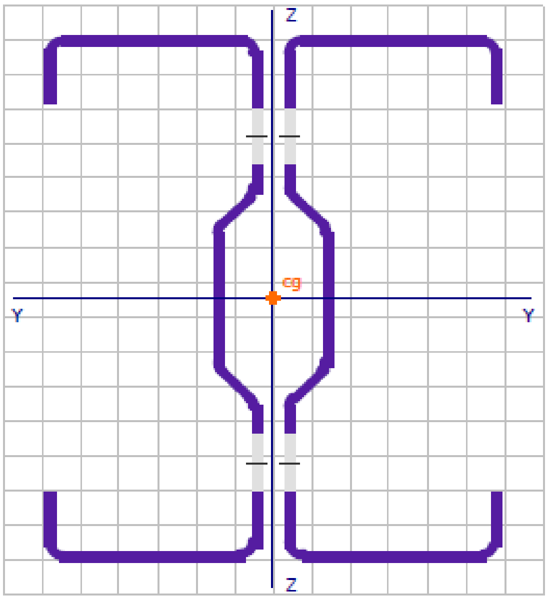
Member 5

Sgm 150-55-1,5 Delta Factory



Description	Symbol	Value	Unit
Cross-sectional area	A	7,685	cm^2
Second moment of area	I_y	268,248	cm^4
Section modulus for the top flange	W_{yt}	35,776	cm^3
Section modulus for the bottom flange	W_{yb}	35,776	cm^3
Radius of gyration	i_y	5,908	cm
Second moment of area	I_z	69,513	cm^4
Section modulus	W_z	11,989	cm^3
Radius of gyration	i_z	3,007	cm

Figure 2.3.34 – *Net cross-section properties*

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Member 5

Design criterion	Inequality	Value		Clause (formula) EN 1993-1-3
Design resistance of net cross-section for axial compression and bending	$\frac{N_{Ed}}{N_{c,Rd\,net}} + \frac{M_{Ed} + \Delta M_{Ed}}{M_{c,Rd\,net}} \leq 1$	0,772 < 1	✓	6.1.9
Bending and axial compression. Check using interaction formula	$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1$	0,884 < 1	✓	6.2.5
Bending and axial compression. Check using interaction formula (6.61)	$\frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}} + k_{yy}\frac{M_{Ed} + \Delta M_{Ed}}{\chi_{LT} M_{yRk}/\gamma_{M1}} \leq 1$	0,781 < 1	✓	6.3.3 EN 1993-1-1
Bending and axial compression. Check using interaction formula (6.62)	$\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}} + k_{zy}\frac{M_{Ed} + \Delta M_{Ed}}{\chi_{LT} M_{yRk}/\gamma_{M1}} \leq 1$	0,794 < 1	✓	6.3.3 EN 1993-1-1
Slenderness limitation	$\lambda_{max} \leq \lambda_u$	58 < 150	✓	

Design resistance of net cross-section for axial compression and bending

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Design axial compression Force	N_{Ed}	20,10	kN	
Net cross-sectional Area	A_n	7,685	cm²	
Yield strength	f_y	350,0	N/mm²	
Partial factor	γ_{M2}	1,250		
Design resistance of net cross-section for axial compression	$N_{c,Rd\,net}$	215,19	kN	
Design bending Moment (strength)	$M_{s,Ed}$	6,800	kN·m	
Design moment resistance of net cross-section	$M_{c,Rd\,net}$	0,000	kN·m	6.1.9

Bending and axial compression. Check using interaction formula (clause 6.2.5)

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Design axial compression Force	N_{Ed}	20,10	kN	
Design bending Moment	M_{ed}	6,800	kN·m	
Shift of the centroidal axis	e_N	0,000	cm	
Member actual Length	L	1,660	m	

Figure 2.3.35,a – *Design results*

Buckling length about the y-y axis	$L_{cr,y}$	1,660 m	
Buckling length about the z-z axis	$L_{cr,z}$	1,660 m	
Non-dimensional slenderness about the y-y axis	$\bar{\lambda}_y$	0,356	
Non-dimensional slenderness about the z-z axis	$\bar{\lambda}_z$	0,722	
Yield strength	f_y	350,0 N/mm^2	
Partial factor	γ_{M1}	1,000	
Design buckling resistance for flexural mode about the y – y axis	$N_{yb,Rd}$	263,01 kN	
Design buckling resistance for flexural mode about the z – z axis	$N_{zb,Rd}$	210,42 kN	
Design buckling resistance for torsional/torsional-flexural mode	$N_{bTF,Rd}$	229,61 kN	
Design buckling resistance of a compression member (flexural, torsional or torsional-flexural buckling)	$N_{b,Rd}$	210,42 kN	6.2.5
Elastic critical moment for lateral-torsional buckling	M_{cr}	30,621 kN·m	
Non-dimensional slenderness	$\bar{\lambda}_{LT}$	0,633	6.3.2 EN 1993-1-1
Reduction factor	χ_{LT}	0,820	6.3.2 EN 1993-1-1
Design section modulus	W	35,028 cm^3	
Design bending moment resistance	$M_{b,Rd}$	10,056 kN·m	6.2.4 EN 1993-1-3, 6.3.2 EN 1993-1-1

Bending and axial compression. Check using interaction formula (6.61)

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Design axial compression Force	N_{Ed}	20,10	kN	
Design bending Moment	M_{Ed}	6,800	kN·m	
Shift of the centroidal axis	e_N	0,000	cm	6.1.3
Member actual Length	L	1,660	m	
Buckling length about the y-y axis	$L_{cr,y}$	1,660	m	

Figure 2.3.35,b – *Design results*

Buckling length about the z-z axis	$L_{cr,z}$	1,660	m	
Non-dimensional slenderness about the y-y axis	$\bar{\lambda}_y$	0,356		
Non-dimensional slenderness about the z-z axis	$\bar{\lambda}_z$	0,722		
Reduction factor due to flexural buckling	χ	0,771		6.3.1 EN 1993-1-1
Gross cross-sectional Area	A	8,503	cm^2	
Effective Area of a cross-section (compression)	A_{eff}	7,795	cm^2	
Yield strength	f_y	350,0	N/mm^2	
Partial factor	γ_{M1}	1,000		
Characteristic value of resistance to compression	N_{Rk}	272,82	kN	
Reduction factor due to lateral torsional buckling	χ_{LT}	0,820		6.3.2 EN 1993-1-1
Design section modulus	W	35,028	cm^3	
Characteristic value of resistance to bending moment	M_{Rk}	12,260	kN·m	
Interaction factor	k	1,033		Annex A EN 1993-1-1

Bending and axial compression. Check using interaction formula (6.62)

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Design axial compression Force	N_{Ed}	20,10	kN	
Design bending Moment	M_{Ed}	6,800	kN·m	
Shift of the centroidal axis	e_N	0,000	cm	6.1.3
Member actual Length	L	1,660	m	
Buckling length about the y-y axis	$L_{cr,y}$	1,660	m	
Buckling length about the z-z axis	$L_{cr,z}$	1,660	m	
Non-dimensional slenderness about the y-y axis	$\bar{\lambda}_y$	0,356		
Non-dimensional slenderness about the z-z axis	$\bar{\lambda}_z$	0,722		
Reduction factor due to flexural buckling	χ	0,771		6.3.1 EN 1993-1-1
Gross cross-sectional Area	A	8,503	cm^2	

Figure 2.3.35,c – *Design results*

Effective Area of a cross-section (compression)	A_{eff}	7,795	cm^2	
Yield strength	f_y	350,0	N/mm^2	
Partial factor	γ_{M1}	1,000		
Characteristic value of resistance to compression	N_{Rk}	272,82	kN	
Reduction factor due to lateral torsional buckling	χ_{LT}	0,820		6.3.2 EN 1993-1-1
Design section modulus	W	35,028	cm^3	
Characteristic value of resistance to bending moment	M_{Rk}	12,260	kN·m	
Interaction factor	k	1,033		Annex A EN 1993-1-1

Slenderness limitation

Description	Symbol	Value	Unit	Clause (formula) EN 1993-1-3
Max slenderness	λ_{max}	58,0		
Limit slenderness	λ_u	150,0		

Figure 2.3.35,d – *Design results*

2.4. Design according to North American Specification AISI S100

2.4.1. Tension

2.4.1.1. Design procedure

You can choose design method: Allowable Strength Design (ASD) or Load and Resistance Factor Design (LRFD).

The following calculations are performed for a tension member:

– prevention of excessive elongation of the member;
– prevention of rupture of weakened cross-section if the weakening takes place along the member;
– slenderness check.

At the point of attachment calculations are carried out according to the following criteria:

– rupture in net section at connection;
– bearing strength of the member at connection;
– block shear rupture strength of the member at connection.

In general, the design is performed in the form of inequality (B3 [5])

ASD:

$$P \leq P_{tn}/\Omega, \quad (2.4.1,a)$$

LRFD:

$$P \leq \phi\, P_{tn}, \quad (2.4.1,b)$$

where P = required strength; P_{tn} = nominal strength; Ω = safety factor; ϕ = resistance factor; P_{tn}/Ω = allowable strength; ϕP_{tn} = design strength.

The nominal tensile strength [resistance] due to yielding of the gross cross section (D2 [5])

$$P_{tgn} = A_g F_y, \quad (2.4.2)$$

Ω= 1,67 (ASD)

ϕ = 0,90 (LRFD)

ϕ = 0,90 (LSD),

where A_g = gross area of cross-section; F_y = design yield stress as determined in accordance with Section A3.3.1 [5].

The nominal tensile strength [resistance] due to rupture of the net section away from connection (D3 [5])

$$P_{tnn} = A_n F_u, \tag{2.4.3}$$

Ω= 2,00 (ASD)

ϕ = 0,75 (LRFD)

ϕ = 0,75 (LSD),

where A_n = net area of cross-ection; F_u = tensile strength.

Slenderness check (if required) is performed in accordance with the inequality

$$\lambda_{max} \leq \lambda_u, \tag{2.4.4}$$

where λ_{max} = maximum slenderness of the member: λ_{max} = max (λ_x, λ_y); λ_u is the ultimate slenderness, which is specified by the user; $\lambda_x = K_{tx}L/i_x$, $\lambda_y = K_{ty}L/i_y$; $K_{tx} = K_{ty}$ =1; L = length of the member; i_x and i_y = radiuses of gyration of cross section about appropriate axes.

The nominal tensile strength [resistance] for rupture in the net section at connection (J6.2) [5]

$$P_{trn} = F_u A_e, \tag{2.4.5}$$

Ω= 2,22 (ASD)

ϕ = 0,65 (LRFD)

ϕ= 0,75 (LSD),

where A_e = effective net area subject to tension.

$$A_e = U_{sl} A_n , \tag{2.4.6}$$

where U_{sl} = shear lag factor (Table J6.2-1 [5]): U_{sl} = 1 for members when the load is transmitted directly to all of the cross-sectional parts. Otherwise, for a bolted channel

$$U_{sl} = \frac{1}{1{,}1 + \dfrac{b_f}{b_w + 2b_f} + \dfrac{x}{L}} \tag{2.4.7}$$

where x = distance from shear plane to centroid of cross section (Figure 2.4.1); L = length of the connection; b_f = width of part of cross-section not connected; b_w = width of part of cross-section connected.

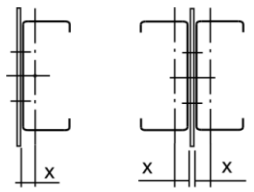

Figure 2.4.1 – Dimension *x*

For a single cross row of bolts in connection the design for rupture in the net section is not implemented.

The nominal bearing strength [resistance] of the member at the connection (J3.3.1) [5]

$$P_{tbn} = C m_f\, d_b t F_u n_b, \tag{2.4.8}$$

Ω= 2,50 (ASD)

ϕ = 0,60 (LRFD)

ϕ = 0,50 (LSD)

where C = bearing factor, determined in accordance with Table J3.3.1-1 [5] (connection with standard holes); m_f = modification factor for the type of bearing connection, determined in accordance with Table J3.3.1-2 [5]; d_b = nominal bolt diameter; n_b = number of the bolts in the connection.

The twice bearing resistance is taken for double cross-sections.

The nominal block shear rupture strength [resistance] of the member with $t \leq 4{,}76$ *mm* at connection is determined as the lesser of the following (J6.3 [5]) :

$$P_{tbsn} = 0{,}6\, F_y\, A_{gv} + U_{bs} F_u\, A_{nt}\,, \tag{2.4.9,a}$$

$$P_{tbsn} = 0{,}6\, F_u\, A_{nv} + U_{bs} F_u\, A_{nt}\,, \tag{2.4.9,b}$$

Ω= 2,22 (ASD)

ϕ = 0,65 (LRFD)

ϕ= 0,75 (LSD),

where F_y = yield stress; A_{gv} = gross area subject to shear (parallel to force) (Figure 2.4.2,b); A_{nv} = net area subject to shear (parallel to force) (Figure 2.4.2,a); A_{nt} = net area subject to tension (perpendicular to force), U_{bs} = nonuniform block shear factor (in accordance with J6.3 [5] U_{bs} =*1*).

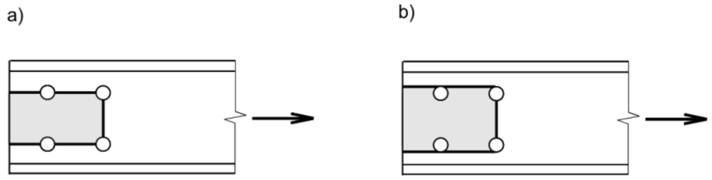

Figure 2.4.2 – Determination of shear areas: a) - net area, b) – gross area

2.4.1.2. Input data

To input data, select in main menu *Member → Tension*. Then, an input window appears, as shown in Figure 2.4.3.You can define member name (name of calculation or design), tension load *P*, member length *L*.

To determine the construction of attachment to adjacent element, click the left button of mouse on the place of connection in the *Member Scheme* (Figure 2.4.3). In dialog box *Type of Connection* (see Figure 2.3.4) select construction of the connection to adjacent element. The hole diameter at the point of attachment is defined in *Options → Design Details → General (clause 3.1).*

If there is a weakening along the member, you should click the left button of the mouse on the middle part of the member on the *Member Scheme* (Figure 2.4.3). In dialog box *Type of Opening along the Member* (see Figure 2.3.5) select construction of the weakening and input the diameter of the equivalent hole. By varying the diameter, you can enter the equivalent value of another form of weakening. It is assumed, that opening is symmetrical about longitudinal axis of the member.

Then you can input connection dimensions (Figure 2.4.3).

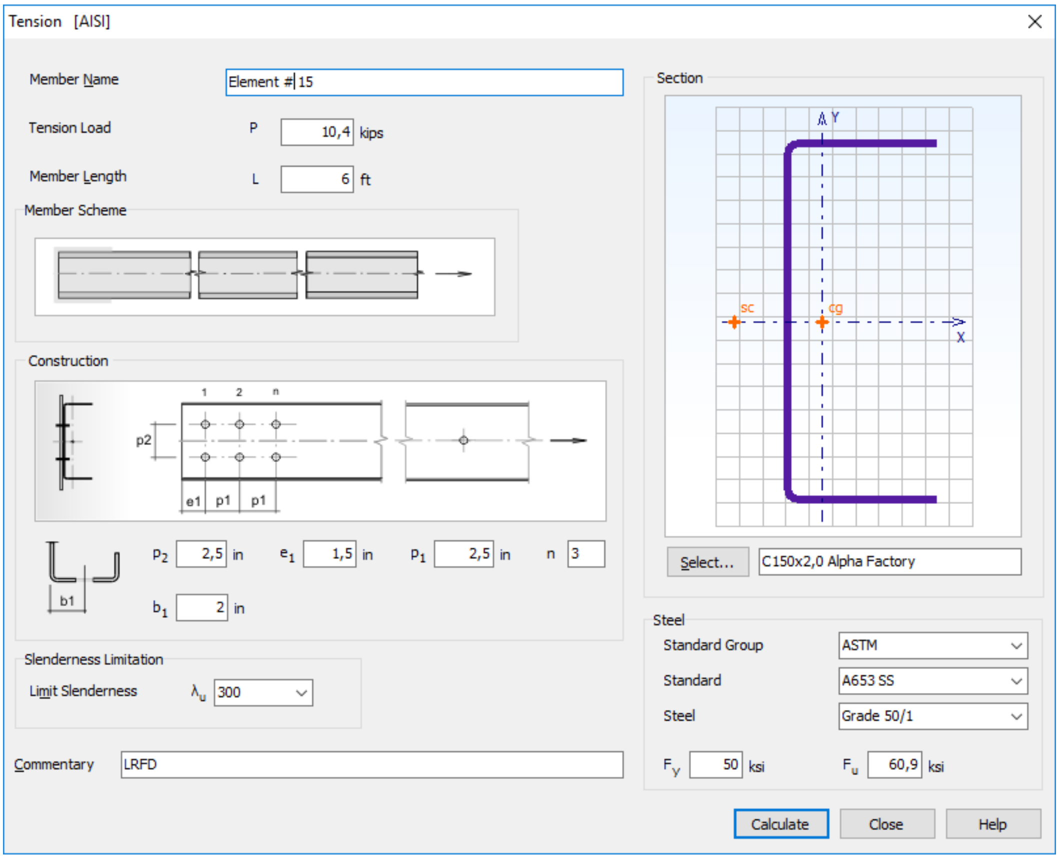

Figure 2.4.3 – Input data window for tension members

To select the cross-section of the member, click a *Select* button. Figure 2.3.6 presents the *Profile Selection* window. You can select: a single or a double section, *Profile Type*, a database of this profile and a profile from database. At the first appearance of the window, a favorite cross section is automatically selected. The user can assign a favorite cross section (clause 3.1). When you first sign in the window for the session with the program, it will automatically select a favorite cross section. Next time you enter the window, the last cross section will be selected.

Additionally, a user can enter its own dimensions of the selected profile type. This can be done by selecting *Edit*. Dimensions must be in the permissible range values stipulated in 1.2. In this mode you can also edit the thickness of the zinc coating t_{coat}.

Use button to show the information window with properties of the entered cross-section.

Steel can be assigned by selecting from the steel library or by directly entering data on the *Steel* panel (Figure 2.3.3). In the latter case, mandatory fields are as follows: yield strength and ultimate tensile strength. At the first appearance of the *Tension* window, favorite steel is automatically selected. The user assigns the favorite steel (clause 3.1). When you first sign in the window for the session with the program, it will automatically select a favorite steel. Next time you enter the window, the last steel will be selected. This data can be edited.

If it is necessary to perform the member slenderness check (clause 3.1 - *Design Details*), enter the limit slenderness in the *Tension* window (Figure 2.4.3).

2.4.1.3. Design results

Design results are displayed on the screen and, if necessary, can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the design results is divided into two parts (Figure 2.4.4). The right side shows a cross-section of a member. The left part contains three tabs. A *General data* tab displays the name of the member (name of calculation or design), a tension force, a member length, construction of the element and connection dimensions, a section name, the name of the manufacturer or the name of the database, a cross section with dimensions, steel data, comments.

Gross cross-section properties tab contains the properties of the gross cross-section, including the weight per meter of the profile.

Design results tab (Figure 2.4.5) is functionally divided into two parts. The upper part contains the list of the executed checks (design criterion). This list depends on the values of the entered data, as well as design settings defined by user in the *Options → Design Details* item of the menu (clause 3.1). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates the check is satisfied or not, and the clause (section) or the formula (equation) of the relevant code, according to which this calculation was performed.

In the bottom of the window detailed information is provided about the values of the calculation parameters included in the current check. The following characteristics are given for each parameter: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.

The user can set units within the metric system and a number of decimal places in the main menu *Options → Units and decimal places* (clause 3.2).

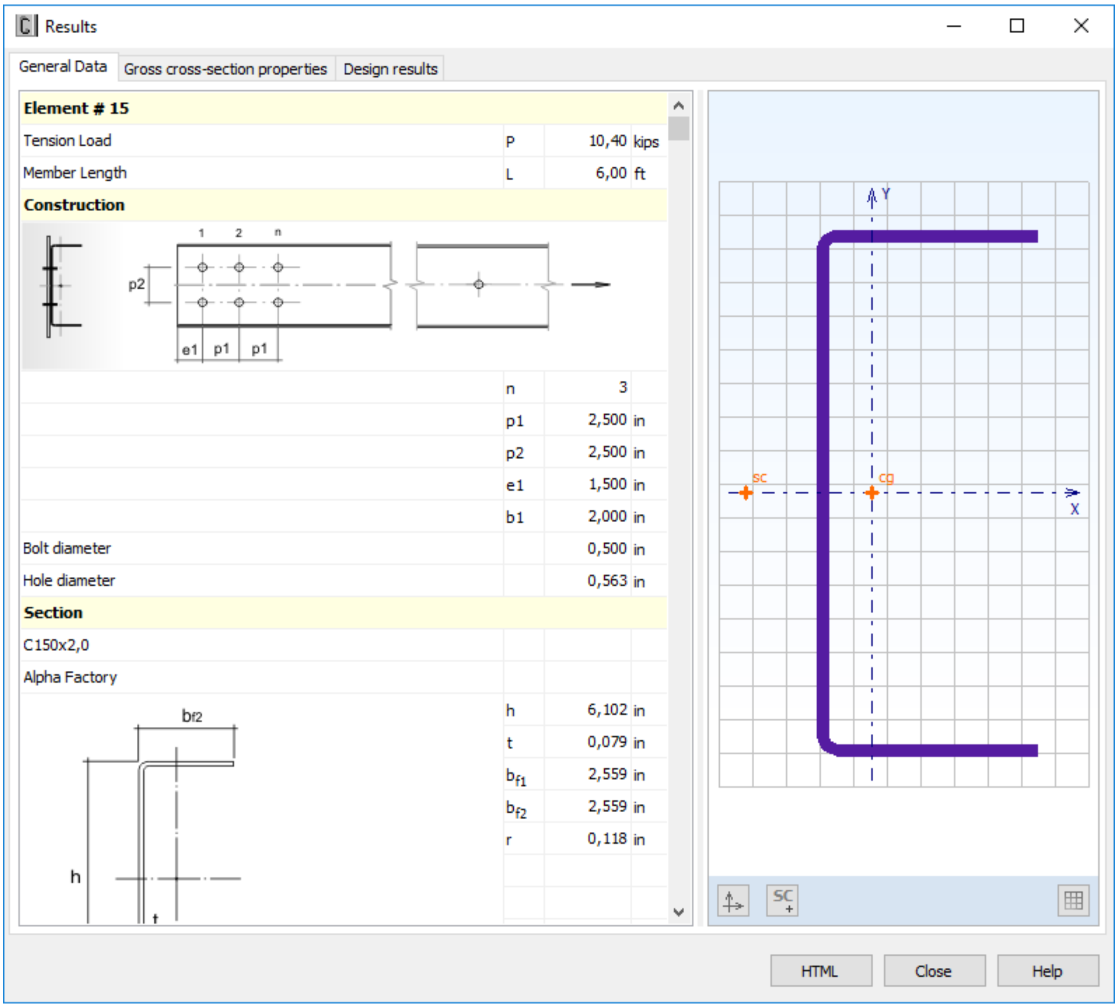

Figure 2.4.4 – Window of results: *General data*

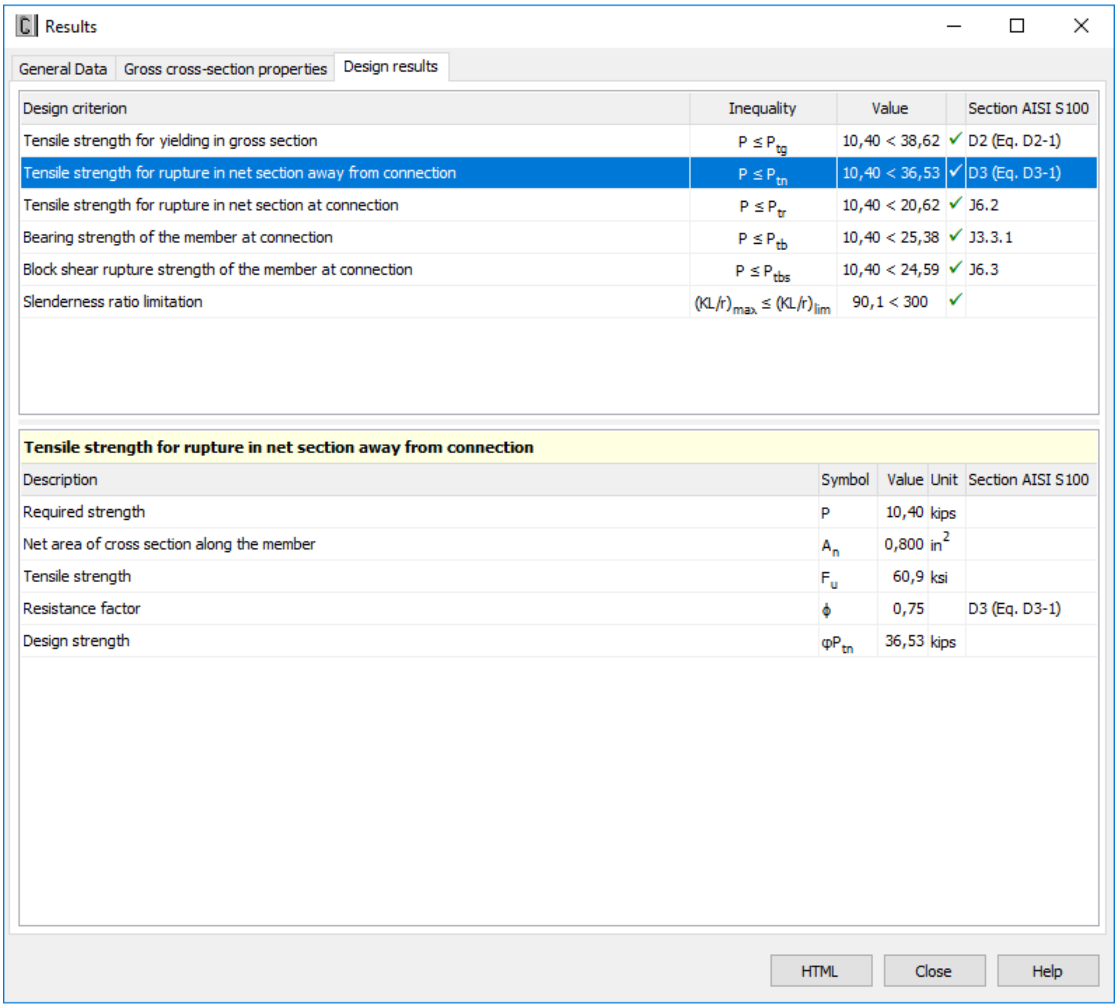

Figure 2.4.5 – Window of results: *Design results*

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in to Microsoft Excel® for further processing or converted to HTML format. You can define the item *Options → Program Options* in the menu (clause 3.3) where it will be sent to the output stream by default. Also, you can specify the full amount of results information or some part of it will be converted.

The Figures 2.4.6 – 2.4.7 present the document, obtained after exporting results to Microsoft Excel®.

Calculations for the rupture in the net section at the point of attachment for the elements of channel section (single or double) in the case of connection through the wall are carried out in accordance with the methods proposed by G.L. Kulak and E.Y. Wu [9,10], C.L. Pan [12], L. H. Teh and B.P. Gilbert [13] .

The design tensile strength for rupture in net cross-section at connection by G.L. Kulak and E.Y. Wu is calculated accordance with

$$N_{tr} = 0{,}9\, f_u\, A_{cn} / \gamma_{M1} + \beta f_y A_0 / \gamma_{M0}, \qquad (2.4.10)$$

where A_{cn} = net area of the connected web, computed with taken the diameter of holes 2 *mm* larger than the nominal size or without, depending on user selection [4,7,8]; A_0 = gross area of both flanges; β = 1 for connections with number of cross rows of bolts n_b four or more, β = 0,75 for number of cross rows = 3, β = 0,5 then number of cross rows ≤ 2; γ_{M1} = partial factor for resistance of net section at bolt holes; γ_{M0} = partial factor for resistance of cross-section to excessive yielding. To provide the necessary level of design reliability, a user can vary the factor γ_{M1} and γ_{M0}. For reasonable assignment of numerical values of the factors γ_{M1} and γ_{M0}, there are many verification calculations by (2.4.10) in the document: CFSteel v.4.1 Documentation. Volume II. Verification examples [16]. This document presents the nominal value of tensile strength (without factors γ_{M1} and γ_{M0}) and design values (with factors). The results of calculations were compared with experimental data of various researches.

The design tensile strength for rupture in the net cross-section at connection by C.L. Pan is calculated as follows (number of cross rows of bolts n ≥ 2):

$$P_{tr} = \phi\, U\, A_n\, f_u. \tag{2.4.11}$$

Where reduction coefficient U is calculated from empirical equation

$$U = \left[1,15 - 0,86\left(\frac{x}{L}\right) - 0,14\left(\frac{W_u}{W_c}\right)\right], \tag{2.4.12}$$

where x = distance from shear plane to centroid of the cross section [4,7] (Figure 2.4.1); L = length of the connection [4,7]; W_u = sum width of the flanges; W_c = width of the web. If $U \le 0,5$ the element shall be designed as tensioned with bending.

The design tensile strength for rupture in the net cross-section at the connection with a number of cross rows of bolts $n \ge 2$ by L. H. Teh and B.P. Gilbert is calculated as follows

$$P_{tr} = \phi\, A_n f_u \left[\frac{1}{1,1 + \dfrac{W_f}{W_c + 2W_f} + \dfrac{x}{L}}\right], \tag{2.4.13}$$

where W_f = width of the flange minus t_{nom}; W_c = height of the channel.

Numerical values of resistance factors ϕ are assigned by the user. For reasonable assignment of numerical values of these factors, there are many verification calculations by (2.4.11 and 2.4.13) in the document: CFSteel v.4.0.1 Documentation. Volume II. Verification examples [16]. This document presents the nominal value of tensile strength (without factors ϕ) and design values (with factors ϕ). The results of calculations were compared with the experimental data of various researches. In the works of the authors [12] and [13] and verification calculations the accepted value of ϕ = 0,65.

The twice design tensile strength is taken for double cross-sections.

The results of calculations using these method are shown in Figure 2.4.7.

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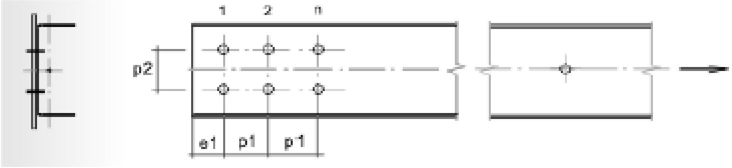
Tension Load	P	10,40 kips
Member Length	L	6,00 ft

Construction

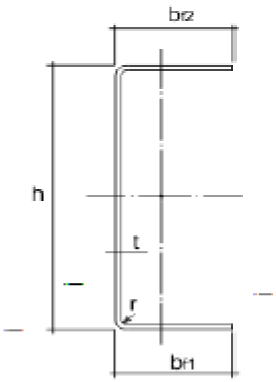


	n	3
	p_1	2,500 in
	p_2	2,500 in
	e_1	1,500 in
	b_1	2,000 in
Bolt diameter		0,500 in
Hole diameter		0,563 in

Section

C150x2,0

Alpha Factory



h	6,102 in
t	0,079 in
b_{f1}	2,559 in
b_{f2}	2,559 in
r	0,118 in
t_{coat}	0,001575 in

Steel

Standard Group		ASTM
Standard		A653 SS
Steel		Grade 50/1
Yield stress (strength)	F_y	50,0 ksi
Tensile strength	F_u	60,9 ksi
Modulus of elasticity	E	29441,6 ksi
Poisson ratio	μ	0,3
LRFD		

Figure 2.4.6 – *General data*

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Member # 15

Design criterion	Inequality	Value		Section AISI S100
Tensile strength for yielding in gross section	$P \le P_{tg}$	10,40 < 38,62	✓	D2 (Eq. D2-1)
Tensile strength for rupture in net section away from connection	$P \le P_{tn}$	10,40 < 36,53	✓	D3 (Eq. D3-1)
Tensile strength for rupture in net section at connection	$P \le P_{tr}$	10,40 < 20,62	✓	J6.2
Bearing strength of the member at connection	$P \le P_{tb}$	10,40 < 25,38	✓	J3.3.1
Block shear rupture strength of the member at connection	$P \le P_{tbs}$	10,40 < 24,59	✓	J6.3
Slenderness ratio limitation	$(KL/r)_{max} \le (KL/r)_{lim}$	90,1 < 300	✓	

Additionally

Design criterion	Inequality	Value		Design according method
Tensile strength for rupture in net section at connection	$P \le P_{tr}$	10,40 < 20,68	✓	L. H. Teh and B.P. Gilbert

Tensile strength for yielding in gross section

Description	Symbol	Value	Unit	Section AISI S100
Required strength	P	10,40	kips	
Gross area of cross section	A_g	0,843	in^2	
Average yield stress	F_{ya}	50,9	ksi	A3.3
Resistance factor		0,900		D2 (Eq. D2-1)
Design strength	P_{tg}	38,62	kips	

Tensile strength for rupture in net section away from connection

Description	Symbol	Value	Unit	Section AISI S100
Required strength	P	10,40	kips	
Net area of cross section along the member	A_n	0,800	in^2	
Tensile strength	F_u	60,9	ksi	
Resistance factor		0,750		D3 (Eq. D3-1)
Design strength	φP_{tn}	36,53	kips	

Tensile strength for rupture in net section at connection

Description	Symbol	Value	Unit	Section AISI S100
Required strength	P	10,40	kips	
Net area of cross section at connection	A_n	0,756	in^2	J6.2
Reduction coefficient	U	0,689		J6.2 Table J6.2-1
Tensile strength	F_u	60,9	ksi	
Nominal diameter of the hole	h_0	0,563	in	

Figure 2.4.7,a – *Design results*

Resistance factor	φ	0,650		Table J6-1
Design strength	φP_{tr}	20,62	kips	

Bearing strength of the member at connection

Description	Symbol	Value	Unit	Section AISI S100
Required strength	P	10,40	kips	
Design thickness	t	0,077165	in	
Bolt diameter	d_b	0,500	in	
Bearing factor	C	3,000		Table J3.3.1-1
Modification factor for type of bearing connection	m_f	1,000		Table J3.3.1-2
Number of bolts in the connection	n_b	6		
Tensile strength	F_u	60,9	ksi	
Resistance factor	ϕ	0,600		J3.3.1
Design strength	ϕP_{tb}	25,38	kips	

Block shear rupture strength of the member at connection

Description	Symbol	Value	Unit	Section AISI S100
Required strength	P	10,40	kips	
Gross area subject to shear	A_{gv}	1,003	in^2	
Net area subject to shear	A_{nv}	0,786	in^2	
Net area subject to tension	A_{nt}	0,149	in^2	
Yield stress	F_y	50,0	ksi	
Tensile strength	F_u	60,9	ksi	
Resistance factor	ϕ	0,650		Table J6-1
Design strength	ϕP_{tbs}	24,59	kips	

Slenderness ratio limitation

Description	Symbol	Value	Unit	Section AISI S100
Max slenderness ratio	$(KL/r)_{max}$	90,1		
Limit slenderness ratio	$(KL/r)_{lim}$	300,0		

Tensile strength for rupture in net section at connection according to L. H.Teh and B.P.Gilbert method

Description	Symbol	Value	Unit
Required strength	P	10,40	kips
Net area of cross section at connection	A_n	0,756	in^2
Tensile strength	F_u	60,9	ksi
Resistance factor		0,650	
Design strength	P_{tr}	20,68	kips

Figure 2.4.7,b – *Design results*

2.4.2. Concentrically loaded compression members

2.4.2.1. Design procedures

You can choose design method: Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) or Limit States Design (LSD).

In general, the design is performed in the form of inequality (Section A4 [5])

ASD:

$$P \le P_{cn}/\Omega_c, \qquad (2.4.14,a)$$

LRFD, LSD:

$$P \le \phi_c\, P_{cn}, \qquad (2.4,14,b)$$

where P = required strength; P_{cn} = nominal strength; Ω_c = safety factor; ϕ_c = resistance factor; P_{cn}/Ω_c = allowable strength; $\phi_c P_{cn}$ = design strength.

Concentrically loaded compression member is the member in which the resultant of all loads is an axial load passing through the centroid of the effective section calculated at the stress F_n. If the individual components of compression single section members have small *w/t* ratios, local buckling will not occur before the compressive stress reaches the column buckling stress or the yield stress of steel. These members are calculated as a concentrically loaded compression members. For single section members with large *w/t* ratios, local buckling of individual component plates may occur. In this case an effective area A_e is taken into account. Centroid of the effective section does not coincide with the centroid of a gross cross-section. Therefore, there is eccentricity e in the load application, and the member cannot be calculated as the concentrically loaded. These members are calculated as combined axial load and bending members (see Section 2.4.3). Double section members are always calculated as a concentrically loaded members, regardless of the required or not reduction of the cross section.

Maximum flat width-to-thickness ratios are checked in accordance with Table B4.1-1 [5].

The available axial strength (factored compressive resistance) of concentrically loaded compression member is accepted as a smaller of the strength for yielding, flexural, torsional, flexural-torsional and distortional buckling.

The nominal axial strength (resistance) for local buckling interacting with yielding and global buckling (flexural, torsional and flexural-torsional) P_{nl} is calculated as follows (Section E3 [5]):

$$P_{nl} = A_e F_n \leq P_{ne} \tag{2.4.15}$$

Ω_c= 1,80 (ASD)

ϕ_c = 0,85 (LRFD)

= 0,80 (LSD)

where A_e = effective area calculated at stress F_n. The program performs a reduction of cross-section in accordance with Appendics 1 [5]. For sections with circular holes A_e is determined from the effective width in accordance with Section E3.1.2 [5]. If the number of holes in the effective length region times the hole diameter divided by the effective length does not exceed 0,015, A_e is calculated ignoting the holes.

$$P_{ne} = A_g F_n \tag{2.4.16}$$

A_g = gross cross-sectional area, F_n = global column stress.

For $\lambda_c \leq 1,5$

$$F_n = \left(0{,}658^{\lambda_c{}^2}\right) F_y \tag{2.4.17,a}$$

For $\lambda_c > 1,5$

$$F_n = \left(0{,}658^{\lambda_c{}^2}\right) F_y \tag{2.4.17,b}$$

where

$$\lambda_c = \sqrt{\frac{F_y}{F_{cre}}}, \tag{2.4.18}$$

F_y = yield stress, F_{cre} = the least of the applicable elastic flexural, torsional (flexural-torsional) buckling stress.

For single cross section members and double cross sections members the elastic flexural buckling stress F_{ef} is calculated by (Section E2.1 [5]):

$$F_{ef} = \frac{\pi^2 E}{(KL/r)^2} \tag{2.4.19}$$

where K = effective length factor (K_x, K_y), L = laterally unbraced length of member (L_x, L_y), r = radius of gyration of full unreduced cross section about axis of buckling (r_x, r_y). $F_{ef} = min\ (F_{efx}, F_{efy})$.

For double cross section members K_yL_y/r_y is replaced by $(K_yL_y/r_y)_m$ (Section D1.2 [5]) as follows:

$$\left(\frac{KL}{r}\right)_m = \sqrt{\left(\frac{KL}{r}\right)_0^2 + \left(\frac{a}{r_i}\right)^2} \tag{2.4.20}$$

where $(K_yL_y/r_y)_0$ = overall slenderness ratio of entire section about axis Y, a = intermediate fastener spacing, r_i = minimum radius of gyration of full unreduced cross-sectional area of individual shape in a built-up member. The fastener strength (resistance) and spacing shall satisfy requirements stipulated in Section I1.2 [5].

For single section members the elastic flexural-torsional buckling stress F_{eft} is calculated by (Section E2.2 [5]):

$$F_{eft} = \frac{1}{2\beta}\left[(\sigma_{ex} + \sigma_t) - \sqrt{(\sigma_{ex} + \sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right] \tag{2.4.21}$$

where $\beta = 1 - (x_o/r_o)^2$, x_o = distance from shear centre to centroid along principal X-axis, taken as negative, r_0 = polar radius of gyration of cross-section about shear center:

$$r_0 = \sqrt{r_x^2 + r_y^2 + x_0^2} \tag{2.4.22}$$

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2} \tag{2.4.23}$$

where K_x = effective length factor for bending about X-axis (Chapter C), L_x = unbraced length of member for bending about X-axis.

$$\sigma_t = \frac{1}{A_g r_0^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right] \tag{2.4.24}$$

where J = St. Venant torsion constant of cross-section, C_w = torsional warping constant of cross-section, K_t = effective length factor for twisting, L_t = unbraced length of member for twisting.

For double section members the elastic torsional buckling stress ($F_{et} = \sigma_t$) is calculated by equation (2.4.24).

The nominal axial strength (resistance) for distortional buckling of a single and a double section members that employ flanges with edge stiffeners P_d is calculated as follows (Section E4[5]):

For $\lambda_d \leq 0{,}561$ $\quad P_d = P_y$,

For $\lambda_d > 0{,}561$

$$P_d = \left(1 - 0{,}25\left(\frac{P_{crd}}{P_y}\right)^{0,6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0,6} P_y \tag{2.4.25}$$

where

$$\lambda_d = \sqrt{\frac{P_y}{P_{crd}}} \tag{2.4.26}$$

$$P_y = A_g \cdot F_y \tag{2.4.27}$$

$$P_{crd} = A_g \cdot F_{crd} \tag{2.4.28}$$

F_{crd} = elastic distortional buckling stress calculated in accordance with Appendix 2 Section 2.3.1.3 [5]):

$$F_{crd} = \frac{k_{\Phi fe} + k_{\Phi we} + k_{\Phi}}{\tilde{k}_{\Phi fg} + \tilde{k}_{\Phi wg}} \tag{2.4.29}$$

The elastic rotational stiffnes provided by the flange to the flange/web juncture, $k_{\Phi fe}$ (Eq. 2.3.1.3-3 [5]):

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}\left(x_{0f} - h_{xf}\right)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}\left(x_{0f} - h_{xf}\right)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f \tag{2.4.30}$$

The elastic rotational stiffness provided by the web to the flange/web juncture, $k_{\Phi we}$ (Eq. 2.3.1.3-4 [5]):

$$k_{\phi we} = \frac{Et^3}{6h(1-\mu^2)} \tag{2.4.31}$$

The geometric rotational stiffness demanded by the flange from the flange/web juncture, in accordance with Eq. 2.3.1.3-5 [5]:

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_{0\text{f}} - h_{xf})^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_{0\text{f}}\left(x_{0\text{f}} - h_{xf}\right)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_{xf}^2 + y_{0\text{f}}^2\right) + I_{xf} + I_{yf}\right] \tag{2.4.32}$$

The geometric rotational stiffness demanded by the web from the flange/web juncture (Eq. 2.3.1.3-6 [5]):

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{th^3}{60} \tag{2.4.33}$$

where L = minimum of L_{crd} and L_m.

$$L_{crd} = \left[\frac{6\pi^4 h(1-\mu^2)}{t^3}\left(I_{xf}\left(x_{0f} - h_{xf}\right)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}\left(x_{0f} - h_{xf}\right)^2\right)\right]^{\frac{1}{4}} \tag{2.4.34}$$

L_m = Distance between discrete restraints that restrict distortional buckling (enterd by user). For continuously restrained members $L_m = L_{crd}$.

Geometric flange properties adopted in accordance with a Table 2.3.1.3-1 [5].

k_Φ = rotational stiffness provided by restraining elements ($k_\Phi = 0$ – flange unrestrained).

The check for slenderness ratio KL/r is performed according to inequality

$$(KL/r)_{max} \le (KL/r)_{lim} \tag{2.4.35}$$

where $(KL/r)_{lim}$ = limit slenderness ratio (entered by user).

2.4.2.2. Input data

To input data, select in main menu *Member → Column*. Then, an input window appears, as shown in Figure 2.4.8.

You can define a member name (name of calculation or design), compression load P, unbraced length for bending about X and Y axes (L_x and L_y), effective length factor for buckling about X and Y axes (K_x and K_y), unbraced length of member for twisting L_t, effective length factor for twisting K_t.

On the *Distortional buckling* panel you shall enter a distance between discrete restrains that restrict distortional buckling L_m. If such restrains along the length of the member does not exist, it is considered that restrains available on supports. In this case, you shall enter the length of the element. If the member is continuously restrained, you shall mark the corresponding check box.

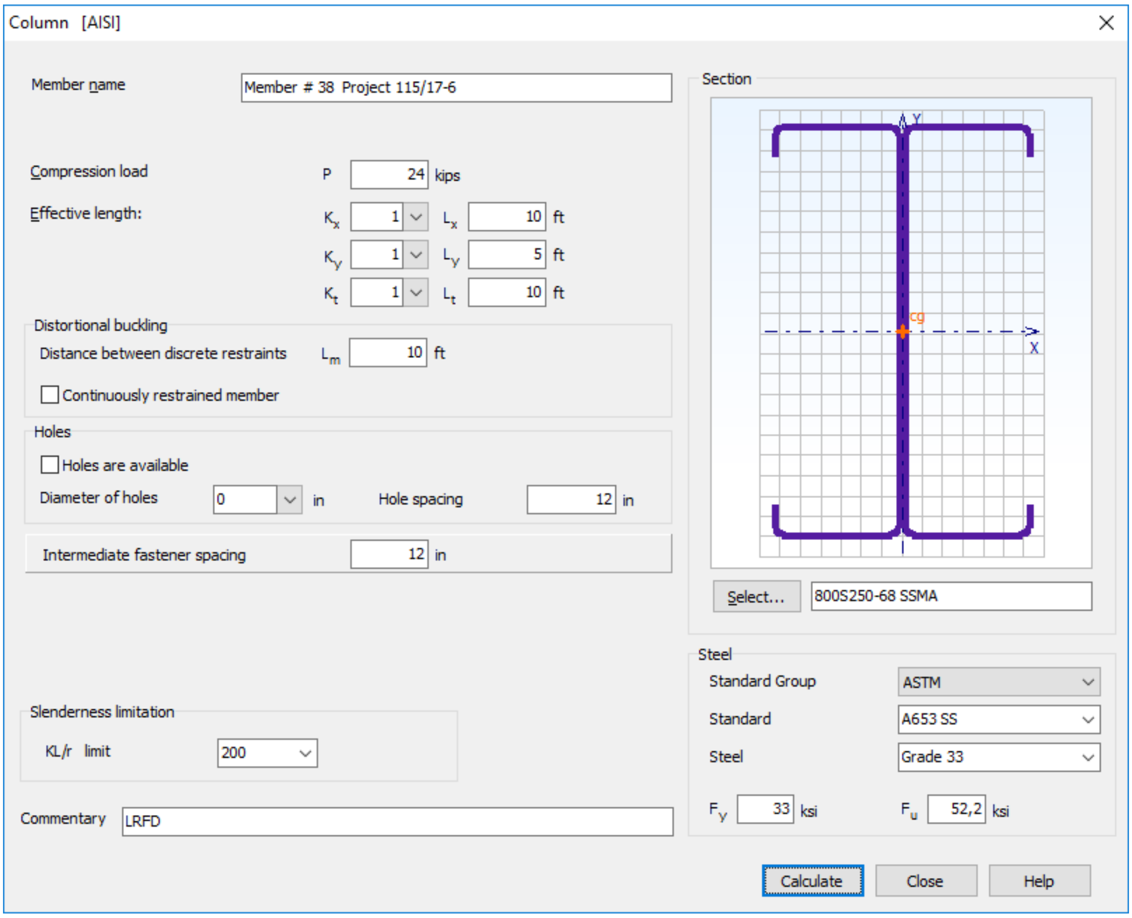


Figure 2.4.8 – Input data window for compression members

Further, you can assign a cross-section of the member. To do it, click the *Select…* button. The dialog box appears (Figure 2.3.6), where you define the cross-section.

Steel can be assigned by selecting from the steel library or by directly entering data on the *Steel* panel (Figure 2.4.8). In the latter case, mandatory fields are: yield strength and ultimate tensile strength. At the first appearance of the *Column* window, steel is automatically selected – steel is favorite. The user assigns the favorite steel (Section 3.1). When you first sign in the window for the session with the program, it will automatically select steel as favorite. Next time you enter the window, the last steel will be selected. These data can be edited.

For double section members you need to enter intermediate fastener spacing.

If the member has holes along the length, you must mark appropriate check box and enter hole diameter and hole spacing.

If it is necessary to perform the member slenderness ratio *KL/r* check (Section 3.1 - *Design Details*), enter the limit slenderness ratio in the *Column* window *(Figure 2.4.8)*.

2.4.2.3. Design results

Design results are displayed on the screen and, if necessary, they can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the design results is divided into two parts (Figure 2.4.9). The right side shows a cross-section of a member. The left part contains three tabs. *General data* tab displays the data entered by the user.

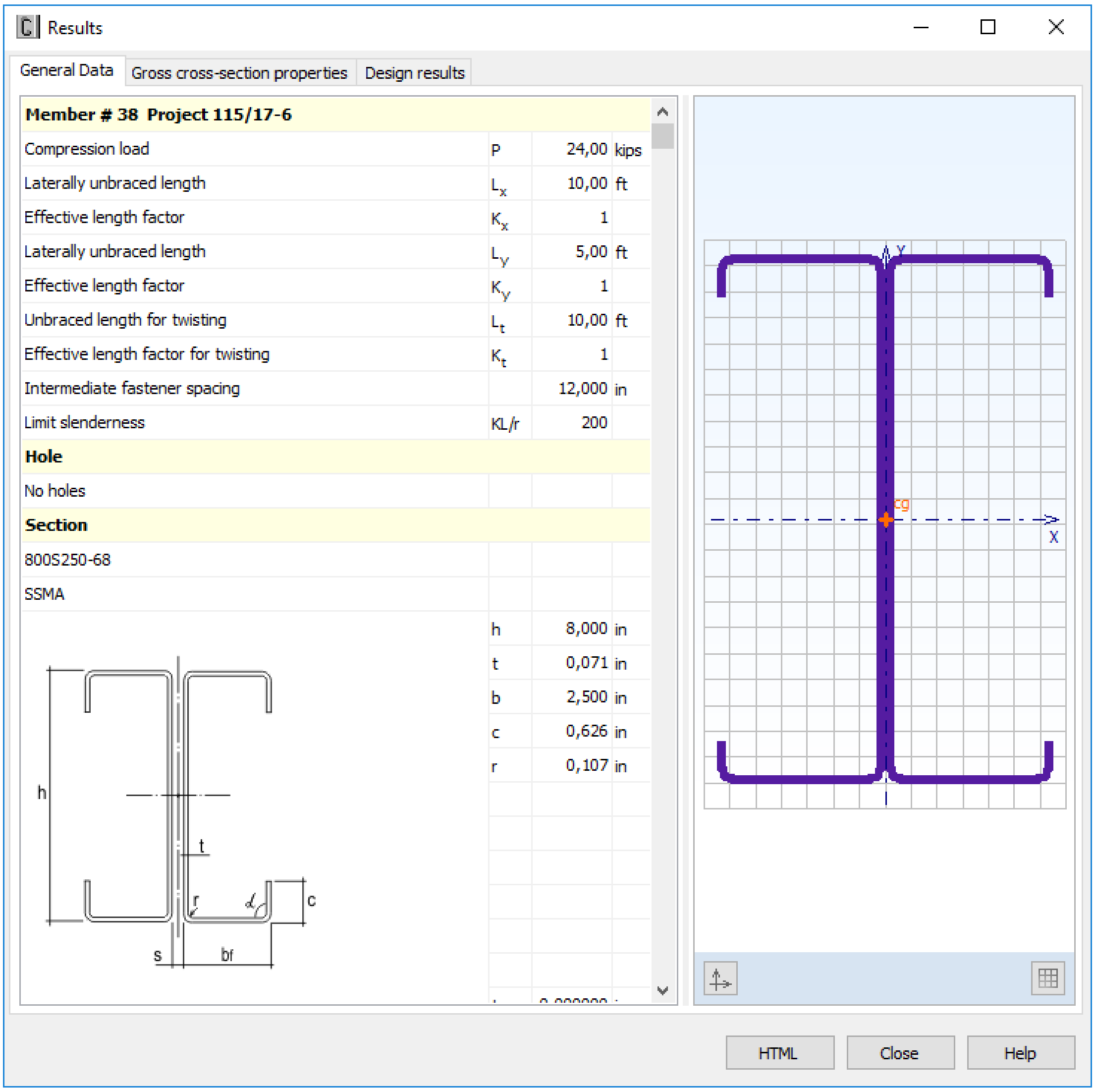
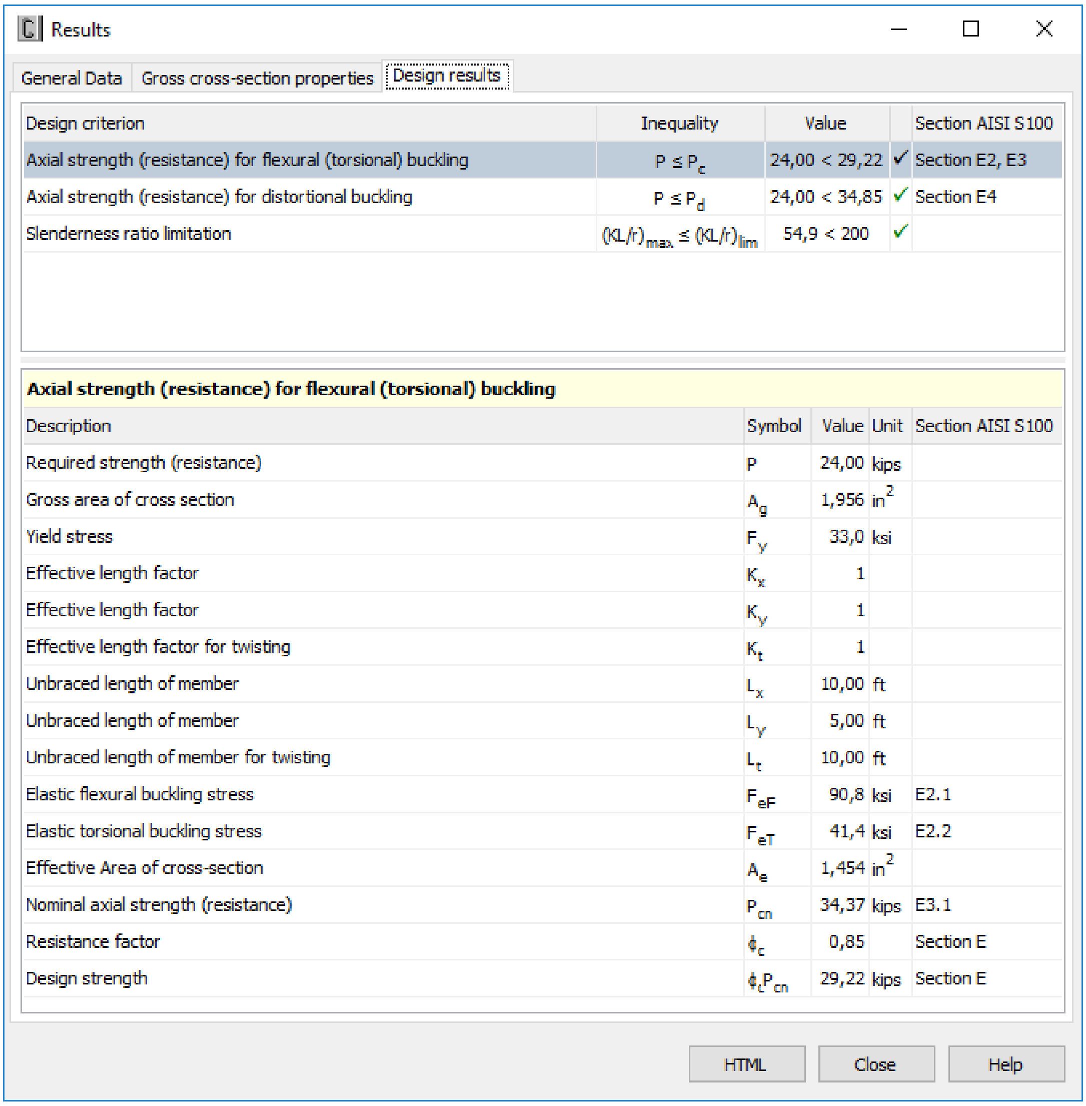


Figure 2.4.9 – Window of results: *General data*

Design results tab (Figure 2.4.10) is functionally divided into two parts. The upper part contains the list of the executed checks (design criterion). This list depends on the type of cross section, the entered data is, as well as design settings defined by user in the menu item *Options* → *Design Details* (Section 3.1). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates the check is satisfied or not, and the section or the equation of the code, according to which this calculation was performed.



Results

General Data | Gross cross-section properties | Design results

Design criterion	Inequality	Value		Section AISI S100
Axial strength (resistance) for flexural (torsional) buckling	$P \le P_c$	24,00 < 29,22	✓	Section E2, E3
Axial strength (resistance) for distortional buckling	$P \le P_d$	24,00 < 34,85	✓	Section E4
Slenderness ratio limitation	$(KL/r)_{max} \le (KL/r)_{lim}$	54,9 < 200	✓	

Axial strength (resistance) for flexural (torsional) buckling

Description	Symbol	Value	Unit	Section AISI S100
Required strength (resistance)	P	24,00	kips	
Gross area of cross section	A_g	1,956	in^2	
Yield stress	F_y	33,0	ksi	
Effective length factor	K_x	1		
Effective length factor	K_y	1		
Effective length factor for twisting	K_t	1		
Unbraced length of member	L_x	10,00	ft	
Unbraced length of member	L_y	5,00	ft	
Unbraced length of member for twisting	L_t	10,00	ft	
Elastic flexural buckling stress	F_{eF}	90,8	ksi	E2.1
Elastic torsional buckling stress	F_{eT}	41,4	ksi	E2.2
Effective Area of cross-section	A_e	1,454	in^2	
Nominal axial strength (resistance)	P_{cn}	34,37	kips	E3.1
Resistance factor	ϕ_c	0,85		Section E
Design strength	$\phi_c P_{cn}$	29,22	kips	Section E

HTML | Close | Help

Figure 2.4.10 – Window of results: *Design results*

In the bottom of the window detailed information is provided on the values of the calculation parameters included in the current check. The following features are given for each parameter: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.

Units within the metric system and number of decimal places the user can use, can be set in the main menu *Options → Units and decimal places* (Section 3.2).

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in Microsoft Excel® for further processing or convert to HTML format.

2.4.3. Combined compressive axial load and bending

2.4.3.1. Design procedures

You can choose design method: Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) or Limit States Design (LSD).

Effective Length Method used in the program (Section C1.3 [5]).

It is assumed that the bending of a single section occurs about the Y - axis, and the bending of a double section occurs about the X - axis.

In general, the design is performed in the form of the following interaction equation (*Eq.* H1.2-1 [5]):

$$\frac{P}{P_a} + \frac{M}{M_a} \leq 1{,}0 \tag{2.4.36}$$

where P = rerquired compressive axial strength (compressive axial force due to factored loads) determined in accordance with ASD, LRFD or LSD load combinations - entered by user; M = required flexural strength (moment due to factored loads) with respect to centroidal axis of effective section determined for required compressive axial strength (factored axial force) alone; P_a = available axial strength (factored resistance) determined in accordance with Chapter E [5]; M_a = available flexural strength (factored resistance) about centroidal axes determined in accordance with Chapter F [5].

Required flexural strength (moment due to factored loads) with respect to centroidal axis of effective section (for required compressive axial force) is determined for single cross-sections as: $M = M_{user} + P \cdot e$. Where M_{user} = value entered by user, e = eccentricity from determining of effective area at uniform compressive stress $\sigma_{com} = P/A$. The second term is takes in to account if it increases the value of M. Otherwise, $M = M_{user}$. For double cross-sections $M = M_{user}$ always.

Maximum flat width-to-thickness ratios are checked in accordance with Table B4.1-1 [5].

The nominal axial strength (resistance) P_n is the smaller of the values of axial strength for yielding, flexural, flexural-torsional (single cross-sections) torsional (double cross-sections) buckling and distortional buckling (Section E [5]). Method of calculating P_n is given above in Section 2.4.2.1.

The available flexural strength (factored resistance) $M_a = \phi_b M_n$ or $M_a = M_n / \Omega_b$ is the smallest of the values: yielding and global (lateral-torsional) buckling and interacting with local buckling or distortional buckling (Section F2, F3 and F4 [5]).

The nominal flexural strength [resistance] for yielding and global (lateral-torsional) buckling considering capacity up to first yield (Section F2.1 [5] *Eq.* F2.1-1):

$$M_{ne} = S_f F_n \leq M_y \tag{2.4.37}$$

where S_f = elastic section modulus of full unreduced section calculated to extreme compression fiber; $M_y = S_{fy} \cdot F_y$. S_{fy} – Elastic section modulus of full unreduced cross-section relative to extreme fiber in first yilding.

F_n is determined as follows:

For $F_{cre} \geq 2{,}78\, F_y$ $F_n = F_y$

For $2{,}78\, F_y > F_{cre} > 0{,}56\, F_y$

$$F_n = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_{cre}}\right) \tag{2.4.38}$$

For $F_{cre} \leq 0{,}56\, F_y$ $F_n = F_{cre}$

where F_{cre} = critical elastic lateral-torsional buckling stress that is calculated as follows (F2.1 [5]):

For single sections

$$F_{cre} = \frac{C_S A_g \sigma_{ex}}{C_{TF} S_f} \left[j + C_S \sqrt{j^2 + r_0^2 (\sigma_t / \sigma_{ex})} \right] \tag{2.4.39}$$

where C_S = +1 for moment causing compression on shear center side of centroid and C_S = -1 for moment causing tension on shear center side of centroid. Value of C_{TF} is entered by user. For members subject to combined axial load and bending moment it is recommended ([17]) C_{TF} = 1.

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}, \tag{2.6.40}$$

$$\sigma_t = \frac{1}{A_g r_0^2} \left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2} \right], \tag{2.6.41}$$

$j = \beta_y / 2$ where

$$\beta_y = \frac{\beta_w + \beta_f + \beta_1}{I_y} - 2x_0 \tag{2.4.42}$$

Formulas for computing of β_w, β_f and β_1 are given in Appendix C of [17]. σ_{ex}, r_o, x_0 and σ_t are defined in Section 2.4.2.1.

For double sections

$$F_e = \frac{C_b r_0 A_g}{S_f}\sqrt{\sigma_{ey}\sigma_t} \tag{2.4.43}$$

where C_b = bending coefficient that can be entered by user or calculated from equation

$$C_b = \frac{12{,}5M_{max}}{2{,}5M_{max} + 3M_A + 4M_B + 3M_C} \tag{2.4.44}$$

where M_{max} = absolute value of maximum moment in unbraced segment; M_A = absolute value of moment at quarter point of unbraced segment; M_B = absolute value of moment at centerline of unbraced segment; M_C = absolute value of moment at three-quarter point of unbraced segment. C_b shall be permitted to be conservatively taken as unity for all cases. AISI Specification [5] allows conservatively to take $C_b = 1$. Other symbols were defined previously.

Potential reduction in available strength (factored resistance) due to interaction of the yielding or global buckling with local buckling is taken into account (F3.1 [5]). The nominal flexural strength (resistance) for local buckling (*Eq.* F3.1-1 [5]):

$$M_{nl} = S_e F_n \le S_{et} F_y \tag{2.4.45}$$

where S_e = effective section modulus calculated at extreme fiber commpressive stress of F_n. S_{et} = effective section modulus calculated at extreme fiber tension stress of F_y.

The nominal flexural strength (moment resistance) for distortional buckling M_{nd} is determined as follows (F4.1 [5]):

For $\lambda_d \le 0{,}673$ $M_{nd} = M_y$

For $\lambda_d > 0{,}673$

$$M_{nd} = \left(1 - 0{,}22\left(\frac{M_{crd}}{M_y}\right)^{0,5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0,5} M_y \tag{2.4.46}$$

where

$$\lambda_d = \sqrt{\frac{M_y}{M_{crd}}} \tag{2.4.47}$$

$M_y = S_{fy} F_y$

where S_{fy} = elastic section modulus of full unreduced section relative to extreme fiber in first yield.

$M_{crd} = S_f F_{crd}$

where S_f = elastic section modulus of full unreduced section relative to extreme compression fiber.

F_{crd} = elastic distortional buckling stress calculated in accordance with Appendix 2[5] as follows:

$$F_d = \beta\frac{k_{\Phi fe} + k_{\Phi we} + k_{\Phi}}{\tilde{k}_{\Phi fg} + \tilde{k}_{\Phi wg}} \tag{2.4.48}$$

where β is conservatively taken as 1,0 (Section 2.3.3.3 [5]).

$k_{\Phi fe}$ = elastic rotational stiffnes provided by the flange to the flange/web juncture, (Eq. 2.3.1.3-3 [5]):

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}\left(x_{0f} - h_x\right)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}\left(x_{0f} - h_x\right)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_{tf} \tag{2.4.49}$$

$k_{\Phi we}$ = elastic rotational stiffness provided by the web to the flange/web juncture, (Eq. 2.3.3.3-5 [5]):

$$k_{\phi fe} = \frac{Et^3}{12(1-\mu^2)}\left(\frac{3}{h_0} + \left(\frac{\pi}{L}\right)^2\frac{19h_0}{60} + \left(\frac{\pi}{L}\right)^4\frac{h_0^3}{240}\right) \tag{2.4.50}$$

k_{Φ} = rotational stiffness provided by restraining elements (k_{Φ} = 0 – flange unrestrained).

The geometric rotational stiffness (devided by the stress F_d) demanded by the flange from the flange/web juncture (Eq. 2.3.1.3-5 [5]):

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_0 - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_0(x_0 - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_0^2\right) + I_{xf} + I_{yf}\right] \tag{2.4.51}$$

The geometric rotational stiffness demanded by the web from the flange/web juncture (Eq. 2.3.3.3-6 [5]):

$$\tilde{k}_{\phi wg} = \frac{h_0 t \pi^2}{13440}\left[\frac{(45360(1-\xi_{web}) + 62160)\left(\frac{L}{h_0}\right)^2 + 448\pi^2 + \left(\frac{L}{h_0}\right)^2 (53 + 3(1-\xi_{web}))\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_0}\right)^2 + 420\left(\frac{L}{h_0}\right)^4}\right] \tag{2.4.52}$$

where ξ_{web} = stress gradien in the web, ξ_{web} = 2 (Section 2.3.3.3 [5]).
Where L = minimum of L_{cr} and L_m.

$$L_{cr} = \left[\frac{4\pi^4 h_0(1-\mu^2)}{t^3}\left(I_{xf}(x_0 - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_0 - h_x)^2\right) + \frac{\pi^4 h_0^4}{720}\right]^{\frac{1}{4}} \tag{2.4.53}$$

L_m = Distance between discrete restraints that restrict distortional buckling (enterd by user). For continuously restrained members $L_m = L_{cr}$.

Geometric flange properties in equations above are adopted in accordance with a Table 2.3.1.3-1 [5].

The check for slenderness ratio KL/r is performed according to inequality

$$(KL/r)_{max} \leq (KL/r)_{lim} \tag{2.4.54}$$

where $(KL/r)_{lim}$ = limit slenderness ratio (entered by user).

2.4.3.2. Input data

To input data, select in main menu *Member → Beam-Column*. Then, an input window appears, as shown in Figure 2.4.11.

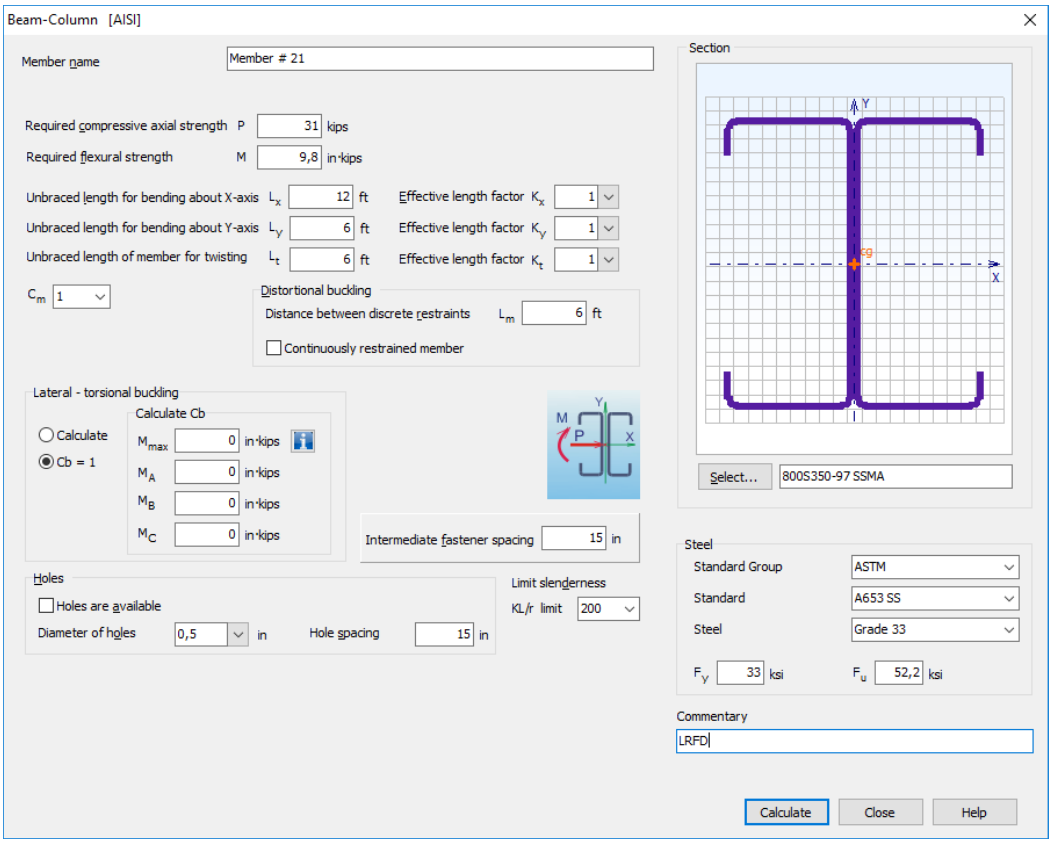


Figure 2.4.11 - Input data window for compressive with bending members

You can define a member name (name of calculation or design), required compressive axial strength P, required flexural strength M, unbraced length for bending about X-axis L_x, unbraced length for bending about Y-axes L_y, effective length factor for buckling about X-axis K_x effective length factor for buckling about Y-axis K_y, unbraced length of member for twisting L_t, effective length factor for twisting K_t and coefficient C_m (Section C5.2 [5]).

On the *Distortional buckling* panel you shall enter a distance between discrete restrains that restrict distortional buckling L_m. If such restrains along the length of the member does not exist, it is considered that restrains available on supports. In this case, you shall enter the length of the element. If the member is continuously restrained, you shall mark the corresponding check box.

For single section members you should enter coefficient C_{TF} and direction of acting of the bending moment according to Section C3.1.2.1 [5].

For double section members you should enter the value of the coefficient C_b or you can choose *Calculate*. In the latter case you should enter the values of M_{max}, M_A, M_B, M_C (see Section 2.4.3.1). For double section members you need to enter intermediate fastener spacing.

If the member has holes along the length, you shall mark appropriate check box and enter hole diameter and hole spacing.

Further, you can assign a cross-section of the member. To do it, click the *Select…* button. The dialog box appears (Figure 2.3.6), where you define the cross-section.

Steel can be assigned by selecting from the steel library or by directly entering data on the *Steel* panel (Figure 2.4.11).

If it is necessary to perform the member slenderness ratio *KL/r* check (Section 3.1 - *Design Details*), enter the limit slenderness ratio in the *Beam-Column* window (Figure 2.4.11).

2.4.3.3. Design results

Design results are displayed on the screen and, if necessary, they can be transferred to Microsoft Excel® for further processing or converted to HTML format.

The window of the design results is divided into two parts (Figure 2.4.12). The right side shows a cross-section of a member. The left part contains three tabs. *General data* tab displays the data entered by the user.

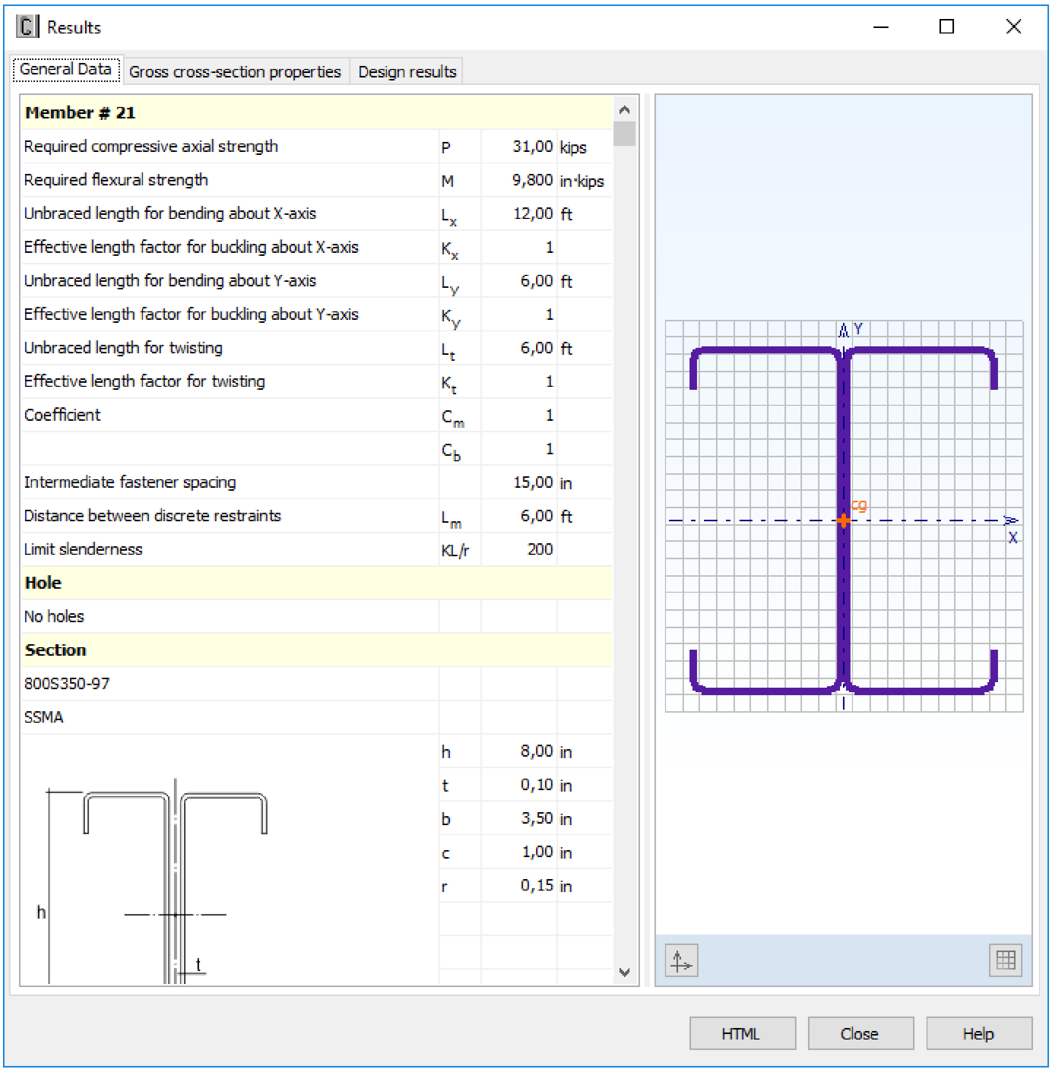
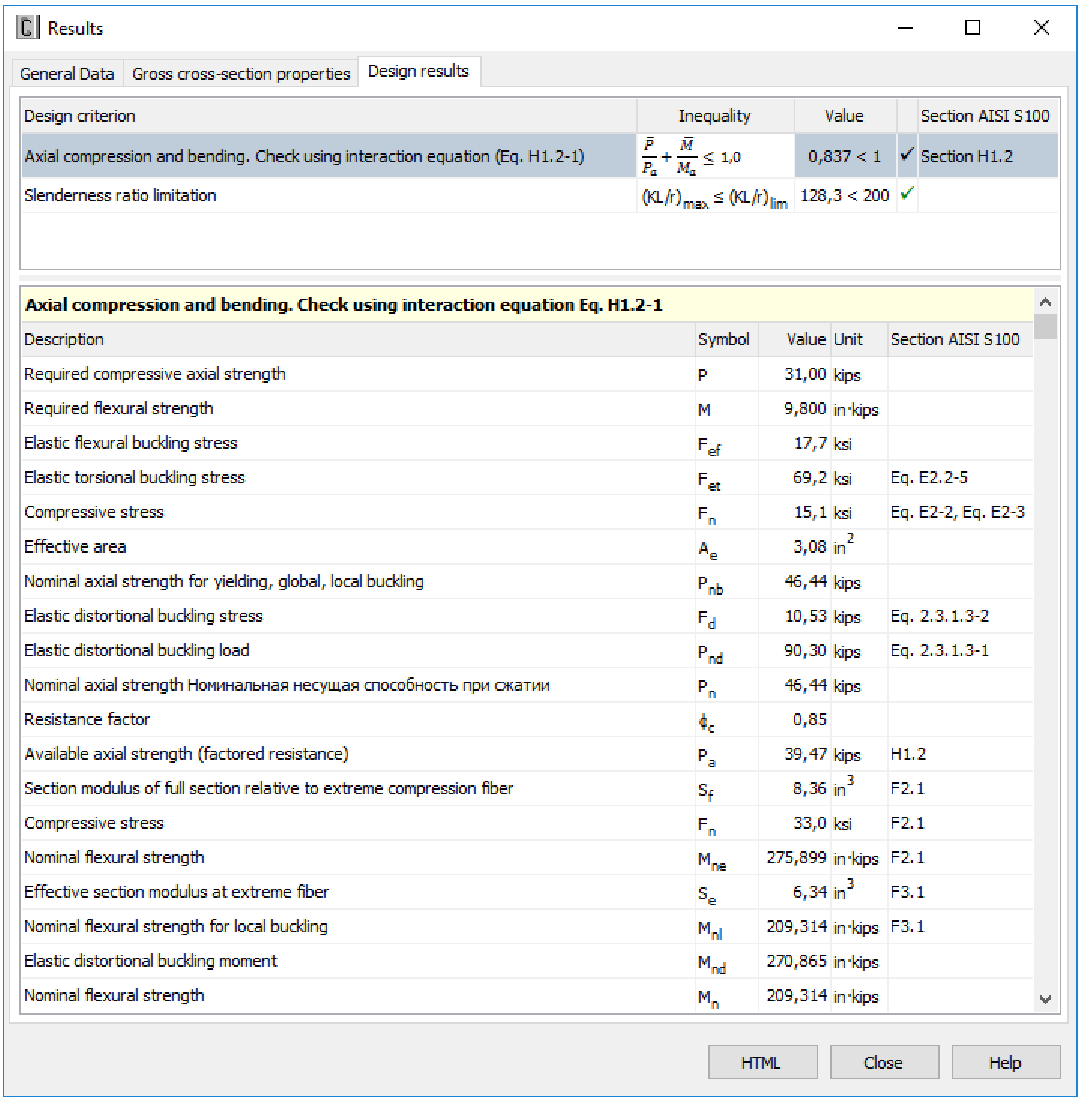


Figure 2.4.12 – Window of results: *General data*

Design results tab (Figure 2.4.13) is functionally divided into two parts. The upper part contains the list of the executed checks (design criterion). Each check displays its name, symbolic representation of the design inequality, the numerical representation of the result, the icon that indicates the check is satisfied or not, and the section or the equation of the code, according to which this calculation was performed.



Results

General Data | Gross cross-section properties | Design results

Design criterion	Inequality	Value		Section AISI S100
Axial compression and bending. Check using interaction equation (Eq. H1.2-1)	$\frac{\bar{P}}{P_a}+\frac{\bar{M}}{M_a}\leq 1{,}0$	0,837 < 1	✓	Section H1.2
Slenderness ratio limitation	$(KL/r)_{max} \leq (KL/r)_{lim}$	128,3 < 200	✓	

Axial compression and bending. Check using interaction equation Eq. H1.2-1

Description	Symbol	Value	Unit	Section AISI S100
Required compressive axial strength	P	31,00	kips	
Required flexural strength	M	9,800	in·kips	
Elastic flexural buckling stress	F_{ef}	17,7	ksi	
Elastic torsional buckling stress	F_{et}	69,2	ksi	Eq. E2.2-5
Compressive stress	F_n	15,1	ksi	Eq. E2-2, Eq. E2-3
Effective area	A_e	3,08	in^2	
Nominal axial strength for yielding, global, local buckling	P_{nb}	46,44	kips	
Elastic distortional buckling stress	F_d	10,53	kips	Eq. 2.3.1.3-2
Elastic distortional buckling load	P_{nd}	90,30	kips	Eq. 2.3.1.3-1
Nominal axial strength Номинальная несущая способность при сжатии	P_n	46,44	kips	
Resistance factor	ϕ_c	0,85		
Available axial strength (factored resistance)	P_a	39,47	kips	H1.2
Section modulus of full section relative to extreme compression fiber	S_f	8,36	in^3	F2.1
Compressive stress	F_n	33,0	ksi	F2.1
Nominal flexural strength	M_{ne}	275,899	in·kips	F2.1
Effective section modulus at extreme fiber	S_e	6,34	in^3	F3.1
Nominal flexural strength for local buckling	M_{nl}	209,314	in·kips	F3.1
Elastic distortional buckling moment	M_{nd}	270,865	in·kips	
Nominal flexural strength	M_n	209,314	in·kips	

HTML | Close | Help

Figure 2.4.13 – Window of results: *Design results*

In the bottom of the window detailed information is provided on the values of the calculation parameters included in the current check. The following features are given for each parameter: its name, symbol, numerical value, units and clause (section) or equation from relevant codes.

Units within the metric system and number of decimal places the user can use, can be set in the main menu *Options → Units and decimal places* (Section 3.2).

By clicking the button located at the bottom of the window, a user can submit the information about the performed calculation in Microsoft Excel® for further processing or convert to HTML format.

3. OPTIONS

3.1. Design details

Design details are available after selecting in main menu *Options* → *Design details*. Dialog box *Design Details* is shown in Figure 3.1.1.

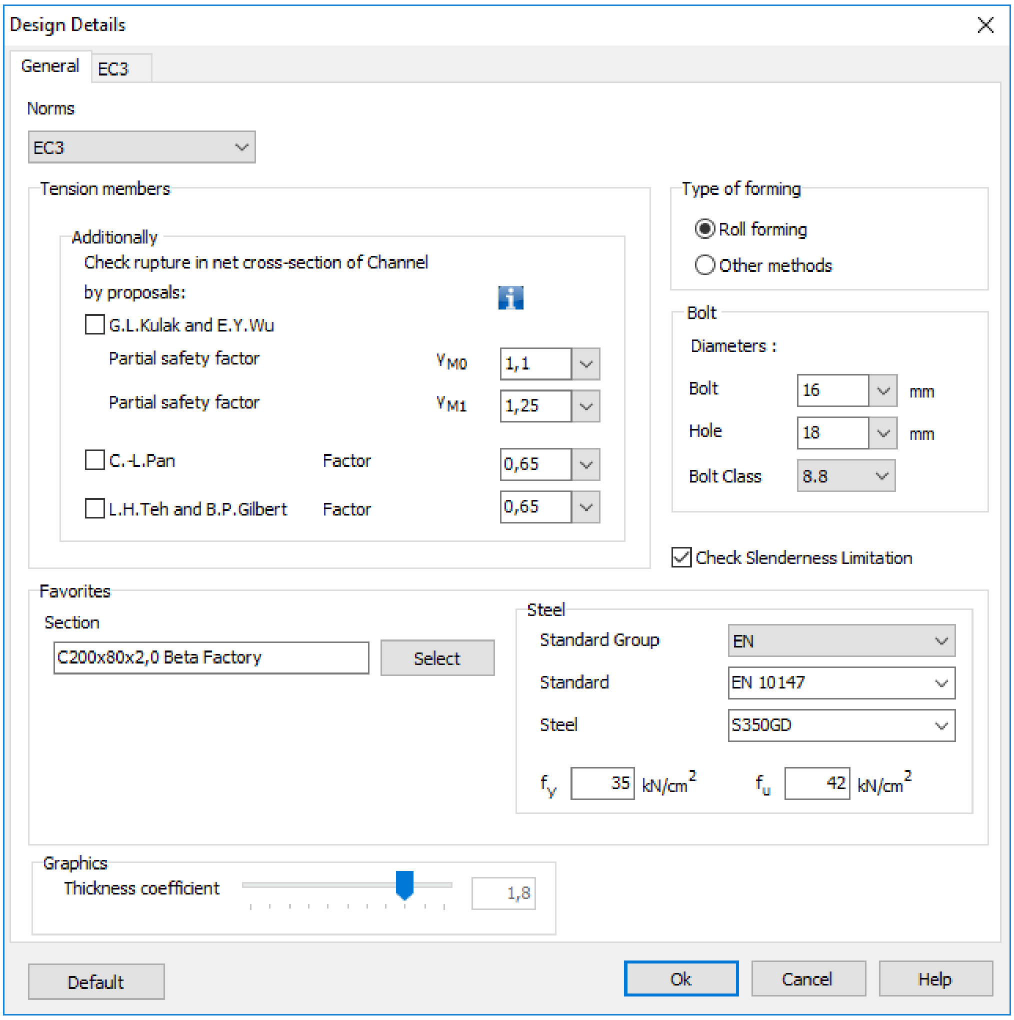


Figure 3.1.1 – Dialog box *Design Details*: *General* tab

In *General* tab you can choose the design norms. European EN 1993, North American Specification AISI S100 and Russian codes СП 16.13330.2011, СП 260.1325800.2016 are available. In addition, a calculation for rupture of the net cross-section at the connection for channels and double channels in tension is available in accordance with the methods proposed by G.L. Kulak and E.Y. Wu [9,10], C.L. Pan [12], L. H. B.P. Gilbert [13]. To include one or another method to the calculation, it is necessary to select it in panel *Additionally*. The user can adjust the reliability of the calculation by modifying the partial factors for resistance and resistance factors., There are many verification calculations by (2.4.10) in the document for reasonable assignment of numerical values of the factors γ_{M1} and γ_{M0}: CFSteel v.4.1 Documentation. Volume II. Verification examples [16]. This document presents the nominal value of tensile strength (without factors γ_{M1} and γ_{M0}) and design values (with factors). The results of the calculations were compared with the experimental data of various researches.

Also, in this tab you can select a type of profile forming, enter the bolt diameter and the hole diameter, select favorites: cross section and steel. If it is necessary to perform the check of member slenderness you should mark the box *Check slenderness limitation*.

By selection from the Section Library and the Steel Library, you can assign a Section favorite and a Steel favorite which will be loaded by default when you first enter into the appropriate input window of member design.

In the tab *EC3* user can enter parameters, which are specified in the National Annexes to Eurocodes, as well as some other parameters.

You can assign the following parameters related to the competence of National Annexes:

– partial factors γ_{M0}, γ_{M1} and γ_{M2} (clause 6.1(1) [1], 2(3) [2]);
– lateral torsional buckling curves: general case (clause 6.3.2.2 [1]) or according to clause 6.3.2.3 [1];
– imperfection factors for lateral torsional buckling curves α_{LT} (clause 6.3.2.2 (2) [1]);
– parameters $\overline{\lambda}_{LT,0}$, β ;
– to use $\chi_{LT\,mod}$ or not to use in the case of the choice of clause 6.3.2.3 [1].

Thus, the user may adjust the calculation in accordance with any National Annex by assigning the above parameters.

You can choose which value of yield strength to take into account while calculating the design resistance of a gross cross-section $N_{tg,Rd}$ (2.3.2) (equation 6.1 [2]): basic yield strength f_{yb} or average yield strength f_{ya} of cross-section due to cold working according (2.3.3) and clause 3.2.2 [2].

In the current version of the Eurocodes [1,2] there is no method of calculation of the elastic critical moment for lateral torsional buckling M_{cr}. Therefore, while calculating the compression members the user can choose to calculate M_{cr} according to [15] (clause 2.3.3.1) or directly enter the numeric value of M_{cr} in the input window *Column* (clause 2.3.3.2). While calculating the compression with bending members, the value of M_{cr} is always calculated according to [15].

The user can choose what method to use to perform the calculation of compressed with bending members: according to clause 6.2.5 [2] or according to clause 6.3.3 [1] (interaction equations (6.61), (6.62)). The interaction factors k_{ij} in the latter case are computed according to Method 1 (Annex A) [1]. The calculation by both methods is, also, possible. Calculation of compressed members is always performed according to clause 6.2.5 [2].

EC3 allows two alternative approaches of defining the effective cross-section of the channel cross sections in relation to the local buckling of flanges: a) by removing ineffective portion of the flange (clause 5.5.2 [2]) and b) by reducing the thickness (Annex D [2]). The user can choose one of these methods.

You can select how to determine flexural buckling length: a) directly enter buckling length or b) enter member length and buckling length factors k_y, k_z and further calculation of buckling lengths $L_{cr,y} = k_y\, L$, $L_{cr,z} = k_z\, L$. In the calculation of an axially compressed members always apply the second case.

Also, you can assign limit slenderness for compressed and compressed with bending members, which will be by default in the corresponding windows for input data. In any case, the values of limit slenderness can be adjusted in these input windows.

The user can include (or exclude) the calculation the check for resistance of net cross-section when calculating compression members. This choice is relevant only in case the net cross-section parameters are entered in the appropriate input window. For tension members the check for resistance of the net cross-section is always performed.

Thus, the user can define the design calculation parameters in accordance with the National Annex of any state, and also customize the design according to their preferences.

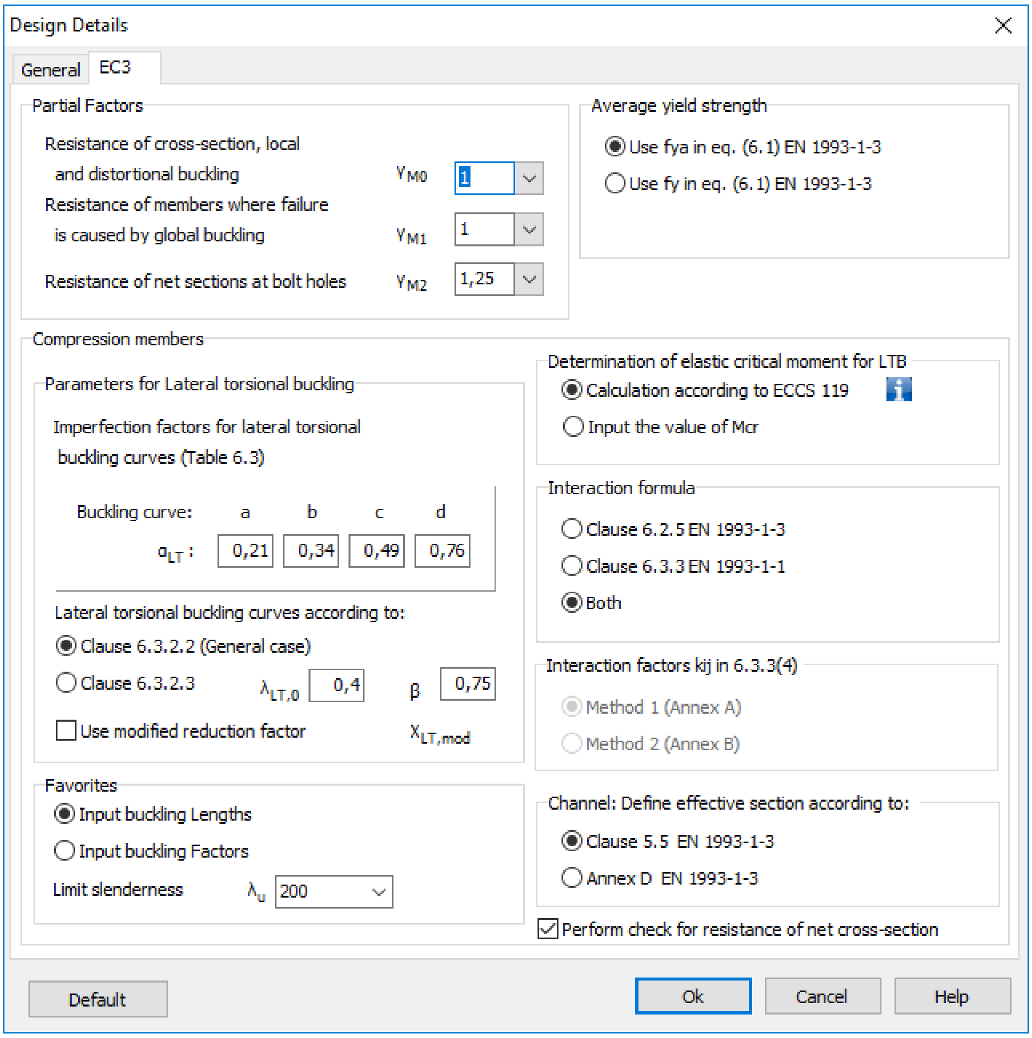


Figure 3.1.2 – Dialog box *Design Details*: *EC3* tab

In the *AISI* tab the user can choose which method (ASD, LRFD or LSD) to perform the design according to American Specification [4,5]. According to AISC Specification [4,7] while computing the net cross-section area for tension, the width of a bolt hole shall be taken as 2 *mm* greater than the nominal dimension of the hole. In the AISI Specification [5] no such provision. The user can choose to add or not to add 2 *mm* to the nominal diameter. The bearing strength of the tension member at connection (2.4.8) according to AISI S100 depends on the presence or absence of washers under the nut and the bolt head. The user can choose the construction of the connection: with or without washers. Also, the user can choose which value of yield strength F_y to take into account when calculating the design resistance of a gross cross-section P_{tgn} (2.4.2): basic yield strength F_y or average yield strength F_{ya} of cross-section due to cold working according to Section A3.3 [5].

By clicking *Default* you can return to the settings accepted in the software by default.

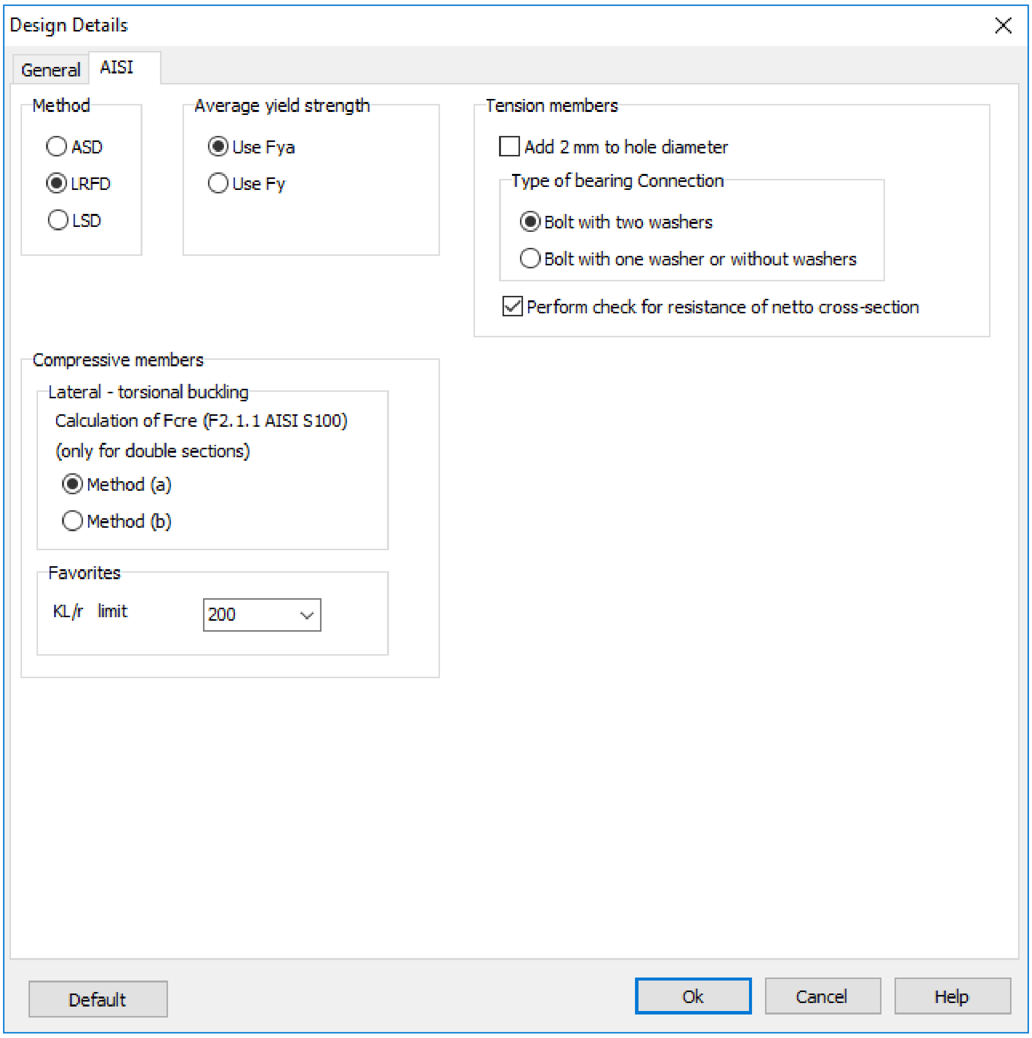


Figure 3.1.3 – Dialog box *Design Details*: *AISI* tab

3.2. Units and decimal places

The user can choose the units of measure input and output quantities. The settings can be modified as required. All numerical values will be converted or adjusted. To access the dialog box for changing units and decimal places (Figure 3.2.1) select in main menu *Options* → *Units and Decimal Places*.

Three dialog tabs are offered to specify settings separately for *Structure*, *Loads* and *Results*. In the *Structure* tab you can assign values to the units associated with the constructive solution of the structure or structural members: dimensions of the structure or structural members (*Lengths* and *Angles*), parameters of *Cross-section* and units of *Stresses* including strength characteristics of steel. In the *Loads* tab you can assign values to the units of *Forces*, *Moments* and *Lengths* for distributed loads. *Results* Tab determines the units for the *Displacement* and *Ratios* of output quantities (for example, $N_{Ed} / N_{t,Rd}$).

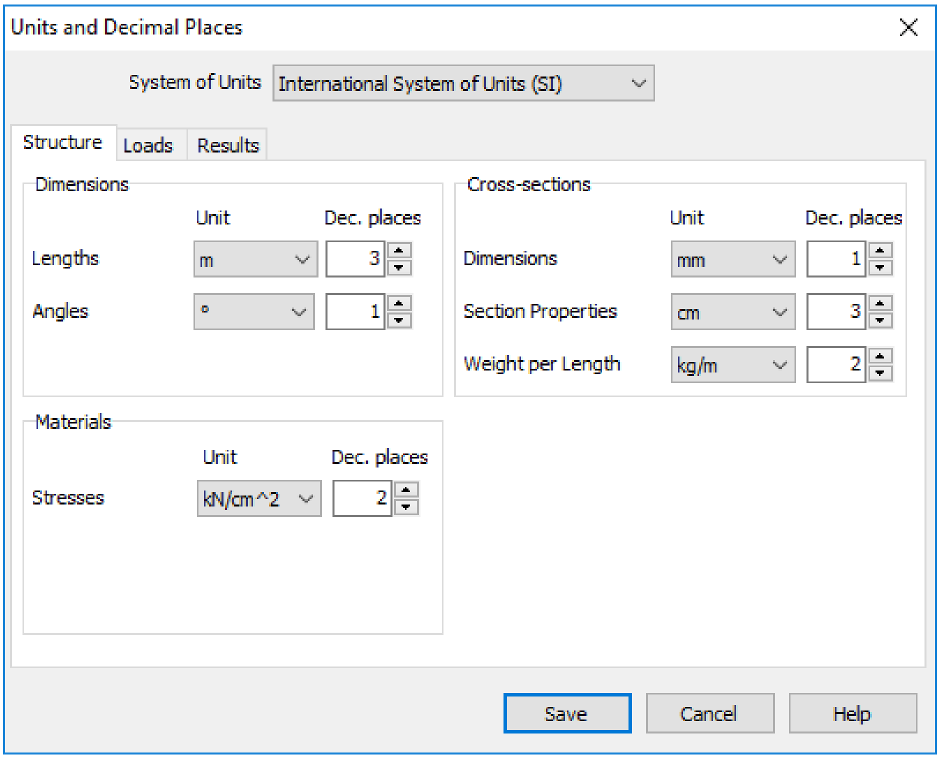


Figure 3.2.1 – Dialog box *Units and Decimal Places*

3.3. Program options

In the dialog box *Program Options (Options → Program Options)*, you can select interface *Language* (English or Russian). The changed language settings will be effective after restarting the software. Also, in this window are displayed folders for Steel Library and Section Library.

You can export design results to Microsoft Excel® or convert to HTML format. In latter case you can appoint a content of convertible information.

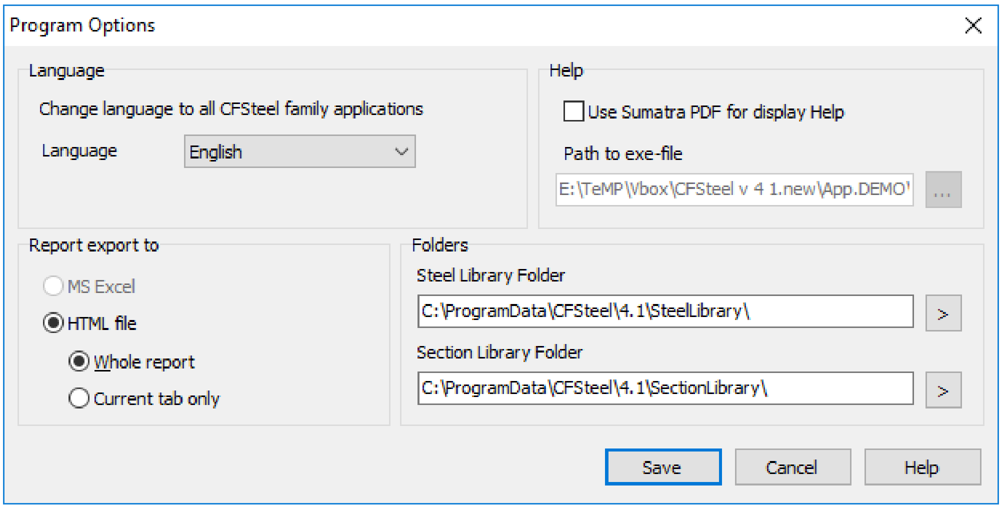


Figure 3.3.1 – Dialog box *Program Options*

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